NASA
National Aeronautics and
Space Administration

Chronological History
Fiscal Year 1989
Budget Submission

Prepared by:
Comptroller
Budget Operations Office
Code BT

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National Aeronautics and Space Administration

Fiscal Year 1989

Legislative Reference

Item	Statistics	Authorization Page Numbers: House Auth Comm	Senate Auth Comm	Auth Conf Comm	Appropriations Page Numbers: House Approp Comm	Senate Approp Comm	Appro Conf Comm
Summary by Appropriation	1,2,3,4	27,28	186		258		
Research and Development	1,3,5	27,41	186-190		259	268	277
253 Space Station	3,5	27,28,41,42	187,190	251	259	269	277
253 Space Transportation Capability Developement	3,5	27,28,41,49	187,193	251	260	269	
254 Physics and Astronomy	3,6	41,56	187,196	251	259,260	269,270	
254 Life Sciences	3,6	41,66	187,201	251	260	270	
254 Planetary Exploration	3,6	41,69	187,203	251	260		
254 Space Applications	3,7	41,73	188,207	251	260	270	
254 Technology Utilization	7	41,85	188,218	251	260	270	
254 Commercial Use of Space	7	41,87	188,218	252	260	270	
402 Aeronautical Research and Technology	3,7	41,88	188,220	252	260	270	
254 Transatmospheric Research and Technology	3,7	41,108	188,225	252	260	270	
254 Space Research and Technology	3,8	41,110	188,226	252	260	269,270	
254 Safety, Reliability, and Quality Assurance	3,8	41,136	188,232	252			
255 Advanced Systems	3,8	41,137	188,233	252			
Space Flight, Control and Data Communications	1,3,8	139	186,188,233		260	271	277
253 Shuttle Production and Operational Capability	3,8	139	188,234	252	260	271	
253 Space Transportation Operations	3,9	139,143	188,237	252	260	271	
255 Space and Ground Network Communications and Data Systems	3,9	139,146	188,239	252	260	271	
253 Expendable Launch Vehicles	3,9	146	188,237,239		260	271,272	

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Item	Statistics	Legislative Reference: Authorization Page Numbers — House Auth Comm	Senate Auth Comm	Auth Conf Comm	Appropriations Page Numbers — House Approp Comm	Senate Approp Comm	
Construction of Facilities	1,2,4,9	155	188,241		261	272	278
Space Station Facilities	9	155,156	241	252	261	272	
Space Flight Facilities	10	155,157,158	241	252			
Johnson Space Center	10	155,159	241	252			
Marshall Space Flight Center	10	155,159	241	252			
Goddard Space Flight Center	11	155,156,159,16	241	252			
Jet Propulsion Laboratory	11	156,160	241	252			
Aeronautical Facilities	11	156,161,162	241	252			
Lewis Research Center	11	156,163	241	252			
Repair	11	156,163,164	241	252			
Rehabilitation and Modification	11	156,164	241	252			
Minor Construction	11	156,164,165	241	252			
Facility Planning and Design	12	156,165	241	252			
Environmental Compliance and Restoration	12	156,165	241	252			
General Reduction	12		242		261		
General Increase	12						
Transfer From SFC&DC	12				261	272	
Transfer To Trust Fund	12						
Research and Program Management	1,2,4,12,13	166	188,242	252	261	272	278

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Chronological History of the FY 1989 Budget Submission
(in thousands of dollars)

Item	Budget Submission to Congress	AUTHORIZATION: House Comm. H. R. 4561 Rpt. 100-650 5-24-88 Appd. 6-2-88	AUTHORIZATION: Senate Comm. S. 2209 Rpt. 100-429 7-26-88 Appd. 8-9-88	AUTHORIZATION: P. L. 100-685 Appd 11-17-88	AUTHORIZATION: Difference from Budget Submission	APPROPRIATION: House Comm. H. R. 4800 Rpt. 100-701 6-14-88 Appd. 6-22-88	APPROPRIATION: Senate Comm. H. R. 4800 Rpt. 100-401 6-24-88 Appd. 7-13-88	APPROPRIATION: Conf Comm. P. L. 100-404 Rpt. 100-817 8-3-88 Appd. 8-19-88	APPROPRIATION: Difference from Budget Submission
Total Appropriation									
Research and Development	4,446,700	4,446,700	4,278,200	4,322,100	-124,600	4,166,700	3,552,800	4,191,700	-255,000
Space Flight, Control and Data Communications	4,841,200	4,841,200	4,686,200	4,686,200	-155,000	4,414,200	4,452,200	4,364,200	-477,000
Construction of Facilities	285,100	285,100	260,100	290,100	5,000	270,100	270,100	275,100	-10,000
Research and Program Management	1,915,000	1,915,000	1,880,000	1,915,000	0	1,855,000	1,870,000	1,855,000	-60,000
Trust Fund	---	---	---	---	---	---	---	15,000	15,000
Total NASA	11,488,000	11,488,000	11,104,500	11,213,400	-274,600	10,706,000	10,145,100	10,701,000	-787,000
R&D Appropriation									
OSS	967,400	967,400	867,400	900,000	-67,400	902,400	200,000	900,000	-67,400
OSF	631,100	631,100	606,600	606,600	-24,500	606,100	606,100	606,100	-25,000
OSSA	1,859,600	1,859,600	1,880,600	1,891,900	32,300	1,819,600	1,872,700	1,819,600	-40,000
OCP	57,900	57,900	57,900	57,900	0	52,900	57,900	52,900	-5,000
OAST	889,500	889,500	824,500	824,500	-65,000	769,500	774,500	769,500	-120,000
OSRMQA	22,400	22,400	22,400	22,400	0	22,400	22,400	22,400	0
OSIDS	18,800	18,800	18,800	18,800	0	18,800	18,800	18,800	0
Adjustment	---	---	---	---	---	-25,000	400	2,400	2,400
Total Research and Development	4,446,700	4,446,700	4,278,200	4,322,100	-124,600	4,166,700	3,552,800	4,191,700	-255,000
SFC&DC Appropriation									
OSF	3,805,900	3,805,900	3,700,900	3,700,900	-105,000	3,495,900	3,533,900	3,805,900	0
OSIDS	1,035,300	1,035,300	985,300	985,300	-50,000	945,300	945,300	1,035,300	0
Transfer to CofF	---	---	---	---	---	-27,000	-27,000	---	0
General Reduction	---	---	---	---	---	---	---	-477,000	-477,000
Total SFC&DC	4,841,200	4,841,200	4,686,200	4,686,200	-155,000	4,414,200	4,452,200	4,364,200	-477,000

Item	Budget Submission to Congress	AUTHORIZATION: House Comm H R 4581 Rpt 100-650 5-24-88 Appd 6-2-88	AUTHORIZATION: Senate Comm S 2209 Rpt 100-429 7-26-88 Appd 6-9-88	AUTHORIZATION: P L 100-685 Appd 11-17-88	AUTHORIZATION: Difference from Budget Submission	APPROPRIATION: House Comm H R 4800 Rpt 100-701 6-14-88 Appd 6-22-88	APPROPRIATION: Senate Comm H R 4800 Rpt 100-401 6-24-88 Appd 7-13-88	APPROPRIATION: Conf Comm P L 100-404 Rpt 100-817 8-3-88 Appd 8-19-88	APPROPRIATION: Difference from Budget Submission
C of F Appropriation									
OSS	27,900	27,900	12,900	12,900	-15,000	0	0	0	-27,900
OSF	42,000	42,000	42,000	69,000	27,000	42,000	42,000	42,000	0
OSSA	29,300	29,300	29,300	29,300	0	29,300	29,300	29,300	0
OAST	69,900	69,900	69,900	69,900	0	69,900	69,900	69,900	0
other	116,000	116,000	116,000	116,000	0	116,000	116,000	116,000	0
General Reduction	---	---	-10,000	-7,000	-7,000	-14,100	-14,100	---	0
General Increase	---	---	---	---	---	---	---	32,900	32,900
Transfer from SFCEDC	---	---	---	---	---	27,000	27,000	---	0
Transfer to Trust Fund	---	---	---	---	---	---	---	-15,000	-15,000
Total C of F	285,100	285,100	260,100	290,100	5,000	270,100	270,100	275,100	-10,000
Research and Program Management	1,915,000	1,915,000	1,860,000	1,915,000	0	1,855,000	1,870,000	1,855,000	-60,000
Science, Space, And Technology									
Education Trust Fund	---	---	---	---	---	---	---	15,000	15,000
Total NASA	11,488,000	11,488,000	11,104,500	11,213,000	-274,600	10,706,000	10,145,100	10,701,000	-787,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Chronological History of the FY 1989 Budget Submission
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Research and Development	4,446,700	4,446,700	4,278,200	4,322,100	-124,600	4,166,700	3,552,800	4,191,700	-255,000
253 Space Station	967,400	967,400	867,400	900,000	-67,400	902,400	200,000	900,000	-67,400
253 Space Transporation Capability Development	631,100	631,100	606,600	606,600	-24,500	606,100	606,100	606,100	-25,000
254 Physics and Astronomy	791,600	791,600	761,600	761,600	-30,000	735,600	745,600	735,600	-56,000
254 Life Sciences	101,700	101,700	91,700	91,700	-10,000	76,700	89,000	76,700	-25,000
254 Planetary Exploration	404,000	404,000	399,000	410,300	6,300	394,000	404,000	394,000	-10,000
254 Space Applications	562,300	562,300	628,300	628,300	66,000	613,300	633,300	613,300	51,000
254 Commercial Programs	57,900	57,900	57,900	57,900	0	52,900	57,900	52,900	-5,000
402 Aeronautical Research and Technology	414,200	414,200	404,200	404,200	-10,000	404,200	409,200	404,200	-10,000
254/402 Transatmospheric Research and Technology	84,400	84,400	69,400	69,400	-15,000	69,400	69,400	69,400	-15,000
254 Space Research and Technology	390,900	390,900	350,900	350,900	-40,000	295,900	295,900	295,900	-95,000
254 Safety, Reliability and Quality Assurance Program	22,400	22,400	22,400	22,400	0	22,400	22,400	22,400	0
255 Advanced Systems	18,800	18,800	18,800	18,800	0	18,800	18,800	18,800	0
Adjustment	---	---	---	---	---	-25,000	400	2,400	2,400
Space Flight, Control and Data Communications	4,841,200	4,841,200	4,686,200	4,686,200	-155,000	4,414,200	4,452,200	4,364,200	-477,000
253 Shuttle Production and Operational Capability	1,400,500	1,400,500	1,335,500	1,335,500	-65,000	1,405,500	1,405,500	1,400,500	0
253 Space Transporation Operations	2,209,900	2,209,900	2,209,900	2,209,900	0	2,209,900	2,209,900	2,209,900	0
253 Expendable Launch Vehicles	195,500	195,500	155,500	155,500	-40,000	85,500	123,500	195,500	0
253 General Reduction	---	---	---	---	---	-205,000	-205,000	---	0
255 Space and Ground Network Communications and Data Systems	1,035,300	1,035,300	985,300	985,300	-50,000	945,300	945,300	1,035,300	0
Transfer to CoIF	---	---	---	---	---	-27,000	-27,000	---	0
General Reduction	---	---	---	---	---	---	---	-477,000	-477,000

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Construction of Facilities	285,100	285,100	260,100	290,100	5,000	270,100	270,100	275,100	-10,000
253 Johnson Space Center	14,100	14,100	14,100	14,100	0	4,900	4,900	4,900	-9,200
254 Johnson Space Center	7,800	7,800	7,800	7,800	0	7,800	7,800	7,800	0
253 Kennedy Space Center	24,700	24,700	9,700	9,700	-15,000	9,700	9,700	9,700	-15,000
253 Marshall Space Flight Center	17,200	17,200	17,200	17,200	0	13,500	13,500	13,500	-3,700
254 Marshall Space Flight Center	11,400	11,400	11,400	11,400	0	11,400	11,400	11,400	0
253 National Space Technology Lab	3,500	3,500	3,500	3,500	0	3,500	3,500	3,500	0
253 Various Locations	2,600	2,600	2,600	29,600	27,000	2,800	2,600	2,600	0
254 Goddard Space Flight Center	2,800	2,800	2,800	2,800	0	2,800	2,800	2,800	0
55 Goddard Space Flight Center	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0
4 Jet Propulsion Lab	12,000	12,000	12,000	12,000	0	12,000	12,000	12,000	0
4 Lewis Research Center	6,100	6,100	6,100	6,100	0	6,100	6,100	6,100	0
42 Lewis Research Center	14,500	14,500	14,500	14,500	0	14,500	14,500	14,500	0
402 Ames Research Center	36,500	36,500	36,500	36,500	0	36,500	36,500	36,500	0
402 Langley Research Center	12,800	12,800	12,800	12,800	0	12,800	12,800	12,800	0
255 N-Repair of Facilities	27,000	27,000	27,000	27,000	0	27,000	27,000	27,000	0
255 N-Rehabilitation and Modification of Facilities	34,000	34,000	34,000	34,000	0	34,000	34,000	34,000	0
255 N-Minor Construction and Additions to Facilities	9,000	9,000	9,000	9,000	0	9,000	9,000	9,000	0
255 N-Facility Planning and Design	20,000	20,000	20,000	20,000	0	20,000	20,000	20,000	0
255 N-Environmental Compliance and Restoration Program	26,000	26,000	26,000	26,000	0	26,000	26,000	26,000	0
General Reduction	---	---	-10,000	-7,000	-7,000	-14,100	-14,100	---	0
General Increase	---	---	---	---	---	---	---	32,900	32,900
Transfer from SFC&DC	---	---	---	---	---	27,800	27,800	---	0
Transfer to Trust Fund	---	---	---	---	---	---	---	-15,000	-15,000
Research and Program Management	1,915,800	1,915,800	1,880,800	1,915,800	0	1,855,800	1,870,800	1,855,800	-60,000
Science, Space, And Technology									
Education Trust Fund	---	---	---	---	---	---	---	15,000	15,000
TOTAL	11,488,800	11,488,800	11,104,500	11,213,400	-274,600	10,706,800	10,145,100	10,701,800	-787,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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(in thousands of dollars)

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Research and Development	4,446,700	4,446,700	4,278,200	4,322,100	-124,600	4,166,700	3,552,800	4,191,700	-255,000
Office of Space Station	967,400	967,400	867,400	900,000	-67,400	902,400	200,000	900,000	-67,400
253 Space Station	967,400	967,400	867,400	900,000	-67,400	902,400	200,000	900,000	-67,400
Development	935,400	935,400	935,400	935,400	0	935,400	935,400	935,400	0
Pressurized Modules	188,000	188,000	188,000	188,000	0	188,000	188,000	188,000	0
Assembly Hardware/Subsystems	288,000	288,000	288,000	288,000	0	281,000	288,000	288,000	0
Platforms and Servicing	56,000	56,000	56,000	56,000	0	56,000	56,000	56,000	0
Power System	154,000	154,000	154,000	154,000	0	154,000	154,000	154,000	0
Operations Capability/Utilization	80,000	80,000	80,000	80,000	0	80,000	80,000	80,000	0
Management and Integration	169,400	169,400	169,400	169,400	0	169,400	169,400	169,400	0
Flight Teleorobotic System	20,000	20,000	20,000	20,000	0	20,000	20,000	20,000	0
Transition Definition	12,000	12,000	12,000	12,000	0	12,000	12,000	12,000	0
Congressional Action	---	---	-100,000	-67,400	-67,400	-65,000	-767,400	-67,400	-67,400
Office of Space Flight	631,100	631,100	606,600	606,600	-24,500	606,100	606,100	606,100	-25,000
253 Space Transportation									
Capability Development	631,100	631,100	606,600	606,600	-24,500	606,100	606,100	606,100	-25,000
Spacelab	80,400	80,400	80,400	80,400	0	80,400	80,400	80,400	0
Upper Stages	146,200	146,200	153,200	153,200	7,000	156,200	156,200	156,200	10,000
Engineering and Technical Base	158,900	158,900	158,900	158,900	0	158,900	158,900	158,900	0
Payload Operations and Support Equipment	67,300	67,300	67,300	67,300	0	67,300	67,300	67,300	0
Advanced Programs	45,000	45,000	45,000	45,000	0	45,000	45,000	45,000	0
Advanced Launch Systems	13,000	13,000	6,500	6,500	-6,500	13,000	13,000	13,000	0
Tethered Satellite System	23,800	23,800	23,800	23,800	0	23,800	23,800	23,800	0
Orbital Maneuvering Vehicle	96,500	96,500	96,500	96,500	0	96,500	96,500	96,500	0
Congressional Action	---	---	-25,000	-25,000	-25,000	-35,000	-35,000	-35,000	-35,000

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Office of Space Science and Applications	1,859,600	1,859,600	1,880,600	1,891,900	32,300	1,819,600	1,872,700	1,819,800	-40,000
254 Physics and Astronomy	791,600	791,600	761,600	761,600	-30,000	735,600	745,600	735,690	-56,000
Hubble Space Telescope Development	102,200	102,200	102,200	102,200	0	102,200	102,200	102,200	0
Gamma Ray Observatory Development	41,900	41,900	41,900	41,900	0	41,900	41,900	41,900	0
Global Geospace Science	101,400	101,400	76,400	76,400	-25,000	66,400	66,400	66,400	-35,000
Advanced X-Ray Astrophysics Facility Development (AXAF)	27,000	27,000	27,000	27,000	0	16,000	16,000	16,000	-11,000
Payload and Instrument Development	77,100	77,100	77,100	77,100	0	77,100	77,100	77,100	0
Shuttle/Spacelab Payload Mission Management and Integration	61,500	61,500	61,500	61,500	0	61,500	61,500	61,500	0
Space Station Integrated Planning and Attached Payloads	8,000	8,000	8,000	8,000	0	8,000	8,000	8,000	0
Explorer Development	82,100	82,100	82,100	82,100	0	82,100	82,100	82,100	0
Mission Operations and Data Analysis	156,200	156,200	156,200	156,200	0	146,200	156,200	146,200	-10,000
Research and Analysis	89,100	89,100	89,100	89,100	0	89,100	89,100	89,100	0
Suborbital Program	45,100	45,100	45,100	45,100	0	45,100	45,100	45,100	0
Congressional Action	---	---	-5,000	-5,000	-5,000	---	---	---	0
254 Life Sciences	101,700	101,700	91,700	91,700	-10,000	76,700	89,800	76,700	-25,000
Life Sciences Flight Experiments	54,500	54,500	54,500	54,500	0	54,500	54,500	54,500	0
Research and Analysis	47,200	47,200	47,200	47,200	0	47,200	47,200	47,200	0
Congressional Action	---	---	-10,000	-10,000	-10,000	-25,000	-11,900	-25,000	-25,000
254 Planetary Exploration	404,000	404,000	399,000	410,300	6,300	384,000	404,000	394,000	-10,000
Galileo Development	61,300	61,300	61,300	61,300	0	61,300	61,300	61,300	0
Magellan	33,900	33,900	33,900	33,900	0	33,900	33,900	33,900	0
Ulysses	10,300	10,300	10,300	10,300	0	10,300	10,300	10,300	0
Mars Observer (MGCO)	102,200	102,200	102,200	102,200	0	102,200	102,200	102,200	0
Mission Operations and Data Analysis	112,700	112,700	112,700	112,700	0	112,700	112,700	112,700	0
Research and Analysis	83,600	83,600	83,600	83,600	0	83,600	83,600	83,600	0
Congressional Action	---	---	-5,000	6,300	6,300	-10,000	---	-10,000	-10,000

Item	Budget Submission to Congress	AUTHORIZATION: House Comm H R 4561 Rpt 100-650 5-24-88 Appd 6-2-88	AUTHORIZATION: Senate Comm S 2209 Rpt 100-429 7-28-88 Appd 8-9-88	AUTHORIZATION: P L 100-685 Appd 11-17-88	Difference from Budget Submission	APPROPRIATION: House Comm H R 4800 Rpt 100-701 6-14-88 Appd 6-22-88	APPROPRIATION: Senate Comm H R 4800 Rpt 100-401 6-24-88 Appd 7-13-88	APPROPRIATION: Conf Comm P L 100-404 Rpt 100-817 8-3-88 Appd 8-19-88	Difference from Budget Submission
254 Space Applications	562,300	562,300	628,300	628,300	66,000	613,300	633,300	613,300	51,000
Solid Earth Observations	82,100	82,100	82,100	82,100	0	82,100	82,100	82,100	0
Environmental Observations	368,300	368,300	368,300	368,300	0	348,300	363,300	348,300	-20,000
Materials Processing in Space	73,400	73,400	73,400	73,400	0	73,400	73,400	73,400	0
Communications	16,200	16,200	92,200	92,200	76,000	92,200	92,200	92,200	76,000
Information Systems	22,300	22,300	22,300	22,300	0	17,300	22,300	17,300	-5,000
Congressional Action	---	---	-10,000	-10,000	-10,000	---	---	---	0
Office of Commercial Programs	57,900	57,900	57,900	57,900	0	52,900	57,900	52,900	-5,000
254 Technology Utilization	19,100	19,100	19,100	19,100	0	19,100	19,100	19,100	0
Product Development	2,100	2,100	2,100	2,100	0	2,100	2,100	2,100	0
Acquisition, Dissemination and Network Operations	5,400	5,400	5,400	5,400	0	5,400	5,400	5,400	0
Program Development, Evaluation and coordination	1,500	1,500	1,500	1,500	0	1,500	1,500	1,500	0
Technology Applications	7,300	7,300	7,300	7,300	0	7,300	7,300	7,300	0
Industrial Outreach	2,800	2,800	2,800	2,800	0	2,800	2,800	2,800	0
254 Commercial Use of Space	38,800	38,800	38,800	38,800	0	38,800	38,800	38,800	0
Commercial Applications R&D	36,600	36,600	36,600	36,600	0	36,600	36,600	36,600	0
Commercial Development Support	2,200	2,200	2,200	2,200	0	2,200	2,200	2,200	0
General Reduction	---	---	---	---	---	-5,000	---	-5,000	-5,000
Office of Aeronautics and Space									
Technology	889,500	889,500	824,500	824,500	-65,000	769,500	774,500	769,500	-120,000
402 Aeronautical Research and									
Technology	414,200	414,200	404,200	404,200	-10,000	404,200	409,200	404,200	-10,000
Research and Technology Base	314,200	314,200	314,200	314,200	0	314,200	314,200	314,200	0
Systems Technology Programs	100,000	100,000	100,000	100,000	0	100,000	100,000	100,000	0
General Reduction	---	---	-10,000	-10,000	-10,000	-10,000	-5,000	-10,000	-10,000
254/402 Transatmospheric Research and									
Technology	84,400	84,400	69,400	69,400	-15,000	69,400	69,400	69,400	-15,000
Research and Technology Base	84,400	84,400	69,400	69,400	-15,000	69,400	69,400	69,400	-15,000

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254 Space Research and Technology	390,900	390,900	350,900	350,900	-40,000	295,900	295,900	295,900	-95,000
Research and Technology Base	134,100	134,100	134,100	134,100	0	134,100	134,100	134,100	0
Civil Space Technology Initiative (CSTI) Program	156,800	156,800	156,800	156,800	0	121,800	121,800	121,800	-35,000
Pathfinder Program	100,000	100,000	60,000	60,000	-40,000	40,000	40,000	40,000	-60,000
Office of Safety, Reliability, Maintainability and Quality Assurance	22,400	22,400	22,400	22,400	0	22,400	22,400	22,400	0
256 Safety, Reliability, Maintainability, and Quality Assurance Program	22,400	22,400	22,400	22,400	0	22,400	22,400	22,400	0
Office of Space Tracking and Data Systems	18,800	18,800	18,800	18,800	0	18,800	18,800	18,800	0
255 Advanced Systems	18,800	18,800	18,800	18,800	0	18,800	18,800	18,800	0
Adjustment	---	---	---	---	---	-25,000	400	2,400	2,400
Space Flight, Control and Data Communications	4,841,200	4,841,200	4,686,200	4,686,200	-155,000	4,414,200	4,452,200	4,364,200	-477,000
Office of Space Flight	3,805,900	3,805,900	3,700,900	3,700,900	-105,000	3,495,900	3,533,900	3,805,900	0
253 Shuttle Production and Operational Capability	1,400,500	1,400,500	1,335,500	1,335,500	-65,000	1,405,500	1,405,500	1,400,500	0
Orbiter Operational Capability	320,000	320,000	280,000	280,000	-40,000	330,000	330,000	320,000	0
Launch and Mission Support	343,700	343,700	343,700	343,700	0	343,700	343,700	343,700	0
Propulsion Systems	711,800	711,800	711,800	711,800	0	708,800	708,800	711,800	0
Changes and System Upgrading	25,000	25,000	0	0	-25,000	25,000	25,000	25,000	0

Item	Budget Submission to Congress	House Comm H R 4561 Rpt 100-650 5-24-88 Appd 6-2-88	Senate Comm S 2209 Rpt 100-429 7-26-88 Appd 8-9-88	P L 100-685 Appd 11-17-88	Difference from Budget Submission	House Comm H R 4800 Rpt 100-701 6-14-88 Appd 6-22-88	Senate Comm. H R 4800 Rpt 100-401 6-24-88 Appd. 7-13-88	Conf Comm P L 100-404 Rpt 100-817 8-3-88 Appd 8-19-88	Difference from Budget Submission
	AUTHORIZATION					APPROPRIATION			
253 Space Transportation Operations	2,405,400	2,405,400	2,365,400	2,365,400	-40,000	2,295,400	2,333,400	2,405,400	0
Flight Operations	660,100	660,100	660,100	660,100	0	660,100	660,100	660,100	0
Flight Hardware	1,035,200	1,035,200	1,035,200	1,035,200	0	1,035,200	1,035,200	1,035,200	0
Launch and Landing Operations	514,600	514,600	514,600	514,600	0	514,600	514,600	514,600	0
Expendable Launch Vehicles and Services	195,500	195,500	155,500	155,500	-40,000	85,500	123,500	195,500	0
253 General Reduction	---	---	---	---	---	-205,000	-205,000	---	0
Office of Space Tracking and Data Systems	1,035,300	1,035,300	985,300	985,300	-50,000	945,300	945,300	1,035,300	0
255 Space and Ground Network Communications and Data Systems	1,035,300	1,035,300	985,300	985,300	-50,000	945,300	945,300	1,035,300	0
Space Network	538,900	538,900	538,900	538,900	0	538,900	538,900	538,900	0
Ground Network	248,100	248,100	248,100	248,100	0	248,100	248,100	248,100	0
Communications and Data Systems	248,300	248,300	248,300	248,300	0	248,300	248,300	248,300	0
Congressional Action			-50,000	-50,000	-50,000	-90,000	-90,000	---	0
Transfer to CofF	---	---	---	---	---	-27,800	-27,000	---	0
General Reduction	---	---	---	---	---	---	---	-477,000	-477,000
Construction of Facilities	285,100	285,100	260,100	290,100	5,000	270,100	270,100	275,100	-10,000
253 Space Station Facilities	27,900	27,900	12,900	12,900	-15,000	0	0	0	-27,900
SS - Construction of Space Station Processing Facility (KSC)	15,000	15,000	0	0	-15,000	0	0	0	-15,000
SS - Modification of Process Technology Facility for Space Station (MSFC)	3,700	3,700	3,700	3,700	0	0	0	0	-3,700

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SS - Construction of Addition for Space Systems Automated Integration and Assembly Facility (JSC)	9,200	9,200	9,200	9,200	0	0	0	0	-9,200
253 Space Flight Facilities	34,200	34,200	34,200	61,200	27,000	34,200	34,200	34,200	0
SF - Replacement of High Pressure Gas Storage Vessels (SSC)	3,500	3,500	3,500	3,500	0	3,500	3,500	3,500	0
SF - Increase Chiller Capacity, LC - 39 Utility Annex (KSC)	2,300	2,300	2,300	2,300	0	2,300	2,300	2,300	0
SF - Rehabilitation of PAD A, Launch Complex 39 (KSC)	4,600	4,600	4,600	4,600	0	4,600	4,600	4,600	0
SF - Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility (JSC)	4,900	4,900	4,900	4,900	0	4,900	4,900	4,900	0
SF - Modifications for Advanced Engine Development, Test Stand 116 (MSFC)	13,500	13,500	13,500	13,500	0	13,500	13,500	13,500	0
SF - Modifications to Orbiter Modification and Refurbishment Facility (OMRF) for Safing and Deservicing (KSC)	2,800	2,800	2,800	2,800	0	2,800	2,800	2,800	0
SF - Construction of National Resource Protection (Various Locations)	2,600	2,600	2,600	2,600	0	2,600	2,600	2,600	0
SF - Construction of an Advanced Solid Rocket Motor Facility	0	0	0	27,000	27,000	0	0	0	0
255 Johnson Space Center	7,800	7,800	7,800	7,800	0	7,800	7,800	7,800	0
SF - Construction of Auxiliary Chiller Facility	7,800	7,800	7,800	7,800	0	7,800	7,800	7,800	0
256 Marshall Space Flight Center	11,400	11,400	11,400	11,400	0	11,400	11,400	11,400	0
SSA - Modification to the X - Ray Calibration Facility (XRCF)	11,400	11,400	11,400	11,400	0	11,400	11,400	11,400	0

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254 Goddard Space Flight Center	2,800	2,800	2,800	2,800	0	2,800	2,800	2,800	0
SSA - Modernization of Space Environment Simulator	2,800	2,800	2,800	2,800	0	2,800	2,800	2,800	0
255 Goddard Space Flight Center	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0
SSA - Modifications for Utility Reliability	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0
254 Jet Propulsion Laboratory	12,000	12,000	12,000	12,000	0	12,000	12,000	12,000	0
SSA - Refurbishment of 25-Foot Space Simulator	12,000	12,000	12,000	12,000	0	12,000	12,000	12,000	0
402 Aeronautical Facilities	63,800	63,800	63,800	63,800	0	63,800	63,800	63,800	0
AST - Repair and Modernization of the 12-Foot Pressure Wind Tunnel (ARC)	36,500	36,500	36,500	36,500	0	36,500	36,500	36,500	0
AST - Rehabilitation and Modifications to 10x10 Supersonic Wind Tunnel (LaRC)	14,500	14,500	14,500	14,500	0	14,500	14,500	14,500	0
AST - Refurbishment of Hypersonic Facilities Complex (LaRC)	12,800	12,800	12,800	12,800	0	12,800	12,800	12,800	0
254 Lewis Research Center	6,100	6,100	6,100	6,100	0	6,100	6,100	6,100	0
AST - Refurbishment of Electric Power Laboratory	6,100	6,100	6,100	6,100	0	6,100	6,100	6,100	0
255 Mgt - Repair of Facilities	27,000	27,000	27,000	27,000	0	27,000	27,000	27,000	0
255 Mgt - Rehabilitation and Modification of Facilities	34,000	34,000	34,000	34,000	0	34,000	34,000	34,000	0
255 Mgt - Minor Construction and Additions to Facilities	9,000	9,000	9,000	9,000	0	9,000	9,000	9,000	0

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255 Mgt - Facility Planning and Design	20,000	20,000	20,000	20,000	0	20,000	20,000	20,000	0
255 Environmental Compliance and Restoration Program	26,000	26,000	26,000	26,000	0	26,000	26,000	26,000	0
General Reduction	---	---	-10,000	-7,000	-7,000	-14,100	-14,100	---	0
General Increase	---	---	---	---	---	---	---	32,900	32,900
Transfer From SFC&DC	---	---	---	---	---	27,000	27,000	---	0
Transfer To Trust Fund	---	---	---	---	---	---	---	-15,000	-15,000
Research and Program Management	1,915,000	1,915,000	1,888,000	1,915,000	0	1,855,000	1,870,000	1,855,000	-60,000
By Installation :									
Johnson Space Center	301,526	301,526	301,526	301,526	0	301,526	301,526	301,526	0
Kennedy Space Center	270,475	270,475	270,475	270,475	0	270,475	270,475	270,475	0
Marshall Space Flight Center	249,104	249,104	249,104	249,104	0	249,104	249,104	249,104	0
Stennis Space Center	23,348	23,348	23,348	23,348	0	23,348	23,348	23,348	0
Goddard Space Flight Center	256,823	256,823	256,823	256,823	0	256,823	256,823	256,823	0
Ames Research Center	179,398	179,398	179,398	179,398	0	179,398	179,398	179,398	0
Langley Research Center	185,255	185,255	185,255	185,255	0	185,255	185,255	185,255	0
Lewis Research Center	191,453	191,453	191,453	191,453	0	191,453	191,453	191,453	0
Headquarters	248,171	248,171	248,171	248,171	0	248,171	248,171	248,171	0
Inspector General	9,447	9,447	9,447	9,447	0	9,447	9,447	9,447	0
General Reduction	---	---	-35,000	---	---	-60,000	-45,000	-60,000	-60,000

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By Function									
Personnel and Related Costs	1,131,008	1,131,008	1,131,008	1,131,008	0	1,111,008	1,131,008	1,111,008	-20,000
Travel	51,000	51,000	51,000	51,000	0	51,000	51,000	51,000	0
Facilities Services	302,588	302,588	302,588	302,588	0	302,588	302,588	302,588	0
Technical Services	183,958	183,958	183,958	183,958	0	183,958	183,958	183,958	0
Management and Operations Support	246,446	246,446	246,446	246,446	0	246,446	246,446	246,446	0
General Reduction			-35,000			-40,000	-45,000	-40,000	-40,000
Science, Space, And Technology									
Education Trust Fund	---	---	---	---	---	---	---	15,000	15,000
TOTAL NASA	11,488,000	11,488,000	11,104,500	11,213,400	-274,600	10,706,000	10,145,100	10,701,000	-787,000

100TH CONGRESS | HOUSE OF REPRESENTATIVES | REPORT
2d Session | | 100-650

MULTIYEAR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT

MAY 24, 1988.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. ROE, from the Committee on Science, Space, and Technology, submitted the following

REPORT

together with

SUPPLEMENTAL VIEWS

[To accompany H.R. 4561]

[Including cost estimate of the Congressional Budget Office]

The Committee on Science, Space, and Technology, to whom was referred the bill (H.R. 4561) to authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes, having considered the same, reports favorably thereon with an amendment and recommend that the bill as amended do pass.

The amendment strikes out all after the enacting clause of the bill and inserts a new text which appears in italic type in the reported bill.

CONTENTS

That this Act may be cited as the "Multiyear National Aeronautics and Space Administration Authorization Act".

TITLE I—NATIONAL AERONAUTICS AND SPACE CAPITAL DEVELOPMENT PROGRAM

FINDINGS

SEC. 101. Congress finds that—

(1) the Administrator of the National Aeronautics and Space Administration (hereafter in this Act referred to as the "Administrator") shall construct a space station, hereafter referred to as the United States International Space Station in order to establish a permanent presence for man in space for the following purposes—

(A) the conduct of scientific experiments, applications experiments, and engineering experiments;

(B) the servicing, rehabilitation, and construction of satellites and space vehicles;

(C) the development and demonstration of commercial products and processes; and

(D) the establishment of a space base for other civilian and commercial space activities including an outpost for further exploration of the solar system;

(2) the Administrator should undertake a program of launching on expendable launch vehicles those payloads that do not require the presence of man;

(3) the Administrator should establish a program of space shuttle launches in order to fulfill the Nation's needs for manned access to space;

(4) preeminence in space and aeronautics is key to the national security and economic well being of the United States;

(5) United States space policy needs long-range goals and direction in order to provide understanding for near-term space projects and programs;

(6) human settlement of space is fully consistent with the policies and objectives of the Nation's space program as articulated in the National Aeronautics and Space Act of 1958.

(7) over the next five years the Administrator should pursue leadership in science through an aggressive set of major and moderate missions while maintaining a robust series of cost effective missions that can provide frequent flight opportunities to the scientific community;

(8) over the next five years the Administrator should prepare for the transition to the United States International Space Station of those science and technology programs that can be most efficiently and effectively conducted on that facility;

(9) the Administrator should encourage the United States private sector investment in space and, to the maximum extent practicable provide frequent flight opportunities for the development of technologies, processes and products that benefit from the space environment;

(10) the Administrator should enhance the existing space transportation capability through a robust mixed fleet of manned and unmanned vehicles in order to increase the reliability, productivity, and efficiency and reduce the cost of the Nation's access to space;

(11) the United States faces an increasingly successful foreign challenge to its traditional preeminent position in aeronautics which is rapidly reducing its lead in both civil and military aircraft; and

(12) the Administrator should seek ways and means of developing NASA's personnel as an integral component and resource for the Nation's space program.

POLICY

SEC. 102. The aeronautical and space activities of the United States shall be conducted so as to contribute materially to the following:

(1) The establishment of a permanently manned presence in space, leading ultimately to space settlements.

(2) The United States civil space activities shall contribute significantly to enhancing the Nation's science, technology, economy, pride, sense of wellbeing, and direction, as well as United States world prestige and leadership. Civil sector activities shall comprise a balanced strategy of research, development, operations, and technology for science, exploration, and appropriate applications.

(3) Assured access to space, sufficient to achieve all United States space goals, is an essential element of United States space policy. United States space transportation systems must provide a balanced, robust, and flexible capability with sufficient resiliency to allow continued operation despite failures in any single system.

(4) The goals of United States space transportation policy are—

(A) to achieve and maintain safe and reliable access to, transportation in, and return from, space;

(B) to exploit the unique attributes of manned and unmanned launch and recovery systems;

(C) to encourage, to the maximum extent feasible, the development and use of United States private sector space transportation capabilities without direct Federal subsidy; and

(D) to reduce the costs of space transportation and related services.

(5) Communications advancements are critical to all United States space activities. To ensure that necessary capabilities exist the National Aeronautics and Space Administration shall continue research and development efforts for future advances in space communications technologies.

(6) The goal of aeronautical research and technology development and validation activities shall be to contribute to a national technology base that will—

(A) enhance United States preeminence in civil and military aviation; and

(B) improve the safety and efficiency of the United States air transportation system.

(7) Aeronautical research and technology development and validation activities shall—

(A) emphasize emerging technologies with potential for breakthrough advances;

(B) consist of—

(i) fundamental research in all aeronautical disciplines, aimed at greater understanding of aeronautical phenomena and development of new aeronautical concepts; and

(ii) technology development and validation activities aimed at laboratory-scale development and proof-of-concept demonstration of selected concepts with high payoff potential;

(C) assure maintenance of robust aeronautical laboratories, including a first-rate technical staff and modern national facilities for the conduct of research and testing activities;

(D) be conducted with the close, active participation of the United States aircraft industry so as to accelerate the transfer of research results to aviation products;

(E) include providing technical assistance and facility support to other government agencies and United States industry;

(F) include conducting joint projects with other government agencies where such projects contribute materially to the goal set forth in subsection (b);

(G) assure strong participation of United States universities both in carrying out aeronautical research and training future aeronautical research personnel; and

(H) be conducted, where practical, so that United States industry receives research results before foreign competitors.

SCIENCE AND APPLICATIONS 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 103. (a) For fiscal years 1989 through 1993, the Administrator shall in no case request less than 20 percent of the total NASA budget for science and applications activities.

(b) For fiscal years 1989 through 1993, the Administrator shall, consistent with funding available under subsection (a), start the development of major missions in the following order of priority:

(1) Advanced X-Ray Astrophysics Facility.

(2) Comet Rendezvous/Asteroid Flyby in combination with the Cassini mission to Jupiter.

(3) The Earth Observing System to be accomplished on the United States International Space Station polar orbiting platform.

(4) The Space Infrared Telescope Facility.

(5) The Solar Probe.

(c) For fiscal years 1989 through 1993, the Administrator shall, after undertaking missions under subsection (b) to the extent funding is available under subsection (a), initiate development activities for missions in the following order of priority:

(1) High Resolution Solar Observatory.

(2) Gravity Probe-B.

(d) For fiscal years 1989 through 1993, the Administrator shall establish budget line items for the following:

(1) Planetary Observers.

(2) Physics and Astronomy Explorers.

(3) Earth observing probes.

(4) Life science satellites.

(e) Before December 31, 1992, the Administrator shall establish a program of focused Earth studies hereafter referred to as "Mission to Planet Earth", utilizing space borne satellites directed at establishing a comprehensive understanding of the biogeochemical processes which influence global change.

SPACE RESEARCH AND TECHNOLOGY 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 104. (a) The Administrator shall, before October 1, 1992, increase the request for the space research and technology program, including basic research, technology validation and demonstration activities, to at least 10 percent of the total NASA budget.

(b) The Administrator shall, in fiscal years 1989 through 1993—

(1) Maintain a vigorous research and technology Base program to provide the innovative research for future NASA and other civil space missions. This includes fundamental research to explore opportunities for application of emerging technologies and applied research to formulate future focused technology programs, such as those described below.

(2) Conduct a focused program in civil space technology, hereafter referred to as the "Civil Space Technology Initiative" aimed at fulfilling the critical technology gaps for Earth-to-Orbit Transportation, Earth-orbiting operations, and conduct of science missions.

(3) Initiate development of Pathfinder, a focused program to develop the emerging, innovative technologies that will enable extended manned and unmanned missions beyond Earth orbit into the solar system. This initiative should focus on critical technologies needed for exploration of, operations in, transportation to and transfer vehicles for, and support for human presence during missions to the Moon, Mars, and other planets in the solar system.

(4) Initiative development of a focused effort of in-space experimentation to verify and validate advanced space technologies in space on the Space Shuttle, expendable launch vehicles, and the Space Station, with an emphasis on those techologies to be utilized in the development of future spacecraft and in the conduct of future space missions.

(5) Develop and validate the key technologies that will enable space-based platforms and low-cost expendable satellites to monitor global change. This technology program will complement the science program defined as Mission to Planet Earth.

(6) Initiate a program directed at developing a new generation of inherently reliable and cost-effective technologies to enable long-term and sustainable access to and operations in space to serve the needs of NASA, industry, and other space users. This will include new technologies and components, such as those required to support the development of expendable launch vehicles.

(7) Ensure that the external community contributes to and benefits from NASA's technology development role by increasing cooperative programs with industry, universities, and other civil agencies, specifically by—

(A) expanding and enhancing programs with the university community, such as establishing additional University Space Engineering Research Centers as required each year to maintain a level of 20 centers and also maintaining other programs with the goal to encouraging strong NASA-university partnerships; and

(B) increasing cooperative programs with industry to maximize the commercial use of space by providing access to NASA's ground and in-space facilities for technology experiments.

SPACE EXPLORATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 105. (a) The Congress declares that the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements, will fulfill the purposes of advancing science, exploration, and development and will enhance the general welfare.

(b) In pursuit of the establishment of an International Space Year in 1992 pursuant to Public Law 99-170, the United States shall exercise leadership and mobilize the international community in furtherance of increasing mankind's knowledge and exploration of the solar system.

(c) The Congress hereby declares that the United States shall prepare for and carry out an International Manned Mission to Mars as a major goal for the United States space program, and shall seek the participation of the Soviet Union and any other interested nations in the conduct of an International Manned Mission to Mars.

(d) For fiscal years 1989 through 1992, the Administrator shall maintain a vigorous program of mission development studies for the human exploration of the solar system which shall identify critical technologies needed to expand man's presence in the solar system.

(e) Before December 31, 1992, the Administrator shall initiate development of a focused program of human exploration of the solar system directed toward a manned mission to Mars.

(f) The Administrator may plan for the conduct of activities on the Moon that are necessary to accomplish a manned mission to Mars, including the establishment of a Lunar Outpost.

(g) Once every 2 years after the date of the enactment of this Act, the National Aeronautics and Space Administration shall submit a report to the President and to the Congress which—

(1) provides a review of all activities undertaken under this section including an analysis of the focused research and development activities on the Space Station, Moon, and other outposts that are necessary to accomplish a manned mission to Mars;

(2) analyzes ways in which current science and technology can be applied in the establishment of space settlements;

(3) identifies scientific and technological capacity for establishing space settlements, including a description of what steps must be taken to develop such capacity;

(4) examines alternative space settlement locations and architectures;

(5) examines the status of technologies necessary for extraterrestrial resource development and use and energy production;

(6) reviews the ways in which the existence of space settlements would enhance science, exploration, and development;

(7) reviews mechanisms and institutional options which could foster a broad-based plan for international cooperation in establishing space settlements;

(8) analyzes the economics of financing space settlements, especially with respect to private sector and international participation;

(9) discusses sociological factors involved in space settlement such as psychology, political science, and legal issues; and

(10) addresses such other topics as the National Aeronautics and Space Administration considers appropriate.

SPACE TRANSPORTATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 106. (a) In order to enhance the safety and efficiency of the space shuttle and to reduce its cost of operation, the Administrator shall undertake a focused program to—

(1) reduce manpower intensive operations;

(2) reduce flight preparation time and turnaround time; and

(3) increase system reliability.

(b)(1) It is the sense of the Congress that the United States will require the services of a heavy-lift launch vehicle during the decade of the 1990s.

(2) The Administrator shall complete system definition studies for a Shuttle derived heavy-lift launch vehicle.

(3) The Administrator shall submit a report outlining the optimum configuration, performance, development and operations costs, and mission scenario for the Shuttle derived heavy-lift vehicle by September 30, 1989.

(4) The Administrator, in cooperation with other appropriate Federal agencies, shall, consistent with the requirements of this title, initiate before December 31, 1993, the development of a heavy-lift expendable launch vehicle, considering all technical options and architectures.

(c) The Administrator shall initiate concept studies for advanced space transfer and support vehicles in fiscal year 1990.

(d) The Administrator shall initiate and implement a plan to manifest on expendable launch vehicles all missions that do not require the presence of man.

(e) The Administrator shall initiate an active research program to develop new technologies and components that will be required to support the development of expendable launch vehicles.

COMMERCIAL USE OF SPACE 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 107. The Administrator shall undertake vigorous activities to maximize the commercial use of space with a goal of establishing a leadership role for the United States in the commercialization of space as follows:

(1) The Administrator shall promote Joint Endeavor Agreements and ensure the availability of flight opportunities for commercial users seeking to conduct research in space pursuant to the following goals:

(A) For fiscal years 1989 through 1992, the Administrator shall set a goal of five new Joint Endeavor Agreement start approvals annually.

(B) Each experiment identified pursuant to a Joint Endeavor Agreement shall be provided a flight opportunity within 3 years after approval by the Administrator.

(C) Each experiment identified pursuant to a Joint Endeavor Agreement shall be provided sufficient flight opportunities on available carriers, to achieve the research and development and pilot program activities pursuant to the Joint Endeavor Agreement.

(2) The Administrator shall charge space shuttle launch prices for commercial and foreign users pursuant to title II of Public Law 99-170.

(b) The Administrator, in cooperation with other appropriate agencies, shall ensure that the civil space program is conducted in a manner that will facilitate the commercialization of activities in space, expand opportunities to realize the poten-

tial benefits offered by the development of space, and utilize the expertise and innovation of interested parties. This shall include but not be limited to:

(1) Establishing clear, consistent, and stable ground rules to provide the private sector with the confidence needed to make the necessary investments.

(2) Performing high-risk innovative research and development and turning over the results of that research and development to the private sector as quickly as possible.

(3) Avoiding duplicating those activities which can be performed by the private sector.

(4) Providing support on a reimbursable basis in those situations where the Government has unique capabilities, such as those derived from Government-owned facilities, and where those capabilities cannot reasonably be duplicated in a timely and affordable fashion, and providing that it is done in such a way as to not discourage the private sector development of that capability.

(5) Seeking creative means of encouraging and assisting entrepreneurs in contributing to the development of space in such a way that it does not lead to a permanent reliance on Government assistance.

AERONAUTICAL RESEARCH AND TECHNOLOGY DEVELOPMENT AND VALIDATION 5-YEAR CAPITAL PROGRAM

SEC. 108. (a) The Administrator shall, before October 1, 1992, increase the request for aeronautical research and technology development and validation activities to 15 percent of the total NASA budget.

(b) The Administrator shall, in fiscal years 1989 through 1993—

(1) conduct fundamental research in aeronautical disciplines including aerodynamics, propulsion, materials, structures, controls, guidance, human factors, information sciences, flight systems, and aeronautical systems studies;

(2) conduct technology development and validation activities aimed at improving the performance, safety, usefulness, and cost of transport aircraft, rotorcraft, high-performance aircraft, and general aviation aircraft;

(3) in cooperation with the Department of Defense, conduct a technology maturation program and initiate a flight demonstration program to prove the feasibility of an air-breathing, hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere; and

(4) maintain and enhance a complement of national aeronautical facilities, including wind tunnels, simulators, computational facilities, and research test-bed aircraft.

(c) The Administrator shall, before October 1, 1992, increase the number of full-time civil service personnel engaged in aeronautical research and technology development and validation activities by 50 percent above the number engaged in such activities in fiscal year 1989.

TECHNOLOGY UTILIZATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 109. (a) The Congress finds that technological spinoffs from the National Aeronautics and Space Program are an important national asset contributing to American scientific, economic, and technological growth through the development of new products and processes.

(b) The Administrator shall encourage and facilitate, to the maximum extent possible, the practical application of new technologies developed in the course of activities of the National Aeronautics and Space Administration.

(c) The Administrator shall seek to expand the Industrial Application Center network system in order to develop greater linkages among government, academic, and private sector research and engineering efforts.

(d) The Administrator shall contract for implementation of the Industrial Applications Center located in Oklahoma through the National Aeronautics and Space Administration's Rural Technology Applications Team.

FEDERAL FACILITIES 5-YEAR CAPITAL DEVELOPMENT PROGRAM

SEC. 110. (a) For fiscal years 1989 through 1993 the Administrator shall develop a plan for the construction of facilities needed to maintain the Nation's ability to conduct programs at the forefront of aeronautical and space research and technology development and shall submit such plan with each annual budgetary request.

(b) Planning under subsection (a) shall be undertaken to the maximum extent practicable in coordination with the Department of Defense.

REPORT ON CAPITAL DEVELOPMENT

SEC. 111. In order to carry out the provisions of this title the Administrator shall, by January 15, 1989, submit to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a 5-year capital development plan including, but not limited to the following:

(1) Economic assumptions and budgetary requirements for fulfilling the objectives of this title.

(2) Estimates of national launch capacity and any potential shortfalls in such capacity that may affect the execution of this title.

(3) Estimates of total expenditures needed to maintain the operation of the national launch systems, related tracking and data services, civil service requirements, and all other current services.

(4) Estimates of total projected investments in space hardware, facilities, and other capital improvements needed to fulfill the objectives of this title.

TITLE II—3-YEAR AUTHORIZATION

3-YEAR AUTHORIZATION

SEC. 201. (a) There is hereby authorized to be appropriated to the National Aeronautics and Space Administration:

(1) For "Research and development" for the following programs:

(A) United States International Space Station, $967,400,000 for fiscal year 1989, $2,130,200,000 for fiscal year 1990, and $2,912,500,000 for fiscal year 1991; provided that the aggregate of authorizations for achieving initial operating capability shall not exceed $24,200,000,000.

(B) Space transportation capability development, $631,100,000 for fiscal year 1989, $775,000,000 for fiscal year 1990, and $885,000,000 for fiscal year 1991.

(C) Space science and applications, $1,859,600,000 for fiscal year 1989, $2,189,000,000 for fiscal year 1990, and $2,400,000,000 for fiscal year 1991.

(D) Commercial programs, $57,900,000 for fiscal year 1989, $62,000,000 for fiscal year 1990, and $74,000,000 for fiscal year 1991.

(E) Aeronautical research and technology, $414,200,000 for fiscal year 1989, $609,500,000 for fiscal year 1990, and $764,900,000 for fiscal year 1991.

(F) Transatmospheric research and technology, $84,400,000 for fiscal year 1989, $149,400,000 for fiscal year 1990, and $99,300,000 for fiscal year 1991.

(G) Space research and technology, $390,900,000 for fiscal year 1989, $520,000,000 for fiscal year 1990, and $637,000,000 for fiscal year 1991.

(H) Safety, reliability and quality assurance, $22,400,000 for fiscal year 1989, $23,000,000 for fiscal year 1990, and $24,000,000 for fiscal year 1991.

(I) Tracking and data advanced systems, $18,800,000 for fiscal year 1989, $20,000,000 for fiscal year 1990, and $21,000,000 for fiscal year 1991.

(2) For "Space flight, control and data communications" for the following programs:

(A) Space shuttle production and operational capability, $1,400,500,000 for fiscal year 1989, $1,468,000,000 for fiscal year 1990, and $1,571,000,000 for fiscal year 1991.

(B) Space transportation operations, $2,405,400,000 for fiscal year 1989, $2,721,000,000 for fiscal year 1990, and $2,522,000,000 for fiscal year 1991.

(C) Space and ground network, communications and data systems, $1,035,300,000 for fiscal year 1989, $1,190,000,000 for fiscal year 1990, and $1,168,000,000 for fiscal year 1991.

(3) For "Construction of facilities" including land acquisition, as follows:

(A) Construction of Processing Facility for the United States International Space Station, Kennedy Space Center, $15,000,000 for fiscal year 1989.

(B) Modifications to Processing Technology Facility for United States International Space Station, Marshall Space Flight Center, $3,700,000 for fiscal year 1989.

(C) Construction of Addition for Space Systems Automated Integration and Assembly Facility, Johnson Space Center, $9,200,000 for fiscal year 1989.

(D) Replacement of High Pressure Gas Storage Vessels, National Space Technology Laboratory, $3,500,000 for fiscal year 1989.

(E) Increase Chiller Capacity, LC-39 Utility Annex, Kennedy Space Center, $2,300,000 for fiscal year 1989.

(F) Rehabilitation of PAD A, Launch Complex 39, Kennedy Space Center, $4,600,000 for fiscal year 1989.

(G) Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility, Johnson Space Center, $4,900,000 for fiscal year 1989.

(H) Modification for Advanced Engine Development, Test Stand 116, Marshall Space Flight Center, $13,500,000 for fiscal year 1989.

(I) Modifications to Orbiter Modification and Refurbishment Facility (OMRF) for Safing and Deservicing, Kennedy Space Center, $2,800,000 for fiscal year 1989.

(J) Modification to the X-Ray Calibration Facility (XRCF), Marshall Space Flight Center, $11,400,000 for fiscal year 1989.

(K) Construction of Auxiliary Chiller Facility, Johnson Space Center, $7,800,000 for fiscal year 1989.

(L) Modernization of Space Environment Simulator, Goddard Space Flight Center, $2,800,000 for fiscal year 1989.

(M) Modifications for Utility Reliability, Goddard Space Flight Center, $3,100,000 for fiscal year 1989.

(N) Refurbishment of 25-Foot Space Simulator, Jet Propulsion Laboratory, $12,000,000 for fiscal year 1989.

(O) Repair and Modifications of 12-Foot Pressure Wind Tunnel, Ames Research Center, $36,500,000 for fiscal year 1989.

(P) Rehabilitation and Modifications to 1010 Supersonic Wind Tunnel, Lewis Research Center, $14,500,000 for fiscal year 1989.

(Q) Refurbishment to Hypersonic Facilities Complex, Langley Research Center, $12,800,000 for fiscal year 1989.

(R) Refurbishment of Electric Power Laboratory, Lewis Research Center, $6,100,000 for fiscal year 1989.

(S) Construction of National Resource Protection at various locations, $2,600,000 for fiscal year 1989.

(T) Repair of facilities at various locations, not in excess of $750,000 per project, $27,000,000 for fiscal year 1989.

(U) Rehabilitation and modification of facilities at various locations, not in excess of $750,000 per project, $34,000,000 for fiscal year 1989.

(V) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project, $9,000,000 for fiscal year 1989.

(W) Environmental compliance and restoration, $26,000,000 for fiscal year 1989.

(X) Facility planning and design not otherwise provided for, $20,000,000 for fiscal year 1989.

(Y) Of the amounts authorized pursuant to subparagraphs (T) through (X), the Administrator may obligate up to $5,600,000 in order to expand the Launch Complex-39 Operation Support Building at the Kennedy Space Center.

(Z) The Administrator shall request authorization for additional construction of facilities not to exceed $341,100,000 for fiscal year 1990 and $401,100,000 for fiscal year 1991.

(4) For "Research and program management" $1,915,000,000 for fiscal year 1989, $2,115,100,000 for fiscal year 1990, and $2,234,000,000 for fiscal year 1991.

(b) Of the funds authorized to be appropriated under this title for fiscal year 1989, $89,000,000 is authorized to be transferred for funding the Advanced Communications Technology Satellite program, except that not more than 20 percent of the funds so transferred may be from amounts authorized for the programs of the Office of Space Science and Applications. There is authorized to be appropriated for such program for fiscal year 1990, $75,000,000, and for fiscal year 1991, $32,000,000.

(c) Appropriations hereby authorized for "Research and development" and "Space flight, control and data communications" may be used (1) for any items of a capital nature (other than acquisitions of land) which may be required at locations other than installations of the National Aeronautics and Space Administration for the performance of research and development contracts, and (2) for grants to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities; and title to such facilities shall be vested in the United States unless the Administrator determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Each such grant shall be made under such conditions as the Administrator shall determine to be required to ensure that the United States will receive therefrom benefit adequate to justify the making of that grant. None of the funds appropriated for "Research and development" and "Space flight, control and data communications" pursuant to this Act may be used in accordance with this subsection for the construction of any major facility, where the estimated cost, including collateral equipment, exceeds $500,000, unless the Administrator or the Administrator's designee has notified the Speaker of the House of Representatives and the President of the Senate and the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate of the nature, location, and estimated cost of such facility.

(d) When so specified and to the extent provided in an appropriation Act, (1) any amount appropriated for "Research and development" for "Space flight, control and data communications" or for "Construction of facilities" may remain available without fiscal year limitation, and (2) maintenance and operation of facilities, and support services contracts may be entered into under the "Research and program management" appropriation for periods not in excess of twelve months beginning at any time during the fiscal year.

(e) Appropriations made pursuant to subsection (a)(4) may be used, but not to exceed $35,000, for scientific consultation or extraordinary expenses upon the approval or authority of the Administrator, and his determination shall be final and conclusive upon the accounting officers of the Government.

(f)(1) Funds appropriated pursuant to subsection (a) (1), (2), and (4) may be used for the construction of new facilities and additions to, repair, rehabilitation, or modification of existing facilities, provided the cost of each such project, including collateral equipment, does not exceed $100,000.

(2) Funds appropriated pursuant to subsection (a) (1) and (2) may be used for unforeseen programmatic facility project needs, provided the cost of each such project, including collateral equipment, does not exceed $500,000.

(3) Funds appropriated pursuant to subsection (a)(4) may be used for such work on facilities controlled by the General Services Administration, provided the cost of each such project, including collateral equipment, does not exceed $500,000.

CONSTRUCTION OF FACILITIES REPROGRAMMING

SEC. 202. Authorization is hereby granted whereby any of the amounts prescribed in section 201(a)(3) (A) through (Y)—

(1) may be varied upward 10 percent, in the discretion of the Administrator or the Administrator's designee, or

(2) following a report by the Administrator or the Administrator's designee to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate on the circumstances of such, may be varied upward 25 percent to meet unusual cost variations.

The total cost of all work authorized under paragraphs (1) and (2) shall not exceed the total of the amounts specified in section 201(a)(3) (A) through (Y).

SPECIAL REPROGRAMMING AUTHORITY FOR CONSTRUCTION OF FACILITIES

SEC. 203. Where the Administrator determines that new developments or scientific or engineering changes in the national program of aeronautical and space activities have occurred; and that such changes require the use of additional funds for the purposes of construction, expansion, or modification of facilities at any location; and that deferral of such action until the enactment of the next authorization Act would be inconsistent with the interest of the Nation in aeronautical and space activities; the Administrator may transfer not to exceed ⅛ of 1 percent of the funds appropriated pursuant to section 201(a) (1) or (2) to the "Construction of facilities" appropriation for such purposes. The Administrator may also use up to $10,000,000 of the amounts authorized under section 201(a)(3) for such purposes. The funds so made available pursuant to this section may be expended to acquire, construct, convert, rehabilitate, or install permanent or temporary public works, including land acquisition, site preparation, appurtenances, utilities, and equipment. No such funds may be obligated until a period of 30 days has passed after the Administrator or the Administrator's designee has transmitted to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a written report describing the nature of the construction, its cost, and the reasons therefor.

LIMITATIONS ON AUTHORITY

SEC. 204. Notwithstanding any other provision of this Act—

(1) no amount appropriated pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House Committee on Science, Space, and Technology or the Senate Committee on Commerce, Science, and Transportation;

(2) no amount appropriated pursuant to this Act may be used for any program in excess of the amount actually authorized for that particular program by section 201(a) (1), (2), and (4); and

(3) no amount appropriated pursuant to this Act may be used for any program which has not been presented to either such committee,

unless a period of thirty days has passed after the receipt by the Speaker of the House of Representatives and the President of the Senate and each such committee, of notice given by the Administrator or his designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such proposed action.

GEOGRAPHICAL DISTRIBUTION OF RESEARCH FUNDS

SEC. 205. It is the sense of the Congress that it is in the national interest that consideration be given to the widest geographical distribution of Federal research funds whenever feasible, and that the National Aeronautics and Space Administration should explore ways and means of distributing its research and development funds whenever feasible.

ARREST AUTHORITY

SEC. 206. Section 304 of the National Aeronautics and Space Act of 1958 is amended by adding at the end the following new subsection:

"(f) Under regulations to be prescribed by the Administrator and approved by the Attorney General of the United States, those employees of the Administration and of its contractors and subcontractors authorized to carry firearms under subsection (a) may arrest without warrant for any offense against the United States committed in their presence, or for any felony cognizable under the laws of the United States if they have reasonable grounds to believe that the person to be arrested has committed or is committing such felony. Persons granted authority to make arrests by this subsection may exercise that authority only while guarding and protecting property owned or leased by, or under the control of, the United States under the administration and control of the Administration or one of its contractors or subcontractors, at facilities owned by or contracted to the Administration.".

NATIONAL MARS COMMISSION

SEC. 207. (a) There is established a commission to be known as the "National Mars Commission" (hereafter in this section referred to as the "Commission").

(b) The purpose of the Commission is—

(1) to prepare a strategy for cooperation among the Soviet Union and any other interested nations and the United States on unmanned Mars projects by such nations in anticipation of a cooperative manned mission;

(2) to assess the implications of such cooperation, and to devise strategies for such cooperation, including the prevention of unwanted transfer of technology; and

(3) to prepare a detailed proposal for a cooperative manned Mars mission with the Soviet Union and any other interested nations.

(c) The Commission shall be composed of twelve members, appointed from among experts in space policy or space science, as follows:

(1) Four members shall be appointed by the President, one of whom shall be named Chairman by the President.

(2) Four members shall be appointed by the Speaker of the House of Representatives, of which one shall be the Chairman of the Committee on Science, Space, and Technology of the House of Representatives.

(3) Four members shall be appointed by the President Pro Tempore of the Senate, of which one shall be the Chairman of the Committee on Commerce, Science, and Transportation of the Senate.

A vacancy in the Commission shall be filled in the manner in which the original appointment was made.

(d)(1) Except as provided in paragraphs (2) and (3), members shall be appointed for terms of two years.

(2) Of the members first appointed—

(A) two of the members appointed under subsection (c)(1), not including the member who is named Chairman, shall be appointed for terms of one year;

(B) two of the members appointed under subsection (c)(2) shall be appointed for a term of one year; and

(C) two of the members appointed under subsection (c)(3) shall be appointed for a term of one year.

(3) Any member appointed to fill a vacancy occurring before the expiration of the term for which his predecessor was appointed shall be appointed only for the remainder of such term. A member may serve after the expiration of his term until his successor has taken office.

(e) Members of the Commission shall serve without pay.

(f) The Commission shall, without regard to section 5311(b) of title 5, United States Code, have a Director who shall be appointed by the Commission and who shall be paid at the rate of basic pay payable for GS-15 of the General Schedule.

(g) Subject to subsection (h) and such rules as may be prescribed by the Commission, without regard to section 5311(b) of title 5, United States Code, the Commission may appoint and fix the pay of such additional personnel as the Commission considers appropriate.

(h) The staff of the Commission shall be appointed subject to the provisions of title 5, United States Code, governing appointments in the competitive service, and shall be paid in accordance with the provisions of chapter 51 and subchapter III of chapter 53 of such title relating to classification and General Schedule pay rates.

(i) Subject to such rules as may be prescribed by the Commission, the Commission may procure temporary and intermittent services under section 3109(b) of title 5 of the United States Code.

(j) Upon request of the Commission, the head of any Federal agency is authorized to detail, on a reimbursable basis, any of the personnel of such agency to the Commission to assist the Commission in carrying out its duties under this Act.

(k) The Commission may, for the purpose of carrying out this section, hold such hearings, sit and act at such times and places, take such testimony, and receive such evidence, as the Commission considers appropriate.

(l) Any member or agent of the Commission may, if so authorized by the Commission, take any action which the Commission is authorized to take by subsection (k), (m), (n), (o), or (p).

(m) The Commission may secure directly from any department or agency of the United States information necessary to enable it to carry out this section. Upon request of the Chairman of the Commission, the head of such department or agency shall furnish such information to the Commission.

(n) The Commission may accept, use, and dispose of gifts or donations of services or property.

(o) The Commission may use the United States mails in the same manner and under the same conditions as other departments and agencies of the United States.

(p) The Administrator of General Services shall provide to the Commission on a reimbursable basis such administrative support services as the Commission may request.

(q) The Commission shall, within six months after the date of the enactment of this Act, prepare and submit to the President and the Congress a report—

(1) outlining a preliminary strategy for cooperation among the Soviet Union and any other interested nations and the United States with respect to unmanned Mars projects of such nations and a cooperative manned mission to Mars; and

(2) including an initial proposal for a cooperative manned mission among the cooperating nations, in coordination with the preliminary strategy referred to in paragraph (1).

(r) At any time between the submission of a report under subsection (q) and the submission of a report under subsection (s), the Commission shall revise the report submitted under subsection (q) as necessary to reflect new information obtained or strategies developed.

(s) The Commission shall prepare and submit to the President and the Congress a final proposal for a joint manned Mars mission by the Soviet Union, any other interested nations, and the United States.

(t) All activities authorized for the Commission under this section are subject to the advance availability of appropriations.

(u) The Commission shall cease to exist thirty days after submitting its final report pursuant to subsection (s), unless the President or the Congress have requested further revisions to the report.

MICROGRAVITY RESEARCH SPACE FACILITY

SEC. 208. (a) The Administrator may issue a request for proposals to acquire only by means of a competitive procurement a commercially developed microgravity research space facility to be placed in orbit no later than the end of fiscal year 1993, to be used for (1) the development of Space Station technologies; (2) commercial activities that uniquely benefit from the facility; and (3) scientific investigations that uniquely benefit from such facility. Such request for proposals shall provide options for the Government to lease, lease/purchase, or purchase such facility or consider any other innovative financing arrangement that will enhance the commercialization of space.

(b) For the purposes of this section, the procurement authorized under subsection (a) shall only be considered competitive if no less than two good-faith proposals are received by the Administrator in response to the request for proposals authorized under subsection (a).

(c) No later than the date upon which the President submits the budget request for the National Aeronautics and Space Administration for fiscal year 1990, the Administrator shall submit to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a final selection; proposed terms and conditions for a lease, lease/purchase, purchase, or other innovative financing arrangement; an accompanying authorization request for funding such arrangement on an annual and multiyear basis; and a request for authorization for and projected schedule of termination liability, if any.

(d) The Administrator shall keep the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate fully and currently informed of activities conducted pursuant to this section, while maintaining the confidential nature of the procurement process, including—

(1) providing the source list to whom the request for proposal was mailed the day after release;

(2) providing the number of proposers on the day following the close of the proposal period;

(3) within a week following receipt of proposals, providing the number of proposals considered to be acceptable for evaluation;

(4) within 30 days following the close of the proposal period, identifying the number of proposals that are competitive and have a reasonable chance of selection; and

(5) identifying the proposer(s) selected for negotiation.

(e) No contract for the acquisition of a commercially developed microgravity research space facility shall be signed by the Administrator without the express authorization of the Congress. This Act does not authorize the Administrator to enter into any contract or expend any funds for the acquisition of a commercially developed space facility.

(f) The Administrator shall certify, at the time of the submission of information required pursuant to subsection (c), that any request for authorization for a commercially developed microgravity research space facility would entail a request for new budget authority and would not impact in any way current or future policies or funding for any other authorized program of the National Aeronautics and Space Administration.

(g) If the Administrator cannot make the certification described in subsection (f), the Administrator shall report to the Congress what impacts, if any, in his opinion such acquisition of a commercially developed microgravity research space facility would have on current or future policies or funding for the United States International Space Station or other authorized programs of the National Aeronautics and Space Administration.

(h) Facilities available for scientific and commercial in-flight use and experimentation shall be maintained and utilized by the Administrator on a nondiscriminatory basis.

(i) Nothing in this section shall affect the ability of the Administrator to encourage and facilitate the use of commercially provided hardware or services, or otherwise negotiate arrangements or innovative financing with commercial users or providers consistent with public law.

STUDIES ON MICROGRAVITY RESEARCH CAPABILITY

SEC. 209. (a) The Administrator shall contract with the National Academy of Sciences to undertake a review of the Nation's microgravity research capability and issue a report addressing—

(1) the scientific and commercial value to the Nation of achieving a man-tended capability through a Commercially Developed Space Facility (CDSF) prior to man-tended operations of the space station;

(2) the technical characteristics of a CDSF that would enable its optimum use;

(3) the anticipated microgravity research and manufacturing requirements of commercial users and the Government;

(4) the extent to which existing and proposed facilities could support these requirements;

(5) the likelihood that a CDSF would become commercially self-sustaining an estimate of when that could occur;

(6) the state of space automation technology and its relevance to the capabilities required for a CDSF;

(7) how a decision by the Government to lease facilities on a CDSF might affect the viability of other proposed commercial microgravity research facilities; and

(8) the effect a commitment to the CDSF would have on the current space transportation system launch schedule.

(b) The Administrator shall contract with the National Academy of Public Administration to—

(1) estimate the developmental, operational, and other costs to the Government associated with a CDSF;

(2) consider the practicability of various financial options by which the Government could participate in a CDSF, including leasing, lease-purchase, and purchase;

(3) consider, as regards the lease option, instead of providing for a flat level of lease obligations, the practicability of reducing on a yearly basis the level of Government lease operations during the years of operation of a CDSF; and

(4) consider, as regards the lease option, the practicability of making the minimum levels of Government lease obligations in the years of operation of a CDSF contingent on the attainment, by the CDSF operator, of certain minimum levels of irrevocable contract commitments with entities other than the United States Government.

(c) Based on the above reports, the Administrator shall provide a report to the House Committee on Science, Space, and Technology and the Senate Committee on Commerce, Science, and Transportation with policy options related to a CDSF and microgravity facilities, to be delivered no later than February 1, 1989.

EXTERNAL TANKS

SEC. 210. (a) The Administrator shall make available for 5 years after the date of the enactment of this Act expended external tanks of the Space Shuttle fleet at no cost, except as provided in subsection (d), to any feasible United States commercial and nonprofit endeavor for such uses as research, storage, and manufacturing in space.

(b) During the first 3 years, no less than 5 external tanks shall be made available to nonprofit institutions of higher education or to nonprofit organizations whose primary purpose is the conduct of scientific research for suborbital intertank experiments. The Administrator shall be prepared to enter into one or more agreements to this effect within 30 days after the date of the enactment of this Act.

(c) The availability of external tanks under this section shall be subject to the launch of a sufficient number of Space Shuttle missions, and to uses consistent with the safety of such missions.

(d) Any organization that enters into an agreement with the National Aeronautics and Space Administration for the experimental or operational use of an external tank shall reimburse the National Aeronautics and Space Administration for any direct costs that are incurred by the National Aeronautics and Space Administration in providing any necessary technical or other assistance, or in making any necessary modifications to the external tank.

MANUFACTURING TECHNOLOGY

SEC. 211. Section 102(d) of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451(c)) is amended—

(1) by striking "and" at the end of paragraph (7);

(2) by striking the period at the end of paragraph (8) and inserting in lieu thereof "; and"; and

(3) by adding at the end the following new paragraph:

"(9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.".

BUY AMERICAN

SEC. 212. (a) The Administrator shall award to a domestic firm a contract that, under the use of competitive procedures, would be awarded to a foreign firm, if—

(1) the final product of the domestic firm will be completely assembled in the United States;

(2) when completely assembled, not less than 50 percent of the final product of the domestic firm will be domestically produced; and

(3) the difference between the bids submitted by the foreign and domestic firms is not more than 6 percent.

(b) This section shall not apply to the extent to which—

(1) such applicability would not be in the public interest;

(2) compelling national security considerations require otherwise; or

(3) the United States Trade Representative determines that such an award would be in violation of the General Agreement on Tariffs and Trade or an international agreement to which the United States is a party.

(c) For purposes of this section—

(1) the term "domestic firm" means a business entity that is organized under the laws of the United States and that conducts business operations in the United States; and

(2) the term "foreign firm" means a business entity not described in paragraph (1).

(d) This section shall apply only to contracts for which—

(1) amounts are made available pursuant to this Act; and

(2) solicitations for bids are issued after the date of the enactment of this Act.

SPACE STATION STANDARDIZATION

SEC. 213. Within one year after the enactment of this Act, the Administrator shall report to Congress on the advisability of designing and constructing a docking mechanism using the metric system of measurement which is compatible with other space stations and space vehicles.

TITLE III—TEN YEAR STRATEGIC PLAN

AERONAUTICS AND SPACE STRATEGIC PLAN

SEC. 301. The Administrator shall undertake an aggressive and balanced program of science and applications including but not limited to—

(1) the robotic exploration of other solar system bodies;

(2) the study and observation of other celestial bodies and phenomena at spectral wave lengths and resolutions that will enhance our understanding of the universe;

(3) the enhanced study and monitoring of Earth as an interacting system;

(4) the development of a full understanding of the behavior of biological systems in the space environment; and

(5) the development of a full understanding of physics and chemistry of the macroscopic behavior of materials in the microgravity environment.

SPACE RESEARCH AND TECHNOLOGY STRATEGIC PLAN

SEC. 302. The Administrator shall undertake an aggressive and balanced program of space research and technology including but not limited to—

(1) fundamental and innovative research as the seedbed for enabling technologies for future civil space missions;

(2) focused technology programs keyed to long range, high priority civil space missions;

(3) technology research and demonstrations, extending laboratory activities from Earth to space-based facilities such as the Space Shuttle, Space Station, orbital platforms, and eventually the Moon and other planetary bodies; and

(4) cooperation with, and service to, other space program sectors with advanced technology and use of ground and space-based facilities.

SPACE EXPLORATION STRATEGIC PLAN

SEC. 303. The Administrator shall pursue the continued manned exploration of the solar system and low-Earth orbit consistent with section 103 of this Act, including but not limited to—

(1) the establishment of an operational United States International Space Station that shall be permanently manned;

(2) the development of those technologies and systems required for a manned mission to Mars; and

(3) the continued exploitation of the Moon and its resources.

SPACE TRANSPORTATION STRATEGIC PLAN

SEC. 304. The Administrator shall take the necessary steps to improve the manned and unmanned space transportation system including—

(1) the continued enhancement of the space shuttle and its ground system in order to increase safety and efficiency and reduce costs;

(2) consistent with the requirements of sections 301 and 302, the completion of the development of a heavy-lift expendable launch vehicle; and

(3) the initiation of preliminary design activities for the next generation of a manned space launch system beyond the space shuttle.

AERONAUTICAL RESEARCH AND TECHNOLOGY DEVELOPMENT AND VALIDATION LONG-RANGE PLAN

SEC. 305. The Administrator shall—

(1) conduct a vigorous program in aeronautics research and technology development and validation, emphasizing emerging technologies with the potential for breakthrough advances to enhance United States preeminence in civil and military aviation; and

(2) in cooperation with the Department of Defense, conduct a flight demonstration program (with first flight in 1995) to prove the feasibility of an air-breathing hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere.

TITLE IV—COMMERCIAL SPACE LAUNCH ACT AUTHORIZATIONS

COMMERCIAL SPACE LAUNCH ACT AUTHORIZATIONS

SEC. 401. Section 24 of the Commercial Space Launch Act (49 U.S.C. App. 2623) is amended by adding at the end the following: "There are authorized to be appropriated to the Secretary to carry out this Act $3,500,000 for fiscal year 1989, $3,850,000 for fiscal year 1990, and $4,235,000 for fiscal year 1991.".

TITLE V—CIVIL SPACE PROGRAMS IN THE DEPARTMENT OF COMMERCE

CIVIL SPACE PROGRAMS IN THE DEPARTMENT OF COMMERCE

SEC. 501. The Secretary of Commerce shall propose authorizing legislation for activities within the Department of Commerce in support of civil space commercial activities. Such legislation, together with proposed budgetary requirements, shall be submitted to the Committee on Science, Space, and Technology of the House of Representatives, and the Committee on Commerce, Science, and Transportation of the Senate, not later than July 15, 1988.

TITLE VI—DRUG-FREE WORKPLACE

DRUG-FREE WORKPLACE

SEC. 601. No funds authorized to be expended under this Act shall be expended in any workplace which is not free from illegal use of controlled substances.

INTRODUCTION

The Committee has taken a significant departure from its previous practice of authorizing appropriations for the Nation's space and aeronautics programs on an annual basis by setting three year funding levels. The authorization bill also establishes an aggressive set of goals and objectives for the next decade. The major provisions of the bill:

—Establish a core space program that relies on the Space Shuttle, expendable launch vehicles, and the development of a permanently manned Space Station.

—Establish a multi-year funding authorization plan for the first time. This plan includes specific authorization levels for fiscal years 1989, 1990, and 1991; outlines a five-year capital development plan; and establishes a 10-year strategic plan.

—Authorize the release of a request for a proposal from industry on the lease or purchase of a Commercially Developed Microgravity Research Space Facility. The bill prohibits acquisition or lease of such a facility without further review and authorization by the Congress. It also requires a study of the facility by the National Research Council and the National Academy of Public Administration.

—Instruct NASA to construct the United States International Space Station with 1989 funding set at $967.4 million, 1990 funding at $2.1 billion, and 1991 funding at $2.9 billion.

—Require NASA to establish before 1993 a "Mission to Planet Earth" designed to obtain a comprehensive understanding of the biogeochemical processes that influence global change.

—Direct NASA to establish as a major goal an International Manned Mission to Mars and to seek the participation of the Soviet Union and other interested nations in the pursuit of this goal. This effort is to begin in 1992 as a major focus of the International Space Year.

—Direct NASA in partnership with the Department of Defense to carry out a flight demonstration (in 1995) of a single-stage-to-orbit, hypersonic aerospaceplane.

—Direct NASA to report to Congress every two years on its analysis of the focused research and development activities on the Space Station, the Moon, and other outposts that are necessary to accomplish a manned mission to Mars.

—Establish a 12-member National Mars Commission to prepare a strategy for cooperation among the United States and any other interested nations on unmanned Mars projects in anticipation of a cooperative manned mission to Mars. The commission will also assess the implications of such cooperation including the prevention of unwanted transfer of technology.

—Authorize funding for the Department of Transportation's Office of Commercial Space Transportation.

—Direct the Secretary of Commerce to propose authorizing legislation for Department of Commerce activities done in support of civil space commercial activities. The report shall be submitted no later than July 15, 1988.

—Prohibit NASA from expending authorized funds in any workplace not free of illegal controlled substances.

PURPOSE OF THE BILL

TITLE I

The purpose of Title I is to set forth a Capital Development Program for the National Aeronautics and Space Administration covering fiscal years 1989 through 1993. This Capital Development Program establishes specific goals and objectives for Science and Applications, Space Research and Technology, Space Exploration, Space Transportation, Commercial Use of Space, Aeronautical Research and Technology Development and Validation, Technology Utilization, and Federal Facilities. Title I also requires the formulation of a Capital Development plan by NASA which will outline estimates of national launch capacity, total operating expenditures for the national space program, and total capital investments needed for hardware, facilities, and other improvements.

TITLE II

The purpose of Title II is to authorize appropriations for the National Aeronautics and Space Administration for fiscal years 1989 through 1991 for Research and Development, Space Flight, Control and Data Communications, Construction of Facilities, and Research and Program Management. Title II also contains certain provisions intended to establish policies and guidelines for carrying out the national space and aeronautics program.

TITLE III

The purpose of Title III is to establish a ten year strategic plan for the National Aeronautics and Space Administration, Specific long term policies are set forth for Aeronautics and Space Science Activities, Space Research and Technology, Space Exploration, Space Transportation, and Aeronautical Research and Technology Development and Validation.

TITLE IV

The purpose of Title IV is to authorize appropriations for fiscal years 1989 through 1991 for the Department of Transportation's Office of Commercial Space Transportation for Planning and Development, Licensing Procedures, Risk Management, Industry Analysis and Planning, Administrative Costs, and Personnel Compensation and Benefits.

TITLE V

The purpose of Title V is to require the Secretary of Commerce to request authorizing legislation for the activities within the Department of Commerce which relate to Civil Space Commercial activities.

TITLE VI

This title sets forth a strong Congressional mandate to the Administrator so that policies and procedures are implemented to assure that NASA and its contractors and grantees conduct their activities in a workplace which is free from illegal use of controlled substances.

EXPLANATION OF THE BILL

TITLE I: NATIONAL AERONAUTICS AND SPACE CAPITAL DEVELOPMENT PROGRAM

The Committee adopted Title I of the bill to establish a five year capital development program for the National Aeronautics and Space Administration. This title establishes specific goals and objectives for carrying out the fundamental purposes of the National Aeronautics and Space Act of 1958.

SECTION 101: FINDINGS

Section 101(1) establishes, as part of the core capital program, the requirement to construct the United States International Space Station for science and engineering experimentation, satellite servicing and construction, commercial product development and demonstration, and as a base for space operations.

Section 101(2) establishes, as part of the core capital program, the requirement to move toward a mixed fleet for access to space including expendable launch vehicles.

Section 101(3) establishes, as part of the core capital program, the Space Shuttle as the primary means for manned access to space.

Section 101(4) states the finding of Congress that space and aeronautics activities, and preeminence in those activities are related to our National security and economy.

Section 101(5) recognizes that long range planning can promote understanding of near term projects and programs. That is, a clear identification of goals and objectives is beneficial to establish a basis for more focused technology development and scientific programs. This finding responds, in particular, to the needs of the science community and the industry to be able to anticipate well in advance the sequence of major new initiatives to be undertaken by the Government. This certainty is directly related to the program stability which, as has been pointed out by many witnesses in testimony, has been lacking.

Section 101(6) states that human settlements in space are fully consistent with the goals of the Space Act.

Section 101(7) declares that leadership in science over the next five years should be maintained through a balance of major and moderate missions and a program for frequent flight opportunities in each major discipline. This balance is intended to be the foundation on which future initiatives, such as a manned Mars mission, will be based.

Section 101(8) encourages the Administrator to prepare for the transition to and effective use of the Space Station. This finding, however, is intended to address those uses and programs that actually benefit from the Station.

Section 101(9) expresses the intent that the Administrator should encourage private sector investment in space and ensure an adequate access to space to provide for the development of commercial technologies, processes, and products.

Section 101(10) states the need to enhance the reliability, productivity, efficiency, and cost effectiveness of the space transportation system.

Section 101(11) stresses the need for improved technology if the United States is to maintain its traditional preeminent position in aeronautics.

Section 101(12) requires the Administrator to develop NASA's personnel as an integral component of the capital program.

SECTION 102: POLICY

Section 102(1) states that it is the policy of the United States to establish permanent presence in space as a step toward space settlements.

Section 102(2) states the fundamental social and technical purposes of the space program.

Section 102(3) emphasizes the need to assure robust access to space.

Section 102(4) states the goals of the space transportation policy.

Section 102(5) directs NASA to provide for advanced research and development in the field of space and communications.

Section 102(6) states that the goal of aeronautical research and technology development and validation activities shall be to contribute to a national technology base that will enhance United States preeminence in civil and military aviation and improve the safety and efficiency of the United States air transportation system.

Section 102(7) states that aeronautical research and technology development and validation activities shall emphasize emerging technologies with potential for breakthrough advances; consisting of fundamental research in all aeronautical disciplines, aimed at greater understanding of aeronautical phenomena and development of new aeronautical concepts, and technology development and validation activities aimed at laboratory-scale development and proof-of-concept demonstration of selected concepts with high payoff potential; assure maintenance of robust aeronautical laboratories, including a first-rate technical staff and modern national facilities for the conduct of research and testing activities; be conducted with the close, active participation of the United States aircraft industry so as to accelerate the transfer of research results to aviation products; include providing technical assistance and facility support to other government agencies and United States industry; include conducting joint projects with other government agencies where such projects contribute materially to the goal set forth in subsection (a); assure strong participation of United States universities both in carrying out aeronautical research and training future aeronautical research personnel; and be conducted, where practical, so that United States industry receives research results before foreign competitors.

SECTION 103: SCIENCE AND APPLICATIONS 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 103(a) directs the Administrator to submit funding requests for the Science and Applications program and its enabling Space Transportation requirements that are at least 20% of the annual budget for all NASA activities. This funding level is estimated as that which will sustain a minimum science program and constitutes a reasonable balance between science and other agency activities.

Section 103(b) directs the Administrator to initiate a specific series of major science missions sequentially as allowed by funding available within this Act, and the minimum guidelines in subsection (a). Funding specified in Title II is anticipated to allow the initiation of the Advanced X-Ray Astrophysics Facility in FY 1989, the Comet Rendezvous/Asteroid Flyby—Cassini mission in FY 1990 and the Earth Observing System in FY 1991. This specific set of major missions has been developed by NASA and various disciplinary advisory committees and is accepted as a reasonable priority of new starts.

Section 103(c) directs the Administrator to initiate a specific series of moderate science missions sequentially as allowed by the funding available within this Act, the minimum guidelines in subsection (a) and as a secondary option to the major missions in subsection (b). This section is intended to maintain a steady sequence of new mission starts in the absence of sufficient funding to initate the major missions specified in subsection (b).

Section 103(d) directs the Administrator to establish flight programs in each of four major disciplines that will ensure continuity and frequent access to space for each discipline. These are intended to be budgetary line items and should allow the initiation of new missions as the budgetary line allows. The Committee intends that NASA, the science community and the contractor community share in the responsibility to maintain strict cost and management controls to ensure that mission frequency can be maximized. Fixed price contracts, high inheritance hardware and prudent selection of mission objectives are key to the success of these types of missions.

Section 103(e) directs the Administrator to initiate a focused Earth oriented study of FY 1992. This study is intended to carry out the objectives of the "Mission to Plant Earth" identified in the report by Dr. Sally Ride. The Committee intends that NASA undertake this study in cooperation with other Federal Agencies having a role in environmental and Earth research and monitoring.

SECTION 104: SPACE RESEARCH AND TECHNOLOGY 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 104(a) directs the Administrator to expand the Space Research and Technology program over the next 5 years to reach 10% of the total NASA budget. This responds to the National Research Council's conclusions that ". . . NASA's preoccupation with short-term goals has left the agency with a technology base inadequate to support advanced space missions. . .", and ". . . the advanced space R&T program continues to be seriously under funded by at least a factor of three . . ."

Section 104(b) directs the Administrator to conduct both broad based and focused programs needed to develop the technologies for future NASA and other civil space missions. A program directed at relatively near term technology needs should focus on advanced booster technology, aerobraking techniques, autonomous systems and robotics and high capacity power conversion techniques. Technologies to enhance science missions would include large precision segmented reflectors, sensor technology and space data systems research.

The Pathfinder program should focus on the longer term technology needs for missions beyond Earth orbit such as robotic and piloted missions to the Moon, Mars, and other planets on the solar system. These should include the critical technologies for autonomous rendezvous and docking, resource processing, in-space assembly and construction, space nuclear power, human performance and closed-loop life support; and also the technologies for transportation to and from the planets such as chemical transfer propulsion, high-energy aerobraking, and fault-tolerant systems.

Project Pathfinder will support research in a wide variety of technology areas key to achieving the national long-range goal of expanding human presence and activity beyond the Earth's orbit into the Solar System. The Committee encourages NASA to utilize the resources and expertise of the Department of Energy's National Laboratories to enhance, support and complement the capabilities of the NASA Research Centers.

The Administrator is also directed to conduct technology validation and demonstration programs including, where practical, in-space experiments using both the Shuttle and expendable launch vehicles and, when available, the Space Station.

It is the Committee's intent that space technology development should be responsive to the needs of both the private sector users and other government users as well as to the needs of NASA. Technologies that will enhance NASA's capability to monitor global change will support the efforts of the Office of Space Science and Applications. This section also directs the Administrator to establish a research and development program aimed at developing advanced technologies for space transportation which will support NASA, industry and other government users. This would include expendable launch vehicle technology as well as manned systems. It is the Committees intent that this activity parallel the aeronautics R&D program; it is not directed at *developing* new vehicles but rather conducting the high-risk generic research that would not otherwise be done by the private sector and should not be done as effectively by other government users.

The Administrator is directed to increase the number of cooperative programs with industry, universities, and other government agencies and also provide these groups with access to NASA's ground and in-space facilities. It is the intent of the Committee that NASA make more effective the use of the talent outside the agency as well as facilitate the transfer of technology to the users. Specifically the Administrator is directed to increase the number of University Space Engineering Research Centers to 20 and as each of these Centers becomes self-sustaining new ones should be established to maintain a level of 20.

SECTION 105: SPACE EXPLORATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 105(a) declares that the extension of human life beyond Earth's atmosphere will benefit science and exploration and will enhance the general welfare.

Section 105(b) establishes space exploration as a basic goal of the International Space Year in 1992.

Section 105(c) declares that an International Manned Mission to Mars is a major goal of the space program and that the U.S. should seek, in addition to other interested nations, the participation of the Soviet Union.

Section 105(d) directs the Administrator to undertake mission development studies over the next four years in preparation for the next major space exploration initiative.

Section 105(e) directs the Administrator to establish by 1992 a program for a manned mission to Mars. This section is not intended to preclude the exploration and exploitation of other solar system bodies such as the Moon and Phobos if such activities contribute toward the objective of Mars exploration. The Committee fully intends that such a manned mission to Mars be undertaken as a first step toward the colonization of Mars.

Section 105(f) authorizes the Administrator to plan for a Lunar Outpost insofar as it is necessary to accomplish a manned Mars mission.

Section 105(g) incorporates the substance of H.R. 4218, "Space Settlement Act of 1988." This section requires the Administrator to submit a report every two years on the progress toward achieving the goal of establishing space settlements.

SECTION 106: SPACE TRANSPORTATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 106(a) directs the Administrator to set, as objectives for the enhancement of the Shuttle, the reduction of manpower requirements, the reduction of turnaround time, and an increase in system reliability. The Committee intends, however, that safety be the context within which all system changes are implemented.

In carrying out this section, the Committee intends that NASA maintain an adequate inventory of maintenance and repair parts to support planned Space Shuttle launch operations. Major improvements in existing Space Shuttle flight hardware should be made, when those improvements can be justified on the basis of one of the following: they are required for safety reasons; they would produce overall cost savings; or, they would make a significant improvement in the unique man-related capabilities of the Space Shuttle.

Where necessary to enhance overall operating safety or cost-efficiency, improvements should also be made in production facilities and processes and other ground support facilities and equipment.

Section 106(b) directs the Administrator to initiate development of a heavy-lift vehicle before 1994 consistent with the program requirements in Sections 102 and 103. The Committee does not intend that earlier start dates be precluded if mission needs dictate such a requirement.

It is the intent of the Committee that heavy-lift launch vehicles should be designed to meet the availability dates, reliability requirements, payload lift requirements, and operating economies required by the programs that they are intended to support.

This Section also requires the Administrator to complete the "phase B" system definition studies for a Shuttle derived heavy-lift vehicle in order to maintain that option in future decisions and to submit a report on this option by September 30, 1989.

Section 106(c) directs the Administrator to initiate a program to enhance the orbital infrastructure for space transfer and support. This requirement is meant to encompass the Orbital Transfer Vehicle and appropriate cryogenic resupply capabilities.

Section 106(d) establishes a policy to manifest on expendable launch vehicles all those missions that do not require man. The Committee fully recognizes that, at present, some unmanned payloads have been designed for the dimensions and load environment of the Shuttle and would be impractical to redesign. Thus, this policy is primarily directed toward new payloads in which design flexibility allows a choice in launch systems.

Section 106(e) directs the Administrator to establish a research and development program that will enhance the level of technology ready for application to new expendable launch vehicles. The intent of this section is not directed toward *developing* new vehicles per se, but rather to provide for the high risk research which would otherwise not be done by the private sector. The Committee views this function as essential in maintaining a commercial sector that will be competitive with future foreign launch systems.

Notwithstanding the current policy of the Administration that prohibits NASA from maintaining a stable of expendable launch vehicles, it is the intent of the Committee that NASA and the Department of Defense coordinate and cooperate in ensuring that the expendable launch vehicle requirements of the United States government are provided for in the most timely and cost-efficient manner possible.

Consistent with meeting programmatic requirements, NASA may provide for the research needed to make improvements in expendable launch vehicles to accomplish the following purposes:

(a) Increase their reliability,
(b) Improve their cost-efficiency, and
(c) Increase their payload lift capability.

SECTION 107: COMMERCIAL USE OF SPACE 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 107(a) establishes an overall policy of achieving a leadership role in the commercial use of space. The Committee intends that NASA take a lead role in fostering this leadership role. Section 107 also directs the Administrator to undertake an active and progressive program of Joint Endeavor Agreements with commercial users to encourage commercial payload development. The Committee has set, as goals for this program, five new Joint Endeavor Agreements per year with a maximum flight manifest date of three years and assurance reflight frequency to achieve R&D and

pilot program activities pursuant to the Joint Endeavor Agreement.

Section 107(b) declares that the civil space program should be conducted in such a manner as to encourage broad private sector participation. The Committee recognizes that a critical element for private sector investment is assurance that the ground rules will not change and the government will not become a competitor. This section also authorizes the Administrator in cooperation with other appropriate agencies to provide the support needed to make U.S. industry competitive such as performing high-risk generic research and development or making unique government assets available on a reimbursable basis.

SECTION 108: AERONAUTICAL RESEARCH AND TECHNOLOGY DEVELOPMENT AND VALIDATION 5-YEAR CAPITAL PROGRAM

Section 108 states the Administrator shall, before October 1, 1992, increase the request for aeronautical research and technology development and validation activities to 15 percent of the total NASA budget.

The Administrator shall, in fiscal years 1989 through 1993, conduct fundamental research in aeronautical disciplines including aerodynamics, propulsion, materials, structures, controls, guidance, human factors, information sciences, flight systems, and aeronautical systems studies; conduct technology development and validation activities aimed at improving the performance, safety, usefulness, and cost of transport aircraft, rotorcraft, high-performance aircraft, and general aviation aircraft; in cooperation with the Department of Defense, conduct a technology maturation program and initiate a flight demonstration program to prove the feasibility of an iar-breathing, hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere; and maintain and enhance a complement of national aeronautical facilities including wind tunnels, simulators, computational facilities and research test-bed aircraft.

The Administrator shall, before October 1, 1992, increase the number of full-time civil service personnel engaged in aeronautical research and technology development and validation activities by 50 percent above the number engaged in such activities in fiscal year 1989.

SECTION 109: TECHNOLGY UTILIZATION 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 109(a) declares that technical spinoffs from the space program are important to science, the economy and technological growth.

Section 109(b) requires the Administrator to encourage and facilitate the practical application of new technologies.

Section 109(c) requires the Administrator to seek to expand the Industrial Applications Center Network.

Section 109(d) directs the Administrator to merge through a contract action, the Industrial Applications Center located in Oklahoma with the NASA Rural Technology Applications Team.

SECTION 110: FEDERAL FACILITIES 5-YEAR CAPITAL DEVELOPMENT PROGRAM

Section 110(a) requires the Administrator to submit a five year plan for Construction of Facilities and to submit this plan and any appropriate revisions each year accompanying the budget request for fiscal years 1989 through 1993.

Section 110(b) recognizes the need to coordinate such long range plans with the Department of Defense. Plans submitted under subsection (a) should address joint use facilities and facilities which satisfy dual mission requirements. This section does not require this plan to be jointly submitted.

SECTION 111: REPORT ON CAPITAL DEVELOPMENT

Section 111 directs the Administrator to submit a Capital Development Plan in order to carry out the provisions of this title. This plan should include budgetary factors, launch requirements, and estimates of operating and capital expenses.

TITLE II—NASA 3-YEAR AUTHORIZATION

Title II provides a three year authorization of appropriations for the National Aeronautics and Space Administration and related provisions. Sections 201(a)(1), (2), (3), and (4) contain authorization levels for NASA programs for fiscal years 1989, 1990, and 1991, which are reflected in the chart below.

FISCAL YEARS 1989, 1990, AND 1991 NASA AUTHORIZATION—SUMMARY

	Authorization fiscal year 1989	Authorization fiscal year 1990	Authorization fiscal year 1991
Research and Development:			
Space Station	$967,400,000	$2,130,200,000	$2,912,500,000
Space Transportation Capability Development	631,100,000	784,000,000	889,000,000
Space Science and Applications	1,859,600,000	2,255,000,000	2,428,000,000
Commercial Programs	57,900,000	62,000,000	74,000,000
Aeronautical Research and Technology	414,200,000	609,500,000	764,900,000
Transatmospheric Research and Technology	84,400,000	149,400,000	95,500,000
Space Research and Technology	390,900,000	520,000,000	637,000,000
Safety, Reliability, and Quality Assurance	22,400,000	23,000,000	24,000,000
Tracking and Data Advanced Systems	18,800,000	20,000,000	21,000,000
Subtotal, Research and Development	4,446,700,000	6,553,100,000	7,849,700,000
Space Flight, Control, and Data Communications:			
Shuttle Production and Operational Capability	1,400,500,000	1,468,000,000	1,571,000,000
Space Transportation Operations	2,405,400,000	2,721,000,000	2,522,000,000

FISCAL YEARS 1989, 1990, AND 1991 NASA AUTHORIZATION—SUMMARY—Continued

	Authorization fiscal year 1989	Authorization fiscal year 1990	Authorization fiscal year 1991
Space and Ground Networks, Communications and Data Systems	1,035,300,000	1,190,000,000	1,168,000,000
Subtotal, Space Flight, Control, and Data Communications	4,841,200,000	5,379,000,000	5,261,000,000
Construction of Facilities:			
Construction of Space Station Processing Facility, Kennedy Space Center	15,000,000		
Modifications of Process Technology Facility for Space Station, Marshall Space Flight Center	3,700,000		
Construction of Addition for Space Systems Automated Integration and Assembly Facility, Johnson Space Center	9,200,000		
Replacement of High Pressure Gas Storage Vessels, National Space Technology Laboratories	3,500,000		
Increase Chiller Capacity, LC-39 Utility Annex, Kennedy Space Center	2,300,000		
Rehabilitation of Pad A, LC-39, Kennedy Space Center	4,600,000		
Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility, Johnson Space Center	4,900,000		
Modifications for Advanced Engine Development, Test Stand 116, Marshall Space Flight Center	13,500,000		
Modifications to Orbiter Modification and Refurbishment Facility (OMRF) for Safing and Deservicing, Kennedy Space Center	2,800,000		
Construction of National Resource Protection, Various Installations	2,600,000		
Construction of Auxiliary Chiller Facility, Johnson Space Center	7,800,000		
Modifications to the X-Ray Calibration Facility, (XRCF), Marshall Space Flight Center	11,400,000		
Modernization of Space Environment Simulator, Goddard Space Flight Center	2,800,000		
Modifications for Utility Reliability, Goddard Space Flight Center	3,100,000		
Refurbishment of 25-foot Space Simulator, Jet Propulsion Laboratory	12,000,000		
Repair and Modernization of the 120-foot Pressure Wind Tunnel, Ames Research Center	36,500,000		
Rehabilitation and Modifications to 10 x 110 Supersonic Wind Tunnel, Lewis Research Center	14,500,000		
Refurbishment of Hypersonic Facilities Complex, Langley Research Center	12,800,000		
Refurbishment of Electric Power Laboratory, Lewis Research Center	6,100,000		
Repair of Facilities, not in excess of $750,000 per project, Various Locations	27,000,000		
Rehabilitation and Modification of Facilities, not in excess of $750,000 per project, Various Locations	34,000,000		
Minor Construction of New Facilities and Additions to Existing Facilities, not in excess of $500,000 per project, Various Locations	9,000,000		
Facility Planning and Design	20,000,000		
Environmental Compliance and Restoration Program, Various Locations	26,000,000		
Subtotal, Construction of Facilities	285,100,000	341,100,000	401,100,000
Research and Program Management	1,915,00,000	2,115,100,000	2,234,000,000
Total	11,488,000,000	14,388,300,000	15,745,800,000

SECTION 201: 3 YEAR AUTHORIZATION

Section 201(a)(1)(A) authorizes appropriations for the United States International Space Station of $967,400,000 for fiscal year 1989, $2,130,200,000 for fiscal year 1990, and $2,912,500,000 for fiscal year 1991. In addition, the Committee authorizes a total amount of $24,200,000,000 (in FY 1989 dollars) to achieve the initial operating capability. These estimates were based on testimony received during authorization hearings and the report entitled *Space Station Capital Development Plan—Fiscal Year 1989* received March 1988.

Section 201(a)(1)(B) authorizes $631,100,000 for fiscal year 1989 to support Space Transportation Capability Development activities. The Committee authorizes $784,000,000 in FY 1990 based upon a

baseline budget of $655,000,000 and the addition of $9,000,000 for the ACTS upper stage and $120,000,000 to initiate development of the Crew Escape Rescue Vehicle (CERV) for the U.S. International Space Station. The Committee authorizes $889,000,000 in FY 1991 based on a baseline budget of $635,000,000 and the addition of $4,000,000 for the ACTS upper stage and $25,000,000 to initiate development activities for the CRAF/Cassini mission transportation system, and $225,000,000 to continue work on the CERV.

Section 201(a)(1)(C) provides funding of $1,859,600,000 in FY 1989 to support the Physics and Astronomy, Life Sciences, and Planetary Exploration programs. The Committee authorizes a total of $2,255,000,000 for FY 1990 based on a baseline budget of $1,876,000,000 and the addition of $153,000,000 to provide for adjustments and normal program growth; $66,000,000 for the ACTS program; $48,000,000 for the initiation of development activities for the Stratospheric Observatory for infrared Astronomy; $27,000,000 for the initiation of a Space Biology program for the Space Station; $15,000,000 for the initiation of an Earth Probes satellite program; and $70,000,000 for the initiation of development activities for the CRAF/Cassini mission.

For FY 1991, the Committee authorizes a total of $2,428,000,000 based on a baseline budget of $1,899,000,000 and the addition of $59,000,000 to provide for adjustments and normal program growth; $28,000,000 for the Acts program; $30,000,000 for the Stratospheric Observatory for Infrared Astronomy; $29,000,000 to continue the Space Biology program for the Space Station; $30,000,000 for the Earth Probes program; $210,000,000 to continue the development of the CRAF/Cassini mission; and $143,000,000 to initiate development activities for the Earth Observing System.

Section 201(a)(1)(D) authorizes appropriations for Commercial Programs of $57,900,000 for fiscal year 1989. In addition, the Committee authorizes $62,000,000 in FY 1990 and $74,000,000 in FY 1991. This provides for the necessary growth beyond inflation to support ongoing programs in Technology Utilization and the Commercial Use of Space. This growth is necessary to achieve the enhanced level of Joint Endeavor Agreements required by Section 106.

Section 201(a)(1)(E) authorizes appropriations for aeronautical research and technology, $414,200,000 for fiscal year 1989, $609,500,000 for fiscal year 1990, and $764,900,000 for fiscal year 1991. The FY 90 and FY 91 funds provide for a Technology Development and Validation Augmentation (Subsonic Transport, High-Performance Aircraft, High-Speed Civil Transport, Generic Hypersonic, Tiltrotor/Commuter).

Section 201(a)(1)(F) authorizes appropriations for transatmospheric research and technology, $84,400,000 for fiscal year 1989, $149,400,000 for fiscal year 1990, and $99,300,000 for fiscal year 1991.

Section 201(a)(1)(G) authorizes $390,900,000 in fiscal year 1989 for activities related to Space Research and Technology. The Committee authorizes $520,000,000 in FY 1990 based on the baseline budget of $460,000,000 and the addition of $60,000,000 to augment the Pathfinder program. The Committee authorizes $637,000,000 in FY 1991 based on the baseline budget of $487,000,000 and the addition of $150,000,000 to augment the Pathfinder program.

Section 201(a)(1)(H) authorizes $22,400,000 for fiscal year 1989; $23,000,000 for fiscal year 1990; and $24,000,000 for fiscal year 1991 for Safety, Reliability, and Quality Assurance. The constitutes normal program growth to keep pace with inflation.

Section 201(a)(1)(I) provides funding for Tracking and Data Advanced Systems of $18,800,000 for fiscal year 1989; $20,000,000 for fiscal year 1990; and $21,000,000 for fiscal year 1991. This constitutes normal program growth to keep pace with inflation.

Section 201(a)(2)(A) authorizes $1,400,500,000 for fiscal year 1989 to support Shuttle Production and Capability Development. The Committee authorizes $1,468,000,000 for FY 1990 based on a baseline budget of $1,458,000,000 to support the anticipated Shuttle flight rate and the addition of $10,000,000 to provide for the initiation of development activities for advanced space transfer and support vehicles such as an on-orbit cryogenic resupply capability. The Committee authorizes $1,571,000,000 in FY 1991 based on a baseline budget of $1,532,000,000 to support the anticipated Shuttle flight rate and the addition of $39,000,000 to continue work on advanced space transfer and support vehicles.

Section 201(a)(2)(B) authorizes appropriations for fiscal year 1989 of $2,405,200,000 for Space Transportation operations. The Committee authorizes $2,721,000,000 for FY 1990 based upon a baseline budget of $2,334,000,000 for Shuttle operations and $387,000,000 for expendable launch vehicle operations. This authorization assumes a reimbursement of $82,500,000 from the Department of Defense for Shuttle operations. For FY 1991, the Committee authorizes $2,522,000,000 based on baseline budget of $2,187,000,000 for Shuttle operations; $319,000,000 for expendable launch vehicle services; and the addition of $16,000,000 for additional Scout vehicle acquisition to support the initiation of the Earth Probes program. This authorization assumes a reimbursement of $392,500,000 from the Department of Defense for Shuttle Operations.

Section 201(a)(2)(C) provides authorization of $1,035,300,000 for Space and Ground Network programs for fiscal year 1989. The Committee authorizes $1,190,000,000 for FY 1990 based on a baseline budget of $1,185,000,000 and the addition of $5,000,000 to initiate development activities in support of the CRAF/Cassini mission. The Committee authorizes $1,168,000,000 for FY 1991 based on a baseline budget of $1,158,000,000 and the addition of $6,000,000 to continue work on the CRAF/Cassini mission and $4,000,000 to initiate development activities in support of the next Observer mission.

Section 201(a)(3) provides for authorization of $285,100,000 for fiscal year 1989 to support new construction as well as refurbishment of existing facilities. The Committee authorizes $341,100,000 for FY 1990 on a projected requirement of $265,000,000 for space related facilities and $76,100,000 for aeronautical facilities. The Committee authorizes $401,100,000 for FY 1991 based on a projected requirement $280,000,000 for space related facilities and $121,000,000 for aeronautical facilities. Such authorizations require a request for specific facility projects.

Section 201(a)(4) authorizes $1,915,000,000 for fiscal year 1989 for Research and Program Management. Included in this funding are

amounts to support an additional 525 full-time equivalent employees. The Committee authorizes a total of $2,115,100,000 in FY 1990 based on a baseline budget of $1,938,000,000 and an additional $100,000,000 to augment personnel levels for NASA's space related activities and $7,100,000 for NASA's aeronautical activities. The Committee authorized $2,234,000,000 in FY 1991 based on a baseline budget of $1,976,000,000 and an additional $100,000,000 to augment personnel levels for NASA's space related activities and $158,000,000 for NASA's aeronautical activities.

Section 201(b) authorizes appropriations of $89,000,000 in fiscal year 1989 to support the Advanced Communications Technology Satellite (ACTS) program. Of the funds authorized to be appropriated for fiscal year 1989, there is a general reduction of $89,000,000 to fund the ACTS program. Not more than 20% of this reduction may be applied against the programs of the Office of Space Science and Applications. The Committee appropriates $75,000,000 for fiscal year 1990 and $32,000,000 for fiscal year 1991 to support the ACTS project.

Section 201(c) provides that appropriations authorized for "Research and Development" and "Space Flight, Control, and Data Communications" may be used for (1) items of a capital nature (other than acquisitions of land) at non-NASA locations for the performance of research and development contracts and (2) grants to nonprofit organizations for scientific research and purchase or construction of additional research facilities, provided that construction of any facility does not exceed $500,000.

Section 201(d) authorizes appropriations made available under this Act and subject to an appropriations Act (except those for "research and program management") to remain available without fiscal year limitation. Certain research and program management contracts may be entered into at any time during the fiscal year, but not to exceed a period of 12 months.

Section 201(e) provides that up to $35,000 of "Research and Program Management" funds may be used for scientific consultations or extraordinary expenses.

Section 201(f) allows certain funds designated for "Research and Development," "Space Flight, Control, and Data Communications," and "Reseach and Program Management" to be used for construction or repair of facilities provided that the cost of each project does not exceed $100,000. It also allows funds designated for "Research and Development" and "Space Flight, Control, and Data Communications" to be used for unforeseen programmatic facility projects less than $500,000. Funds for "Research and Program Management" may be used for work on facilities controlled by the General Services Administration provided each project does not exceed $500,000.

SECTION 202: CONSTRUCTION OF FACILITIES REPROGRAMMING

Section 202 authorizes transfers among line item accounts (A) through (Y) under "Construction of Facilities" of up to 10 percent of any individual line item or a cumulative amount of 10 percent of the sum of those line items. These amounts may be varied up to 25 percent to meet unusual cost variations following a report by the Administrator to the appropriate authorization committees of the Congress.

SECTION 203: SPECIAL REPROGRAMMING FOR CONSTRUCTION OF FACILITIES

Section 203 allows appropriations not to exceed ½ of 1 percent to be transferred from "Research and Development" and "Space Flight, Control, and Data Communications" to "Construction of Facilities" to be used for programs not presented to the Congress only after a written report has been transmitted to be the appropriate authorizing committees of the Congress and 30 days have passed. The Administrator may also use up to $10,000,000 from the "Construction of Facilities" authorization for these purposes.

SECTION 204: LIMITATIONS ON AUTHORITY

Section 204 prohibits appropriations under this Act from being used for any program deleted by Congress from the original request to the appropriate authorizing committeese of the Congress and prohibits appropriations authorized under Section 201(a) (1), (2), and (4) from exceeding the authorized levels. Appropriations authorized under this Act may be used for programs not presented to the Congress only after notice has been given by the Administrator to the Congress of such plans and 30 days have passed.

SECTION 205: GEOGRAPHICAL DISTRIBUTION OF RESEARCH FUNDS

Section 205 states that consideration be given to geographic distribution of research funds and requires NASA to explore methods of accomplishing this task.

SECTION 206: ARREST AUTHORITY

Section 206 amends the NASA Act in order to provide for arrest authority for those employees and contractors authorized to carry firearms.

Presently, subsection 304(e) of the National Aeronautics and Space Act of 1958, as amended, provides the authority for certain employees of contractors and subcontractors to carry firearms in the fulfillment of their official duties.

This amendment to section 304 of the National Aeronautics and Space Act, specifically a new subsection (f) (to be codified as 42 U.S.C. 2465a) would provide the authority to arrest without warrant to NASA employees designated by the Administrator as well as those contractor and subcontractor personnel carrying out their official duties while guarding and protecting property of the United States under the administration and control of NASA or its contractors or subcontractors.

These two subsections when read together would allow certain NASA personnel as well as certain subcontractor and contractor personnel to make an arrest for the violation of federal and, in some instances, state laws occurring on NASA property or involving property owned by or in the custody of NASA if the person has reason to believe that the person to be arrested has committed or is committing a felony. Security personnel shall use the minimum

degree of force, including firearms, necessary to effectuate the arrest.

NASA must develop regulations to be prescribed by the Administrator and approved by the Attorney General before this authority is exercised.

SECTION 207: NATIONAL MARS COMMISSION

Section 207 incorporates the substance of H.R. 3858 "The National Mars Commission Act." The Committee intends that the Commission established under this section play a key role in implementing Section 105 of this Act to undertake an international manned mission to Mars.

SECTION 208: MICROGRAVITY RESEARCH SPACE FACILITY

Section 208(a) authorizes the Administrator to release a request for proposals (RFP) for a microgravity research space facility which may be used for the development of Space Station technologies, the conduct of unique commercial activities, and the conduct of unique scientific investigation. This section requires that any such RFP include lease, lease-purchase, and purchase options, or any other innovative financing arrangement that will enhance the commercialization of space.

It is the intent of the Committee that such an acquisition provide an interim microgravity research capability prior to the Space Station. The Committee also recognizes the additional potential benefit of allowing the private sector to provide such a facility and thus more firmly establish a commercial space industry. In adopting language to explore the lease-purchase and purchase option, the Committee intends that NASA explore alternative commercial options and their respective benefits to the government. For example, under a purchase option the Administrator may request, as a part of the solicitation, the offerors' plans for carrying out commercial operation with additional follow-on facilities developed exclusive of the Government's purchase. This model would follow the success of the Medium Lift launch vehicle acquisition plan recently developed by the Department of Defense. The Committee also intends that NASA incorporate as much flexibility as allowed by the Federal Acquisition Regulation into the government's oversight role. For example, an acquisition which establishes a delivery on orbit may have the effect of reducing the cost to the offeror of maintaining documentation.

Section 208(b) establishes the competitive nature of the acquisition as requiring at least three good faith offers.

Section 208(c) requires the Administrator to request authorization of funds no later than the fiscal year 1990 budget submission. This section also requires the Administrator to report at that time on the final selection, proposed terms and conditions of the acquisition, and other special authorities needed such as for termination liability payments.

Section 208(d) requires the Administrator to keep the Committee informed in accordance with the agreement contained in the letter of April 19, 1988 to the Committee. The Committee intends that the integrity of the procurement process be fully upheld.

Section 208(e) prohibits any contract or obligation of funds for the acquisition of a commercially developed space facility. The language does not affect the ability of the Administration to expend funds in connection with the release of the RFP authorized under this section without the expressed authorization of Congress.

Section 208(f) requires the Administrator to certify that all obligation for this acquisition will entail new budget authority beyond that authorized in Title II and will not impact current or future authorized programs.

Section 208(g) requires the Administrator to report to Congress on any adverse effects this acquisition would have on the Space Station or any other program if the certification under Section 208(f) cannot be made.

Section 208(h) requires the Administrator to use all facilities available for microgravity experimentation on a nondiscriminatory basis. This provision is intended to ensure that other potential offerors of microgravity research facilities and provided with a reasonable opportuity to compete for government payloads.

Section 208(i) states that notwithstanding this section, the Administrator may reach agreements with other offerors of microgravity reseach facilities exclusive of the offeror selected under Section 208(a). Under a separate section of this report (see "Committee Views") the Committee discusses the NASA role in fostering the growth of commercially provided hardware and services.

SECTION 209: STUDIES ON MICROGRAVITY RESEARCH CAPABILITY

Section 209(a) requires the Administrator to contract with the National Academy of Sciences to study the utilization of microgravity research facilities.

Section 209(b) requires the Administrator to contract with the National Academy of Public Adminstration to study the budgetary and financial aspects of acquiring a commercially developed microgravity research facility.

Section 209(c) requires the Administrator to report to Congress on the results of these studies by March 15, 1989.

SECTION 210: EXTERNAL TANKS

Section 210 directs the Administrator to make expended external tanks available at no cost for five years to any U.S. commercial or nonprofit institute. During the first three years of this period, no less than five external tanks must be made available to nonprofit institutions of higher education or to nonprofit institutions whose primary purpose is the conduct of scientific research for suborbital inter-tank experiments. The Committee intends that these provisions establish a "critical mass" of expended external tanks to demonstrate the technical and commercial feasibilty of utilizing this potential space asset. The Committee expects the recipients of such tanks to comply with all safety measures and to bear any direct costs incurred by NASA in providing technical assistance or in modifying the external tanks.

SECTION 211: MANUFACTURING TECHNOLOGY

Section 211 amends Section 102(c) of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451(c)). Relative to manufacturing technology: NASA and its predecessor organization, the National Advisory Committee on Aeronautics, have been extremely successful at achieving their objective, as stated in the Space Act, "The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;". There are many examples of technology developed by NASA that have enhanced the competitiveness of U.S. aircraft.

The Committee is committed to assuring that the relationship continues at a healthy level. In today's marketplace, however, the competitiveness of many products is determined as much by the processes used to manufacture them as by the technology contained in the products. The U.S. has lost out frequently to superior process technology in other countries. The automotive and semiconductor industries and good examples.

NASA, except in the realm of composites and ceramics processing, has limited its role in preserving U.S. aviation preeminece to product technology. The Committee believes process technology will become increasingly important and that NASA should develop the necessary expertise to play a useful role.

SECTION 212: BUY AMERICAN

Section 212 requires the Administrator to "buy American" for products completely assembled in the United States. This is same language that was contained in PL 100-147, Section 114. When completely assembled, not less than 50 percent of the final product will be domestically produced and the difference between foreign and domestic bids should not exceed 6 percent. This section does not apply where such an acquisition would not be in public interest, national security considerations would dictate otherwise, or the U.S. Trade Representative determines that such an award would be inconsistent with international agreements to which the U.S. is a part.

SECTION 213: SPACE STATION STANDARDIZATION

Section 213 requires the Administrator to submit a report to Congress addressing the advisability of designing and constructing a docking mechanism, using metric measurements, which is compatible with other space stations and space vehicles.

TITLE III: TEN YEAR STRATEGIC PLAN

The Committee adopted Title III of the bill which lays out long range policy and program objectives over the next ten years. These long range objectives are intended to function as the strategic plan for the civilian space program for science and applications, space research and technology, space exploration, space transprotation, and aeronautical research and technology.

SECTION 301: AERONAUTICS AND SPACE STRATEGIC PLAN

Section 301 establishes program objectives for NASA's Science and Applications efforts in planetary exploration, astronomy, Earth applications, life sciences, and microgravity sciences.

SECTION 302: SPACE RESEARCH AND TECHNOLOGY STRATEGIC PLAN

Section 302 directs the Administrator to undertake an aggressive and balanced program in fundamental research and focused technology development to provide the enabling technologies for NASA's future missions and also to support the needs of the private sector and other government users. The Committee's intent is to strengthen NASA's role in fundamental space research and technology and reverse the shift toward large operational programs that has taken place in recent years.

SECTION 303: SPACE EXPLORATION STRATEGIC PLAN

Section 303 sets program objectives for NASA's manned exploration program. The Committee intents that the long range focus remain on a mission to Mars and that the development and evolution of the Space Station and the lunar resources be undertaken as logical steps toward that goal.

SECTION 304: SPACE TRANSPORTATION STRATEGIC PLAN

Section 304 directs the Administrator to make improvements in the safety and efficiency of the Space Shuttle, complete the heavy lift vehicle, and initiate work on the next manned space transportation system. The Committee's intent is to provide for diversity in our access to space, while making incremental improvements in the safety and efficiency of our space system.

SECTION 305: AERONAUTICAL RESEARCH AND TECHNOLOGY DEVELOPMENT AND VALIDATION LONG-RANGE PLAN

Section 305 states the Administrator shall conduct a vigorous program in aeronautics research and technology development and validation, emphasizing emerging technologies with the potential for breakthrough advances to enhance United States preeminence in civil and military aviation; and in cooperation with the Department of Defense conduct a flight demonstration program (with first flight in 1995) to prove the feasibility of an air-breathing hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere.

TITLE IV—COMMERCIAL SPACE LAUNCH ACT AUTHORIZATIONS

Section 401 authorizes appropriations for the Office of Commercial Space Transportation (OCST) for fiscal year 1989 of $3,500,000. In addition, funding levels of $3,850,000 and $4,235,000 are authorized for fiscal years 1990 and 1991 respectively. Increases in funding provide additional support for the OCST primarily in the "Licensing Procedures, Operations and Enforcement" and "Space Hazards Analysis and Management" categories.

TITLE V—CIVIL SPACE PROGAMS IN THE DEPARTMENT OF COMMERCE

Sction 501 requires the Department of Commerce to submit budgetary requirements to the Congress for the Office of Commerical Space Programs. These proposed funding levels should be submitted to the appropriate authorizing committees in the Congress by July 15, 1988.

TITLE VI—DRUG-FREE WORKPLACE

The Committee is deeply concerned that the rampant use of controlled substances is undermining the very fabric of American society. The efforts taken by the government to further science and technology are and essential part of our economic progress and further our ability to compete in the world marketplace. Those efforts are threatened by the current plague of illegal drug use in the United States.

This section sets forths a strong Congressional mandate to the Administrator so that policies and procedures are implemented to assure that NASA and its contractions and grantees conduct their activities in a workplace which is free from illegal use of controled substances. The section states that on funds which are authorized by the Act shall be expended in any workplace that is not free illegal use of controlled substances. The section relies on the Administrator to implement the drug free policy, under applicable law. The Committee adopted this language with the intent to use the heavy threat of withholding Federal funds to ensure that employers take active step to ensure that their employees who are acting within the scope of their employment maintain a drug free workplace.

The term "workplace" as used in the section means a workplace for the preformance of work undertaken using funds authorized by this Act. The term "controlled substances" as used in the section means controlled substance in schedule I through V of section 202 of the Controlled Substances Act.

COMMITTEE VIEWS

ESTABLISHMENT OF LONG-RANGE PLAN

A continuing concern of the Committee has been the absence of a long-range plan and clearly defined set of goals to guide the nation's space program. Numerous studies have made recommendations regarding the future of the United States space program. Although the specific proposals have varied slightly, they have all substantiated the need for the establishment of long-term initiatives.

The National Commission on Space was directed by Congress to develop long-term goals for the Civilian space program. The Commission's report identified a goal to open the inner solar system for science, exploration and development. The Commission also suggested specific objectives to meet this goal including space ports in Earth orbit and settlements on the Moon and Mars.

In P.L. 100-147, Congress directed NASA to submit "a recommendation for a long-range implementation plan, including an impact assessment of such implementation on personnel, budget, and other resources." In that regard, the Committee was disappointed in NASA's response to the report of the National Commission on Space which stated that NASA was "not ready to recommend a long-range implementation plan for the particular structure laid out in the Commission report or for any alternative single-sequence master plan." The Committee is concerned that this is an indication of NASA's reluctance to address the future budgetary needs of our nation's space effort.

The establishment of specific, long-term goals and associated time lines will have a positive effect on the nation's perception of the space program and our international leadership role. This approach has proven successful in NASA's past and needs to be expanded to address future space initiatives.

In summary, the Committee recognizes that the setting of specific long-range goals is a challenging endeavor in times of continuing fiscal constraints. However, this year's legislation has been designed to focus not only on current year needs but to address out year funding as well. The development of an effective long-range strategic plan is essential to ensure the fruition of existing as well as future NASA programs.

SPACE STATION OPERATIONS COSTS

The Committee's review of NASA's efforts to address the long-term Station operations requirements indicates that NASA has made good progress in developing an operations concept and toward controlling future operations costs. This progress is evidenced in NASA's October 1987 update of its report on operations

cost management and in the operations framework outlined in the report of the Operations Task Force.

The Committee recognizes, however, that many technical and management issues concerning operations costs remain to be resolved and that progress has been slower than expected in developing an operations cost control process. Also, although NASA's updated operations cost management report identifies major drivers of operations costs, the report does not indicate how or when NASA plans to establish the operations cost benchmarks or objectives discussed in its 1985 report. The Committee understands that NASA plans to provide designers with target allocations of space station resources but has not yet determined how or when to translate such allocations into cost objectives. The Committee believes that cost objectives are needed to ensure that program designers and managers give future operations costs an appropriate degree of attention during Phases C/D.

The Committee is aware of NASA's recent work in drafting an overall Space Station design-to-life-cycle-cost process. This cost management approach will enhance the program's potential for predicting and controlling operations costs. The merits of this systematic approach have been pointed out by the General Accounting Office in recent information provided to the Committee on NASA's efforts to establish such a Space Station design-to-life-cycle process. The Committee urges NASA to continue and accelerate this progress and to formally establish a rigorous management process that will require full and consistent consideration of operations cost impacts in evaluating design and process changes. Towards this end, the Committee requests that, prior to the preliminary design review, now scheduled for the third quarter of 1989, NASA provide the Committee with a detailed report on the process that it ultimately adopts. The report should also explain how the process being adopted compares to the approaches described in the 1985 and 1987 NASA reports on operations cost management.

Space Station Management and Integration Costs

The Committee has noted that the management concept for the development phase of the Space Station which has resulted in the need for a large fraction of the program's resources to be committed, in the initial phase of this program, to management and integration. Because of the diverse nature of the Space Station program, a large number of interfaces exist among the various work package Centers and contractors. It is essential that all participants in the program share a common understanding of the technical and program requirements and that system engineering changes are properly addressed throughout the program. As pointed out by the National Research Council Committee on the Space Station, the management of this program represents a challenge at least as great as the technical development.

The challenge now facing the Space Station program is to move ahead and firmly establish the technical team in the face of continuing budgetary pressure. As a result of the large number of organizational interfaces, however, a large fraction of funding has been directed toward first establishing the management team.

The Committee notes that in the FY 1988 budget, when the overall funding for the development program was decreased from $700,800,000 to $366,800,000, the portion identified as "management and integration" *increased* from $121,100,000 to $146,500,000. In other words, as the overall resources available decreased by 48%, the amount available for actual hardware development decreased by a substantially greater fraction, 62%.

The Committee also notes that NASA's current estimate for civil service personnel needed for this program is greater than the onboard staffing by over 500 full time equivalent personnel. This suggests that the civil service and contractor staffing and other resources needed to manage the program may be greater than is now planned. In addition, the Committee is concerned that in later years, when inter-center delivery of common hardware components must be accomplished for integration and test, additional technical problems may be recognized leading to additional costs. Because all hardware elements will be developed in parallel, any single element problem will result in costs and delays throughout the program.

Notwithstanding the clear necessity to utilize the full scope of the capabilities at the NASA Centers and contractors, the Committee is concerned that the management and integration costs needed to coordinate these organizations may become overwhelming at the expense of actual hardware production. This view, however, does not signify that the Committee differs from the conclusion of the assessments of the "Sam Phillips Task Force," the National Research Council, the Rogers Commission, and others that a strong central management focus exist in Washington for such major programs.

The Committee requests that by October 1, 1988, NASA submit a comprehensive report on the management and integration of the Space Station including:

a. The projected costs attributable to the management and integration function including both civil service and contractor costs;

b. Any alternatives that may reduce the management and integration costs; and

c. NASA's plan for reducing the complexity of the integration and test and component flows among the NASA Centers.

Commercially Developed Space Facility

The Committee is concerned, in the event NASA is authorized by the Committee to proceed with a lease option for space on a CDSF, that the commercial operator of the facility be prepared to operate it on a commercial basis with little or no U.S. government leasing after that lease expires. The Committee therefore recommends that NASA, in its development of a request for proposals for a CDSF, consider ways of encouraging the operator to seek and sign lease contracts with foreign and commercial entities.

For example, the Committee suggests NASA consider the practicability of a lease agreement that, instead of providing for a flat level of obligations over a period of years, would reduce the government's lease obligations on a yearly basis. In order to provide

stable funding in the initial years of operations of a CDSF, NASA might consider beginning these reductions only after the second year of operations.

Similarly, the Committee suggests NASA consider the practicability of a lease agreement that would make the minimum levels of government lease obligations in the third and all subsequent years of operation of a CDSF contingent on the attainment, by the CDSF operator, of certain minimum levels of irrevocable contract commitments with entities other than the U.S. government.

Space Shuttle Pricing Policy for Commercial Users

During the Committee's review of the FY 1989 NASA Authorization request and related commercial space policies, public testimony revealed that a White House interagency group on space had met on March 25 and agreed to designate a price for a dedicated, commercial launch on the Space Shuttle of $245 million. This new price would be a significant increase from the previous 1982 price of $74 million. The interagency group, consisting of representatives of the Office of Management and Budget, Department of Commerce, Department of State, Department of Transportation, Department of Defense, Central Intelligence Agency, National Security Council, and National Aeronautics and Space Administration had sanctioned this decision against NASA's recommendation.

At the hearings of the Committee, NASA witnesses for commercial space matters testified that the higher Shuttle price would "jeopardize everything in commercial space." Commercial microgravity users are already lacking in space based experimentation as a result of the high cost and risk of doing business in space. Even before the Challenger accident, the cost of going to space was consistently identified in testimony before the Committee as the primary issue affecting space commercialization. Former NASA Administrator James M. Beggs, currently Chairman of the Board of Spacehab, testified that "You can forget Spacehab and you can forget the rest of commercialization" if the higher price prevailed. He further testified that any price over $100 million would jeopardize the commercial market. The Committee concurs.

The Committee's view of the importance of reasonable Shuttle prices for commercial payloads is firmly rooted in Public Law (P.L. 99-170), Title II of the National Aeronautics and Space Administration Authorization Act of 1986, which established a Shuttle pricing policy for commercial and foreign users. That law set forth a reimbursement pricing policy for Shuttle that would encourage the full and effective use of space, preserve the role of the U.S. as leader in space research and development, and enhance the international competitive position of the United States. Clearly, none of these objectives would be accomplished if the Administration were to adopt a $245M price for the Space Shuttle.

Title II of P.L. 99-170 assigned the task of setting a Shuttle price *to the NASA Administrator,* which would be not less than $74 million or the additive cost of the launch. The law provides considerable flexibility in the Administrator's authority to ensure that the Space Shuttle is accessible to commercial and foreign users.

Information available to the Committee indicates that the Shuttle pricing decision has recently been reevaluated, leading to a new $110 million recommendation, which suggests that in the current case, there will be an acceptable outcome for Shuttle's commercial users. Details of how the original recommendation of $245 million was reached will remain unknown, characteristic of the lack of accountability for these interagency decisions. What the Committee can rely on in this assessment, however, is public testimony concerning the impact of high Shuttle prices on the microgravity community, as well as the legal basis for soundly justifying a pricing decision based on "additive cost."

The Shuttle pricing debate presents the best example to date of the growing inconsistency of the space policy decision making within the Executive branch dominated by fragmented agency agendas. The result is detrimental to NASA and to the space program. In recent years, this Committee has been concerned about the Senior Interagency Group process in view of the trend toward its greater involvement in space policy decisions without public discussion or congressional input. Today, the Committee's tolerance of this process is saturated, and recommends the Administration review means by which interagency input on space policies can be obtained without subordinating NASA in the process.

The Committee recognizes that, in part, this situation arises out of NASA's own lack of leadership in fostering commercial space activity. In 1984, the Committee amended the National Aeronautics and Space Act to include the fostering of commercial use of space as one NASA's objectives. To date, NASA has not been aggressive in implementing this new charter, leading to growth frustration in many quarters. The situation worsened following the Challenger tragedy. However, whatever shortcoming toward its commercial responsibilities by NASA, it should not justify severance of NASA from the policy process, which is the practical effect of the growing interagency role in space matters.

Rather, NASA should boost its efforts in commercial space, and seek a more "user-friendly" posture toward commercial users. NASA's little-used regulatory authority under the Space Act, should be contemplated as a significant channel for communicating with the public and private sectors. Policies affecting commercial and foreign users should be published in the Federal Register in order that comment can be solicited and NASA can benefit from the participation of the industry. The growing maturity of the commercial space sector warrants this new departure in policymaking for NASA.

The Committee would also suggest that if the Administration is serious about its own commercial space initiatives, it would do well to abide by public law; to recognize the expertise and knowledge that lies within the National Aeronautics and Space Administration, the agency chartered by Congress to foster the commercial use of space; and to respect the needs of the user community which it professes to promote.

In recognition of the need to foster a stable policy environment for commercial users, the Committee adopted in Title I of the Bill a long range plan for commercial space which reiterates the duty of the Administrator to set Shuttle prices in accordance with P.L. 99-

170. The Committee believes that long term investments by the private sector will only be made if such stability can be anticipated.

Need for Frequent Flight Opportunities

In adopting Section 102 of the Bill, the Committee explicitly recognized that a major and essential component of a balanced science program must be a provision for frequent and sustained flight opportunities for each major discipline. In the past, the Committee has supported augmented funding for the Explorer program and the establishment of a Planetary Observer program. On the whole, the Committee is satisfied that NASA has taken affirmative steps toward developing a viable Explorer program with the budgetary augmentation requested in FY 1989 and the addition of Scout class missions. The Committee is not yet satisfied, however, with NASA's commitment toward the identity and budgetary approach for a Planetary Observer program as envisioned by the Solar System Exploration Committee in its 1983 report entitled *Planetary Exploration Through the Year 2000.* The Committee believes that an identification of fixed budgetary resources for a series of observers will be of great benefit in establishing strict cost controls and evolutionary mission development.

In addition to the Explorer and Observer mission, the Committee has directed the establishment of an Earth Probes program for the Earth Sciences and a Lifesat program for the life sciences. The Committee believes that the Earth Sciences are emerging with sufficient scientific merit to justify the establishment of a series of applications satellites within the next two fiscal years. This mission series should be identified, funded and managed separately from the Explorer missions.

The Committee views with concern the recently discovered depletion of ozone in the Antarctic. The contribution to this research by the Total Ozone Mapping Spectrometer (TOMS) on the Nimbus-7 satellite is clearly recognized. In order to supplement the record of ozone measurements, the Committee recommends that NASA provide for an early flight opportunity for TOMS as a part of this Earth Probes program.

Advanced Communications Technology Satellite Program

The Committee is disappointed that the Office of Management and Budget has, once again, failed to include funds for the Advanced Communications Technology Satellite (ACTS) program. The value of this program to U.S. competitiveness in the communications area has been well documented in the Committee's past deliberations.

Although the Committee has generally welcomed the Administration's budget request as a realistic recognition of the needs of the space program, the failure to include ACTS appears to be a misguided ideological decision. For the Administration to leave out a program of significant national importance which has strong Congressional support is an effort in budgetary gamesmanship which does not reflect well on the commitments contained in the recently adopted National Space Policy.

The Committee recognizes that the overall effect of restoring the unrequested ACTS funding will cause great budgetary pressures on other programs even under the best of circumstances. However, given the present stage of investment in this program, such restoration is deemed necessary and in the public interest. The Committee adopted an amendment to restore the ACTS funding in the amount of $89,000,000 in fiscal year 1989 from within available funds. The Committee has also limited to 20 per centum the amount of that reduction that may be applied to the programs of the Office of Space Science and Applications. This limitation is designed to ensure that the result of this general reduction does not impact upon the space science and applications programs in a disproportionate manner.

The Committee has also provided for the estimated funding requirements for the spacecraft and upper stage for ACTS in FY 1990 and FY 1991. The Committee directs the Administrator to make the reductions required by this provision in fiscal year 1989 in such a manner that will minimize the impact of the reductions on any on-going program or proposed new start.

The Committee points out, in the strongest possible manner, that continued signals from the Administration that it supports the civil space sector involved in space commercialization, while at the same time failing to meet contract obligations in the EOSAT contract, and repeatedly attempting to kill the ACTS program, cannot lead to real efforts to develop a true civil space sector. The obvious message to the commercial sector from the EOSAT and ACTS experience is that the United States Government is a totally unreliable partner.

Space and Ground Networks, Communications and Data Systems

The communications capabilities embodied in NASA's space and ground networks and scientific satellites are a key element that effects all of the agency's activities in space. These systems receive, store, transmit and forward a broad range of information including data, tracking, telemetry, commands, and other communications vital to successful missions.

Therefore, the Committee is concerned by recent accounts which have alleged that NASA's communications and data systems may lack sufficient capability to permit researchers to extract information needed for studies on a timely basis and that some data stored on magnetic tapes may be lost if the archived tapes are not soon duplicated.

In the post-Challenger era as missions increase in capability and data rate, the Committee is concerned that an even greater potential will exist for delaying researcher access to needed information. Thus, NASA should take steps to ensure that reliable and maintainable communications services are carried forward in their long-term plans and that adequate capacity exists for NASA's future science and exploration needs.

At the same time, the Committee notes that NASA's budget for the Tracking and Data elements have required substantial increases in recent years, and we anticipate NASA will request

larger increases in the future. However, to ensure these services are provided in the most cost-effective manner possible, efficiencies must be incorporated into the programs through an integrated strategy for the next decade that provides both effective networks and sound financial plans.

The Committee intends to review and carefully monitor NASA's programmatic and budgetary plans for the operation and eventual expansion of its Tracking and Data network.

Advanced Solid Rocket Motor

The Committee notes that NASA has undertaken activities in the past year to comply with the language in the FY 88 Authorization Bill (P.L. 100-147) that directs the Agency to undertake the competitive development of an Advanced Solid Rocket Motor for the Space Shuttle program. The Committee continues to believe that this motor should be developed as soon as possible in order to enhance the reliability and payload lift capability of the Shuttle.

The Committee also believes that the contracts that are used to procure these motors should be structured in such a way as to provide incentives to increase the long-term safety and reliability of the motors. The Committee notes that the Acquisition strategy presented by the Agency allows for three options: a government owned-contractor operated facility (GOCO) funded by the government, a facility constructed on government property and funded by private means, and a fully private facility on private land and funded by private means. The Committee is concerned that each of these options is given full and fair consideration.

The Committee is also concerned that the acquisition strategy should permit the Agency to maintain some form of competition throughout the life of the Advanced Solid Rocket Motor program. This competition may, in part, be addressed through the establishment of terms and conditions that ensure that ownership of production facilities does not detract from the Government's prerogative to solicit additional or alternate sources for solid rocket motors.

The Committee intends to review the final acquisition that is proposed by the NASA Administrator for the procurement of the Advanced Solid Rocket Motor and the continuing administration of this program to ensure that these objectives are met.

Use of Shuttle External Tanks by Nonprofit Institutions and the Private Sector

The Committee notes that the External Tanks (ETs) used by the Space Shuttle, which are normally expended and then discarded early in Shuttle missions, could become a valuable national space resource if placed in appropriate orbits and suitably modified, outfitted, and in some cases, attended or staffed. Used in this fashion, the Shuttle ETs could make significant contribution to U.S. efforts to promote the commercial and scientific development of space.

The Committee has expressed a strong interest in using ETs for these purposes in previous reports, and notes with satisfaction the progress made by the nonprofit research community (such as the Spaced Phoenix program developed by the University Corporation for Atmospheric Research), the private sector (such as Global Outpost, Inc.), NASA, and the Executive Branch of the Federal Government in the past year toward developing a program for the use of ETs in accordance with the President's recently announced commerical space policy. However, the Comittee is concerned about the slow progress in implementing this program at a time when action is clearly required. Furthermore, the Committee is concerned that further delay will exhaust the private funds already raised in good faith by interested users.

The Committee adopted Section 209 which directs NASA to make available for five years expended External Tanks of the Space Shuttle fleet at no cost (except as outlined below) to all feasible U.S. commercial and nonprofit endeavors. These endeavors may include such activities as research, storage, and manufacturing in space.

The Section also directs NASA to make available to nonprofit institutions of higher education or to nonprofit organizations whose primary purpose is the conduct of scientific research, during the next three years of Space Shuttle flight operations, no less than five External Tanks for the sole purpose of carrying out suborbital intertank experiments. The Committee instructs NASA to enter into negotiations and be prepared to reach one or more agreements to this effect with such institutions and organizations (e.g., UCAR) within 30 days of enactment.

The Committee expects NASA to enter into agreements for nonprofit institutional and private sector use of Space Shuttle External Tanks as soon as possible and expects the agency to report back to the Committee on progress being achieved within 90 days of enactment.

It is the intent of the Commitee that nonprofit institutions and private sector users should reimburse NASA for only those additive costs that are incurred by NASA in making External Tanks available for use. These costs shall include those that are directly attributable to making the External Tanks available for non-government use, including, but not limited to, feasibility analyses, engineering efforts, safety assessments, certification analyses and tests, hardware manufacturing and modification, equipment installation and checkout, crew training, and direct impacts on flight operations.

It is also the intent of the Committee that the availability of External Tanks shall be subject to the launch of a sufficient number of Space Shuttle missions, and experimental and operational designs that are consistent with the safety and operational constraints of Shuttle missions.

National Space Transportation Policy

The Committee recognizes the unquestioned importance that reliable, cost-effective access to space holds for all of the activities that the United States needs to conduct in outer space. In the coming months and years, the Administration and the Congress will have to make many key decisions related to this country's space transportation infrastructure. These decisions will include the number and types of space transportation sysems that will be developed; the improvements that will need to be made in existing space

transportation systems; the schedules that will be followed for these developments, procurements, and improvements; and which missions or types of activities these various sytems will be called upon to support when they become available.

The Committee believes that the process of arriving at these decisions could be enhanced if an overall policy framework was formulated to serve as a consistent context for making these decisions.

The Committee adopted Titles I and III of this bill, which lay out the guidelines for the development of this policy. These guidelines are based on the extensive reviews and hearings the Committee has undertaken over the past several years on assured access to space and on the additional information developed as a part of the Committee's investigation of the Challenger accident. Central to these findings is the view that, in order to ensure that this country has assured access to space, the government must maintain, or have available from domestic commercial suppliers, a robust fleet of manned and unamnned space launch vehicles. This fleet should be structured to provide versatile, flexible, reliable, and cost-effective space transportation services to meet the civil and military needs of the United States Government.

Fostering the Growth of Commercially Provided Hardware and Services

In the past, the Committee has encouraged NASA to seek creative use of procurement authority to encourage the growth of privately developed space hardware and services. The purchase by NASA of commercially provided space products and services to meet NASA requirements or other established needs has been seen as offering distinct advantages to NASA and the Nation, including enhanced competition, lower costs and the availability of new and alternative technologies, products and capabilities.

It is important that NASA's role in fostering the growth of commercially provided hardware and services not be limited by a strict procurement relationship. NASA has a significant role as facilitator of commercial space, even where NASA may not ultimately end up as purchaser of the hardware or services.

To this end, the Committee urges NASA to seek ways and means of facilitating commercial access to space. One important means is through the use of deferred payments for Shuttle launch costs, which recognizes that for a fledgling entrepreneur, a revenue stream may not be expected until post-launch. Where the Agency envisions that requirements may be met through commercially provided services or hardware, the committee encourages the Administrator to seek on a mutually agreeable basis an exchange of services, in lieu of funds. Launch service costs could be waived, for example, in exchange for government use of commercially-provided hardware or services.

This can be a particularly important means of bringing on-line Shuttle-associated products and services that would provide new capabilities for government and commercial markets.

Development of the Earth Sciences Satellite Program

During the past decade, the Committee recognized that there has been a major shift in NASA policy regarding the development of earth science missions. Before the 1980's, the emphasis was on developing several moderate-sized research missions that were focused on a few major diverse science problems, many of which would directly benefit operational agencies (e.g., NOAA). Therefore, in many instances, NASA would fly research missions that would be the prototype for subsequent operational flights. Also, the research missions would make technological progress in a series of evolutionary steps.

Major advances in the earth science program for the next few years will result from the proposed development of the polar platform (Earth Observing System, EOS). The U.S. sponsored portion of the polar platform concept is for two large serviceable platforms with a mixture of operational and research sensors (approximately 20 sensors/platform). Two other platforms are planned by the international community. This is a significant departure from the Nimbus program of the 1970's based on expendable satellites. The EOS will cover a tremendous range of diverse scientific objectives. The planned launch would be in the late 1990's.

The Committee recommends that this concept be accompanied by a program of "explorer" type expendable satellites with focused objectives. This will maintain the evolutionary approach for the development of the earth science satellites. Each mission should have a clear focus. Often, the simultaneous flight of satellites in different orbits will yield more productive scientific results than a very large effort in a single orbit. These orbits are polar sun synchronous, geosynchronous, and low altitude and low inclination (mostly viewing the tropics). This would also be of great benefit to agencies like NOAA for the development and demonstration of operational concepts and instruments. An evolutionary approach allows the technological and scientific communities to develop at a reasonable pace to keep up with the program development.

An initial step in this direction is the development of Earth Probe missions. Thus, the Committee adopted Section 102(d) which requires the initiation of an earth probes line item. The Committee intends that the earth science program be balanced and provide for both the EOS major missions while retaining frequent flight opportunities for smaller focused missions. This balance will yield great scientific benefits and will result in a healthy science community.

Solar Dynamic Power Option

The Committee remains concerned with the unanswered questions regarding Space Station electrical power requirements versus capability. As the result of a recent planning exercise undertaken by the Office of Space Science and Applications it is now obvious that the U.S. payload allocation is already seriously oversubscribed as soon as we reach the permanently manned configuration.

In worst case analysis, which is admittedly unrealistic, the total peak power requirements for Space Station housekeeping, and U.S. and foreign payloads, will more than double Space Station capability.

It seems obvious to the Committee that power requirements will increase. Therefore the solar dynamic power option remains a critical program. The Committee is disappointed that NASA does not seem concerned that this technology should be moving forward at a much faster pace.

The Committee is aware that NASA currently plans to conduct a solar dynamic technology flight demonstration in the near future. That test will supply critical answers that will allow a decision to be made based on sound engineering analysis. The Committee believes that the decision to go forward with the solar dynamic power option is one of the most important to face NASA as the Space Station is being developed. Therefore, the committee wishes to stress our strong support of the flight demonstration program.

In recognition of the fact that solar dynamic technology is a critical element of future U.S. competitiveness is space, and in view of the strong support for the solar dynamic program within the Committee, the Administrator is requested to report to the Committee by October 1, 1988, with a detailed plan for preliminary design, including "hooks and scars" for the implementation of proof of concept tests for this technology.

Because of the relatively near term requirement for this technology the Committee urges NASA to budget the same level of effort for solar dynamic power as it does for other advanced space power technologies.

NASA's Role in the Global Change Program

In Section 102(e) the Committee has directed NASA to initiate development activities for a Mission to Planet Earth in 1992. This is intended to form the basis for a major component of the International Space Year and will involve a multinational effort to study and understand the Earth as a system. The Committee encourages NASA to assert a strong leadership role in developing cooperative relationships with other nations to ensure the success of the International Space Year.

As an essential part of the Mission to Planet Earth the Committee has directed NASA to initiate the Earth Observing System (EOS) payload to be carried on the Polar Orbiting Platform. In order to fulfill the full scope of the science objectives of the Mission to Planet Earth, the Committee recognizes that the U.S. must make an early commitment to two platforms. It is therefore the view of the Committee that this initiative can be made more cost effective by establishing a program baseline and acquisition strategy for two spacecrafts. Inasmuch as the Polar Platform will also carry NOAA's operational sensors, a second spacecraft would also serve as a potential backup in the event of a launch failure.

In addition to initiating the Mission to Planet Earth program in 1992, the Committee recommends that NASA also use the occasion of the International Space Year to conduct a Global Information demonstration program in which prototype information is acquired, integrated and used to illustrate the benefit to mankind. The Committee views such an "end-to-end" system test as a valuable step toward making the larger commitment that will be necessary for the full Mission. In addition, such a test will help establish a pattern of interaction among segments of the science community, governmental organizations and other nations that will have profound benefits for a successful Global change effort.

U.S.-Latin American Cooperation

The U.S. space program has been and will continue to be a valuable asset for improving international relations and strengthening the bonds of friendship with our allies. This asset has not been fully exploited with respect to Latin America and the Committee believes that U.S.-Latin American cooperation in space activities could have an extremely beneficial impact on the spirit of inter-American cooperation in other areas as well.

The Committee strongly endorses NASA's cooperative venture with Argentina in support of their scientific satellite, the SAC-1, and suggests promoting an expanded role for Latin America in the study of solar terrestrial environment. One potential means of accomplishing this objective is through the International Solar Terrestrial Physics (ISTP) program. Currently the Space Physics Analysis Network (SPAN), which has very active nodes in Argentina and Brazil, is the primary communications system for this effort. The expansion of this network to other countries in Latin America would permit their involvement at whatever level they desire.

The Committee believes that U.S.-Latin American cooperation in space activities can be mutually beneficial to all participating countries. In particular, in the areas of remote sensing and satellite communications, there are issues peculiar to the Western hemisphere that can best be addressed by a Pan-American space coalition with common goals and interests. Therefore, it is a desire of this Committee to help foster the establishment of a Latin American space organization which could represent the interests of all Latin American countries in much the same way as the European Space Agency represents the European nations.

The Committee recognizes that the success of such an endeavor depends on a strong internal motivation on the part of the individual member states and it is not the intent of the Committee to direct these efforts in any way. However, the Committee believes that NASA could play a key role in facilitating this activity by contributing its expertise and pursuing opportunities for potential cooperative ventures in space research and technology. Accordingly, the Committee encourages NASA to take an active role in support of a conference to be held in Costa Rica in 1989 to explore means of establishing a cooperative Latin American space program.

Space Technology for Archaeological Research and Documentation

The committee recognizes that space technology can play a key role in archaeological research and documentation of large-scale constructions of prehistoric civilizations where significant archaeological features may not be accurately discernible from the ground. The committee notes that NASA has made a good start in exploring the uses of space technology for archaeological purposes in its work on the ancient road network of the Chaco civilization of northwestern New Mexico.

NASA allocated $65,000 in 1988 to investigate and map the Chaco roads. It is expected that by the end of 1988 several roads will be mapped; gaps in the known roads will be identified; the general expression of roads on the remote sensing imagery will be known; preliminary field investigations will be done; and a Geographic Information System for the Chaco cultural region will be initiated.

The committee recommends that NASA continue its remote sensing survey of the Chaco region for evidence of roads and that it investigate thoroughly and map those that are detected; through radar imaging, data analysis, image processing, archaeological ground checking, and completion of the Geographic Information System.

The work of identifying the Chaco road network would be facilitated if NASA were to utilize the Global Positioning System. This system employs satellites presently deployed to image surface features with extraordinary degrees of accuracy—precisely the degree of accuracy essential to fully comprehend the Chaco road system.

The committee believes that NASA can, by bringing its resources to bear on the archaeology of the Chaco region, develop a research and documenation model which can then be tested and used for the study and management of archaeological sites throughout the United States, and indeed, the world.

Aeronautical Research and Technology

The Committee strongly supports the overall level and direction of NASA's FY 89 Aeronautical Program. Neverthless, there are several areas where concerns exist.

The Committee is disappointed in NASA's lack of commitment to assisting the commuter/general aviation and rotorcraft industries. NASA should develop a strategy and a plan to develop and validate the technology needed for U.S. industry to regain competitiveness in producing these aircraft.

In recent years, generic research on hypersonic flight has suffered because of a need to solve immediate problems associated with the National Aerospaeplane (NASP). The Committee strongly supports the NASP, but urges NASA to mainain a broadly based program of hypersonic research.

The Committee supports the need for a greatly expanded technology development and validation program, including a major focus on high-speed civil transport technology. The associated potential environmenal problems of such an aircraft could preclude its successful commercialization. Therefore, the Committee strongly recommends NASA concentrate its efforts on understanding and solving these environmental problems before other related research is expanded significantly.

National Aerospaceplane (NASP)

In two hearings that addressed the NASP, witnesses from NASA, DARPA, and the Air Force expressed strong support for the funding Memorandum of Understanding being developed by DOD and NASA. The Assistant Secretary for the Air Force said, "I think it is important to recognize the DARPA, NASA, Air Force, Navy, industrial relationship, and we are in fact dedicated to preserve that support and that relationship".

The issue of NASA's *total* funding percentage in the program was summarized by the Director of the Defense Advanced Research Projects Agency (DARPA), ". . . it is clear that their (NASA) contribution is higher than one would arrive at if they just did the accounting in the direct R&D line".

On the other hand, concern has been expressed over the Air Force funding commitment for the entire life of the NASP program. Of particular concern is the funding commitment for fiscal year 1990 and beyond. For example, the Committee is aware of communications between the President's Science Adviser to the Deputy Secretary of Defense in which the Science Adviser ponits out that the Air Force's funding projections for fiscal years 1990–1994, are approximately 50 percent of the baseline established to satisfy the milestones approved by the NASP Steering Committee.

The Committee expresses strong support for full and complete funding for the NASA program in accordance with the negotiated Memorandum of Understanding between NASA and DOD, as outlined during hearings.

Criticisms have been made that the management of NASP is pushing the program faster than advances in technology developments warrant. The Committee has found this not to be the case. For example, the materials-structures maturation program, includes a cooperative research effort by all five of the competing NASP contractors. Such industrial cooperation and coordination is essentially unheard of, but is necessary if materials technology is to be developed during the time scale of the program.

The Committee finds that the NASP program management is as innovative and creative as is the NASP project itself. The Committee expresses strong support for the managemnt and the overall program.

Aviation Safety

The Committee strongly supports the increased research effort proposed in aviation safety and aviation human factors programs. If major advances in improving safety in aviation are to be realized in the near future, an aggressive long-term research effort in the basic sciences underlying both of these areas is needed. The Committee also urges NASA to increase its communication and coordination with the Federal Aviation Administration so that the research results may be incorporated into federal safety standards and guidelines.

Aviation Noise Research

The long-term objective of the NASA research in aviation noise is to eventual contain within the boundaries of the airport all aircraft noise which is appreciably greater than the typical ambient noise in the community. A concerted effort has been placed in developing more accurate prediction techniques and to quantify the benefits of various noise reduction alternatives.

The Committee supports those research efforts and encourages NASA to assist local airports in applying the results of these stud-

ies especially in locations that have difficulty scientifically determining noise levels.

The Committee also requests that NASA undertake an assessment of research programs on new and innovative technologies for controlling aircraft and airport noise. The growing concern over reducing airport noise may be incompatible with the goal of improving aviation safety while at the same time increasing service. Consequently it is imperative that a noise reduction research program be reevaluated especially in view of improved materials, technologies, etc. that could be applied in such a program.

DETAILED EXPLANATION OF NASA PROGRAMS AND FISCAL YEAR 1989 AUTHORIZATION

RESEARCH AND DEVELOPMENT

FY 1989 NASA REQUEST, $4,446,700,000

FY 1989 AUTHORIZATION, $4,446,700,000

FY 1990 AUTHORIZATION, $6,553,100,000

FY 1991 AUTHORIZATION, $7,849,700,000

SUMMARY

		Estimated fiscal year 1988	Authorization fiscal year 1989	Authorization fiscal year 1990	Authorization fiscal year 1991	Page No.
1	Space station	$392,300,000	$967,400,000	$2,130,200,000	$2,912,500,000	57
2	Space transportation capability development	609,800,000	631,100,000	784,000,000	889,000,000	71
	Space science and applications:	1,575,800,000	1,859,600,000	2,255,000,000	2,428,000,000	
3	Physics and astronomy	(610,800,000)	(791,600,000)			86
4	Life sciences program	(69,500,000)	(101,700,000)			105
5	Planetary exploration program	(329,200,000)	(404,000,000)			111
6	Space applications	(566,300,000)	(562,300,000)			120
	Commercial programs:	73,700,000	57,900,000	62,000,000	74,000,000	
7	Technology utilization	(17,700,000)	(19,100,000)			144
8	Commercial programs	(56,000,000)	(38,800,000)			147
9	Aeronautical research and technology	334,800,000	414,200,000	609,500,000	764,900,000	149
10	Transatmospheric research and technology	52,500,000	84,400,000	149,400,000	99,300,000	190
11	Space research and technology	223,600,000	390,900,000	520,000,000	637,000,000	193
12	Safety, reliability, and quality assurance	14,100,000	22,400,000	23,000,000	24,000,000	246
13	Tracking and data advanced systems	17,900,000	18,800,000	20,000,000	21,000,000	248
	Total	3,294,500,000	4,446,700,000	6,553,100,000	7,849,700,000	

1. SPACE STATION

FY 1989 NASA REQUEST, $967,400,000

FY 1989 AUTHORIZATION, $967,400,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Development	$366,800,000	$935,400,000
Flight telerobotics servicer	21,500,000	20,000,000
Transition definition	4,000,000	12,000,000
Total	392,300,000	967,400,000

Development of the United States permanently manned Space Station, as directed by President Reagan, will add new momentum to the civil space program and is essential to realizing the national goal of U.S. leadership in space. The Space Station program gives us our first opportunity to gain direct experience in long term human operations in space, and knowledge essential to future space exploration. The Station will uniquely enhance the U.S. Space Science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an avenue of cooperation with our allies, demonstrating the peaceful use of space for the benefit of all.

The Space Station will be unique because it will provide the United States with a permanently manned presence in space. It will be versatile because its capabilities will be remarkably diverse. This diversity is reflected in the Station's design, which features pressurized laboratories, accommodations for attached payloads, and free-flying unmanned platforms. This new national laboratory, a research center in space, will stimulate new technologies, enhance industrial competiveness, further commercial space enterprises, and add greatly to our storehouse of scientific knowledge. Perhaps the most significant feature of the Space Station, essential to its utility for science, commerce, and technology, is the continuing presence of its crews. Men and women will be aboard the Station base full-time. The potential of humans—their creativity, their dexterity, their ability to perceive, to interact with instruments, and to respond to the unexpected—is unique and essential. The Space Station will be designed to exploit these human capabilities. The Space Station's microgravity environment, high levels of power, and extended time in orbit, will enable scientists to make new discoveries in materials research and life sciences. The Space Station's substantive research capabilities include far more than its pressurized volume. Its free-flying platforms will enable truly synergistic studies of the Earth's atmosphere, land masses, and oceans—referred to as Earth system science. Moreover, the Station's external structure is designed to be a stable platform that will be available for mounting a number of specialized instruments and telescopes. Scientific instruments, whether in a laboratory or on a boom, require maintenance, upgrading, repair and replacement. The Station will accommodate these servicing functions. The Space Station will be designed to evolve, to be capable of growth in its capabilities, so that future needs and challenges can be met.

The U.S. Space Station will be a multi-purpose, international facility. In 1984, President Reagan invited the full participation of other nations. During the ensuing definition phase, Canada, member states of the European Space Agency (ESA), and Japan worked closely with the U.S. to define their participation. These parallel definition and preliminary design studies have resulted in the identification of the Space Station elements they are considering for development. Negotiations with these international partners for the development phase of the program are in their final stages. Negotiators from NASA and the Canadian Ministry of State for Science and Technology reached agreement in December 1987 on the text of a memorandum of understanding for Canadian cooperation, whereby Canada will provide a mobile servicing system for use on the Station. A preliminary agreement has also been reached with ESA members and Japan on their participation in the Space Station program.

The basic configuration of the Space Station and the supporting elements has been arrived at as a result of a lengthy and iterative three-year process involving NASA centers, U.S. industry, our international partners, and the national and international science communities. A detailed assessment of the Space Station program was also conducted by the National Research Council's Committee on Space Station. During this definition period, the design evolved in response to user requirements, developments of advanced technology, trade studies and cost assessments. The evaluation of the various Space Station options led to the selection of a baseline configuration, commonly known as the "dual keel" configuration. The launch of the first element of this configuration was planned for January 1994. Since this estimate represented a considerable cost increase over the target cost estimate made in 1983-84, the reasons for the increase were closely examined. Following intensive review during early 1987, a phased approach for development of the Space Station was adopted. A "Revised Baseline Configuration" which includes major elements of the dual keel configuration was selected, with a commensurate reduction in design and development costs. As a result of necessary fiscal restraint during the FY 1988-1990 period, the planned launch date for the first element launch was adjusted to March 1994. This schedule is currently under review as a result of the funding revised in the 1988 budget. This revised baseline is comprised of a single horizontal boom structure with 75 KW of photovoltaic power, the U.S. laboratory and habitability modules and two international laboratory modules (one European and one Japanese), and a Canadian mobile servicing capability. These elements comprise the manned base, and provide both internal and external accommodations for science and application payloads. There are also two science and applications platforms, one U.S. and one European, to be launched into polar orbits. A Man-Tended Free Flyer is also under consideration by the European Space Agency as a co-orbiting platform with the manned base.

In addition to the development of the manned base and U.S. polar platform, the Space Station program will include develop-

ment of a Flight Telerobotics System (FTS). The FTS will be a highly automated telerobotic device capable of precise manipulations in space. The FTS onboard the Space Station will increase crew safety and productivity by reducing EVA time, allowing the use of robotics for hazardous tasks, and free crew members for scientific tasks. The FTS will play a key role in the development of automation and robotics (A&R) technologies.

As noted above, a key design objective of the Space Station is to enable hardware and software to evolve in response to increased user demands and the need for augmented operational capabilities. The Transition Definition activities will provide for systems studies to define options for evolution of the Space Station consistent with future agency missions and for technology developments, primarily in automation and robotics, that will enhance Space Station productivity. These activities are essential for the long-term cost-effective utilization of the Space Station.

The Office of Space Station initiated a definition study during FY 1987 to reevaluate the requirements for an assured crew return capability. This activity, the crew emergency return vehicle definition study, will be continued in FY 1988 and FY 1989 under Space Transportation Capability Development and managed by the Office of Space Flight.

Space Station operations encompass all activities required to maintain the Space Station and platforms for its planned lifetime. This includes logistics support, crew training, mission operations, engineering support, launch processing, and user training and operations. The FY 1988 budget requested funds to support preliminary operations planning. These funds have been deferred based on an assessment that it was premature to initiate operations planning tasks at this time.

Since submission of the FY 1988 budget last year, the Space Station program has completed a series of intensive reviews regarding program content and rationale, flight system configuration, and overall reasonableness of the total cost estimates.

The most comprehensive review was conducted at the request of the President by the National Research Council Committee on Space Station. The NRC's task was to assess NASA's cost estimates for the Space Station program and to examine Space Station mission requirements and alternative configurations. This Committee issued its final report on September 10, 1987. The Committee found that the revised baseline configuration was "a satisfactory starting point for the Space Station . . . and reflects thoughtful compromises among the priorities and sometimes conflicting requirements of its early scientific and engineering users." The Committee also stressed the importance of having a robust space transportation system, development of an adequate ground test program and backup hardware policy, strengthened Space Station program management, and emphasis on the operational aspects of the program. Preparation of a new Space Station program cost estimate in early 1988 was also advocated. These recommendations will receive special attention during the upcoming Program Requirements Review.

The NASA studies include an extensive series of analyses relating to the Space Station operations, led by the Space Station Operations Task Force (SSOTF). The results of the SSOTF's work were sent to Congress in the fall of 1987. Concurrent and subsequent study efforts were also conducted in the areas of operations cost management and Space Station science operations management concepts. These reports were sent to Congress in August and October 1987, respectively. NASA also conducted a transportation study that reviewed the capability of the Shuttle as well as other unmanned launch vehicle systems to provide space transportation in support of on-orbit assembly and Space Station operations. Results of this study were furnished to the NRC and subsequently documented in a report transmitted to Congress in January 1988.

Also, as directed in Congressional legislation, NASA prepared and forwarded to Congress an additional Development report, the Space Station program plan for selective design parameters, submitted in April 1987. This report is consistent with and supportive of the revised baseline program's flight hardware configuration and overall transportation, assembly, and operations planning.

Due to the bipartisan budget agreement, the Congress directed a significant reduction in the funding appropriated for the Space Station program in FY 1988. The amount requested by NASA for FY 1988, $767.0 million, was reduced to $425.0 million including $100.0 million transferred from 1987 replacement orbiter production funds. After adjustments for a directed realignment between the research and development appropriation and the research and program management appropriation, the revised plan for FY 1988 is $392.3 million.

NASA is developing revised program cost estimates, both annual and total, consistent with the current budget allocation. The revised estimates will include necessary adjustments to program milestones. The report requested by Congress in late February will provide NASA's initial assessment. In addition, NASA will complete a management plan responsive to the recommendations of the National Research Council which will also address necessary civil service staffing levels to support the program. The final capital development plan and a revised Space Station development plan will be submitted following review of the revised program costs and milestones.

This budget requests the funding levels for the Space Station of $962.5 million for the present budget year, $2,130.2 million for FY 1990 and $2,912.5 million for FY 1991. The Administration is requesting legislation for a Congressional commitment to a three year advance authorization and appropriation of Space Station funds for FY 1989 through FY 1991. Later this year, the Administration plans to request legislation to establish a total program cost ceiling. These measures on the part of Congress and the Administration will provide increased program stability while maintaining cost control discipline for both development and operations. The long term commitment will help assure potential international participants that the U.S. will recognize the importance of cooperation on the Space Station program.

In support of the President's policy on the commercial use of space, NASA will, in consultation with OMB, revise its guidelines on the commercialization of the Space Station to reaffirm, clarify and strengthen its commitment to private sector investment and involvement in the Space Station program. Proposals for commer-

cial involvement in the development of the revised baseline program will be considered in the Program Requirements Review (PRR). NASA will give position consideration to proposals to accelerate private sector investment in Space Station development and operations in the form of either goods or services which have not yet been contracted. Further, NASA will seek to reply on private sector design, financing, construction and operation of future Space Station requirement, including those currently under study.

DEVELOPMENT

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Management and integration	$146,500,000	$169,400,000
Pressurized modules	55,000,000	188,000,000
Assembly hardware/subsystems	82,000,000	288,000,000
Platforms and servicing	26,000,000	56,000,000
Power system	31,000,000	154,000,000
Operations/utilization capabilty	26,300,000	80,000,000
Total	366,800,000	935,400,000

As a research facility in space, the Space Station will provide opportunities for significant advances in science, technology and commerce. It must be flexible yet durable in its capabilities, as the Station will be on orbit for many years. It must be operationally affordable for its success will be measured by its operational utility. The objectives of the program are: (1) to establish a permanently manned research facility in low-Earth orbit by the mid-1990's with the capability to evolve to meet future needs; (2) to enhance mankind's evolving ability to live and work safely in space; (3) to stimulate technologies of national importance (especially automation and robotics) by using them to provide needed capabilities; (4) to provide cost-effective operation and utilization of continually improving facilities for scientific, technological, and operational activities enabled or enhanced by the presence of man in space; (5) to foster mutually beneficial international cooperation in space; (6) to create and expand opportunities for private sector activity in space; (7) to enable the evolution of the Space Station to meet future needs and challenges; and, (8) to provide unmanned platforms for long duration scientific and operational observations. The combination of manned, unmanned, and automated systems will establish a broad spectrum of capabilities responsive to both currently identified and evolutionary needs of space science, technology, and commerce.

Following completion of a three-year definition and advanced technology development phase, the development program was initiated in FY 1987. The selected revised baseline configuration includes a permanently manned Space Station, unmanned platforms, and the associated ground-base infrastructure. The major physical elements of the configuration to be developed by the U.S. include pressurized habitation and laboratory modules, with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions; resource nodes linking the modules in which command and control, docking, and extravehicular activity (airlocks) functions will be based; high power solar arrays; a truss structure featuring accommodations for attached payloads and the Flight Telerobotics Servicer; logistics elements; extravehicular capabilities; and a polar platform carrying Earth Observing System instruments to be developed under the Space Science and Applications program. The configuration is expected to include elements provided by the program's international partners. These elements are the Japanese Experiment Module, which includes a pressurized laboratory, an exposed module for payloads, and a logistics module; the Canadian Mobile Servicing System; and the European Space Agency's pressurized laboratory, polar platform, and Man-Tended Free Flyer. The Space Station will be able to support a crew of eight and provide a total average power level of not less than 75 kilowatts, using photovoltaic arrays.

The ground-based infrastructure needed for the development and operations of the Space Station include the development of capabilities for systems engineering and integration, a distributed system for technical and management information transmission, software development tools, prelaunch processing, mission operations, engineering support, integrated testing, and payload operations support.

The space station hardware elements will be developed by four NASA field centers. The Space Station Program Office in Reston, Virginia has the task of managing and integrating the technical development of the entire program. The four "work package" centers are the Marshall Space Flight Center in Huntsville, Alabama; the Johnson Space Center in Houston, Texas; the Goddard Space Flight Center in Greenbelt, Maryland; and the Lewis Research Center in Cleveland, Ohio. While not work package centers, the Kennedy Space Center at Cape Canaveral, Florida, and the Langley Research Center in Hampton, Virginia have key Space Station responsibilities. The Jet Propulsion Laboratory in Pasadena, California, will also play a central role in Space Station program requirements and assessment. NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company was not viewed as being in the best interest of the government. Moreover, the work package approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA will have the responsibility to perform the overall systems engineering and integration and program management. The Space Station Program Office (SSPO) will be assisted in these program-wide integration functions by a Program Support Contractor (PSC), a Software Support Environment (SSE) contractor and a Technical and Management Information System (TMIS) contractor.

In 1987, the development contractors for the Space Station were selected. In May 1987, Boeing Computer Services was selected for the TMIS contract. This contract will facilitate both program control and engineering by enabling the transmission of information products and providing a means of distributing, maintaining, and

archiving controlled data throughout the program. In July 1987, Grumman Aerospace was selected for the Program Support Contract. Grumman and its team will support NASA in a variety of areas, including systems engineering and analysis, distributed systems integration, technical integration, element and launch package integration, user interface planning, and program management and control. Also in July, the Lockheed Missiles and Space Company was selected for the SSE system contract. The SSE system is designed to assure a standardized software development and maintenance environment, in order to minimize the development and cost risk inherent in the task of integrating flight and ground systems software developed by the various Space Station contractors. On December 1, 1987, NASA announced selection of four aerospace firms—Boeing Aerospace Company; McDonnell Douglas Astronautics Company; General Electric Company; and the Rocketdyne Division of Rockwell International—for final negotiations leading to award of contracts for the design, development and support of the components and systems comprising the permanently manned Space Station. Signing of these detailed contracts is anticipated in the spring of 1988.

The development program also includes the critical supporting development activities at the four NASA work package centers, and the development of the capability to operate and utilize the Space Station. Work package supporting development includes design engineering, hardware integration and test capabilities, and assembly and check-out test capabilities; the provision of Government Furnished Equipment (GFE); R&D facility outfitting; and engineering management and analysis. These efforts support all of the work package prime contractors as well as overall NASA system engineering and integration efforts. The Operational and Utilization Capability Development (OUCD) activities support major facility development at the NASA work package centers and the Kennedy Space Center. These facilities are critical to the integration, pre-launch processing, and the missions operations and crew training of the Space Station systems.

Due to budgetary reductions made by the Congress in the FY 1988 appropriation process, Space Station development activities will build up at a slower pace than originally planned. Funding constraints will delay the accomplishment of the program requirements review (PRR) process. The PRR will provide the requirements baseline from which the prime work package contractors will proceed to design Space Station systems and elements. This will lead into the integrated Space Station Preliminary Design Review (PDR) in 1989, which will provide an evaluation of the design approach of the work packages. Successful completion of the PDR will result in the readiness to proceed with detailed design of the Space Station flight and ground hardware and software. The effects of the FY 1988 funding cutbacks and the revised phasing of subsequent year funding are currently being assessed by the Space Station Program Office, in concert with the development contractors.

Management and Integration

The Space Station program includes the participation of all NASA centers, numerous contractors from all over the United States, and international partners. An activity this large and complex requires a central focus for managing the systems engineering and integration (SE&I), data management and information systems efforts, and safety, reliability, and quality assurance (SR&QA) activities. NASA, rather than a single prime contractor, will perform this essential task. To assist NASA in this function, the Space Station Program Office has procured the services of a Program Support Contractor (PSC), a Software Support Environment System Contractor (SSE) and a Technical and Management Information System Contractor (TMIS). The Jet Propulsion Laboratory is providing an independent assessment capability of program requirements and status.

The SE&I responsibilities include overall systems engineering; work package integration for prime contractors and supporting development activities; integration of potential international elements and private sector goods or services, as well as the U.S. Flight Telerobotics System (FTS) into the Space Station system; and overall safety, reliability, and quality assurance program. Also included are the development of integrated engineering models, trade-off studies on design parameters, allocation of Space Station resources among the program elements, configuration control of the overall design, and resolution of competing design requirements. Grumman Aerospace, Bethpage, New York, was awarded the Program Support Contract (PSC) in July 1987 to assist the Space Station Program Office in these and other activities.

Management and Integration also includes responsibility for the Space Station Information System (SSIS). The primary SSIS tools are composed of the Technical Management and Information System (TMIS) and the Software Support Environment (SSE). The SSIS is the operational end-to-end system by which the data flow between the onboard systems and ground control or data processing systems and the scientific users will be provided. The SSIS will be a distributed system spanning the total information flow networks required to operate the Space Station.

TMIS is an integrated system of technical and management information processes, automatic data processing hardware and software, communications networks, and procedures designed to support the design, development, and operations of the Space Station. TMIS will allow all NASA centers and contractors to have a standardized process and procedure for the sharing of information. Boeing Computer Services was selected in May 1987 as the TMIS prime contractor.

The Software Support Environment contract provides a set of rules and tools used to govern the development of Space Station software. The SSE development facility will be used to develop and maintain the SSE software requirements, design and test tools, compilers, debuggers, models and simulations. These tools will be used by the software production facilities to develop, integrate, and maintain the program's ground and flight software. The SSE system will be developed incrementally with its capabilities time-

phased to meet essential program needs. In July 1987, Lockheed Missiles and Space Company was selected for this contract. The Johnson Space Center will be responsible for the SSE contract management.

In FY 1989, the Program Support Contractor (PSC) will support the critical System Engineering activities that will begin after completion of the Preliminary Requirements Review in 1988. This system engineering effort includes activities at the Space Station Program Office, along with critical system engineering and integration support to the Program Integration Offices at each Work Package center as well as at KSC. This includes updating all key systems level schedules and documentation, refining systems level assembly and check-out logic, and establishing systems level verification requirements and procedures. The PSC effort is key to successful completion of the system-level Preliminary Design Reviews currently anticipated to begin in late 1989.

During 1989, the TMIS contractor will be working under the direction of SSPO to define, design, and implement the requisite components of the system as well as provide training to TMIS users as the system evolves. During 1989, the SSE contractor will prepare the preliminary design document for the software production facility, complete the facility contract end item list, and bring the facility on line to support the preliminary and critical design reviews.

Safety, reliability, and quality assurance reviews have been an essential element of the Space Station program since inception. FY 1989 emphasis will be on the development of criteria to perform critical reviews at both the black box and system level, application of the criteria to assess safety of the proposed design, and refinement of established program-wide quality assurance standards.

Pressurized Modules

Boeing Aerospace Company of Huntsville, Alabama has been selected for negotiations and is proceeding under letter contract in support of the Program Requirements Review (PRR). As the prime contractor, Boeing will develop flight hardware for the pressurized modules and related services. Members of the Boeing prime contract team include Teledyne Brown Engineering (Huntsville, Alabama), Lockheed Missile and Space Company (Sunnyvale, California), Hamilton Standard (Windsor Locks, Connecticut), Garrett Airesearch (Torrance, California), Grumman Aerospace Corporation (Houston, Texas), ILC Space Systems (Houston, Texas), and Fairchild-Weston Systems (Syossett, New York).

Major components of this work package include the U.S. laboratory and habitability modules and logistics modules and elements; nodes structure; airlock systems; environmental control and left support system; internal thermal, audio, and video systems; basic module outfitting; and associated software.

On-going activities include procurement and development of the engineering breadboard components, including long-lead ECLSS components; development and evaluation of computerized structural models of the manned modules' components; preparation of Pressurized Module program requirement documents in support of the Program Requirements Review; and, continued evaluation and testing of critical materials and on orbit maintenance techniques. Integration of prime contractor efforts into the continuing supporting development activities is a critical part of the on-going effort.

Specific prime contract activities planned to occur in FY 1989 include preparation of preliminary design specifications of all the pressurized modules elements and systems; commonality analyses and trade studies for evaluation of the use of common hardware; mock-up drawings; long lead procurements for the labs and racks; manned systems testing; and detailed engineering drawings for the nodes and airlocks. Also occurring during this period will be the design, development and long lead procurements for internal audio/video and thermal subsystems.

Planned supporting development efforts are necessary to assist the hardware contractors in areas such as overall module integration, independent engineering safety and quality assurance assessments, establishment of test requirements, development of test and test bed facilities, and establishment of design requirements. Critical activities in the Work Package 1 supporting development area include completion of the test beds and breadboards in preparation for extensive use throughout the development phase in areas such as attitude control, audio and video systems, process material management system, electrical systems, propulsion thruster assembly, and mechanisms. Also planned is procurement and testing of the Environmental Control Life Support System (ECLSS) technology demonstration hardware; development of data bases for materials and materials evaluation, including atomic oxygen exposure simulation work as well as evaluation of corrosion, compatibility, and contamination properties; and the development and evaluation of the design requirements for the flight elements (modules and nodes).

Assembly Hardware/Subsystems

McDonnell Douglas Astronautics, of Huntington Beach, California, and Houston, Texas, has been selected as the prime contractor for Work Package 2 and is currently proceeding under letter contract to support the Program Requirements Review (PRR). Assisting them will be IBM (Houston, Texas, and Owego, New York), Lockheed Missile and Space Company (Houston, Texas, and Sunnyvale, California), RCA Corporation (Camden, New Jersey), Honeywell (Clearwater, Florida), and Astro-Aerospace Corporation (Carpinteria, California). The scope of this contract encompasses the design and development of the hardware and software for: the data management system; the truss structure, mechanisms, and utilities; airlocks; guidance, navigation, and control; communication and tracking; propulsion; thermal control; and EVA equipment. Also included are the resource node outfitting; on-orbit assembly planning; mobile servicing system transporter; and associated software.

On-going prime contractor and supporting development contractor activities include design efforts in the areas of supporting truss structure, the mobile base for use with the Canadian Mobile Servicing Center, outfitting requirements of the airlocks and modes, subsystem requirements for thermal, data management, communications and tracking, propulsion, guidance, navigation and control,

and extravehicular activity. All of these efforts are critical to support the PRR schedule for 1988.

Specific activities being performed by the prime and subcontractors during 1989 include the hardware evaluation of breadboards and engineering models for communications and tracking; development testing of fluid system components, rotary joints, and utility mock-up of the truss structure; fabrication of the model to be used for testing the mobile transporter; development and testing of the prototype engineering units for the data management and thermal control systems; real time simulation of the guidance, navigation, and control system; development and testing of the prototype propulsion assembly systems; breadboard mock-up and development testing of the airlock structures; and build up of a high fidelity mock-up of the resource nodes.

Critical supporting development work managed by the Johnson Space Center will be pursued in the areas of technical program design support; automated assembly, test, and analysis; and Government Furnished Equipment (GFE) hardware development. Other supporting development activities include integration and engineering analyses of data management, thermal, communication, manned systems, mechanical, propulsion, EVA, and guidance/navigation subsystems. Government furnished equipment and engineering test beds for thermal, communications, data management, EVA, and manned systems will be developed and utilized to test contractor hardware to ensure a thorough understanding of the functions, performance, and interfaces necessary to build and operate the Station.

Supporting development activities during 1989 include subsystem model development, preliminary design evaluation, breadboard tests of the EVA life support system, hard suit and glove technical demonstration hardware development, and preliminary integration, test, and verification plans. Also included is development of the Multi Systems Integration Facility (MSIF) which will be used for system to system integrated verification testing and hardware/software verification testing.

Platform and Servicing

General Electric Company, Astro Space Division with locations in Valley Forge, Pennsylvania, and East Windsor, New Jersey was selected to design and develop the platform and servicing facility planning activities. GE is currently proceeding under letter contract in support of the Program Requirements Review (PRR). Assisting them will be the TRW Corporation, Redondo Beach, California.

This work package provides for the design and development of a free flying, unmanned, polar-orbiting platform which will carry scientific experiments in Sun-synchronous or other near polar inclination orbits; two sets of attached payload accommodation equipment for the mounting of various scientific instruments on the manned base; and a pointing system for manned base attached payloads requiring a high degree of pointing accuracy, including both Earth-viewing and space-viewing instruments. Also included in this work package is the integration of the Flight Telerobotics System (FTS) to the Station and the definition of requirements and interfaces for a satellite servicing facility which could be used to service Station payloads and free flying spacecraft. Effective interface with potential users is a key component of this effort and will continue at a high level throughout the entire development program.

Both prime contractor and in-house efforts are focused on developing an integrated, comprehensive set of system requirements to support the upcoming PRR. The Polar Platform requirements for hardware and subsystem technology development, shared with the manned base, will require close integration of Polar Platform and Payload Servicing design requirements with the manned base subsystem design activities. Emphasis is being placed on maintaining an effective interface with potential users of the Station to assure adequate accommodation of the requirements into the baseline manned base design.

Significant activities being performed by the prime contractor during FY 1989 include polar platform design and development; design and development of payload accommodation equipment and course pointing systems; subsystem commonality analysis; evaluation of Phase I servicing architecture; and applications software development.

In order to support the work being done by the prime contractor and his subcontractors, vital supporting development activities will be carried out under NASA direction. This includes technical support studies to define polar platform user requirements and performance; user integration activities, integration planning, software development, and the design and developmemt of thermal and data management test beds. Other efforts encompass platform subsystem and component trade studies; servicing strategy studies; analysis of requirements for common hardware for attached payloads; payload pointing system base motion disturbance studies; and engineering support for early STS thermal flight test experiments.

Power System

Rocketdyne Division, Rockwell International, Canoga Park, California, was selected as the prime contractor to design and develop the power system for the Space Station. Rocketdyne is currently proceeding under letter contract in support of the Program Requirements Review (PRR). Assisting them will be Ford Aerospace, Palo Alto, California; Harris Corporation, Melbourne, Florida; The Garrett Corporation, Tempe, Arizona; General Dynamics Corporation, San Diego, California; and Lockheed Missiles and Space, Inc., Sunnyvale, California.

The scope of this work package consists of development of a 75 KW photovoltaic (PV) power system, using solar arrays to collect power and batteries for storage; the manned base Power Management and Distribution (PMAD) systems; the engineering and system architecture to accommodate the future addition of solar dynamic capability to the manned base; and fabrication of the power systems components for the polar platform.

Early flight hardware delivery requirements impose a strict delivery schedule on this work package to provide hardware in a timely fashion to other centers for inclusion in their development activities. In-house efforts will be focused on procurement and test-

ing of long-lead hardware that will be used in the power subsystems of both the Polar Platform and the Manned Base. Component testing continues on battery life, power management and distribution (PMAD) breadboard module design, and solar cell life-cycle testing. The prime contractor is beginning development of power system design requirements that are consistent with development of the overall Space Station hardware design. Critical activities include design and development of engineering test hardware and identification of critical long-lead components required for the fabrication of the power subsystem flight hardware.

The prime contractor will be working towards baselining the technical specifications and doing the initial design activities required to support the PDR. The prime contractor will prepare the test cells needed for testing the various components of the system; continue the design and development of the flight application and ground support software; continue the design and development of the photovoltaic power module; initiate the electrical systems integrated tests; and continue design and development of the power management and distribution system, including software and hardware verification testing.

The critical supporting development activities that will continue include power subsystem and battery life tests as well as overall evaluation of the contractor design. This involves the construction of breadboards for the power management and distribution system and subsystem engineering support, power system integration planning, and power system operations planning and analysis. In-house design and evaluation of solar array test hardware; models and dynamic analysis and testing of nickel-hydrogen cells are planned. The power systems test equipment and the power management and distribution system breadboards will be acquired so that intensive analysis of the various designs and components can be performed.

Operations/Utilization Capability Development

The purpose of the Operations/Utilization Capability Development (OUCD) program is to integrate operational support planning, and develop the capability to conduct flight and ground operations in support of the Space Station and to fully integrate the users into the planning for and actual operations of the Space Station. The majority of this work is being performed at the Kennedy Space Center, the Marshall Space Flight Center, and the Johnson Space Center, although a number of key operations elements are being designed and developed at other NASA centers. Goddard Space Flight Center will develop engineering support centers for both the platform and attached payload work. Johnson Space Center will be home to the Space Station Training Facility as well as the Space Station Control Center. The Kennedy Space Center will provide much of the user integration pre-launch and post-landing capability, integrated logistics capability, and ground data management systems. Kennedy will also have responsibility for the planning and outfitting of their Software Production Facility and the Space Station Processing Facility. Marshall Space Flight Center will develop, outfit, and manage the Payload Operations Integration Center, develop the payload mission planning center, and be actively involved in the operations training simulation development.

Each of the above centers will also be involved in developing user integration capabilities for the Space Station program. This work will include the development of procedures to establish user requirements and assist in user selection as well as the tools, equipment and systems necessary to plan for and integrate the user fully into the operation of the Space Station ground and flight systems.

In FY 1989, the detailed and development efforts for the Space Station Control Center (SSCC) and Space Station Training Facility (SSTF) at JSC will increase in order to support the late 1989 Preliminary Design Reviews (PDRs). Also, the design and development of the government furnished equipment (GFE) for equipment transportation and the ground data management system hardware used to outfit the Space Station Processing Facility (SSPF) at KSC will continue. Finally, the development of the Payload Operations Integration Center (POIC) at MSFC will continue in order to support early identification and integration of user requirements into the Space Station PDR process.

Flight Telerobotic Servicer

Fiscal years 1988 and 1989 funding levels

Flight telerobotics servicer:	
Estimated fiscal year 1988	$21,500,000
Authorization fiscal year 1989	20,000,000

The Flight Telerobotics Servicer will be a highly automated telerobotic device capable of precise manipulations in space. It will be operated by the astronauts using a mix of remote and supervisory controls. The FTS will be used to assist in assembly and servicing operations. It is intended that the FTS will be an evolutionary product capable of accommodating increasingly sophisticated operations for wide application in space as well as application of the technology for use on the ground. The program is managed by Goddard Space Flight Center with support from other NASA centers and contractors. The definition and development effort includes a program to select and modify evolving technology and identify requirements for new technology; a flight demonstration to verify design and operations concepts; the design and development of the Space Station flight system; and a ground system program to provide continuing capability to evaluate and implement advanced robotic technology and assist in training and on-orbit operations.

In January 1988, two separate $1.5 million contracts for a Phase B definition of the FTS were awarded. The recipients of these firm fixed price, nine month contracts were Grumman Corporation and Martin Marietta. These contracts will culminate in the selection of a concept for the FTS which will be designed and developed by one prime contractor.

TRANSITION DEFINITION

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Transition definition:	
Estimated fiscal year 1988	$4,000,000
Authorization fiscal year 1989	12,000,000

Because the Space Station is planned to have an operational life spanning several decades and because the inherently dynamic nature of the program will require a continuously evolving set of capabilities, it is necessary to provide for evolution planning and advanced development work. The Transition Definition effort which began in FY 1988 has two main components: evolution studies and advanced development. One main objective of this program is to determine the appropriateness and readiness of major new technologies prior to their incorporation in the Space Station system. A second main objective is to define the direction and scope of future Space Station growth capabilities consistent with user requirements. A third main objective is to develop greater private sector investment and involvement in development and operations. The results from the Transition Definition program will provide NASA substantive data on new technologies and changing user requirements, and opportunities for private sector participation in the Space Station, thereby enhancing decisions as to applicability and expected performance of new missions and technologies on whatever evolutionary path the Space Station follows.

FY 1989 Transition Definition activity will include studies involving the definition of Station evolution requirements; operations analyses to establish growth modes to optimize user accommodations; and technology forecasts that will enable cost-effectiveness upgrades to increase the operational efficiency and productivity of the Station.

During FY 1989, efforts will continue on evolutionary proof-of-concept technology as well as identification of technology that may be a good candidate for advanced development in terms of increasing Space Station systems productivity. Areas of focus will be on enabling technology changes to be transparent to users, advanced power systems, and advanced systems automation technology. Efforts to be studied in the area of productivity enhancement may include ECLSS automation enhancements, advanced intelligence systems, and robotics.

2. SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

FY 1989 NASA REQUEST, $631,100,000

FY 1989 AUTHORIZATION, $631,100,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacelab	$66,500,000	$80,400,000
Upper stages	154,900,000	146,200,000
Engineering and technical base	133,900,000	158,900,000
Payload operations and support equipment	84,600,000	67,300,000
Advanced programs	46,400,000	45,000,000
Advanced launch system (ALS)	65,100,000	13,000,000
Tethered satellite system	12,100,000	23,800,000
Orbital maneuvering vehicle	46,300,000	96,500,000
Total	609,800,000	631,100,000

The request for Space Transportation Capability Development for FY 1989 was $631,100,000. The Committee authorized this amount and adopted a provision that would provide $13,000,000 for the upper stage for the Advanced Communication Technology Satellite (ACTS) flight program.

The principal areas of activity in Space Transportation Capability Development include the Spacelab; the Upper Stages required to place satellites in high altitude orbits; the Engineering and Technical Base support at the manned space flight centers; Payload Operations and Support Equipment for accommodating NASA payloads: Advanced Programs study and evaluation efforts; the development and first flight of the United States/Italian Tethered Satellite System; and the development and first flight of the Orbital Maneuvering Vehicle.

Spacelab was developed jointly by NASA and the European Space Agency (ESA). It is a major element of the Space Transportation System (STS) that provides a versatile, reuseable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The development program continues with a recertification program to insure flight safety, the procurement of flight hardware to support the flight program and necessary modification including replacing the onboard computer system.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle or expendable launch vehicles alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket motor integrity program to establish an engineering data base for improving the success rate of U.S. built solid stage components.

The Engineering and Technical base provides the core capability for the engineering, scientific, and technical support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL) for research and development activities. Additional requirements above the core level of capability are funded by the benefiting programs.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the STS payloads during pre-launch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS support services for NASA payloads, satellite servicing tools and techniques development, flight demonstrations, and multi-mission payload support equipment.

Advanced Programs conducts concept feasibility studies and selected system definitions and preliminary design (Phase B) studies and undertakes related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation and system requirements and to evaluate new space transportation initiatives. Complementary objectives are to assimilate generic technology and advanced planning activities, and to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices. Activity is focused on four major areas—advanced transportation, advanced operations support, satellite servicing and advanced missions. Concept definition and key advanced development are underway and planned in these areas to assess performance, reliability and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Included as part of the Advanced Programs Development Program are definition studies of a Crew Emergency Return Vehicle (CERV) to provide approaches for additional crew return capability from the Space Station manned base.

The Advanced Launch System (ALS), as outlined in the joint DOD/NASA Report to Congress, is a joint DOD/NASA program to develop and field this nation's next generation of unmanned launch system. The ALS program will permit this nation to achieve the goal of reduced cost to space. Both NASA and the DOD are moving aggressively forward with ALS and are jointly managing the effort. As directed by Congress in the FY 1988 DOD Appropriation Bill, a total of $70 million has been transferred from DOD to NASA to fund the NASA directed ALS-Propulsion Focused Technology program activities. Within this total, $65.1 million will be utilized in STS Capability Development and $4.9 million will be used in the Research and Program Management Appropriation to fund the necessary support to these propulsion activities. Advanced Program Development will direct and fund study efforts for unique civil mission requirements not satisfied in the joint DOD/NASA ALS baseline design.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reusable capability for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (1) to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of a current drawn through the tether.

The development of the Orbital Maneuvering Vehicle, initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond the reach of the Space Shuttle or the Space Station.

Four dedicated Spacelab flights have been flown on the STS incuding the first Spacelab reimbursable flight, Deutschland-1 (D-1). In addition, several smaller Spacelab elements have flown on other STS flights as partial payloads. These flights have demonstrated the unique capabilities and benefits offered by many of the Spacelab elements. The Spacelab Astro-1 mission, scheduled for the first quarter of 1989, will be the first Igloo Pallet Configuration of the Spacelab Pallet System (SPS). Preparations are now in process for resumption of operational flights for DOD, international, and NASA scientific experiments.

In Upper Stages, funding is included for production, launch, flight support, and integration of Inertial Upper Stages (IUS) vehicles to accommodate the TDRS D, E, and F missions, and the Galileo, Ulysses (including a PAM-S vehicle), and Magellan planetary missions. The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. There are currently no STS requirements for the commercially developed PAM, which is capable of transporting up to 4100 pounds of payload into geosynchronous transfer orbit. The PAM, when utilized in the Delta ELV configuration, is funded with the ELV in Space Flight Control and Data Communications.

The Transfer Orbit Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use with the Shuttle or on Titan. It will have the capability of placing up to 13,000 pounds into geosynchronous transfer orbit. Production of a TOS vehicle for the Mars Observer mission is included in the FY 1989 budget.

The Solid Propulsion Integrity Program (SPIP) objective is to lay in place the necessary engineering capability for improving the success rate of U.S.-built solid rocket motors. The initial phase of the program, started in 1984, addressed motor nozzles and has made good progress in determining root causes and solutions to the persistent problems plaguing motor nozzles. The results and findings are being used in the Shuttle Solid Rocket Motor redesign effort. The program scope is being expanded to examine motor bondlines as well as continuing the nozzle efforts.

In Payload Operations and Support Equipment, payload integration support and payload-related hardware are developed and furnished for NASA payloads. Multi-mission payload support equipment is developed and procured including fiber optic cabling and equipment for communication links between the payload processing facilities; standard sets of wire harnesses for interconnection of mixed cargoes in the orbiter payload bay; and payload display and controls in the orbiter vehicle crew cabin.

The Advanced Programs effort is focused on four major areas—advanced transportation, advanced operations support, satellite servicing, and advanced missions. Concept definition and key advanced development are underway and planned in these areas to assess performance, reliability, and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Advanced transportation study efforts focus on cargo vehicles, manned vehicles, and space transfer vehicles. Studies are underway to define the evolution of manned vehicles, including Space Shuttle enhancement concepts (Shuttle Block II), and next generation concepts (Shuttle II). In addition, definition studies are underway to analyze mission requirements for the design and development of a Crew Emergency Return Vehicle (CERV) to provide approaches for additional crew return capability from the Space Station. Advanced operations support systems efforts focus on the study and assessment of innovative ground, flight and on-orbit operations techniques to achieve

improved safety as well as reduced life-cycle costs for space transportation and orbital systems. The complementary Advanced Operation Effectiveness activity will focus on demonstration of autonomous and expert systems technology to improve the safety and reduce the costs of Shuttle operations. The satellite servicing study effort, encompassing satellite servicing systems and tether applications, focuses primarily on the development of systems and procedures designed to utilize Shuttle capabilities that are compatible with the Space Station and the Orbital Maneuvering Vehicle. Advanced missions activity will continue to focus, with expanded scope and increased depth, on potential manned and unmanned missions beyond the Space Station. Focused orbital debris studies, augmented by the development of a debris measurement radar, will be continued.

Studies, with a directed focus building upon the joint DOD/NASA Advanced Launch System (ALS) baseline design, are planned to examine vehicle and propulsion systems to satisfy national requirements. The ALS-Propulsion Focused Technology program, a NASA-directed element of the core DOD/NASA ALS program, is focused on demonstrating the performance and operating capabilities of critical propulsion system components.

The Tethered Satellite System (TSS) hardware development was initiated in FY 1984 and systems definition studies were completed in FY 1985. Comprehensive design and requirements validation; procurement of long lead time flight hardware elements and tooling; systems development and integration; and deployer manufacturing and integration will continue through FY 1989. The Italians started satellite and core equipment development in FY 1984. U.S. science instruments for the satellite are being funded in the Physics and Astronomy budget. A cooperative first flight on the Space Shuttle is presently planned for 1991.

The OMV will be a reusable, remotely operated propulsion vehicle with the capability to deliver, retrieve and service payloads and spacecraft deployed at a wide range of altitudes and inclinations. The development contract was initiated in late 1986 with a planned initial capability in 1991. Based on budgetary reductions and current shuttle manifest planning, the initial capability requirement has been rescheduled to 1993. The initial operational use of the OMB is in support of the Hubble Space Telescope servicing requirements. The FY 1989 budget request includes funds for continuation of the design and development, initial testing, and production of flight hardware.

SPACELAB

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Development	$16,100,000	$15,300,000
Operations	50,400,000	65,100,000
Total	66,500,000	80,400,000

The Spacelab is a versatile facility designed for installation in the cargo bay of the orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. The reuseable Spacelab system enhances the advancement of scientific research by serving as both an observatory and laboratory in space. Ten European nations, including nine members of the European Space Agency (ESA), have participated in this joint development program with NASA. ESA designed, developed, produced, and delivered the first Spacelab hardware: consisting of a pressurized module and unpressurized pallet segments, Igloo, instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

NASA procured an additional set of Spacelab hardware from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. The remaining development activities include additional hardware to complete the Spacelab system, ground support equipment, hardware modifications, hardware acquisition, system recertification, qualification and procurement of reliable and high capacity AP-101S computers. Support software and procedures development, testing, and training activities not provided by ESA, which are required for the Spacelab, are also included in NASA's funding. Additional Spacelab hardware, including the initial lay-in of space hardware, is being procured from European sources.

NASA is developing two principal versions of the Spacelab Pallet System (SPS). One will support missions requiring the igloo and pallet in a mixed cargo configuration like the Astro series; the other version will support missions that do not require use of the igloo such as the Space Technology Experiment Platform (STEP) and the Tethered Satellite System. Development of the Hitchhiker system is nearly complete. The Marshall Space Flight Center (MSFC) version of the Hitchhiker will fly at the next available opportunity.

The Spacelab operations budget includes mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, system operations support, payload operations control support, payload processing, logistical support and sustaining engineering.

The first Spacelab reimbursable flight, Deutschland-1 (D-1), was flown during the first quarter of FY 1986. Astro-1, originally planned for flight in FY 1986 for observation of Halley's Comet, was delayed for FY 1989 due to the January 1986 Shuttle accident. The initial flight of the Goddard Space Flight Center Hitchhiker (HG-1) took place in the first quarter of FY 1986.

In addition to these missions, analytical and physical integration, configuration management, and software development for future flights will be conducted. Procurement of spares for both NASA-developed hardware and for hardware developed by U.S. companies under contract with ESA will continue throughout FY 1988. Operation of the depot maintenance program for U.S.-provided and European-supplied hardware and the procurement of replenishment spares will continue in FY 1989.

The FY 1989 request reflects significant program restructuring and rescheduling of Spacelab missions resulting from the stand-down of the Shuttle. The current program provides leadtime for the integration and payload processing for launching two to three major Spacelab missions per year.

The FY 1989 development funds are required to complete development and verification of the MSFC Hitchhiker and the Enhanced Multiplexer Pallet System (EMPS) programs, complete the lay-in of both U.S. and European source spares, and for continuation of necessary hardware and GSE modifications and upgrades for return-to-flight recertifications as recommended by the Rogers' Commission in preparation for reflight in 1989.

In addition, funds are required to support payload operations and to continue payload integration support, mission independent training, and logistic support in preparation for launch of the Astro-1 mission and two Hitchhiker systems in FY 1989, and the Materials Science Laboratory (MSL–3 and MSL–4), and two to three Hitchhiker systems in FY 1990. Preliminary operations support will begin on the U.S. Microgravity Laboratory (USML) mission, which is planned for flight in 1992. The support for these missions includes analytical integration, configuration management, hardware integration and software development and integration. Further, funding is also included to operate and maintain the MSFC Payload Operations Control Centers (POCC) required to support training and operations for all the Spacelab missions. Spacelab Operations also provides for replenishment spares, the operation of the depot for United States and European hardware and software, and sustaining engineering of all hardware and software. The FY 1989 estimate also includes activity on the Getaway Special (GAS) program which has been transferred from Shuttle Operations.

In addition to NASA missions the Spacelab program will also support three reimbursable missions: the U.S. DOD Starlab, the German D–2, and the Japanese SL–J.

Upper Stages

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Development	$16,000,000	$6,700,000
Procurement and operations	138,900,000	139,500,000
Total	154,900,000	146,200,000

The STS upper stages are required to deploy payloads to orbits not attainable by the Shuttle or core stage expendable launch vehicle alone. The Inertial Upper Stage (IUS), and the commercially developed Payload Assist Modules (PAM-A, PAM-D and PAM-DII) are currently available for use. Several other upper stages are now being commercially developed, including the Transfer Orbit Stage (TOS), which will become available for use in the near future.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The IUS has been launched from both the Shuttle and Titan 34-D Expendable Launch Vehicle. Four IUS vehicles were procured by NASA for launch of the initial four Tracking and Data Relay Satellite System (TDRSS) spacecraft; later, two additional IUS vehicles were ordered for TDRSS launches. The first three were funded through the TDRSS contract while the others are funded under this budget element. In addition, IUS vehicles will be used for the Magellan, Galileo and Ulysses planetary launches. These vehicles are being configured for launch on the STS although a modification kit is also being procured that will allow launch from a Titan IV in the event the Shuttle schedule cannot support the fixed planetary launch window.

The objectives of the commercially developed PAM program were to provide an early and easy transition from expendable launch vehicles to the STS, and to provide low cost transportation from the Shuttle's low Earth orbit to geosynchronous transfer orbit. The PAM is designed to be launched on the Shuttle, the Delta, and as a kick stage for large payloads in conjunction with other propulsion modules. There have been 41 PAM's flown and they are well established in the U.S. inventory of upper stages. These are no payloads currently planned for STS launch that utilize the PAM exclusively although a PAM is being procured as a kick stage in conjunction with the IUS for the Ulysses launch. The PAM is procured as part of the vehicle when used with the Delta and therefore funding for these requirements is included in the ELV budget under STS Operations.

TOS is a three-axis stabilized perigee stage that is being developed commercially by the Orbital Sciences Corporation for use with the Shuttle. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit. A TOS is being procured for the Mars Observer mission for launch in 1992.

The Solid Propulsion Integrity Program was initiated in FY 1984 to establish an urgently needed engineering data base for use of composite materials in upper stage motor nozzles, to minimize risk to planned missions and to restore user confidence in U.S. launch systems. Underlying root causes of persistent problems in motor nozzles have been identified and required data is being generated. Work to examine motor bondlines has been initiated, in addition to increasing the level of effort in motor nozzle studies. The results of this program will continue to be used in support of the Shuttle Solid Rocket Motor.

Development and Operations funds in FY 1989 are required to continue progress on the Upper Stages for the Galileo, Ulysses and Magellan planetary missions, for TDRSS and Mars Observer and the IUS and TOS modification kit for the ELV capability. Funds are also necessary to support continuation of the Solid Propulsion Integrity Program and to support IUS and TOS Mission unique efforts which had previously been funded in Payload Support Operations for STS launches. This will make the funding for STS Upper Stages consistent with the funding for ELV Upper Stages.

Engineering and Technical Base

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Research and test support	$75,700,000	$94,400,000
Data systems and flight support	22,700,000	23,700,000
Operations support	22,700,000	23,900,000
Launch systems support	12,800,000	16,900,000
Total	133,900,000	158,900,000

The Engineering and Technical Base (ETB) provides the program core capability required to sustain an engineering and development base for various NASA activities at the manned space flight centers. Additional center requirements above the core level are funded by the benefiting programs, such as Space Transportation Operations and Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL).

The core level of support varies from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories and the White Sands Test Facility. Safety, reliability and quality assurance areas are also supported by the ETB core. The core level for the central computer complex is established as a two-shift operation. At KSC, the core level provides for research and development of technology to enhance launch site hardware, ground processing, support services; and safety reliability and quality assurance. ETB funds at MSFC provide for multi program support activities, including technical labs and facilities, reliability and quality assurance, computational and communications services, and at NSTL for facilities operations.

The requested funding for the ETB in FY 1989 provides for a continuation of the FY 1988 level of support for basic research and development facilities and services at the centers with an expansion of computational capability by acquiring a class VI computer for use at JSC and increased SR&QA and engineering support at JSC, KSC and MSFC.

In research and test support, funding is required to support the increase in computational capabilities at MSFC for engineering and science projects through the use of a Class VI computer system. This capability is required for the solution of more complex main engine, three-dimensional dynamics modeling problems and for complex structural analyses. At JSC, the requested funding will provide for a five-day, one-shift operation for the engineering and development laboratories, such as the Electronic Systems Test Laboratory and the Thermal Test Area. SR&QA activities will also be provided. In addition, a Class VI computer system will be acquired at JSC. The computer is required to obtain numerical solutions of very large sector materials for the aerodynamics, thermodynamics and structural mechanics analysis associated with developing and operating manned and robotic space systems.

Data systems and flight support provide a core level of support based on a five-day, two-shift operation of the central computer complex at JSC. Any additional requirements are the responsibility of the benefiting program.

Operations support funding provides for the maintenance of multi-program research and development facilities and equipment, chemical cleaning, engineering design, technical analysis, component fabrication, and logistics support. Examples of specific services to be provided in FY 1989 include: (1) operation and maintenance of specialized electrical and cryogenic systems; (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected items of in-house hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests; (4) mission imaging services, including audio-visual mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; and (6) technical documentation services. In addition, FY 1989 funds will provide the basic level of collateral support at NSTL for continuing main engine testing facilities.

In launch systems support, funding provides for the core capability for the engineering scientific, and technical support for research and development activities at KSC specifically the funds provide for multi-program support activities, including technical labs and facilities, and other engineering support services and safety.

Payload Operations and Support Equipment

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Payload operations	$69,800,000	$53,300,000
Payload support equipment	14,800,000	14,000,000
Total	84,600,000	67,300,000

The Payload Operations and Support Equipment objectives are to centralize payload services, both unique and common, which are required beyond the basic STS standard services for NASA missions, and to provide multi-mission support equipment in support of payload operations. Payload operations provides unique hardware, analyses, and launch site support services to support STS missions. Payload support equipment funds the development and acquisition of multi-mission reuseable ground support equipment required for a wide range of payloads. This includes test equipment required to checkout payload-to-orbiter interfaces at KSC, mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA payloads receiving support during this year include Hubble Space Telescope, TDRS, Galileo, Ulysses, Magellan, Astro, Long Duration Exposure Facility Retrieval, Upper Atmospheric Research Satellite,

and Gamma Ray Observatory. Efforts will continue to provide the means to maintain and repair satellites on-orbit by developing a series of tools, aids, and techniques, and to demonstrate capabilities and methods of improving the efficiency of on-orbit operations.

Payload support equipment estimates reflect the requirement to modify and upgrade selected payload integration facilities for safer, more efficient operations. FY 1989 funding for multi-mission payload support equipment is required for development testing and delivery of payload common communication equipment (PCCE) to accommodate required payload data transmission, and initial spares provisioning for Cargo Integration Test Equipment (CITE) and PCCE. Funds for fiber optic cabling and an upgraded operational intercom system in the industrial area at KSC are included in this budget to provide increased reliability and quality of data transmission among cargo facilities. Multi-mission payload support equipment funding also includes orbiter/payload interface hardware for groups of payloads, cargo bay cabling, modified aft flight deck panels, and associated display and controls.

Advanced Programs

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Advanced programs:	
Estimated fiscal year 1988	$46,400,000
Authorization fiscal year 1989	45,000,000

The principal objectives of Advanced Programs are to conduct concept feasibility studies and selected systems definitions and preliminary design (Phase B) studies and to undertake related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation system requirements and to evaluate new space transportation initiatives. Complementary objectives are to assimilate generic technology and advanced planning activities and to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices. Past program efforts have provided the technical and programmatic data to support new major Agency programs and systems, including the Orbital Maneuvering Vehicle, the Tethered Satellite System, the Shuttle Space Transportation System, and the Space Station. Supporting program objectives emphasize both the conceptual definition of the future space transportation systems architecture and specific elements needed over the next twenty years.

In FY 1988, the Advanced Programs effort is focused on four major areas—advanced transportation, advanced operations support, satellite servicing, and advanced missions. Concept definition and key advanced development are underway and planned in these areas to assess performance, reliability, and operational efficiency improvements and to reduce future program risks and development costs through the effective use of new technology. Advanced transportation study efforts focus on cargo vehicles, manned vehicles and space transfer vehicles. Advanced development efforts are planned for critical launch vehicle and upper stage subsystems including avionics, propulsion, energy storage and cryogenic propellant storage. Conclusions drawn from the joint Space Transportation Architecture Studies (STAS) have permitted NASA and DOD to initiate closely related and coordinated studies (Shuttle C and Advanced Launch System) to define concepts for unmanned heavy lift launch vehicles to satisfy both near and long-term mission requirements. The NASA-led Shuttle C (Cargo) system definition studies, now underway, will define a system making use of existing Shuttle hardware and capable of delivering a minimum of 100,000 lbs. of cargo to low Earth orbit. The system definition studies will assess Shuttle C uses for Space Station assembly and support, and planetary missions. Also, the cost effectiveness of the Shuttle C in terms of the capability and flexibility added to the Space Transportation System will be investigated. Studies also are underway to define the evolution of manned vehicles, including Space Shuttle improvement concepts (Shuttle Block II) and next generation concepts (Shuttle II). In addition, a new study for Liquid Rocket Boosters (LRB) initiated in 1987 examines the feasibility of replacing the Solid Rocket Motors (SRM) with liquid engines that, potentially, could offer advantages in Shuttle performance, safety and operating costs. Definition studies for additional crew return capability were initiated in FY 1987 by the Space Station program, and will be continued under Advanced Programs funding beginning in FY 1988. These definition studies will provide the basis for evaluating and recommending options to provide a crew emergency return vehicle, if required, in support of a permanently manned Space Station.

A new advanced program development thrust, advanced operations support systems, addresses advanced operations effectiveness as the key parameter in improving safety as well as reducing lifecycle costs for space transportation and orbital systems. Innovative ground, flight and on-orbit operations techniques are under study and being assessed for use with existing and future space systems. Program plans focus on techniques and systems to improve the efficiency and reliability of launch and pre-launch operations through the use of autonomous and expert systems technology, improving the efficiency of simultaneously operating multiple vehicles in proximity to each other, and the enhancement of telerobotic-assisted servicing operations.

The satellite servicing effort encompasses satellite servicing systems and transportation-related tether applications. The satellite servicing program focuses primarily on the definition of systems and procedures designed to utilize Shuttle capabilities. The systems are planned to be compatible with the Space Station and the Orbital Maneuvering Vehicle (OMV). The definition of tankers, couplings, telerobotic servicing aids, techniques and procedures to support satellite servicing are well underway. The studies support the servicing activities associated with rendezvous and proximity operations from Shuttle and remote servicing using the OMV. Tether application efforts are directed toward defining and implementing flight experiments and demonstrations for advanced development and proof-of-concept purposes. Applications under study include power generation, orbital altitude changes without the use of propellants, artificial gravity, and tethered space platforms for scientific use.

Advanced mission efforts will continue to focus, with expanded scope and increased depth, on potential manned and unmanned missions beyond the Space Station. Studies will be conducted to explore potential Lunar/Mars missions and their demands on the Space Transportation System. Also, a study is currently underway to define the orbital debris environment. Other studies address identifying ways to minimize orbital debris accumulation and develop prevention and protection/avoidance methods and techniques. The development of a radar to measure and determine orbital debris density of particles on the order of 1 centimeter in diameter is planned to augment this study effort.

In FY 1989, major emphasis will be placed on concept definition and key advanced development in the following areas: advanced space transportation systems (launch vehicles and space transfer vehicles), advanced operations support systems, satellite servicing systems, and advanced missions. Major goals continue to be the conceptual definition of the system architecture and space elements needed for space operations over the next twenty years including heavy lift cargo vehicles, second generation shuttles and satellite servicing near and remote from the orbiter. Advanced development activities focused on improvements to the existing and evolving space transportation systems are planned.

Studies to define the evolution of manned vehicles, including Space Shuttle improvement concepts and next generation concepts, are underway. An area of increased emphasis will be the assessment of operational improvements of existing and future transportation systems including utilization of expert and autonomous systems. Orbital debris studies will be continued including development of an orbital debris radar. The satellite servicing program will continue to explore effective manned servicing concepts to extend STS operational capability for Earth orbit support of spacecraft, platforms, and constellation aggregates. Detailed engineering systems analysis will be continued to determine the efficiency of future tethered platform applications. Advanced manned and unmanned missions beyond the Space Station will continue to be studied with expanded scope and increased depth. Studies will be conducted to explore potential Lunar/Mars missions and their potential demands on transportation systems.

Funding of the crew emergency return vehicle definition effort in FY 1989 will support contractor studies. These definition efforts will build upon the preliminary studies begun in FY 1987 and provide definition of vehicle requirements, identify vehicle capabilities within available funding and schedule constraints, existing technology and mission requirements, and understanding design, schedule, and cost risks as well as Space Station support capabilities. Continuing focused systems definition efforts in FY 1989 is consistent with supporting a decision on whether to proceed with design and development to provide this capability when the Space Station is permanently manned.

Advanced Launch System (ALS)

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Advanced launch system:	
Estimated fiscal year 1988	$65,100,000
Authorization fiscal year 1989	13,000,000

DOD has full funding responsibilities for the joint DOD/NASA Advanced Launch System (ALS) program. NASA has the funding responsibility to satisfy unique civil requirements not addressed by the joint ALS baseline design. As specified in the joint ALS management plan, the ALS-Propulsion Focused Technology program, will be managed by NASA with DOD participation. Congress has directed that in FY 1988 not less than $70 million be transferred to NASA from the DOD to fund ALS-Propulsion Focused Technology activities. Of this amount $65.1 million is being applied to contractual study and technology activities and $4.9 million to related in-house activity funded under the Research and Program Management appropriation. Study efforts are underway in the areas of vehicle systems and propulsion systems for NASA to augment the DOD funded ALS studies for unique civil mission requirements not addressed by the joint ALS baseline design. The ALS-Propulsion Focused Technology program efforts are directed towards demonstrating the performance and operating capabilities of critical propulsion system components prior to committing to a final design for a flight hardware development program. Components and subsystems that will be part of the ALS-Propulsion Focused Technology program include combustors, gas generators, turbopumps, control systems components and instrumentation, and health monitoring system components and diagnostic sensors for liquid oxygen/hydrocarbon and liquid oxygen/liquid hydrogen engine systems. Because the ALS program is in its early definition stage, definitive program plans have not been developed. Efforts are underway to coordinate ALS-Propulsion Focused Technology program activities with DOD in support of ALS concept definition efforts.

The joint DOD/NASA ALS Program is in its early definition stage. Efforts by NASA and DOD are underway to coordinate the ALS-Propulsion Focused Technology activities to most effectively utilize the expertise and facilities of both agencies. Consistent with the basis agreement, funding for the NASA activity to meet the requirements of this program is included in the DOD budget request. The NASA funding for FY 1989 provides for system definition studies with a directed focus building upon the joint ALS baseline design to examine vehicle and propulsion systems to satisfy unique civil requirements.

Tethered Satellite System

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Tethered satellite system:	
Estimated fiscal year 1988	$12,100,000
Authorization fiscal year 1989	23,800,000

The development of a Tethered Satellite System (TSS) will provide a new reuseable facility for conducting space experiments at distances up to 100 kilometers from the Shuttle orbiter while being

held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility such as the observation of important atmospheric processes occurring within the lower thermosphere, new observations of crustal geomagnetic phenomena, and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government. Formal signing by representatives of both governments of a Memorandum of Understanding took place in March 1984.

The United States is responsible for overall program management, overall systems engineering and integration, orbiter integration, ground and flight operations, and development of the deployment mechanism. The U.S. effort was initiated in 1984. The Italians are responsible for the design and development of the satellite and the European instruments being flown on the joint missions. They initiated their development efforts in 1984.

The FY 1989 funding supports continuation of TSS Development activities consistent with the planned engineering verification flight (TSS-1) in early FY 1991. Current plans call for completion of U.S. hardware assembly in early FY 1989 followed by deployer qualification. Integration of the Italian-provided satellite and the deployer mounted science instruments will start in FY 1990 to support a delivery date to KSC in mid-FY 1990, in time to prepare the TSS-1 for flight in early 1991.

Orbital Maneuvering Vehicle

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Orbital maneuvering vehicle:	
Estimated fiscal year 1988	$46,300,000
Authorization fiscal year 1989	96,500,000

The Orbital Maneuvering Vehicle (OMV) will provide a new STS reuseable extension capability for conducting orbital operations with spacecraft and payloads beyond the practical operational accessibility limits of the baseline STS. By means of direct man-in-the-loop control, the spacebased reuseable OMV, operating as far as 1200 nautical miles altitude above the orbiter, will provide delivery, maneuvering, and retrieval of satellite payloads to and from altitudes or inclinations beyond the existing STS capability; reboost satellites to original operational altitudes or higher; deliver multiple payloads to different orbital altitudes and inclinations in a single flight; and safe deorbit of satellites which have completed their useful life. It will be designed to serve the Space Station as well and to accommodate the add-on of future "mission kits" as needed to support more advanced missions such as the servicing of satellites and platforms and the retrieval of space debris which could represent an orbital hazard to all future space missions. TRW was competitively selected and is now under contract to develop the OMV. The preliminary design review will be held in FY 1988 and long lead procurements will be initiated. The flight readiness date for the OMV is mid 1993.

The funds provided in FY 1989 will be used to continue OMV hardware design and development and fabrication of test and flight hardware.

3. PHYSICS AND ASTRONOMY

FY 1989 NASA REQUEST, $791,600,000

FY 1989 AUTHORIZATION, $791,600,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Hubble space telescope development	$93,100,000	$102,200,000
Gamma ray observatory development	53,400,000	41,900,000
Global geospace science	20,000,000	101,400,000
Advanced x-ray astrophysics facility development (AXAF)	0	27,000,000
Payload and instrument development	43,700,000	77,100,000
Shuttle/Spacelab payload mission management and integration	54,200,000	61,500,000
Space station integrated planning and attached payloads	18,900,000	8,000,000
Explorer development	67,900,000	82,100,000
Mission operations and data analysis	132,000,000	156,200.000
Research and analysis	82,900,000	89,100,000
Suborbital program	44,700,000	45,100,000
Total	610,800,000	791,600,000

The objectives of the Physics and Astronomy program are to increase our understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. Objects studied by the Astrophysics program include distant galaxies and galactic clusters, as well as stars and other structures in nearby galaxies and the interstellar medium in our galaxy. Unusual and exotic phenomena—such as quasars, neutron stars, pulsars and black holes—are of particular interest to the Astrophysics program, and are the target of many ground-based and space-based research programs.

Intensive study of our own Sun, with its multitude of time-varying phenomena, provides key answers to a vast range of questions requiring comprehensive research into solar-terrestrial processes and the physics and coupling between the solar wind, magnetosphere, ionosphere, and atomsphere.

The objectives of the Physics and Astronomy program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights and suborbital opportunities. In the future, the Space Station will act as a platform for attached payloads and as a servicing point for major free-flying observatories which require assembly, maintenance and refurbishment in orbit. Space-based research allows observations in wavelength regions such as the infrared or the ultraviolet which cannot be carried out on the ground due to the obscuring effects of the atmosphere. Also, observations in the visible light region are vastly improved when conducted above the atmosphere. The entire

program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the scientific communities and the general public for application to the advancement of scientific knowledge, education and technology.

The first nearby Supernova since the invention of the telescope appeared in the southern skies last year. A broad campaign of observations using the Deep Space Network, aircraft, balloons, rockets, and existing spacecraft was rapidly assembled to take advantage of the unique scientific opportunity provided by this exciting event.

The Physics and Astronomy missions undertaken to date have been extraordinarily successful. Recently, these include the High Energy Astronomical Observatories (HEAO, 1977-1879), the International Ultraviolet Explorer (IUE, 1978), the Solar Maximum Mission (SMM, 1980) the Active Magnetospheric Particle Trace Explorer (AMPTE, 1984), the Dynamics Explorer (DE, 1981), the Interplanetary Monitoring Platform (IMP-8, 1972), International Sun-Earth Explorers (ISEE 1 & 2 and ICE, 1977-78), and the Infrared Astronomy Satellite (IRSA, 1983). The IUE, SMM, AMPTE, IMP, DE and ICE are still operating, and new scientific results are continually emerging from these, as well as from the high quality data sets archived from the HEAOs, ISEE 1 & 2 and IRAS.

The Hubble Space Telescope, to be launched by the Space Shuttle in 1989, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbent atmosphere. This telescope will be able to resolve spatial features by a factor of ten better than the typical ground-based optical telescope, and will observe the universe at approximately seven times the distances now possible. This means some 350 times the volume of the present universe will be available for study. This increased capability will allow us to address basic questions concerning the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe—its beginning and end.

The Gamma Ray Observatory (GRO) mission will be launched by the Space Shuttle in 1990. This mission will measure gamma rays, which are produced by the most energetic and exotic fundamental physical processes occurring in nature. Instruments on this mission will provide unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, supernova, and the nature of the mysterious cosmic gramma-ray bursts.

The Global Geospace Science (GGS) program was approved as an FY 1988 new start. It is a complementary science mission to the Collaborative Solar-Terrestrial Research (COSTR) project and enables the U.S. to move from a supporting to a leadership role in solar-terrestrial physics. Both projects are being conducted in cooperation with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). GGS will make the first coordinated geospace measurements in the key plasma source and storage regions, with emphasis on the cause-effect relations of energy flow.

Definition studies of advanced technology will continue on the Advanced X-ray Astrophysics Facility (AXAF), which is proposed as an FY 1989 new initiative. AXAF will be a major national observatory for x-ray astronomy. The 1.2m class grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of 10 increase in angular resolution and double the energy coverage which was provided by the Einstein observatory (HEAO-2). It will provide new observations and insights in studies of stellar structure and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies and cosmology. It will restore U.S. leadership in a field pioneered by the U.S. astronomers.

Definition studies of the advanced technology necessary for a Space Infrared Telescope Facility (SIRTF) will continue. SIRTF is intended to measure phenomena associated with the beginning of an evolutionary cycle. This includes cosmic dust, cool interstellar material, star formation, and proto-planetary nebulae in both our galaxy and others.

Since the inception of the U.S. space program, the Explorer program has been the means for fast-turnaround scientific space missions. The Physics and Astronomy Explorers have been extremely successful. The IUE, a U.S./ESA endeavor, has recently shown that our galaxy has a halo of gas with a temperature of over a million degrees, while the IRAS, a joint U.S./U.K/Netherlands project, has detected and cataloged over 300,000 infrared sources and has shown star formation in other galaxies to be more prevalent than previously thought. IRAS has also demonstrated that at least one quasar has its dominant energy release in the infrared spectral region. Since IRAS completed operations in late 1983, these discoveries have come from analysis of archival data and many more such results are expected.

ICE, which was designed to provide solar wind data, was redirected in 1985 for the first successful encounter with a comet when it passed through the tail of Comet Giacobini-Zinner, and made Halley's Comet observations in 1986. In March-May 1986, the Polar Region and Outer Magnetosphere International Study (PROMIS) coordinated six satellites (ISEE 1 & 2, ICE, Active Magnetospheric Particle Explorer (AMPTE), Interplanetary Monitoring Platform (IMP-8), Dynamics Explorer (DE-1) and the Swedish Viking satellite to provide unique data on magnetospheric processes.

Two major Explorer missions are now under development: the Cosmic Background Explorer (COBE) and the Extreme Ultraviolet Explorer (EUVE). A third mission, the X-ray Timing Explorer (XTE), is under definition. In addition, a U.S. instrument is being developed for inclusion on the Roentgen Satellite (ROSAT), being built by the Federal Republic of Germany. A Cosmic Ray Isotope Experiment (CRIE) is also being developed, along with a DoD experiment, for flight aboard the Combined Release and Radiation Effects Satellite (CRRES) scheduled for launch in 1990 on a Department of Defense spacecraft. Finally, we are developing an instrument for flight on the Japanese Solar-A mission (previously called the High Energy Solar Physics Mission, HESP). Solar-A will be

launched in 1991 to study the Sun during the upcoming solar maximum.

The Astrophysics program continues its involvement in the Shuttle/Spacelab program with ASTRO-1, a set of ultra-violet and soft x-ray telescopes and spectrometers, scheduled for a launch in 1989. ASTRO-1 will investigate the interstellar medium by following up on discoveries made with the IUE. Mission management activities will continue with increasing emphasis on major life sciences and microgravity research missions such as the Spacelab-Life Sciences (SLS) and International Microgravity Laboratories (IML) series.

Payload and instrument development activities provide the data necessary to conduct basic research projects as well as to provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument activities include Shuttle payloads such as the Shuttle experiment to test the theory of relativity and the Tethered Satellite System (TSS). Also included are Space Plasma Physics flight of opportunity instruments such as those for the Japanese Geotail Spacecraft and the European Solar Heliospheric Observer (SOHO) and Cluster spacecraft. The Collaborative Solar Terrestrial Research (COSTR) instrumentation provides the U.S. complement for the European Solar Terrestrial Science Program (STSP).

During the Shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-flying aircraft has taken on increased significance. This enhanced effort will provide observations and instrument development opportunities for research groups. Furthermore, increased emphasis will also continue in the Research and Analysis (R&A) and the Mission Operations and Data Analysis (MO&DA) areas in order to maintain a vital research base in Physics and Astronomy.

Hubble Space Telescope Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$80,000,000	$90,300,000
Experiments	13,100,000	11,900,000
Total	93,100,000	102,200,000

The Hubble Space Telescope will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The Hubble Space Telescope will operate in space above the atmospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the Hubble Space Telescope will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The Hubble Space Telescope will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible unique observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look farther into the distant past of our universe than ever before. The Hubble Space Telescope will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observation of such highly-evolved objects as supernova remnants and white dwarf stars. With the Hubble Space Telescope, we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The Hubble Space Telescope will be an automated observatory, delivered into orbit by the Space Shuttle in June 1989. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The Hubble Space Telescope is designed for on-orbit maintenance and repair.

During FY 1987, the Hubble Space Telescope Program continued at a reduced level of activity. The schedule for launch and operations was further adjusted, as a result of the post-Challenger changes in the Space Transportation System (STS). Hubble Space Telescope program activity focused on corrections to a few cases of off-nominal systems performance observed in the intensive period of testing in late FY 1986. This included rework of some components and instruments, improvements to the power system, and adjustments to the thermal control system. In addition to this work on the Hubble Space Telecope spacecraft, the planned tests of the ground system continued, building toward final operational capability on the stretched-out launch schedule. Work also continued on preparing for the future on-orbit maintenance of the Hubble Space Telescope spacecraft. A logistics system was put in place, and development was underway on advanced scientific instruments and other components for orbital replacement. Astronauts conducted realistic training with the replacement components, using specially developed tools. Finally, the Failure Modes and Effects Analysis/Critical Items List/Hazard Analysis of the Hubble Space Telescope system, required for STS safety, was successfully completed.

Planning for FY 1988 reflects the added delays in the STS launch schedule. After a pre-ship functional test verifies the readiness of the Hubble Space Telescope spacecraft for shipment, it will enter a period of inactive storage. In FY 1989, approximately three months before the launch date, the spacecraft will be shipped to Kennedy Space Center for final launch preparations. Ground system verification and buildup to full operational capability will continue, consistent with the extended launch schedule.

The FY 1989 funding level is required to complete those program activities that were planned for the previous year, but delayed because of further adjustments to the STS launch schedule. These activities include pre-ship preparation of the spacecraft, shipment to the Kennedy Space Center, launch preparations and launch oper-

ations at Kennedy, and the initial phase of orbital operations. In addition, the requested funding level will support the buildup of the HST ground system to the level required for sustained science operations.

Gamma Ray Observatory Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$38,600,000	$29,900,000
Experiments and ground operations	14,800,000	12,000,000
Total	53,400,000	41,900,000

The Gamma Ray Observatory (GRO) will study the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma-rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma-rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving the fundamental particles of physics. GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma-ray bursts, to the diffuse gamma-ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rests on a foundation of exploratory investigations and developments from previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up both the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Participation in the GRO mission includes the university science community as well as government and industry. International involvement, with a complete Principal Investigator team based in Europe, is extensive.

The low flux of cosmic gamma-rays, their penetrating nature, and the high background produced by cosmic-ray interactions all dictate large and massive instruments to be flown in space for extended periods of time. The four complementary instruments selected for the GRO represent a quantum jump in sensitivity, spectral range, and spectral, spatial, and temporal resolution over any previous missions or instruments in these energy ranges. GRO, scheduled for launch on the Space Shuttle in 1990, is designed to be pointed at fixed directions in space for hours or weeks to obtain the long exposures required.

In FY 1987, instrument calibration and testing and electronic manufacturing continued and the spacecraft structure assembly was completed. In FY 1988, the modal survey and static load tests will be completed and all government-furnished property spacecraft subsystems for GRO will be delivered. Observatory subsystem integration is scheduled to begin late in the year, after the completion of spacecraft attitude control and power systems electronics. The development of the GRO mission operations and data systems will continue, and the implementation of the Payload Operations Control Center (POCC) for GRO will be completed. Funding is also required for final testing, calibration and shipment of all four science instruments to the spacecraft contractor for the beginning of spacecraft integration and testing.

FY 1989 funding is required to complete observatory integration and environmental testing and to complete preparations for shipping the spacecraft from TRW to Kennedy Space Center.

Global Geospace Science

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Global geospace science:	
Estimated fiscal year 1988	$20,000,000
Authorization fiscal year 1989	101,400,000

Global Geospace Science (GGS) will be part of the United States' contribution to the International Solar Terrestrial Physics (ISTP) program. This program is an international, multi-spacecraft, collaborative science mission designed to provide the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the Earth.

GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program to provide instruments and launch support and to gain science return in a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort will be greatly enhanced by the addition of the two spacecraft proposed in the GGS program. The combined program will include five spacecraft missions: two U.S. spacecraft, WIND and POLAR; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, GEOTAIL, most of which are to be launched by NASA.

The GGS mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial environment. GGS consists of two fully-instrumented U.S. spacecraft, WIND and POLAR, making simultaneous measurements in key geospace regions. Instruments and theory investigations were

selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multispectral global auroral imaging, and multi-point study of magnetospheric response to solar wind.

Essentially all commitments by the foreign governments are in place and their development activities have commenced. GGS will allow the United States to become a full partner in the ISTP program, reinforcing our commitments to international cooperation and is essential to maintaining continued leadership in solar terrestrial physics.

Definition studies are complete and FY 1989 funds are required to initiate development of GGS spacecraft, instruments and ground system. FY 1989 funding will allow continuation of these early development efforts in order to take advantage of simultaneous measurements provided by the Collaborative Solar Terrestrial Research (COSTR) program and other solar-terrestrial research efforts.

Advanced X-ray Astrophysics Facility Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$0	$23,000,000
Experiments	$0	4,000,000
Total	0	27,000,000

Our nation is poised for an accomplishment unique in the history of humankind—to observe the universe with unprecedented completeness and resolution. We have the demonstrated capability to construct high technology orbiting telescopes that can observe the universe in all the forms of electromagnetic radiation, and we have the unique capability with the Shuttle, and eventually the Space Station, to maintain these telescopes on orbit. The key to realizing this amibition is the start in FY 1989 of a telescope facility designed to observe the universe in the x-ray region of the electromagnetic spectrum. This telescope, known as AXAF—the Advanced X-ray Astrophysics Facility, is 100 times more senitive, and has 1000 times more capability for spectroscopy, than any previous or planned x-ray mission. AXAF needs to be undertaken immediately in order to fly in concert with the Hubble Space Telescope, which will observe the universe in visible and ultraviolet radiation, and the Gamma Ray Observatory, which will observe in gamma rays. The scientific return of these "Great Observatories" will be enhanced enormously if flown together to observe the whole range of phenomena in the cosmos, from the most tranquil to the most violent, and provide a complete physical picture of the universe's most engimatic objects. Moreover, immediate initiation of AXAF will provide a scientific opportunity that is unlikely to be repeated for many generations. The closest supernova to occur near Earth since the invention of the telescope, 400 years ago, was seen last year, and can be studied by AXAF provided that it is launched by 1995, before the x-rays fade. Supernovae are responsible for the origin of all the heavier elements in the universe including those essential for life.

The AXAF, with its 1.2m class grazing incidence telescope will double the energy coverage which was provided by the Einstein Observatory (HEAO-2). AXAF will be launched in 1995 using the Space Transportation System (STS). It will be a long-lived observatory designed for on-orbit instrument replacement and servicing. With the Shuttle, and eventually the Space Station, the U.S. has the unique capability to maintain this telescope in orbit.

An extensive preparatory program has been completed for AXAF, including completion of 32 months of observatory definition in January 1987, which included the fabrication of the finest x-ray mirror ever built. NASA and industrial teams are in place and ready to proceed with AXAF.

In this era in which United States leadership in space is being challenged, a new start for AXAF will provide a bold statement that in the premier scientific discipline of astrophysics, we will be second to none.

FY 1989 funding will initiate AXAF. During the first year, work will focus on development of the High Resolution Mirror Assembly and the science instruments.

Payload and Instrument Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Collaborative solar terrestrial research	$14,900,000	$43,900,000
Tethered satellite system	3,400,000	3,700,000
Shuttle test of relativity experiment	10,300,000	22,000,000
Astrophysics payloads	5,200,000	5,500,000
Space physics payloads	9,900,000	2,000,000
Total	43,700,000	77,100,000

Instrument development activities support a wide range of instrumentation—from early test, checkout and design of instruments for long-duration free-flying missions to international flights of opportunity.

The Collaborative Solar Terrestrial Research Program (COSTR) will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity. Emphasis is on developing scientific instruments conceived through the Space Physics Research and Analysis and Sounding Rocket programs. Most instruments to be developed in the near term will provide a U.S. contribution to an international thrust in space physics research in the 1989-1995 timeframe, principally, the European Solar Terrestrial Science Program (STSP) and the Japanese Geotail Mission.

The Tethered Satellite System (TSS) will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The objective of the ini-

tial TSS mission is to verify the controlled deployment, retrieval and on-station stabilization of a satellite tethered from the orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter. TSS is an international cooperative project with the Italian government. The U.S. is responsible for overall project management, system integration, developing the tether deployment and retrieval system, developing and integrating U.S. provided instruments, and flight on the Shuttle. Italy is developing the satellite and is responsible for development and integration of Italian provided instruments.

The Shuttle experiment to test the theory of relativity will develop a multigyroscope experimentation package to fly as an attached payload on the Shuttle in 1993, as an integral part of the study of relativity.

Astrophysics and Space Physics Payloads include a number of instruments designed for flight on the Space Transportation System. Emphasis will be on technology definition for the High Resolution Solar Observatory (HRSO) as well as instrument development for study of the complex relationships of solar irradiance and the near-Earth plasma environment (Atmospheric Laboratory for Applications and Science—ATLAS), and the diffuse x-ray background and spectra of point and extended sources (Shuttle High Energy Astrophysics Lab—SHEAL).

In FY 1989, the COSTR program will continue development of U.S. provided instruments for the ISAS/NASA Geotail mission which will explore the Earth's magnetosphere and deep geotail region. NASA will also be developing U.S.-provided instruments and mission support equipment for the ESA/NASA joint Cluster and SOHO missions, which will provide unique capabilities for measurement of solar oscillations and solar corona. Funding is also required to continue development of U.S. provided instruments on TSS-1 and for core equipment development and integration. Funding will be used to support the First Integrated System Test in which a full scale prototype of the Shuttle experiment to test the theory of relativity will undergo developmental testing.

Shuttle/Spacelab Payload Mission Management and Integration

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Shuttle/Spacelab payload mission management and integration:	
Estimated fiscal year 1988	$54,200,000
Authorization fiscal year 1989	61,500,000

The primary objective of the Spacelab Payload Mission Management program is to manage the mission planning, integration, and execution of all NASA Spacelab and attached Shuttle payloads. This includes system management and engineering development of flight support equipment and software; development of certain interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; and data dissemination to experimenters.

Mission management activities are continuing for Physics and Astronomy missions including the ASTRO-1 mission and the Shuttle High Energy Astrophysics Lab (SHEAL). ASTRO-1 is scheduled for flight in 1989 and SHEAL is currently planned for flight in 1992. The primary instrument on SHEAL, a broad-band X-ray Telescope, is also under consideration for an early flight on the Astro mission in order to make timely observations of the Supernova 1987a.

Mission management activities are continuing on several other space science and applications missions, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The first of this series is planned for flight in 1991. The mission will incorporate a large number of instruments designed to study the complex relationships of solar irradiance, atmospheric composition and changes, and the near-earth plasma environment. Other examples include flight of an imaging radar in the early 1990's; a series of Spacelab Life Sciences missions (SLS), the first schedule for launch in December 1989; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); and flight of the on-going series of Materials Science Laboratories (MSL's). Mission management activities also support other (non-OSSA) payloads. For example, the Space Station heat pipe advanced radiator element experiment payload will test a heat rejection system with high potential for future spaceborne applications.

Mission management activities will intensify in FY 1989 as Spacelab missions resume with the flight of ASTRO-1. Besides final preparation for flight of ASTRO-1, mission management will continue for the major Shuttle/Spacelab missions including SHEAL, the ATLAS series, the SpaceLab Life Sciences Missions (SLS) the International Microgravity Laboratories (IML), and flight of an imaging radar. Mission management support for non-OSSA payloads will also continue.

Space Station Integration Planning and Attached Payloads

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Integration planning	$11,100,00	$0
Attached payloads	7,800,000	8,000,000
Total	18,900,000	8,000,000

The primary objective of the Space Station Integration Planning and Attached Payloads program is to initiate the necessary planning, definition and development of payloads and missions as the Office of Space Science and Applications begins its preparations as a future major user of the Space Station complex. This includes the definition of attached payloads suitable for deployment on the early Space Station, as well as the definition of integration and operational requirements, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Studies continue to define the end-to-end science operations requirement for the Space Station era (i.e., the cycle from identifica-

tion of science requirements, through mission planning and operations to dissemination, analysis and archiving of data). Studies also continue to determine the best use of Space Station resources (e.g., power, crew time, volume, data handling capabilities, pointing capabilities) vis-a-vis science requirements. Potential attached payloads have been identified for further feasibility and definition and appropriate studies are under way.

The two-year study phase for Space Station Integration Planning activities will be completed in FY 1988. In FY 1989, definition and development will continue on those attached payloads selected for early flight on the Space Station. Additionally, Space Station payload development activities are augmented in FY 1989 in the cognizant science disciplines where the payloads, hardware and support equipment will be defined and developed through a judicious program of Spacelab test flights. They include facilities and instrumentation for microgravity experiments, as well as Life Sciences hardware, support equipment and studies, and Advanced Technology Development for the polar platform payload (Earth Observing System). The total augmentation for Space Station-related payload activities included in the OSSA FY 1989 budget is approximately $50 million.

Explorer Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Cosmic background explorer	$14,600,000	$5,500,000
Extreme ultraviolet explorer	29,600,000	40,400,000
Roentgen satellite experiments	2,400,000	3,300,000
Combined release and radiation effects satellite experiments	2,200,000	2,200,000
Solar-A	7,600,000	4,600,000
Other explorers	11,500,000	26,100,000
Total	67,900,000	82,100,000

Investigations selected for Explorers are usually of an exploratory or survey nature, or have specific objectives not requiring the capabilities of a major observatory. Past Explorers have discovered radiation trapped within the Earth's magnetic field, investigated the solar wind and its interaction with the Earth, studied upper atmosphere dynamics and chemistry, mapped our galaxy in radio waves and gamma-rays, and determined the properties of the interstellar medium through ultra-violet observations.

Recent Explorers have performed active plasma experiments on the magnetosphere, made *in-situ* measurements of the comet Giacombini-Zinner, and completed the first high sensitivity, all sky survey in the infrared, discovering over 300,000 sources.

Explorers under development will study the properties of the cosmic microwave background, which is important for understanding the early universe and cosmology, survey the sky in the extreme-ultraviolet for the first time, and measure time variable phenomena in x-ray sources. The Explorer program also provides a means of developing instruments for "payload-of-opportunity" missions, such as those involving other Federal agencies or international collaboration.

The San Marco-D mission, a cooperative project with Italy, is scheduled for launch in 1988 on a Scout expendable launch vehicle. This project will include a group of U.S. experiments to study the relationship between solar activity and meteorological phenomena on the Earth. The Cosmic-Ray Isotope Experiment (CRIE) will be included in the Combined Release and Radiation Effects Satellite (CRRES), an Air Force Mission now scheduled for launch in 1990. The CRRES will also release trace chemicals, whose transport in the magnetosphere can be observed from ground and airborne-based instruments.

In FY 1986, a new cooperative mission called Solar-A was initiated with the Japanese. Solar-A will be launched in 1991 to study the Sun during the upcoming solar maximum. The U.S. has selected an instrument for this spacecraft, which will relate energetic solar phenomena and dynamic coronal structures seen in hard and soft x-rays to the topology of evolving solar magnetic fields. This will allow the first simultaneous observations of these phenomena from space.

In FY 1988, development continues on the Cosmic Background Explorer (COBE), the Extreme Ultraviolet Explorer (EUVE), and on the x-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of a micrometer and 9.6 millimeters. Because COBE requires a polar orbit, and the opening of the West Coast Shuttle launch facility has been postponed, the decision was made to launch the COBE spacecraft on a Delta expendable launch vehicle in early 1989. Funding in FY 1988 will be used for integration and testing of the three COBE instruments and the COBE spacecraft vehicle. Design and development also continues on EUVE, which will carry out the first detailed all-sky survey of extreme ultraviolet radiation between 100 and 900 angstroms.

ROSAT, a cooperative project between the Federal Republic of Germany (FRG) and the United States will perform a high resolution imaging survey of the x-ray sky and provide indepth studies on selected objects. The U.S. will provide one of the ROSAT instruments and the launch services; Germany will provide the spacecraft, telescope, and other instruments. The U.S. x-ray imaging instrument will be delivered in the second quarter of FY 1987. Current plans call for ROSAT to be launched on a Delta expendable launch vehicle in early 1990.

Definition and design will continue in FY 1988 on the x-ray Timing Explorer (XTE). This mission, the last currently planned major effort in the Explorer line, can be ready for launch as early as 1993. During FY 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over 43 were received and are currently being evaluated for further definition.

In addition to our efforts in the traditional "Delta-class" Explorer area, current plans call for issuance of an Announcement of Opportunity for Scout-class Explorer missions in early 1988. While subject to more stringent constraints than Delta-class missions

(weight, telemetry, power, etc.), it is anticipated that a significant number of scientifically exciting missions can utilize this capability and be developed on a short time-scale. Following a peer review of proposals, it is anticipated that several Scout missions will be selected for development with the initial one being launched as early as 1991.

During FY 1989, the final testing of the COBE spacecraft will be completed in preparation for a mid-year launch. Development activity will continue on EUVE, and in the instruments scheduled to fly on CRRES, ROSAT and Solar-A. Development activities will begin on the XTE and will increase on the Scout-class payloads.

Mission Operations and Data Analysis

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Hubble space telescope operations	$50,800,000	$59,100,000
Hubble space telescope maintenance and refurbishment	40,800,000	52,200,000
Astrophysics mission operations and data analysis	21,800,000	29,300,000
Space physics mission operations and data analysis	18,600,000	15,600,000
Total	132,000,000	156,200,000

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program also supports the operation of a number of spacecraft after their originally planned objectives had been achieved, for purposes of conducting specific investigations that have continuing high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and space physics operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

Space Physics research activities rely on data received from the Interplanetary Monitoring Platform (IMP), the Active Magnetospheric Particle Trace Explorer (AMPTE), the Dynamics Explorers which are still operational, and the International Sun/Earth Explorers (ISEE-1&2), which reentered in October 1987. IMP continues to provide the only available source of solar wind input measurements to the Earth. IMP, along with ISEE-1&2, DE, AMPTE, and the Swedish Viking satellite successfully conducted a multisatellite campaign called Polar Regions and Outer Magnetospheric International Study (PROMIS) in 1986. The ISEE-3 spacecraft, renamed the International Cometary Explorer (ICE), provided complementary solar wind measurements upstream of Comet Halley in 1986, and was retargeted for a return to Earth orbit in 2014 for retrieval and presentation to the National Air and Space Museum (NASM).

In addition to the normal support required for mission operations, the Hubble Space Telescope program encompasses several unique aspects which must be provided for in advance of the launch. The Hubble Space Telescope is designed to operate for more than a decade, using the Space Shuttle/Orbital Maneuvering Vehicle combination and/or Space Station for on-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments.

The Hubble Space Telescope will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through an independent Hubble Space Telescope Science Institute. The Institute will operate under a long-term contract with NASA. While NASA will retain operational responsibility for the observatory, the Institute will implement NASA policies in the area of planning, management, and scheduling of the scientific operations of the Hubble Space Telescope.

Initiation of the definition and implementation of a unified data system which will ensure the fullest access and exploitation of the various mission data sets, with emphasis on the wealth of data to be returned by the Great Observatories, will be undertaken. An initial definition process involving extensive inputs from the astrophysical community has now been completed, and FY 1989 funding in the Mission Operations and Data Analysis (MO&DA) area will enable the principal elements of this essential system to be put in place.

The FY 1989 funding level is required to maintain critical skills for the operation and maintenance of the Hubble Space Telescope, and to prepare for launch activities in the fourth quarter of FY 1989.

Mission operations, data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM), the Interplanetary Monitoring Platform (IMP), the Dynamics Explorer (DE), the Active Magnetospheric Particle Trace Explorer (AMPTE), and the International Ultraviolet Explorer (IUE). The High Energy Astronomical Observatories (HEAO 1-3), International Sun-Earth Explorers 1 and 2 (IEE-1&2), International Cometary Explorer (ICE) and the Infrared Astronomy Satellite (IRAS) data analysis will also continue. These programs have produced valuable data sets which are used by a wide segment of the physics and astronomy community. FY 1989 funds will also be used to begin development of the unified Astrophysics data system.

Research and Analysis

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorized fiscal year 1989
Supporting research and technology	$67,000,000	$84,800,000
Gravity probe-B definition	2,700,000	0
Advanced technology development	13,200,000	4,300,000
Total	82,900,000	89,100,000

This program provides for the preliminary studies required to define missions and/or payload requirements, as well as a research and technology base necessary to define, plan and support flight projects.

Supporting Research and Technology (SR&T).—The objectives of supporting research and technology are to: (1) optimize the return expected from future missions through scientific problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to understand astrophysics phenomena and solar-terrestrial relationships; and (5) continue the acquisition, analysis and evaluation of data from laboratories, balloons, rocket and spacecraft activities.

Research is supported in the disciplines of astronomy, astrophysics, gravitational physics, and space physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. Space physics research and analysis is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. The theory activities are related to all the Physics and Astronomy disciplines and are critical to the correlation of available information. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments will also be continued. Results achieved in the SR&T program will have a direct bearing on future flight programs. For example, the development of advanced x-ray, ultraviolet, and infrared astronomy imaging devices under this program may enable spacecraft to carry instruments for astronomical observations which have increased orders of magnitude in sensitivity and improved resolution over currently available detectors.

One major thrust of the space physics program is directed at studies of the near-Earth geospace environment, from the flow of the solar wind past the magnetosphere, to manifestations of variations of the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest for basic plasma physics but there are also many practical ramifications, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

The SR&T program carries out its objectives through universities, nonprofit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

Advanced Technological Development (ATD).—The advanced technological development activities support detailed planning and definition of potential new physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. Funding is applied to the definition and preliminary design for specific missions or subsystems/elements critical to eventual mission development in order that technical readiness and resources requirements may be adequately defined before the missions are proposed for implementation.

Candidate missions for the 1980's and early 1990's that require ATD activities include the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). The AXAF mission, which is an FY 1989 new initiative, will study stellar structure and evolution, active galaxies, clusters of galaxies and cosmology. The AXAF's imaging x-ray telescope is planned to have a sensitivity approximately 100 times that of HEAO–2, a resolution increase of nearly a factor of twenty and an increase in wavelength range by a factor of two. The SIRTF will observe faint, cool infrared sources in the universe and will significantly build on the IRAS science foundation. Major Spacelab payloads being considered for future missions and requiring advanced technological development support include the Pinhole/Occulter Facility, a detector for imaging hard x-rays from solar and cosmic sources. During FY 1988, AXAF definition will be completed and a down selection between prime contractor candidates will be performed through a Source Evaluation Board process. Work will continue toward deepening the technological and system understanding of science instruments selected for definition. Technological preparation for SIRTF will also continue.

During FY 1989, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for viable physics and astronomy and space physics programs. Support will be provided for study of Supernova 1987a to take advantage of the unique scientific opportunity provided by this exciting event. FY 1989 funding will also support continued studies on potential future missions. In the data analysis activities to be carried out at university and government research centers in FY 1989, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories).

SUBORBITAL PROGRAM

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Sounding rockets	$24,900,000	$25,700,000
Airborne science and applications	7,300,000	7,800,000
Balloon program	9,900,000	8,600,000
Spartan	2,600,000	3,000,000
Total	44,700,000	45,100,000

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and an international cooperative basis.

Sounding Rockets

A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects.

Additionally, the sounding rocket program provides the physics and astronomy program with the means for flight testing instruments and experiments being developed for later flight on the Shuttle/Spacelab and space probes and for calibrating and obtaining vertical profiles in concert with current orbiting spacecraft. Forty-four rockets are currently scheduled for launch in fiscal year 1988. Included in this number are eight NASA launches in Greenland as a follow-up to the FY 1985 effort.

Airborne Science and Applications

Research with instrumented jet aircraft has been an integral part of the NASA physics and astronomy program since 1965. For astronomy research, the airborne science and applications program operates the Kuiper Airborne Observatory. This full-scale manned facility consists of a C-141 equipped with a 91-centimeter infrared telescope. The C-141 aircraft, able to fly for several hours at altitudes approaching 13 kilometers, provides a cloud-free site for astronomical observations. The ability to carry out observations at this altitude, above most of the infrared-absorbing water vapor in the Earth's atmosphere, has been essential in expanding astronomical observations into the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1987, the C-141 responded rapidly to the discovery of the SN 1987a Supernova, making observations during the crucial expansion phase of the event. Other observations included the exploration of the star-forming regions and of other areas in our own galaxy and solar system. In FY 1988, 72 missions are planned, including support of the SN 1987a campaign with additional flights in the southern hemisphere. FY 1988 activities continue the study of a Stratospheric Observatory For Infrared Astronomy (SOFIA) as a potential follow-on for the C-141 in the 1990's. SOFIA would incorporate a 3-meter class infrared telescope mounted in a suitable aircraft.

Balloon Program

The Balloon Program provides a cost-effective means to test flight instrumentation in the space radiation environment and for making observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared, gamma-ray, and cosmic-ray astronomy. In many instances it is necessary, because of size, weight, cost, or lack of other opportunities, to fly primary scientific experiments on balloons. In addition to the level-of-effort science observations program, significant emphasis has been and will be placed on development of a balloon capable of lifting more than 3,500 pounds, and to support missions lasting several days.

The Balloon Program funding is required for purchase of balloons, helium, launch services, tracking and recovery, as well as for maintenance and operations of the National Scientific Balloon Facility (NSBF) at Palestine, Texas. This facility supports the launch of about 80 percent of NASA's balloon payloads, and it is the nation's primary means for carrying out large scientific balloon operations. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

Spartan Program

The Spartan missions involve low-cost Shuttle payloads flown as autonomous sub-satellites which are deployed and retrieved by the Space Shuttle. Spartans allow the accomplishment of single, specific scientific objectives with efficiency and simplicity. The first Spartan flew successfully in 1985. It obtained valuable, new x-ray data on the nuclear region of our own galaxy and on the vast cluster of galaxies in the constellation Perseus. Detailed analysis of this data is continuing. The second Spartan, Spartan Halley, was lost with the Challenger. A third Spartan mission, Spartan 201, consisting of a 17-inch diameter solar telescope with an ultraviolet coronagraph and a white light coronagraph to measure the intensity and scattering properties of solar light, is being developed for a future Shuttle mission.

FY 1989 funds will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NSBF. This funding is also required to continue definition activities for balloon improvement and long-duration balloon flights. In FY 1989, the Airborne Science and Applications

funding will be used to continue flights of the Kuiper Airborne Observatory.

4. LIFE SCIENCES PROGRAM

FY 1989 NASA REQUEST, $101,700,000

FY 1988 AUTHORIZATION, $101,700,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Life sciences flight experiments	$30,900,000	$54,500,000
Research and analysis	38,600,000	47,200,000
Total	69,500,000	101,700,000

The goals of the Life Sciences program are to advance knowledge in all areas of space life sciences and to develop medical and biological systems which enable human habitation in space. Results from the research program are applied to: the immediate needs of maintaining astronaut health and productivity; understanding the response of biological mechanisms to weightlessness; the design of controlled ecological life support systems; understanding the origin, evolution and distribution of life in the universe; and, understanding the biosphere of the planet Earth.

Continuing support of the Life Sciences program is essential to: understand the basic biological mechanisms of gravitational responsivity; evolve the critical technologies necessary to enable long-term piloted space flight; and, develop the capability to sustain a permanent manned presence in space. The research program includes ground-based and space research efforts which are mutually supportive and integrated, and studies fundamental biological processes and space-related medical problems through a variety of disciplines and techniques.

The Life Sciences research and analysis program includes five major elements: 1) space medicine, which addresses the health and well-being of space crews by seeking to understand and prevent adverse physiological changes which occur in space flight and upon return to Earth; 2) space biology, an integrated basic science research program that studies the fundamental mechanisms of gravitational interaction with all orders of plants and animals in flight and ground experiments; 3) controlled ecological life support systems, a program of research and critical technology development for life support systems necessary to maintain life in space autonomously for long periods of time; 4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and 5) biospheric research, which explores the interaction between life on Earth and its physical and chemical environment.

The Life Sciences Flight Experiment program supports the research and analysis program with the selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations in space involving humans, animals and plants. Experiments are currently conducted on the Shuttle and Spacelab, and are being readied for conduct on the Space Station. An international cooperative program, the U.S./U.S.S.R. working group in space biology and medicine, pursues investigations of joint interest.

LIFE SCIENCES FLIGHT EXPERIMENTS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Life sciences flight experiments:	
Estimated fiscal year 1988	$30,900,000
Authorization fiscal year 1989	54,500,000

The objective of the Life Sciences Flight Experiment program is to assimilate information and scientific questions from various life sciences disciplines and develop payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation of weightlessness. The program includes selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations involving humans, animals and plants. Past experience indicates that humans clearly undergo physiological changes during weightlessness. Many of the observed changes are physiologically significant and are not well understood. Shuttle/Spacelab and Space Station missions are suitable for gaining a greater understanding of the basic mechanisms underlying this response to weightlessness. Flight experiments that lead to a firmer comprehension of the underlying mechanisms of gravitational adaptation enhance our basic science knowledge, make it possible to improve the management of several existing problems, and increase the confidence with which we can estimate the physiological consequences of more sustained weightless exposure and design corresponding countermeasures.

FY 1989 funding is required for the final preparation and flight of approved experiments on the first dedicated Life Science mission (Spacelab Life Sciences-1 (SLS-1)) which is scheduled to be launched in FY 1991 and will concentrate on studies of human and animal biomedical responses, with emphasis on cardiovascular, bone metabolism and vestibular functions. SLS-1 will be unique in several respects. It will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and it will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space. Many of the experiments and associated flight hardware flown on earlier Shuttle flights will support and enhance preparations for SLS-1 and subsequent missions.

Final preparations are also underway to support the flight of the first International Microgravity Laboratory (IML-1) mission in 1990. Approximately 50 percent of the payload relates to space life sciences, with the U.S. focus on plants, neurovestibular studies, human performance, radiation and cullular differentiation.

Efforts will continue on definition and development of new experiments (selected through the Announcement of Opportunity (AO) process) and hardware that will be flown on future Spacelab/Shuttle missions—i.e., Shuttle mid-decks, the Japanese SL-J mission, the second dedicated life sciences mission (SLS-2), the German D-2 mission, IML-2, SLS-3, and the Department of De-

fense Starlab mission. Collaboration with the Soviet Union on its COSMOS biosatellite program will continue with joint research on the next COSMOS flight in 1989.

To ensure that the Space Station will serve life sciences research objectives, studies will be conducted in FY 1989 to determine how space biology research will be accommodated on the Space Station, as well as to define instrument and facility requirements. Studies will identify unique scientific and hardware transition requirements from continuing Spacelab flights to Space Station operations. In addition, technology assessment, advanced technology development, and experiment definition and planning will be conducted.

In FY 1989, research efforts will be increased on the feasibility of extending operational tours of duty of flight crews on the Space Station in order to achieve greater cost-effectiveness. The program will decrease transportation costs by helping to reduce yearly Shuttle flights needed to support crew rotations on the Space Station from eight to an estimated four to five. It will also allow more effective use of human resources by maintaining crew health and productivity with countermeasures that minimize impact on in-flight crew time. Crew debility and rehabilitation time following long duration space flight will also be reduced. Spacelab opportunities will be used to conduct supporting experiments and fly associated payloads. Preparation for the Space Station will commence with investigation planning, technology assessment for flight equipment, and critical technology and hardware development.

In FY 1989, development will begin on an integrated centrifuge facility that will support a broad spectrum of life sciences research using small animals and plants. For the first time, it will provide continuous on-board 1-G control that can separate influences of weightlessness from other effects of space flight. It will allow scientists to test the response of living organisms to operational forces at various stages of adaptation to weightlessness. Two units will be developed. The initial unit will be deployed on Spacelab where in-flight engineering verifications for the centrifuge, associated equipment and logistical support will be performed. The second unit will be deployed on the Space Station. This facility represents a marked enhancement of basic research capability to the Life Sciences program.

Research and Analysis

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Research and analysis:	
Estimated fiscal year 1988	$38,600,000
Authorization fiscal year 1989	47,200,000

The research and analysis activity supports Life Sciences program goals of advancing knowledge in all areas of space life sciences and developing medical and biological systems which enable human habitation in space. The program is composed of five elements: 1) space medicine; 2) space biology; 3) controlled ecological life support systems research; 4) exobiology; and, 5) biospheric research.

The Life Sciences Space Medicine program is responsible for assuring the physical welfare, performance and adequate treatment of in-flight illness or injuries of spaceflight crews. Such conditions as space motion sickness, spatial disorientation, fluid shifts and endocrine changes, can decrease performance and cardiovascular tolerance and possibly aggravate latent disease. These conditions must be carefully evaluated to determine preventative measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the adaptation to space and success of physiological countermeasures will be continually undertaken. In addition, long-term monitoring of space flight crews will be performed in a standardized fashion in order to identify risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. Biomedical research will investigate the fundamental physiological basis for problems encountered in manned spaceflight. Research areas include: neuroscience; cardiovascular, musculoskeletal, and regulatory physiology; cell and developmental biology; human behavior and performance; and environmental health sciences.

The Space Biology program explores the role of gravity in life processes and uses gravity variations as an environmental tool to investigate fundamental biological questions. Specific objectives are to perform the basic science research required to identify and investigate: 1) the role of gravity in plant and animal behavior, morphology, development and physiology; 2) the mechanisms of gravity sensing and the transmission of this information within both plants and animals; 3) the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the physiology of organisms; 4) the uses of gravity to study the normal nature and properties of living organisms; and 5) the effects of microgravity to facilitate plant and animal growth, long-term survival and reproduction in space.

The Controlled Ecological Life Support Systems program seeks to provide air, water and food to support life through bioregenerative closed systems which receive only energy from the external environment. Development of such systems is a critical path element for long duration manned spaceflight and lunar colonization.

The Exobiology program is directed toward understanding the origin and evolution of life, and life-related molecules, on Earth and throughout the universe. Research seeks to trace the pathways leading from the origin of the universe through the major epochs in the evolution of living systems. Research encompasses: the cosmic evolution of the biogenic compounds, prebiotic evolution, early evolution of life, and evolution of advanced life. Emphasis is placed on understanding these processes in the context of the planetary and astrophysical environments in which they occurred. Flight experiments in Earth orbit and on planetary missions are important program elements. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between global biological and planetary processes to develop an understanding of global biogeochemical cycles. Laboratory and field

investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modeling efforts integrate biological data with atmospheric, climate, oceanic, terrestrial, and biogeochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

The Space Medicine program will resume collecting information on occupational exposure in microgravity on each Shuttle flight and conduct in-flight clinical testing of countermeasures, especially in the area of vestibular dysfunction, cardiovascular deconditioning and muscular atrophy. Resolving problems associated with the initial adaptation to weightlessness such as space motion sickness and fluid shifts will continue to be of high priority. Research emphasis will be placed on operational management of space adaptation syndrome. Approaches such as autogenic (biofeedback) techniques will be evaluated in flight to provide a basis for development of specific countermeasures. Research will commence in the field of biomechanics. Understanding the dynamics of bodily adaptation to physical forces and being able to measure stress on the human body is crucial to designing countermeasures to maintain astronaut health and productivity. Research in the fields of psychology and the ergonomics of man/machine interface will be supported for their importance in improving the performance and efficiency of flight crews. Research in radiation biology will continue because it is necessary to precisely measure dosages and the effects of cosmic and solar radiation in order to determine the optimum radiation shielding required for humans in space. Research is in progress to develop pressurized space suits for quick reaction situations and to develop corresponding pressurized suit gloves.

In conjuction with NASA's development of the Space Station, the Space Medicine program will support extended duration crew operations in space with extensive research in the physiological changes associated with longer exposure to weightlessness. Bone demineralization, muscle atrophy and cardiovascular deconditioning will be studied in ground-based simulation so appropriate countermeasures can be designed. This accelerated program of directed research, bed rest studies and protocol development and evaluation will allow more effective use of human resources in space by developing physiological countermeasures that minimize impact on in-flight crew time. Critical technology requirements will be addressed and research on implementation initiated.

In FY 1989, the Office of Space Science and Applications will collaborate with the Office of Aeronautics and Space Technology on the Agency's proposed new initiative: Project Pathfinder. The Project will research critical path elements for long-term manned missions in order to inform policy makers of the requirements (as well as uncertainties, risks and technological issues) involved in such efforts as a lunar base or manned Mars mission. Life science research will be directed to the Humans in Space element of Project Pathfinder and focus on the areas of human performance, extravehicular activity and life support. Critical areas of investigation in human performance include: biomedical requirements for artificial gravity; advanced medical care technology for remote locations; radiation protection; and psychological and habitability factors affecting crew behavior and performance on long duration missions. Research in extravehicular activity will focus on: developing requirements for portable life support systems and habitability of space suits; and gathering the anthropometric and bioengineering data needed to develop pressurized suit gloves that allow adequate manual dexterity. The life support program will develop and test technologies that will provide the capability for closed-loop life support. Important factors include waste processing, food production, air revitalization, and water purification.

The Space Biology program will concentrate ground research on: developing working models of functioning gravity-sensing neural (information) networks to understand neurosensory processing in microgravity; understanding the physiological side effects of centrifugation in preparation for use of the Shuttle/Space Station centrifuge as a research tool; and identifying the cellular events of the gravity perception mechanism in plants. Research in preparation for flight opportunities on the Shuttle and the Soviet biosatellite COSMOS will focus on genetic, cytological, developmental and metabolic effects of gravity on plants and animals. Fundamental research in gravitational response mechanisms in plant and animal development will be developed in preparation for future biosatellite and Space Station experiments.

The Controlled Ecological Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environment of manned spacecraft. In developing such a life support system, the near term emphasis will be on system definition and development of design concepts and critical technologies for flight, and supporting research in the areas of controlled-environment plant production, waste processing and human nutrition.

The Exobiology program will emphasize the development of new flight experiment concepts to investigate models of early Solar System evolution and mechanisms for the synthesis of biologically significant molecules in space. The program will further develop analytic capabilities to utilize an expanding extraterrestrial sample base, participate in the retrieval of samples and focus science on emerging opportunities in planetary exploration. In FY 1989, definition and design phases will be completed in the program's microwave observing project which will analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy. Funds will be used to begin the development phase of signal processing systems which will be used with existing radio astronomy facilities and NASA's Deep Space network antennas.

The Biospheric Research program will place emphasis on improving estimation techniques for determining the structural state of the terrestrial biomass by combining ground-based measurements at tropical, temperate, and wetland sites with remote sensing data and biogeochemical modeling of the interactions of ecosystems on a global scale. Information gathered through remote sensing will also be used to help nations prepare for outbreaks of vector-borne disease (malaria) by allowing predictive modeling of the occurrence of the disease vector (mosquitos).

5. PLANETARY EXPLORATION PROGRAM

FY 1989 NASA REQUEST, $404,000,000

FY 1989 AUTHORIZATION, $101,700,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Galileo development	$51,900,000	$61,300,000
Magellan	73,000,000	33,900,000
Ulysses	7,800,000	10,300,000
Mars observer	53,900,000	102,200,000
Mission operations and data analysis	74,700,000	112,700,000
Research and analysis	67,900,000	83,600,000
Total	329,200,000	404,000,000

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to understand the Earth better through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and (4) to provide a scientific basis for the future use of resources available in near-Earth space. Projects undertaken in the past have been highly successful. The strategy that has adopted calls for a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the small bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies and then proceed to levels of more detailed study.

The reconnaissance phase of inner planet exploration, which began in the 1960's, is now virtually completed, although we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for the next step of detailed study. Analyses of meteorities and the lunar rock samples returned by Apollo continue to be highly productive, producing new insights into the early history of the inner solar system and thus leading to revision of our theoretical concepts. The Pioneer Venus mission is continuing to carry the study of the Earth's nearest planetary neighbor and closest planetary analog beyond the reconnaissance stage to the point where we have now obtained a basic characterization of Venus' thick, massive atmosphere, as well as fundamental data about the formation of the planet.

The exploration of the giant outer planets began more recently. The Pioneer-10 missions to Jupiter in 1973 and 1974 were followed by the Voyager-1 and 2 spacecraft encounters in 1979. Voyager-1 then encountered Saturn in November 1980 and Voyager-2 in August 1981. The Voyager data on these planets, their satellites, and their rings have revolutionized our concepts about the formation and evolution of the solar system. Voyager-2 encountered Uranus in January 1986 and has provided our first look at this giant outer planet. Its trajectory is now carrying it to an encounter with the pianet Neptune in 1989. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories heading out of the solar system, as they continue to return scientific data about the outer reaches of the solar system.

Galileo will be launched on a Shuttle/Inertial Upper Stage (IUS) combination in 1989 on a trajectory using gravity assists at Venus and Earth. The comprehensive science payload will extend our knowlege of Jupiter and its system of satellites well beyond the profound discoveries of the preceding Voyager and Pioneer missions. During twenty-two months of operation in the Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, while orbiter will have the capability to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA and European Space Agency activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's orbit. Ulysses will be launched in 1990 using the Shuttle and IUS/PAM-S launch stages.

Magellan will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to penetrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale features and to address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations. With these data, the evolutionary history of Venus can be compared with that of the Earth. Magellan is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer will follow up on the earlier discoveries of Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. The mission will utilize a modified Earth-orbiting spacecraft, thereby benefiting from the previously developed technology.

Beginning in late 1985, we entered an exciting new phase of exploration by making our first close-up studies of the solar system's mysterious small bodies—comets and asteroids. These objects may represent unaltered original solar system material, preserved from the geological and chemical changes that have taken place in even small planetary bodies. By sampling and studying comets and asteroids, we can begin to make vigorous inquiries into the origin of the solar system itself. These efforts began with the encounter of Comet Giacobini-Zinner by the International Comet Explorer (ICE) spacecraft in September 1985 and continued through our involvement with the 1986 encounters and observations of Comet Halley by U.S. and foreign spacecraft and by intensive studies of the comet from ground-based observatories coordinated through the International Halley Watch. Studies of results obtained by these missions and observations and the archiving of these data are con-

tinuing. In addition, we are conducting preliminary design for development of a new class of spacecraft, Mariner Mark (MM II).

The Planetary Exploration program is also founded on a coordinated ground-based research and analysis effort. Research and analysis activities will continue to maximize the scientific return from both ongoing and future missions and from such Earth-based activities as lunar sample and meteorite analysis, telescope observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups and for the wide dissemination of scientific results. A close coupling is also maintained between the research programs and planning activities that are undertaken to define the scientific rationale and technology needed for future missions. The program also supports the growing involvement of U.S. scientists as participants on foreign-sponsored missions.

Galileo Development

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$26,000,000	$25,100,000
Experiments	11,000,000	10,100,000
Ground operations	14,900,000	26,100,000
Total	51,900,000	61,300,000

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in situ* measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

The orbiter and probe will be launched together in October 1989 as a single combined payload using a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward Venus, followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter not otherwise obtainable with this launch vehicle. When the orbiter arrives at Jupiter it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which both Jupiter's major satellites and the dynamic magnetosphere will be extensively mapped. During this time, ten close flybys of Jupiter's four major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG's) developed by the Department of Energy. The orbiter will carry approximately 100 kg of scientific instruments and the probe will carry approximately 25 kg of scientific instruments.

During FY 1988, activities will continue in completing assembly, integration and initial testing of the modified spacecraft system. In addition, several critical parts changeouts will be completed, which will improve the reliability of the spacecraft computers and science instruments. Modification of the flight software and mission operations system required to accommodate the new trajectory will continue.

FY 1989 funds will provide for completion of spacecraft system testing and for preparing the spacecraft to be shipped to Kennedy Space Center for initiation of integration with the IUS and Shuttle. Mission operations software development and testing will also continue in preparation for a launch in October 1989.

Magellan

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$43,000,000	$14,300,000
Experiments	15,200,000	5,400,000
Ground operations	14,800,000	14,200,000
Total	73,000,000	33,900,000

The objective of the Magellan mission is to address fundamental questions regarding the origin and evolution of Venus through global radar imagery of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The Magellan spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution (120 to 200 meter) images of the planetary surface as well as altimetric data. Gravity data will be obtained by processing radio signals from the spacecraft. Spacecraft development is making extensive use of existing designs, technology, and residual hardware. For example, the spacecraft will use an existing spacecraft structure, large antenna, and propulsion components from the Voyager program.

In April 1989, the Magellan spacecraft will be launched by the Shuttle/Inertial Upper Stage (IUS) on a direct trajectory to Venus. Arriving at Venus in July 1990, the spacecraft will perform a retropropulsive maneuver and enter a near-polar elliptical orbit. After an initial check-out period, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution to about 150 meters.

During FY 1988, spacecraft structural testing will be initiated, the flight model of the radar instrument will be delivered for integration with the spacecraft, the spacecraft assembly will be completed and environmental testing will be initiated for the entire spacecraft flight system. Integration of the mission operations system will be completed to be followed by initiation of operations testing and training preparatory for launch.

In FY 1989, the spacecraft will be shipped to Kennedy Space Center following final testing. Upon arrival, the spacecraft will be integrated with the IUS and Shuttle and undergo final preparation prior to launch in April 1989.

Ulysses

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft	$3,100,000	$2,800,000
Experiments	3,900,000	5,600,000
Ground operations	800,000	1,900,000
Total	7,800,000	10,300,000

Ulysses is a joint mission of NASA and the European Space Agency (ESA). ESA is providing the spacecraft and some scientific instrumentation. The U.S. is providing the remaining scientific instrumentation, the launch, tracking support, and the Radioisotope Thermoelectric Generator (RTG). The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate.

Ulysses was restructured in FY 1981 from a two-spacecraft mission—one provided by the United States and one provided by ESA—to a single ESA spacecraft mission. However, the United States' participation in the program remains substantial. NASA is responsible for five of the nine principal investigator instruments and three of the four European investigations have U.S. co-investigators.

The Ulysses launch is planned for October 1990, using the Shuttle and IUS/PAM-S launch stages. During 1988, documentation of the spacecraft/launch vehicle interface will be completed while support to ESA will continue in order to make the spacecraft compatible with the new upper stage configuration. Launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments will also be continued.

FY 1989 funding will support launch approval activities for the Radioisotope Thermoelectric Generators (RTGs). Periodic testing of the spacecraft and science instruments will also continue.

Mars Observer

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spacecraft development	$21,200,000	$39,300,000
Experiments	28,600,000	56,700,000
Ground operations	4,100,000	6,100,000
Total	53,900,000	102,200,000

The Mars Observer mission is the first in a series of planetary observer missions utilizing a lower cost approach to inner solar system exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well defined and focused set of science objectives and uses modified production-line, Earth-orbital spacecraft and instruments with previous space flight heritage. The objectives of the Mars Observer mission are to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and observe their interaction with the Martian environment over all four seasons of a full Martian year.

The limitation on the number of launch opportunities through 1990 and the further restrictions placed on scheduling by timing requirements for planetary launches have necessitated delaying the planned launch of Mars Observer from 1990 until the following planetary opportunity 25 months later. The current plan is to launch the mission in 1992 with a Transfer Orbit Stage (TOS). The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of a full Martian year, which is about two Earth-years.

In FY 1988, it is planned to continue detailed design of the instrument hardware and system design of the overall mission and to complete design of the Payload Data Subsystem. Detail design of the spacecraft and parts and subassembly procurements will be continued.

FY 1989 funding will support the completion of spacecraft and instrument designs. Initial hardware fabrication for both the spacecraft and instruments will also begin. Funding is also included for the procurement of additional spacecraft and instrument spares.

Mission Operations and Data Analysis

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Magellan operations	0	$17,100,000
Voyager extended mission	$2,716,000	3,300,000
Pioneer programs	7,894,000	9,300,000
Voyager/Neptune mission	22,912,000	40,300,000
Planetary flight support	41,178,000	42,700,000
Total	74,700,000	112,700,000

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions. Currently, two major classes of planetary spacecraft are operating—the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operation systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now exploring the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. In January 1986, Voyager 2 made a close flyby of the planet Uranus, the first time this planet has ever been visited by a spacecraft. During this flyby, it made detailed observations of the planet, its rings, and moons. Upon completion of the Uranus encounter, the spacecraft began its path to the planet Neptune where, in 1989, it will provide us with our first close look at this distant planet.

Pioneers 10 and 11 continue to explore the outermost solar system. Pioneer 10 will soon enter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6–9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun.

The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the Solar Wind. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. The Pioneer Venus was the only spacecraft able to observe the Comet at its closest approach to the Sun, thus providing critical enhancements to the data gathered by foreign spacecraft.

The planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory (JPL). In addition, the activity supports the development of the Space Flight Operations Center (SFOC) at JPL. This facility will be a versatile, cost-effective means for carrying out multimission data acquisition, telemetry, image processing, and for commanding planetary and orbital spacecraft.

FY 1988 funding is providing for operational support for the Voyager and Pioneer operations, for analysis of scientific data returned by the missions, and for the extension of the Voyager 2 mission to a 1989 encounter with the planet Neptune. Activities are also continuing in multimission support development and software designs for activities.

FY 1989 funding is required for the continued operation and data analysis activities in support of the Pioneer missions as well as the August 1989 Voyager/Neptune encounter. Operations activities will also begin for the Magellan mission, which will be launched in April 1989. Development activities will also continue on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

Research and Analysis

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Supporting research and technology	$45,576,000	$50,500,000
Advanced programs	15,642,000	26,600,000
Mars data analysis	3,687,000	4,500,000
Halley's comet co-investigations and watch	2,995,000	2,000,000
Total	67,900,000	83,600,000

The research and analysis program consists of four elements required to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch and provide co-investigator support to the European Space Agency's Giotto mission which encountered Halley's Comet in 1986.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, and U.S. scientist participation on foreign missions.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system bodies, excluding the Sun. Emphasis is on the outermost planets, comets, and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii.

The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of Venus, Jupiter, and Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid components (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution of all planetary bodies, including the Earth. In this respect, data from the Magellan mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties, and other characteristics of solid

material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. Extraterrestrial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system, and its early history. This program is coordinated with the lunar sample and meteorite research, which is supported by other agencies, such as the National Science Foundation. The operation of the Lunar Curatorial Facility is also supported by the planetary materials/geochemical funding.

The instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation, which are optimized for such missions.

The support for U.S. science investigators on foreign missions currently is being provided for U.S. participation on the USSR Phobos missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies; the technological and fiscal feasibility is evaluated, and the scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee (SSEC), an advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system.

The Mars Data Analysis program continues to support analysis of data obtained by Viking and earlier missions so that we are scientifically prepared for the next phase of Mars exploration. It also supports the establishment of a Planetary Data System which will permit the archiving of these and all other data products in a manner which will promote and facilitate their use.

The International Halley's Comet Co-Investigations and Watch program is part of an international program of cooperative astronomical observations of Halley's Comet. During 1986, support was provided to nearly three dozen U.S. co-investigators on the European Space Agency's (ESA) Giotto mission, and to conducting complementary remote sensing investigations carried out with ground based telescopes, aircraft, rockets, and distant spacecraft. Concurrently, an observation program called the International Halley Watch, coordinated by the United States, conducted world-wide scientific observations of the Comet Halley. The objectives of the Watch are: (1) to coordinate scientific observations of Comet Halley through its 1985–1986 apparition; (2) to promote the use of standardized instrumentation and observing techniques; (3) to help insure that data are properly documented and archived; and (4) to receive and distribute data to participating scientists. Activities in FY 1987 were directed to analyzing and archiving data. These activities will continue in 1988 at a reduced level of support.

During FY 1989, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the development of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager. Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1989 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition activities will continue to support development of new state-of-the-art instruments with emphasis on those supporting a future mission to Saturn and its moon Titan and for a Cosmic Dust Collection Facility planned as an attached payload for the Space Station. The Mars Data Analysis Program will support continued analysis of Mars data in preparation for new Mars missions, and for continued development of the Planetary Data System to archive all planetary data for enhanced accessability for all users. Within Advanced Programs, advanced technology development for potential future missions will also be continued with emphasis on the Mariner Mark II spacecraft.

The FY 1989 Halley's Comet Co-Investigations and Watch funding is required to continue support of U.S. co-investigators involved in the European Space Agency's Giotto mission who will be analyzing and archiving the data acquired during the encounter with Halley's Comet. International Halley Watch funding will support the archiving and distribution of ground-based observations.

The FY 1989 funding will also provide for continued operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

6. SPACE APPLICATIONS

FY 1989 NASA REQUEST, $562,300,000

FY 1989 AUTHORIZATION, $562,300,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Solid earth observations	$74,300,000	$82,100,000
Environmental observations	313,500,000	368,300,000
Materials processing in space	62,700,000	73,400,000
Communications	94,900,000	16,200,000
Information systems	20,900,000	22,300,000
Total	566,300,000	562,300,000

SOLID EARTH OBSERVATIONS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Payload and instrument development	$20,800,000	$25,300,000
Geodynamics	32,400,000	33,900,000
Research and analysis	21,100,000	22,900,000
Total	74,300,000	82,100,000

The objectives of the Solid Earth Observations program are to understand the processes controlling the state of the land surface and the interior of the Earth as well as the interaction of the solid Earth with the atmosphere and the oceans. The Solid Earth Observations Program is an integral part of the overall NASA Earth Science and Applications effort to increase understanding of the planet Earth through the study of its dynamics, the physical processes which affect habitability, and solar-terrestrial environment.

The major objectives of the Solid Earth Research and Analysis program are to characterize the current state of the terrestrial landscape, including the biosphere and the hydrosphere, and the changes and change mechanisms that are occurring within that landscape. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climate system, the composition and evolution of the Earth's crust and the processes that shape the Earth's crust are essential to these objectives.

The geodynamics research objectives include determination of the movements and deformation of the Earth's crust, the processes which drive tectonic plates, the rotational dynamics of the Earth and its interactions with the atmosphere and oceans, the Earth's gravity and magnetic fields, and the interior structure and composition of the Earth. These objectives require precise measurements of crustal movements and Earth orientation over an extended period along with accurate knowledge of the Earth's geopotential fields and their variability.

The objective of the Shuttle/Spacelab payload development program is to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data for solid earth observations research. The Shuttle Imaging Radar-B (SIR-B), which was flown on the Shuttle in October 1984, has demonstrated the utility of spaceborne imaging radar for geologic exploration. The Large Format Camera (LFC), required for high resolution mapping applications, was flown successfully on the Shuttle in 1984 and is presently under consideration for commercialization. The next generation Shuttle Imaging Radar (SIR-C), which involves the use of SIR-B components, is a multi-polarized, dual frequency instrument under development for flight in 1991. The imaging spectrometer and solid-state sensor research efforts will continue to focus on the development of such features as electronic scan, inherent geometric and spectral registration and programmable high spatial and spectral resolution.

Payload and Instrument Development

The objective of this program is to develop, test, and evaluate Earth-viewing remote sensing instruments and systems to obtain data for and develop the techniques for land remote sensing research.

Components of the Shuttle Imaging Radar-B (SIR-B) will be used in building the next generation Imaging Radar instrument, SIR-C. The SIR-C will use multi-polarized, dual frequency sensor technology. SIC-C is in the development phase; System Requirements Review, Antenna Preliminary Design Review and System Preliminary Design Review are complete. In October 1987, NASA signed a Memorandum of Understanding with the Federal Republic of West Germany agreeing to joint missions of SIR-C with an X-band imaging radar to be provided by a joint German/Italian project (X-SAR). Preparations continue for commercialization of the Large Format Camera (LFC).

Advanced spectrometer technology developed activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and linear array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the Shuttle Imaging Spectrometer Experiment (SISEX) and the linear array focal plan will continue.

FY 1989 funding is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the Shuttle Imaging Spectrometer Experiment.

Geodynamics

The objective of the Geodynamics program is to understand the origin, evolution, and current state of the solid Earth by measuring the movement and deformation of the tectonic plates and by measuring its rotational dynamics and potential fields. Laser ranging to satellites and the moon, microwave interferometry using astronomical radio sources and transmissions from the Global Positioning Satellite System (GPS) are used to determine precise position locations. The global gravity and magnetic fields are determined from satellite observations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about 6 cm per year. In addition, measurements indicate that about 4 cm of this movement is occurring in Southern California. Measurements of polar motion and changes in the length of day have been correlated, to a high degree, with variations in the angular momentum and the inertial balance of the Earth's atmosphere due to high altitude winds. The Earth's rotation was found to have slowed by five milliseconds due to the El Nino effect. The Earth's rotational dynamics are also influenced by motions of the Earth's core and the oceans. Models of the Earth's gravity field, derived from Laser Geodynamics Satellite

(LAGEOS-1) data have provided the first evidence of gravity field variations. These variations are believed to be caused by continued relaxation of the crust following the last ice age and have confirmed estimates of the viscosity of the Earth's mantle layer. Analysis of the magnetic field, using data from Magsat has confirmed the diameter of the Earth's outer core and has provided new data on secular variations of the magnetic field.

The United States and a consortium of eight European and middle East countries continue measurements of crustal deformation in Greece, Turkey, and Italy. In 1988, a mobile Laser Ranging Station operated by the Federal Republic of Germany will join similar U.S. stations in deformation studies in the U.S.

Development of instrumentation and techniques for use of the DOD GPS system for rapid crustal motion measurements has continued. The geodetic techniques developed by NASA for measurement of polar motion and Earth rotation have been adopted by the International Union of Geodesy and Geophysics (IUGG) as the basis of the new International Earth Rotation Service. Within the U.S., NOAA and the U.S. Naval Observatory (USNO) have adopted Very Long Baseline Interferometry as the basis for the National Earth Orientation Service.

Studies continue to confirm the need for improved gravity and magnetic field measurements. While considerable advances have been made in modeling the gravity field, new data are needed to achieve the resolution and accuracies required for solid Earth research. Laboratory development of a supercooled gravity gradiometer are continuing, and plans are being made for a Shuttle test of this technology. Joint studies are underway with the French on a cooperative Magnolia/Magnetic Field Satellite for extensive, long-duration studies of secular and temporal changes of the main magnetic field.

In FY 1989, measurements of plate motion between North America and Europe will be continued in cooperation with countries in Europe, the Middle East, Far East, South and Central America. Measurements of the motions of the Pacific Plate will be continued in cooperation with Japan and China. Regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. The Caribbean studies will be continued and include more sites along the plate boundary and on the plate itself.

LAGEOS-1 and other satellites will continue to be used for studies of plate motion. NASA systems in the U.S., Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The LAGEOS-2, a joint mission with Italy, is presently under development by Italy and will be launched by the U.S.

Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1989. In addition, system studies of a second magnetic field satellite for long-term measurements of the Earth's field (Magnolia/MFE), studies of geopotential research, and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

Research and Analysis

The broad goal of the Biogeochemical Processes program is to achieve an improved understanding of the role of terrestrial biota in processes of global significance through the use of airborne and spaceborne sensors. Specific objectives are to understand biogeochemical processes and cycles, biotic contributions to the global energy balance, and change in vegetation state and dynamics.

The goals of the Hydrology program are to use remote sensing to achieve a better understanding of the regional and global storages and fluxes of the land component of the Earth's hydrologic cycle, to investigate the role of the hydrologic cycle in regional and global biogeochemistry, and to examine the interactions between land surface processes and regional and global climate.

The goal of the Geology program element is to derive a better understanding of the Earth's geology, geologic history, and the processes that have shaped the surface of the Earth over geologic time using spaceborne sensors. Specific objectives are: to investigate the history and evolution of the continents from early formation through accretionary, depositional, tectonic, deformational, and presently active erosional processes, to investigate quaternary geologic history and processes in order to unravel the course of recent geomorphic, volcanic and climatic processes for a better understanding of the evolution of land surfaces and climate over the last million years.

The Remote Sensing Science program is a cross cutting activity which supports the three other disciplinary program elements through theoretical modeling and field measurements of land surface properties. At this time the focus is on obtaining a firm understanding of the physical and biological factors which control the interaction of electromagnetic radiation with the Earth's surface. The aim is to develop the capability to determine surface properties with remote sensing using only a minimum reliance on empirical or statistical techniques.

In FY 1989 emphasis will be on investigations using multiple sensors operating in the visible, near-infrared, shortwave infrared, thermal infrared, and the microwave. Advanced airborne instruments which are prototypes for the future Earth Observing system (EOS) will be used in a variety of geologic, ecological and hydrological experiments. The theoretical basis for the use of combined sensors will be developed within the Remote Sensing Science program element. Current theoretical models will be used in the design of these experiments which will be designed to meet specific scientific goals in the other program elements.

As a part of NASA's program for the study of Global Change, there will be a series of multitemporal ecosystems studies using the airborne prototypes of EOS instruments. Vegetation is dynamic over a growing season, and remote sensing coverage at an instant in time only captures on stage of the annual cycle. Repetitive coverage of selected sites offers the opportunity to study dynamic, and not just static, properties of ecosystems. We plan to select a small number of sites to be scheduled for multiple data acquisitions spanning the growing season and to encourage several investigators to conduct investigations at any one site.

The two broad goals of the Geology program expressed above will be addressed through focused efforts which will be identified in workshops to be held during 1988. These are expected in the fields of volcanism (volcanic processes, monitoring, and hazard identification/prevention), quaternary land climatologic history, and neotectonics of actively faulting areas.

Operational satellite systems will be used in conjunction with the advanced airborne sensors. Multiyear data sets from the Landsat Multispectral Scanner, the Advanced Very High Resolution Radiometer (AVHRR) and the Scanning Multifrequency Microwave Radiometer (SMMR) will be used to study global change on the decadal scale. Global data sets will be maintained using the AVHRR and the Special Sensor Microwave Imager (SSMI), which replaces the SMMR.

The initial phase of the International Satellite Land Surface Climatology Project's (ISLSCP) First ISLSCP Field Experiment (FIFE), will be completed. Guest investigators will be supported to broaden the base of users of this comprehensive data set and mechanisms will be established to make the data available to other investigators.

Environmental Observations

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Upper atmosphere research and analysis	$32,700,000	$34,000,000
Atmospheric dynamics and radiation research and analysis	31,400,000	32,800,000
Oceanic processes research and analysis	20,200,000	21,600,000
Payload and instrument development	4,100,000	19,700,000
Mission operations and data analysis	14,800,000	18,500,000
Interdisciplinary research and analysis	1,100,000	1,200,000
Scatterometer	22,700,000	15,800,000
Upper atmosphere research satellite mission	89,600,000	103,900,000
Ocean topography experiment	75,000,000	97,800,000
Airborne science and applications	21,900,000	23,000,000
Total	313,500,000	368,300,000

The objectives of the Environmental Observations program are to improve our understanding of the processes in the atmosphere and the oceans; to provide space observations of parameters involved in these processes; and to extend the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively, and sometimes only, observed from space. NASA's programs include scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites provide a unique view of the radiative, chemical, and dynamic processes occurring in the atmosphere and oceans.

To achieve these goals, a number of significant objectives have been established for the next decade. These include advancing the understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; optmizing the use of space-derived measurements in understanding large scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; and improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation, flight of the instruments on the Space Shuttle, dedicated spacecraft and flights of opportunity; collection of *in situ* ancillary or validation data; and scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then to collect appropriate data, through remote and *in situ* means, which will address specific program objectives.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make comprehensive measurements of the state of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable.

Detailed definition studies of the instruments have been completed, and the design and development activities are well underway. Development of the UARS observatory will continue in FY 1989, consistent with a planned launch in 1991.

The Earth Radiation Budget Satellite (ERBS) was successfully launched in 1984, and data continues to be collected from the satellite. NOAA-F was launched December 12, 1984 and NOAA-G was launched September 17, 1986, both equipped with ERBE instrumentation. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis.

Design and development activities are being continued in FY 1989 on the NASA Scatterometer (NSCAT), the objective of which is to acquire global ocean data for operational and research use by both military and civil sectors. While the U.S. Navy reviews the possible continuation of the Navy Remote Ocean Sensing System (N-ROSS) program, Scatterometer instrument development continues along with planning for alternative spacecraft flight opportunities.

Development of the Ocean Topography Experiment (TOPEX) began in FY 1987 and will continue in FY 1989; its objective is to acquire precise observations of the surface topography of the oceans. These data, in conjunction with those from NSCAT, will enable the first determination of the wind forcing and ocean-current response of the global oceans. Spacecraft development efforts have begun at Fairchild, while the Johns Hopkins Applied Physics Laboratory continues work on TOPEX Altimeter development.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long-term trends of the Earth's atmos-

phere, oceans and polar ice, and provides near real time data. Collection and analysis of Solar Mesosphere Explorer (SME) data, the only mesosphere data currently available, continues.

Shuttle payload and instrument development activities provide the airborne and spaceborne data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument activities include Shuttle payloads such as Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS), Active Cavity Radiometer (ACR), and Light Detection and Ranging (LIDAR).

Along with the Solid Earth Observations program, the Environmental Observations activities compose an integral part of NASA's total Earth sciences and applications efforts, with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and solar-terrestrial environment.

Elements of the Mission Operations and Data Analysis Program and the Payload and Instrument Development Program as well as the entire Tether Satellite Payloads, Space Physics Research and Analysis, and Global Geospace Science programs have been transferred to Physics and Astronomy in the recent Office of Space Science and Applications reorganization and creation of the Space Physics Division.

Upper Atmosphere Research and Analysis

The upper atmosphere research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric processes research, and tropospheric chemistry research.

In particular, the goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the stratosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities. In order to accomplish this, efforts are underway to: (1) improve upper atmosphere and global troposphere models, validate them, and assess their uncertainties; (2) measure important trace chemical constituents, temperature, and radiation fields throughout the atmosphere; (3) develop sensors capable of making chemical and physical measurements of the upper atmosphere and the global troposphere both directly and remotely from space; (4) assemble and maintain the existing long-term data base of stratospheric and tropospheric ozone measurements to aid in the detection of long-timescale natural variations and man-made ozone changes; (5) determine the effects of global tropospheric chemistry on the atmosphere; (6) conduct theoretical and field studies of tropospheric/stratospheric exchange; and (7) carry out laboratory kinetics and spectroscopy investigations to support these activities.

A variety of *in situ* and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from a limited number of satellites are now generally available to the scientific community, including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents. This data is being exploited to determine if trends in the ozone amount can be detected and to understand those processes which are directly involved with these trends.

Recent developments in our understanding of the ozone layer have revealed a possible non-linear dependence of ozone depletion on the amount of fluorocarbon released to the atmosphere. These findings place increased urgency on the need to verify the completeness and accuracy of the theoretical stratospheric models. In FY 1989, tests of the models will be continued by means of field measurements, model calculations, and interpretation of satellite data. The development of more realistic two- and three-dimensional models will be continued. The global data sets from past and present satellites will be further analyzed in FY 1989 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1989 to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena of the atmosphere; they also help to validate satellite observations. Studies of potential new instruments for use on future satellites and suborbital measurement platforms will also be conducted in FY 1989 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

The recent observations of a depletion in the amount of ozone over Antarctica in the austral spring have attracted a great deal of attention. In order to understand the chemical and dynamic processes that are causing this phenomena, a major aircraft mission conducted in late FY 1987 early FY 1988 using the NASA ER-2 and DC-8. Analysis and interpretation of the results of this mission will be a critical effort in FY 1988. An Arctic and/or return Antarctic mission is planned for FY 1989 based on the results of the 1987 campaign.

Atmospheric Dynamics and Radiation Research and Analysis

The research and analysis activities within the Atmospheric Dynamics and Radiation program combine a core effort which is essential in order to use space technology to address problems in atmospheric science. The three main thrusts in the program are in the areas of Global-Scale Processes, Mesoscale Processes and Climate Research.

The objectives of the global scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capabilities to observe the atmosphere from space. The program involves the development of advanced remote sensing instrumentation to observe the atmosphere, the development of advanced analysis techniques to better utilize existing me-

teorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively. Recent accomplishments include the development and application of techniques which more fully utilize passive multispectral data (IR and microwave) from the NOAA operational satellites to provide global maps of a number of key atmospheric and surface parameters. The first year of a ten year data set of these Earth science parameters has been completed and made available to the scientific community. Additionally, special attention has been devoted to developing active lidar techniques to provide detailed profiles of atmospheric wind, temperature, pressure, and moisture data from future spaceborne platforms. Simulations of these advanced techniques indicate their increased potential in greatly improving meteorological prediction capability.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and local to regional scales (severe weather, such as tornadoes and hurricanes). Since all of the characteristic parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured. Such an activity requires advanced data handling and analysis techniques which rely upon man-computer interactive display and manipulation. In the area of remote sensor development, initial feasibility studies of instrumentation to observe lightning from space have been completed under the guidance of a joint NASA/NOAA working group. This group continues to study the practical value of lightning mapping from geostationary orbit and the possibility of incorporating experimental lightning mapping observations on a GOES spacecraft. A Memorandum of Agreement with NOAA is being written to fly a research version of the lightning mapper on GOES–M.

The Climate Research Program seeks to develop a space capability for global observations of climate parameters to increase our understanding of the processes that influence climate and its predictability. In accordance with the National Climate Program priority, research in solar and Earth radiation is led by NASA. Future thrusts will be aligned with programs of solar irradiance monitoring, Earth radiation budget monitoring and analysis, stratospheric aerosols on the radiation budget, and on selected process studies which relate to monitoring of climate change. Selected process studies related to monitoring climate change are also included. The first results of the data phase of the International Satellite Cloud Climatology Project (ISCCP) have been successfully archived and two field experiments of the First ISCCP Regional Experiment (FIRE) have been completed. Data from ISCCP and FIRE are being analyzed in conjunction with the Earth Radiation Budget Experiment (ERBE) data to improve our knowledge of cloud-radiation interactions which affect our climate. In addition, measurements of the solar irradiance will continue through the repaired Solar Maximum Mission (SMM) spacecraft, Nimbus 7 and reflights of the Active Cavity Radiometer flown on Spacelab–1.

A significant research effort to develop the capability for observing rainfall from space continues. Studies of instruments, sampling requirements, algorithm development, and modeling indicate the feasibility of sensing rainfall from space for climatic purposes. Under a bilateral agreement with the Science and Technology Agency of Japan, NASA is cooperating in a joint study of a special mission to measure tropical rainfall. Studies to accommodate a rainfall measurement experiment on the Space Station have been initiated and will be continued.

FY 1989 funding is required for support of the Global Backscatter experiment (GLOBE). Two field campaigns are scheduled in GLOBE using the NASA DC–8. These airborne observations and the auxilliary observations to be made from ground-based and satellite observatories will be used to determine the seasonal and geographic variations in the backscatter of laser radiation due to atmospheric aerosols. In addition to increasing our understanding of the optical properties of the atmosphere, these data are needed in the system design of the Laser Atmospheric Wind Sounder (LAWS), a facility instrument for the future Earth Observing System (EOS).

An initiative in Radiative Gas Effects is being planned as a potential new focus for the Climate Research program during FY 1989. In particular, plans for the detection of greenhouse effect on climate from space observations wil be pursued. The plans call for: (1) the identification of the required spaceborne measurements, process studies, and modeling improvements needed for early detection of the climatic effects of changing atmospheric composition; and (2) the development of a NASA interdisciplinary research strategy for acquiring the technology and knowledge needed for understanding the regional and global climatic implications of projected greenhouse changes.

FY 1989 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and weather fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in four-dimensions. Continued analysis of the data collected in interagency field experiments during FY 1986 and 1987 will be performed. These data include the results of the Genesis of Atlantic Lows Experiment (GALE), the Cooperative Huntsville Meteorological Experiment (COHMEX) and the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE). In addition, experimental, theoretical, and computational work will be done to better define the capabilities and requirements for the remote measurement of rainfall. Other activities will involve continued retrieval and archiving of global International Satellite Cloud Climatology Project data sets, analysis of data from the Earth Radiation Budget Experiment and the Stratospheric Aerosol and Gas Experiment, and continued ground-based and rocket flight support for solar irradiance monitoring. Technology development of active temperature, pressure, and moisture sounders as well as basic lidar technology development will also be continued in FY 1987. Preliminary planning, experiment design, and technology development will begin for the large, multi-Agency STORM program to evaluate the

research and operations potential of new meteorological remote sensors such as the sounder on GOES-NEXT, NEXRAD, AWIPS-90, ASOS, SSM/I, AVHRR-3 and high-altitude active and passive sensors to estimate precipitation.

Oceanic Processes Research and Analysis

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems.

The Ocean Processes R&A program is organized into three discipline areas: (1) physical, (2) biological, and (3) polar oceanography. In physical oceanography, satellite scatterometers and altimeters are used to observe surface roughness and topography, from which surface winds and ocean current response can be estimated. In biological oceanography, color scanners are used to observe chlorophyll concentration, from which primary productivity can be estimated. In polar oceanography, microwave radiometers and synthetic aperture radars are used to estimate the characteristics of sea ice cover and the details of its motion.

The Oceanic Process R&A program operates in concert with other federal agencies (Navy, NOAA, and NSF) and foreign countries (Canada, European, Japan), for the World Climate Research Program (WCRP). Component WCRP efforts include the Tropical Ocean/Global Atmosphere (TOGA) and World Ocean Circulation Experiments (WOCE), a Global Ocean Flux Study (GOFS) and a Program for International Polar Oceans Research (PIPOR).

In FY 1989, the physical oceanography research activities will include implementation planning for WOCE and TOGA, as well as the development of assimilation techniques to incorporate altimeter and Scatterometer data into numerical models for use in determining the general circulation of the oceans. In biological oceanography, global ocean productivity will be assessed based on analyses of Nimbus-7 Coastal Zone Color Scanner (CZCS) data, in order to help with the conceptual design of the Global Ocean Flux Study. In addition, implementation studies will be performed with EOSAT for potential flight of an ocean-oriented color scanner (Sea-WIFS) aboard the Landsat-6 spacecraft. In polar oceanography, emphasis will be placed on the experimental design for the Program for International Polar Oceans Research, which is planned to involve direct reception at the Alaska Synthetic Aperture Radar (SAR) Facility in Fairbanks of SAR data from the European Space Agency's ERS-1 (Earth Resources Satellite) and from the Japanese Earth Resources Satellite (JERS)-1 spacecraft, due for launch in 1990 and 1992, respectively.

Significant work on the NASA Ocean Data System will be performed in order to optimize its use as a scientific support facility for the ocean research community. NASA's activities are being coordinated with the Office of Naval Research, NSF, and NOAA in order to assure that appropriate computing facilities, data archives, and communication networks will be available for the utilization of spaceborne observations from missions planned within the next decade.

Advanced technology development activities will also be continued on prospective future sensors for flight aboard both the Shuttle and free-flying spacecraft.

Payload and Instrument Development

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Environmental Observations program has incorporated this capability into the Shuttle-Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and enviromental data gathering for basic research and analysis where long-term observations are impractical. Instrument development activities support a wide range of instrumentation—from airborne to international flights of opportunity.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument was launched in 1985 on Spacelab-3 and data analysis continues. It will be reflown on the ATLAS (formerly EOM) series. The science results from the first flight of ATMOS were of exceptional value, and the basic capability of ATMOS to measure very low concentrations of trace species in the Earth's atmosphere was clearly demonstrated. In FY 1987, ATMOS commenced a ground observation program at Table Mountain Observatory which will continue until the instrument is readied for shipment to KSC for the ATLAS-1 mission.

The Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of troposphere carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two Shuttle flights and data analysis continues. It is planned for four STS flights, one for each season of the year, to provide the first observations of the global seasonal variation of carbon monoxide in the Earth's atmosphere. Reflight of MAPS is also planned on the ATLAS series.

The Active Cavity Radiometer-1 (ACR-1) is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on the ATLAS series are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests and Spacelabs-1 and 2.

FY 1989 funds will be used to support the Measurement of Air Pollution from Satellites (MAPS) science team activities including data reduction, refurbishment for reflight and upgrading of the ground service equipment. The FY 1989 funding for ATMOS is required to support the ground observation program as well as continued science team activities, data processing and analysis, and limited refurbishments. FY 1989 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science

team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Preliminary definition of the advanced instrumentation and data facilities associated with the future Earth Observing System (EOS) will be continued in FY 1989. The EOS is the intended payload on the Space Station's polar platform. Instrument definition and feasibility studies will be continued along with related system engineering and payload accommodation studies. Release of an Announcement of Opportunity to the Scientific Community is presently planned for FY 1988. Further detailed review of those proposals will be conducted in FY 1989.

Development activities will continue on the international (United States and France) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of critical design reviews in preparation for the integration, ground test and first flight in FY 1989 of this multi-phase user program. In this program, both NASA and the French are supplying science knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting.

Mission Operations and Data Analysis

The objective of the extended mission operations program is to provide for the operations, data processing, validation and data analysis of missions which have completed basic operations funded by approved project support.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quantities of both atmospheric and solid earth global data for multi-discipline investigations and applications. These include atmospheric dynamics and chemistry resulting in global ozone measurements that are helping to understand the complicated heat exchanges of the atmosphere-ocean system and, for the first time, global ocean data and sea ice concentration as well as properties of both polar caps. NASA supplies this unique sea ice concentration data in near real-time to the joint U.S. Navy-NOAA Ice Center. The ocean color measurements provide the only data on open ocean and coastal areas chlorophyll concentration, which relates to abundance of phytoplankton, the basic element of the ocean food chain. Current studies of complete ocean basins are expanding the understanding of global productivity. Nimbus-7 operations and data reduction/validation activities will continue in FY 1989 to support the strong demand for data.

The Solar Mesosphere Explorer (SME), launched in October 1981, continues to provide solar irradiance data. SME data analysis results allow us to better understand the complex chemical processes taking place in the mesosphere through scrutiny of data measurements ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesopheric properties. SME data is providing excellent information on the effect of volcanoes on the Earth's atmosphere.

Operation of the Nimbus and SME satellites and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meterological satellite. The SME and Nimbus satellites continue to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in FY 1989; these *in situ* observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, FY 1989 funding is required for operating the ERBS spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE–II instrument on ERBS.

Interdisciplinary Research and Analysis

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological processes on the land, along with the interactions between the land, the oceans, and atmosphere, which are of particular importance in assessing the impact of these phenomena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

In FY 1989, interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radiation, Upper Atmosphere/Troposphere Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the oceans in the global carbon cycle.

Scatterometer

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves). Flight of the instrument in 1992 for three years will provide an overlap of data gathering with the World Ocean Circulation Experiment, Tropical Ocean-Global Atmospheres Experiment planned by the international oceanographic community; and additionally, concurrent flight with the Ocean Topography Experiment (TOPEX) would result in unique measurements of the ocean's driving force (winds) and the resulting ocean response (topography).

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1978. Definition studies conducted by NASA during FY 1983 and early FY 1984 resulted in the determination that the performance re-

quirements as stated jointly by the research community and the Navy could be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for Earth rotational effects.

The Scatterometer was currently planned to fly on the Navy Remote Ocean Sensing System (N-ROSS) satellite in 1992. The N-ROSS program was canceled in December 1986 due to financial constraints but a lower cost version of N-ROSS was proposed by Navy for reinstatement in April 1987; this proposal is currently under review with DoD. In the meantime, NASA has been exploring a number of alternatives to N-ROSS, the most cost effective of which will be selected for implementation should N-ROSS not gain full DoD approval to go forward.

During FY 1988, the antenna contract will be completed and all six flight antennas will be finished. The Traveling Wave Tube (TWT) contract is scheduled to be completed and the development of the other flight hardware items will be continued. The instrument Critical Design Review, which was delayed due to the N-ROSS cancellation, will be held and delivery of the second computer system for the ground data system will occur. Planned activities in FY 1989 include the continuation of flight hardware development leading to the beginning of flight unit integration and testing at the end of the fiscal year; the completion of software requirements definition, the initiation of detailed software design, both for the ground data and flight systems; conducting the PDR for the mission operation system; and confirmation of the science team which was delayed due to the uncertainty of N-ROSS.

Upper Atmosphere Research Satellite Mission

The Upper Atmosphere Research Satellite (UARS) program is the next logical step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for a STS launch in 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity.

A final selection of ten experiments has been made, including infrared and microwave limb sounders with require advances in cryogenics, solid-state devices and microwave antennas beyond earlier capabilities. The instrument design and development activities are underway. A Solar Backscatter Ultraviolet (SBUV) instrument will be modified to fly on the Shuttle during the UARS mission and to provide correlative data. In addition, development of the central ground data handling facility, which will permit near-realtime interactive utilization of data by the twenty-one design and theoretical investigator teams, is underway.

The FY 1989 funds are required for continuation of the development activities on the ten UARS instruments including flight hardware fabrication, instrument assembly and environmental testing leading to instrument delivery to the spacecraft in 1989. The spacecraft development and hardware fabrication activities will continue including completion of the spacecraft mechanical test model program and the start of spacecraft integration in late FY 1988.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the flight hardware so that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time. In order to achieve this, FY 1989 funding is required to continue design and development of the ground data handling facility including hardware delivery and checkout, software preliminary and critical design reviews, science team support and science algorithm development.

Ocean Topography Experiment

The goal of the Ocean Topography Experiment (TOPEX) is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability. The capability of satellite altimetry to address this goal was demonstrated in 1978 by NASA's highly successful Seasat program. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere and ultimately, the role of the oceans in climate.

NASA and the French Space Agency (CNES) are collaborating on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in late 1991 using Ariane. TOPEX is also being planned in concert with the World Ocean Circulation Experiment (WOCE), a major international oceanographic field program being planned under the auspices of the World Climate Research Program (WCRP). WOCE will combine satellite observations from TOPEX with traditional *in situ* observations to enable the first comprehensive determination of the three-dimensional current structure of the global oceans.

When further combined with Ocean surface winds from the NASA Scatterometer (NSCAT), unique measurements of the oceans' driving force (winds) and the resulting ocean response (topography) will have been obtained.

During FY 1988, the recently selected joint NASA/CNES Senior Team will meet for the first time. The definition contract for the satellite contract will be awarded, PDR's for the satellite, sensors, and ground data system will be held, all leading to the conduct of an end-to-end system level PDR towards the end of the fiscal year.

In FY 1989, the design of the satellite, sensor, and ground data system will be completed, leading to the initiation of full scale spacecraft system development. Final arrangements are expected to be made by CNES for the French-provided Ariane launch vehicle. The mission design will be refined based on input from and interaction with the Science Team and the Science Team will be confirmed so that they can begin to refine their post launch research and verification plans.

Airborne Science and Applications

This effort covers operation of an ER-2, two U-2C's, a C-130, and a DC-8 in order to support Earth-sensing and atmospheric research. The DC-8 was acquired to replace the CV-990 research facility, "Galileo II", which was destroyed in 1985. The replacement DC-8 has undergone required upgrades and modifications and carried out initial operations in Antarctica in 1987 as part of the Ozone Hole campaign. Acquisition of a second ER-2, to replace the aging U-2C's is underway. These aircraft support other major segments of the Space Science and Applications program dealing with the Earth, the oceans, and the atmosphere. They may serve as test beds for newly developed instrumentation and allow demonstration of new sensor techniques before their flight on satellites or on Shuttle/Spacelab missions. Data obtained from these aircraft are used to refine analytical algorithms, and to develop ground data handling techniques. For example, the ER-2/U-2C's acquire stratospheric air samples and conduct *in situ* measurements at altitude ranges above the capability of more conventonal aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

Requested FY 1989 funding will allow operation of the DC-8, two ER-2's, and the C-130. Operation of these aircraft will allow continuation of such projects as the collection and analysis of stratospheric air samples, testing of newly developed instrumentation, the demonstration of new sensor concepts, the investigation of the Ozone Hole phenomena, and participation in numerous other field experiments such as First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE). The FY 1989 budget will also provide for NASA's final payment to the U.S. Air Force, thereby completing the purchase of the second ER-2 aircraft.

Materials Processing in Space

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Research and analysis	$12,900,000	$13,600,000
Microgravity shuttle/station payloads	49,800,000	59,800,000
Total	62,700,000	73,400,000

The mission of the Microgravity Science and Applications Program is to foster the development of near-Earth space as a natural resource by exploiting microgravity and other unique attributes that may be attained in an orbiting spacecraft. In this environment, we can advance knowledge about the fundamental nature of matter, increase understanding of the role of gravity in various industrial processes, and produce limited quantities of certain exotic high-value materials for specialized applications. In FY 1989, ground-based research and payload development will be concentrated in six major areas: metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena.

During FY 1989, ground-based research will support definition studies for Shuttle and Space Station experiment candidates in areas such as containerless experiments, solidification and crystal growth, and processing of biological materials. Researchers will conduct experiments in drop tubes, towers and aircraft. The ground-based research program also includes support for studies conducted under Technical Exchange Agreements.

The Microgravity Shuttle/Spacelab Payloads program provides a range of experimental capabilities for all participants in the Materials Processing in Space Program. The payloads program currently supports a wide variety of hardware development, from unique flight experiments necessary to conduct basic research into the fundamental nature of matter to the modular, multi-user research facilities that will be the cornerstone of microgravity science and applications research on the Space Station. Experiments will be flown on Shuttle and Spacelab, as well as any promising commercial space facility.

Research and Analysis

The research and analysis activity provides the scientific foundation for all current and future projects in the Microgravity Science and Applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and applications activities leading toward privately-funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which have been extensively reviewed by peer groups prior to selection. FY 1988 funding will support ongoing research.

Ground-based research and analysis will be continued in FY 1989 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the centers for bioprocessing research located at the University of Arizona and the University City Science Center in Philadelphia, PA as well as the Microgravity Materials Science Lab at the Lewis Research Center.

Microgravity Shuttle/Station Payloads

The Microgravity Shuttle/Space Station payloads program provides a wide range of opportunities for experiments in microgravity science and applications. NASA currently supports the development of STS mid-deck, Spacelab and cargo-bay experiments. This policy maximizes the effective use of the STS by matching an experiment with the hardware location best suited to meet its scientific and technical requirements. In some cases, the payload program supports an evolutionary program of testing flight experiment concepts in the mid-deck before committing to more complex and ambitious Spacelab or cargo-bay mounted hardware.

The Materials Processing in Space program is preparing to use Space Station as a major platform for conducting microgravity research. During FY 1987, NASA received funds from Congress to begin technical definition of six major multi-user research facilities designed to take advantage of Space Station's unique capabilities. NASA's Microgravity Science and Applications Division (MSAD) is developing a strategy for orderly evolution of microgravity experiments from ground-based research to the Shuttle, and finally to Space Station. During FY 1988 and FY 1989, MSAD will continue Space Station hardware definition, and will initiate equipment development for both the first United States Microgravity Laboratory Spacelab mission, and any promising commercial microgravity facility.

In addition to the planned Space Station initiative, the Materials Processing in Space program is placing increased emphasis on NASA's Physics and Chemistry Experiments (PACE) program, which uses microgravity research to challenge and improve existing scientific theory about the fundamental nature of matter. As other nations increase their ability to exploit the characteristics of near-Earth space, the "cutting edge" experiments generated by the PACE program will play an increasingly important role in assuring continued U.S. leadership in microgravity research.

FY 1989 funding is required to continue basic and applied research activities using STS mid-deck, Spacelab and cargo-bay experiments leading to several flights over the next few years. Investigations are planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will continue on a number of Physics and Chemistry Experiments (PACE) as well as several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metallic casting, and levitation. An augmentation has been included, building on the FY 1988 Congressional increase, to develop the advanced second- and third-generation microgravity payloads which will be flown on the STS, Space Station, and any promising commercial space facility.

COMMUNICATIONS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Advanced communications technology satellite (ACTS)	$75,600,000	0
Advanced communications research	14,136,000	$10,486,000
Search and rescue	1,300,000	1,350,000
Radio science and support studies	2,542,000	2,900,000
Communications data analysis	1,322,000	1,464,000
Total	94,900,000	16,200,000

The request for communications for fiscal year 1989 was $16,200,000. The Committee authorized this amount and adopted a provision that would provide $76,000,000 for the Advanced Communications Technology Satellite (ACTS) flight program.

Advanced communications research, formerly communications research and analysis, continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to pursuing technologies with high potential for improving spectrum and orbit utilization, satellite antennas, on-board processing inter-satellite links and around terminal designs since these technologies are the key to future growth of the communication satellite and terminal markets. In addition, the mobile communications technology program will continue to address the development of critical enabling technologies needed to insure growth of a commercial mobile satellite service in the U.S. This effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system in the early 1990's.

The search and rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, Bulgaria, Finland and Denmark also participate.

Radio science and support studies, formerly technical consultation services, will provide for studies of radio interference, propagation and special systems required for the growth of existing satellite services and the extension of new satellite applications. Support to the Department of State, the Federal Communications Commission, the National Telecommunications and Information Administration, and other Agencies in the development of frequency and orbit sharing techniques and strategies for upcoming World Administrative Radio Conferences (WARC's) is continuing.

Funding has not been included for continued development of the Advanced Communications Technology Satellite (ACTS) in FY 1989. It continues to be the Administration's policy that this flight

demonstration project is more appropriately and effectively undertaken by the private sector, without subsidies or possible competition by the government.

The advanced communications research program emphasizes the development of high-risk technology required to maintain U.S. preeminence in the international satellite communications market, to enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies. This program focuses on the "interconnectivity technologies" of onboard switching, inter-satellite links, and antennas, as well as advanced RF technologies. Advanced studies are performed to determine the future satellite communications needs of the country and to define the technology required to meet those needs. The technology is developed and tested through an advanced proof-of-concept (POC) program. The POC devices and components are then integrated into a multiple terminal, satellite communications network in a laboratory where they undergo comprehensive evaluation.

In FY 1988, work is continuing on advanced communications technologies. Laser inter-satellite link communications technologies are being developed that will permit communications between satellites and ground terminals, satellites and low Earth orbiting vehicles, such as the Space Shuttle or Space Station, and between satellites and other geosynchronous orbiting satellites, such as the Tracking and Data Relay Satellite (TDRS). Technology development is also underway in the area of monolithic microwave integrated circuits (MMIC), which have significant potential for applications in multiport spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. A number of industry studies are being sponsored to assess new areas of communications technologies required for the 1990's.

The mobile communications technologies activity is aimed at accelerating the introduction of a commercial mobile satellite service in the U.S., and developing and testing power, bandwidth and orbital-slot efficient ground segment technology and networking techniques needed to insure its growth. An innovative NASA offer to industry was signed in FY 1985 by a consortium of U.S. companies which would provide a launch for the first generation commercial satellite in exchange for satellite transponder capacity that would be used by NASA and other government agencies for experimentation and technology validation. The endeavor to commercialize this new service got a recent boost with the allocation of frequencies and the formation of a single consortium that is applying to the FCC for license approval. NASA is planning a major government industry conference in May to exchange information and facilitate the transfer of technology to industry.

The Research and Analysis program will continue to support development of the technologies necessary for future space communications satellite systems. During FY 1989, NASA will continue to work with U.S. industry and other government agencies to complete field testing of advanced communications hardware and help accelerate the introduction of mobile satellite communications service in the U.S. Work in laser communications technologies will continue.

Search and Rescue

The United States (NASA, NOAA, the Coast Guard, the Air Force, and the FAA), Canada, France, and the Soviet Union developed the search and rescue system, in which Norway, the United Kingdom, Bulgaria, Finland and Denmark also participate. The Search and Rescue (SAR) satellite system was declared operational in July 1985. NOAA maintains operational responsibility for search and rescue, while NASA's role is tightly focused on three research and development aspects of SAR, specifically the development of a low-cost 406 MHz emergency beacon, the next generation satellite-borne SAR equipment, and advanced techniques that will make possible more precise and timely location of downed aircraft and ships in distress.

The Search and Rescue program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve significantly the ability to detect and locate general aviation aircraft and marine vessels during emergencies. The system has received world-wide acclaim and has been credited with saving over 1,000 lives to date.

In FY 1988, NASA work is continuing to develop low-cost 406 MHz beacon hardware. In addition, experiments in geostationary orbit to provide nearly instantaneous alerting will be performed. We will continue to support the FAA to minimize the systems false alarm rate.

Funding in FY 1989 will continue the NASA-unique research and development role in three areas of SAR, low-cost emergency beacon development, the next generation satellite-borne SAR equipment, and advanced techniques to improve system precision.

Radio Science and Support Studies

Radio science and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intra-satellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1988, the radio science and support studies program will continue further development of a geostationary arc allotment concept as part of the U.S. preparations for the FY 1988 Space World Administrative Radio Conference. Also, propagation studies will continue to help minimize radio signals atmospheric interference problems in space communications.

During FY 1989, major emphasis of the radio science and support studies program will be studies to identify and quantify the adverse effects of propagation phenomena on satellite communications as well as remote sensing. Work will continue to identify systems and technologies that make effective use of the frequency spectrum and geostationary orbit.

Communications Data Analysis

The objectives of communications data analysis are to support and to document a wide range of user experiments and demonstrations of the application of satellite communications. Past experiments on experimental satellites, such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to make informed decisions regarding the satellite communications functions. NASA's role to stimulate use of unique space facilities has led to wider application of commercial satellites that better meet the needs of potential users.

The remaining Applications Technology Satellite (ATS) satellite, ATS-3, continues to support the National Science Foundation, the National Oceanic and Atmospheric Administration, the Department of Commerce, the Department of Interior, the Drug Enforcement Administration, several universities, state and local governments, and a number of domestic and international disaster relief organizations. Support is provided through satellite voice and data links for scientific and communications experiments to North and South America, most of the Atlantic Ocean, and a large part of the eastern Pacific, including Hawaii and Antarctica.

Communications data analysis support of ATS-3 will continue, as will experiment definition and data analysis for laser communications.

Communications data analysis, formerly the experiment coordination and operations support, assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. Operation of the Applications Technology Satellite (ATS-3), launched in 1967, will continue.

INFORMATION SYSTEMS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Data systems	$9,700,000	$11,400,000
Information systems	11,200,000	10,900,000
Total	20,900,000	22,300,000

The objectives of the Information Systems program are to: apply advanced data systems technology to support the data management, scientific computing and information systems needs of NASA scientific research programs; conduct research programs and projects in the area of information systems and related technologies to enhance scientific productivity in the handling and analysis of data acquired from space flight experiments and observations; and implement information system standards, coordinate data systems requirements, and promote multi-mission sharing to lower information systems costs.

The information systems program provides the focus for integrated information systems planning across OSSA scientific disciplines. This includes definition of an end-to-end architecture or planning model to exploit commonality of requirements as appropriate, and to define interfaces for integrating mission- and discipline-specific portions with common core capabilities. The information systems program also provides leadership in assessing and evaluating advanced techniques, capabilities, and technologies especially as they support the information systems requirements associated with the highly complex sensors, complicated operational scenarios, extended-duration missions and multi-disciplinary requirements anticipated during the Space Station era.

During FY 1988 the information systems program continued to extend access across the OSSA research community to unique resources such as the NASA Space and Earth Sciences Computing Center, the National Space Science Data Center, and the Massively Parallel Processor. Networking is being emphasized as a key element to support scientists' access to computers and data. In addition, significant effort was made in coordinating data system activities across the Earth science and astrophysics disciplines to promote catalog interoperability and the interdisciplinary sharing of data, software tools, and advanced visualization techniques to enhance scientific interpretation.

The FY 1989 information systems program will continue emphasis on science information systems in support of Space Science and Applications programs, including the ocean, climate, land processes, and planetary and astrophysics systems. Emphasis will be placed on the coordinated development of these systems to promote interdisciplinary studies. In addition, emphasis will continue on the applications of computer science technologies to support the work of the NASA science disciplines. Funding is included for continued operation of scientific computing resources; such as, the NASA Space and Earth Sciences Computing Center, the Massively Parallel Processor, and the National Space Science Data Center. The information systems program will continue to develop common software to support ongoing research in the space and Earth sciences and continue development of data management and data archiving to support flight projects, science, applications, and research disciplines.

7. TECHNOLOGY UTILIZATION

FY 1989 NASA REQUEST, $19,100,000

FY 1989 AUTHORIZATION, $19,100,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Product development	$1,400,000	$2,100,000
Acquisition, dissemination, and network operations	4,665,000	5,400,000
Program development, evaluation, and coordination	2,600,000	1,500,000
Technology applications	7,000,000	7,300,000
Industrial outreach	2,035,000	2,800,000
Total	17,700,000	19,100,000

The NASA Technology Utilization Program is designed to strengthen the national economy and industrial productivity through the transfer and application of aerospace technology resulting from NASA's R&D programs. To accomplish this objective, NASA has established and operates a number of technology transfer mechanisms to provide timely access of useful technologies to the private the public sectors of the economy. The specific objectives of the programs are:

To accelerate and facilitate the application of new technology onto the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist; and

To develop applications of NASA's aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

NASA has continued its broad and comprehensive efforts to promote and encourage the effective application and use of new and innovative aerospace technologies throughout the public and private sectors of the U.S. economy. Of particular note is the upward growth of industrial and business subscribers of NASA Tech Briefs which now exceeds 160,000 readers. This 100% increase since January 1985 represents a growth rate averaging over 5,000 new subscribers per month—an effective measure of the importance and value which U.S. industry places on new and emerging technologies.

Moreover, the NASA-sponsored Industrial Applications Center (IAC) network has made significant strides in developing effective linkages with state-sponsored institutions engaged in industrial and economic growth. This broadening and strengthening of the nationwide technology transfer network is continuing to gather momentum with nearly 30 of the 50 states now being linked to transfer products and services available through the IAC efforts. An additional milestone was reached in late 1986 when the Federal Laboratory Consortium (FLC) for Technology Transfer (established under P.L. 99-502) and NASA elected to enter into an agreement in early 1987 which establishes formal linkages between the NASA IAC network and the various Federal laboratories. NASA is also seeking to familiarize and involve the private sector to a greater extent. The hiatus in Shuttle flights caused by the Challenger accident has shifted the focus of NASA's commercial programs from in-space experimentation of ground-based opportunities and exploitation of available technology. The IACs are a natural focal point for increasing awareness of available technology and opportunities.

Several important events occurred during the past 18 months in which several NASA-sponsored Technology Applications projects came to fruition. Among these was the first human implant of the Programmable Implantable Medication System (PIMS) at the Johns Hopkins University (JHU) Hospital in November 1986. This successful human application of PIMS culminates several years of an intensive collaborative effort between NASA, JHU Applied Physics Laboratory, and various private sector firms, and initiates a two-year clinical test period in which over 20 implantations will occur. All of these applications during the test period will be for patients with chronic diabetes.

Product Development

Based on the increasing response to Tech Briefs and expanding IAC network, increases in new technology identification and reporting are anticipated in FY 1989. These resources will provide for evaluation and packaging of these technologies for publication, thereby stimulating industrial interest and participation in NASA's Technology Utilization and Commercial Use of Space programs.

Acquisition, Dissemination, and Network Operations

In FY 1989, NASA plans continued strengthening of the Technology Counselor network at its field installations to provide for expanded identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA Industrial Applications Centers. To facilitate timely and efficient interaction between Technology Counselors, Industrial Applications Centers and other organizations in the NASA technology transfer network, a coherent, microcomputer-based communications system is planned for functional utilization within the NASA technology utilization infrastructure in FY 1989. Expansion of this capability, increased effective communication, and data storage and retrieval systems will greatly enhance the overall capability of the network to coordinate technology transfer activities, and respond to user needs efficiently with minimum overlap and duplication of effort.

Program Development, Evaluation and Coordination

With an expanded role in industrial outreach, additional emphasis will be required in the development of program goals and objectives in terms of long range plans for NASA Technology Utilization (TU). Focused efforts on assessing potential participants in U.S. industry, preparing information guidelines to support cooperative relationships throughout the NASA technology transfer network, as well as satisfying anticipated increased demand for TU publications and responses to increased number of program inquiries are among the many management planning and support requirements. Specific actions are also planned for FY 1989 to strengthen program development, evaluation and coordination on an internal as well as external basis to support the national technology transfer network and emerging commercial use of space outreach efforts.

Technology Applications

In FY 1989, a broadening of application team responsibilities is anticipated to assist NASA Industrial Applications Centers in

bringing together industrial client problems with existing aerospace technologies leading to project definition and industry-driven cooperative projects. This effort will result in increased tangible and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

Industrial Outreach

In FY 1989, NASA will utilize its existing dissemination center network to contact and acquaint U.S. industrial firms with opportunities to actively interact and participate with NASA in technology transfer and space commercialization. The NASA Industrial Applications Centers are in a unique position to serve as NASA's surrogate in aligning U.S. industrial interests in space commercialization as well as opportunities for terrestrial commercialization of advanced technologies derived from NASA's R&D programs.

8. COMMERCIAL PROGRAMS

FY 1989 NASA REQUEST, $38,800,000

FY 1989 AUTHORIZATION, $38,800,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Commercial applications R&D	$28,600,000	$36,600,000
Commercial development support	2,400,000	2,200,000
Industrial space facility	25,000,000	0
Total	56,000,000	38,800,000

The goal of the Commercial Use of the Space Program is to establish a national focus in support of opportunities for the expansion of U.S. private sector investment and involvement in civil space activities. The specific objectives of the program are to:

Establish close working relations with the private sector and academia to encourage investment in space technology and the use of the in situ attributes of space—vacuum, microgravity, temperature and radiation for commercial purposes;

Facilitate private sector space activities through improved access to available NASA capabilities and the development of new high technology space ventures and markets;

Encourage an increase in private sector investment in the commercial use of space independent of NASA funding; and

Develop and implement commercial space policy NASA-wide.

Sixteen Centers for the Commercial Development of Space (CCDS) have been established since the start of the program. The average cost of a CCDS is just under $1 million per year. Several CCDS's have developed strong linkages with the private sector and are developing flight hardware for applied research in space.

The Office of Commercial Programs (OCP) is building multi-user, multi-use government hardware, in cooperation with the Office of Space Sciences and Applications, that will reduce individual entrepreneur experiment costs to a level that can be afforded. This hardware consists of various types of furnaces, materials processing equipment, and experiment carrier supporting structures that private companies may use for space experiments. Use of the hardware provides access to microgravity through flights on the shuttle, on NASA aircraft, and on sounding rockets.

Commercial Applications R&D

In order to maintain momentum in commercial use of space activities, NASA will develop methods to facilitate private sector agreements and commitments to develop commercial opportunities in space. Institutions with strong research capabilities in sciences and engineering, in collaboration with industry and/or industrial associations, will be encouraged to participate in NASA-sponsored workshops and endeavors to accelerate U.S. commercial leadership in the use of space. Resources support and technical assistance will be partially furnished by NASA with the remainder furnished by the Centers for the Commercial Development of Space.

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities will be partially achieved by increasing the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for potential commercial research.

Through coordination with various industrial sectors and NASA program offices, the commercial R&D enhancement efforts will provide generic, multi-use research experimentation equipment. This equipment, as well as ground-based hardware, software and analytical tools, will be developed in order to expand the technical research database on the commercial uses of space required by the private sector to help make economic decisions to commit to research and, potentially, manufacture. Emphasis will be accelerated to build the required technical infrastructure. The main thrust of the effort will be directed by the private sector in coordination with NASA Centers. Resources will also be made available to obtain flight support experimentation hardware required by industrial researchers. This may include across-the-bay carriers, such as Materials Science Laboratories, as well as mid-deck augmentation racks or derivatives thereof, and the possible use of privately developed facilities. Both analytical and physical integration support are required for experiments conducted under Joint Endeavor Agreements (JEA). The NASA support for JEA's is directly proportional to the number of commercial research and development flight experiments scheduled and it is intended to encourage private sector use of space facilities. The use of ground-based research facilities, aircraft, and sounding rockets for commercial experimentation will

be given emphasis in order to provide limited access to the microgravity environment for certain commercial experiments.

The OCP has assumed responsibility for integration and mission management of unique Joint Endeavor Agreement flight experiments. Work started in FY 1987 to prepare experiments for flight and thus have them in a flight-ready status when the Space Shuttle resumes flight. The work consists of analyzing the experiment's characteristics and requirements and making provision for the physical placement on-board the Shuttle. OCP has two experiments approved for STS flight 26 and two for flight 29. The Space Systems Developement Agreement (SSDA) optional services responsibility has been transferred to OCP from the Office of Space Flight. NASA's current SSDA's are with Geostar and Space Industries Incorporated (now Space Industries Partnership).

Commercial Development Support

The support of the Commercial Use of Space Program requires a broad foundation. *Ad hoc* and continuing studies by experts are required to provide the direction and feedback needed by the program, especially where the economic, commercial and technical circumstances are changing rapidly. Study results assist in the development of short and long range plans and agency policy. Support services, equipment hardware maintenance, and studies and analyses are the other elements of commercial development support.

9. AERONAUTICAL RESEARCH AND TECHNOLOGY

FY 1989 NASA REQUEST, $414,200,000

FY 1989 AUTHORIZATION, $414,200,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Research and technology base	$251,600,000	314,200,000
Systems technology programs	83,200,000	100,000,000
Total	334,800,000	414,200,000

NASA requested $414,200,000 for Aeronautical Reserach and Technology in Fiscal Year 1989. This amount represents a 23.7% increase from the Fiscal Year 1988 Appropriation, the first significant, real increase in many years.

The Committee is pleased that NASA and the Administration have recognized the situation with regard to foreign competition in the world aviation market that has emerged during the 1980's. For example, during the 1970's, the U.S. share of worldwide jet transport orders, the largest component of aerospace exports, was 84%. In 1987, this measure stood at 65 percent, largely reflecting a strong challenge from European aircraft manufacturers.

This trend clearly indicates the U.S. must run harder if it wishes to remain competitive in the aviation market, one of the few remaining sectors with a net positive balance of trade. Improved technology will be a key element in this effort. Breakthroughs in performance have always been the sought-after goal that could change the outcome in air warfare situations or commerical competitions. The United States is preeminent in both areas today largely because unheralded researchers in NASA and DOD laboratories, working with small amounts of money, have found those breakthroughs. Revolutionary advances such as the area rule for supersonic flight, the tilt rotor and the prop fan have profoundly changed aviation. Yet the basic work that led to the ideas was achieved at very low cost.

The Committee believes the level of basic aeronautical research must be enhanced. The FY 89 request is a positive step in this direction. Within the total, the Committee feels a better overall balance could be achieved by earmarking about $3 million of existing funds for research on rotorcraft. Specifically, a portion of the funds planned for advanced materials and structures, guidance and controls, and development of computational tools should be used to address problems within these areas peculiar to rotorcraft.

In addition, the Committee recommends that of the funds authorized, $2 million be redirected to explore the use of ringtail technology to improve the efficiency of rotorcraft at high speeds. The Committee believes that this technology will have valuable application for military usage and, therefore, this effort should be jointly undertaken with DOD to ensure the effective transfer of the technology.

The Committee is gravely concerned about the safety of older aircraft in use today by many airlines. Some of these aircraft have exceeded the manufacturer's original lifetime projections. Furthermore, because of airline deregulation, airlines are often using their aircraft in ways that were not envisioned when the aircraft were built. The resulting accumulation of stress and corrosion of vital fuselage and wing structures and fasteners has created a serious safety hazard. The Committee believes NASA with its expertise in developing inspection techniques, gained from the Challenger accident and other activities, can contribute to the overall solution. Accordingly, the Committee recommends redirecting $0.8 million of the funds authorized for Aeronautical R&T to research aimed at devising improved methods for detecting fatigue, corrosion and bonding failures; at developing advanced ultrasonic inspection tools; and at improving life predicting and repair methods.

The Committee recommends for FY 89, $414,200,000; for FY 90, $609,500,000; for FY 91, $764,900,000. FY 90 and 91 funds provide for Technology Development and Validation (Subsonic Transport, High-Performance Aircraft, High-Speed Civil Transport, Generic Hypersonic, Tiltrotor/Commuter).

The goal of the NASA aeronautical research and technology program is to conduct research which contributes to a technology base that enables preeminence of U.S. civil and military aviation. This goal is supported by five comprehensive program objectives: (1) em-

phasize emerging technologies with potential for order-of-magnitude advances in capacity or performance which will enhance the U.S. defense and economic competitiveness; (2) maintain NASA's laboratory strength by repairing and modernizing critical aging national facilities, ensuring that necessary advanced scientific and engineering computational capabilities are available, and enhancing staff technical excellence by selecting highly qualified personnel and providing them with challenging career opportunities; (3) ensure the timely transfer of research results to the U.S. aeronautics community through reports, conferences, workshops, and active participation of industry in cooperative research programs; (4) ensure the strong involvement of universities in NASA's program to broaden the nation's base of technical expertise and innovation; and (5) provide technical expertise and facility support to the Department of Defense (DoD), other government agencies, and U.S. industry for major aeronautical programs. These objectives require a broad program of fundamental research that focuses on critical technologies and accelerates technology readiness for future vehicles. The program is based on a strong commitment to revitalize American competitiveness in the world aviation marketplace, enhance the safety and capacity of the national airspace system, and assure U.S. superiority for national security.

The NASA aeronautical research and technology program is intended to develop and validate emerging technologies for use by the aviation industry well in advance of specific applications through long-term independent research and technology development which is not driven by the development and operational pressures often encountered by the DoD and industry. Fundamental research in the traditional aeronautical disciplines is pursued concurrently with systems research and technology validation.

With the U.S. superiority in aeronautics challenged as never before, the FY 1989 estimate reflects the need to accelerate technologies which are vital to long-term U.S. competitiveness, to continue a strong program in fundamental disciplines and in key areas of systems research, and to revitalize critical NASA wind tunnels. NASA's FY 1989 aeronautics program is focused on achieving the bold objectives established in the report, "National Aeronautical R&D Goals: Technology for America's Future," by the Office of Science and Technology Policy (OSTP), and by its sequel report, "Agenda for Achievement," which enunciates an eight-point action plan for achieving the goals.

The FY 1989 research and technology program is committed to developing the technology basis for improving the nation's competitiveness and clear-cut product superiority in the international marketplace, enhancing the safety of aviation, and increasing the margin of the country's preeminence in aviation for national security. Technologies are being pursued that offer an order-of-magnitude increase in vehicle capabilities and substantial positive impact on U.S. competitiveness. Research efforts have been expanded in composite materials, advanced propulsion, and aviation safety. The demands for NASA's unique wind tunnels are growing with the emergence of the national aero-space plane (NASP) program, research on high-speed civil transports, and a new generation of military aircraft. In order to ensure wind tunnel availability to meet these demands, a major revitalization program is required over the next five years to modernize NASA's major wind tunnels for productive use for the next decade and into the 21st century. This program is included in the FY 1989 construction of facilities budget. A brief summary of the key elements of the research and technology base and systems technology programs follows.

In fluid and thermal physics, increased research emphasis will be placed on analytical, computational, and experimental studies of turbulence through the focused efforts of a newly formed center for turbulence research. In fundamental fluid physics, investigations using the numerical simulation of the flow instabilities which produce transition from laminar to turbulent flow will be accelerated, leading to an improved understanding of both the mechanisms of transition and the control of transition. This knowledge can enable reductions in aircraft drag and simplification of aircraft thermal management systems. Hybrid laminar flow control for aircraft drag reduction will be validated experimentally through a flight test research program initiated in FY 1989.

In applied aerodynamics, efforts will focus on high angle of attack and separated flow aerodynamics in both ground and flight test. Control of separated flow will be studied to determine cellular formation, control, and wing stall departure and spin resistance. Boundary-layer transition will be investigated for all speed regimes. By utilizing advanced optical and electronic technologies, innovative wind tunnel instrumentation will be developed for infrared boundary-layer transition visualization, micro-encapsulated liquid crystal methods for advanced flow visualization, laser fluorescence for hypersonic flow sensing, and laser velocimetry for supersonic and hypersonic shock propagation measurements. Experimental hardware, which has been under development for the past two years, will be used in an experimental flight investigation program to validate hybrid rotorcraft computational fluid dynamic codes for the prediction of rotor airloads and their resultant effects on aircraft vibration and acoustics.

Propulsion research will continue to emphasize improvement of the fundamental understanding of stationary and rotating component flow fields with the development of unsteady, viscous, computational analysis methods and enhanced experimental verification through three-dimensional nonintrusive measurement capabilities. The focus will be on several specific propulsion technology developments: high-rate fuel injection and adiabatic components for rotary engines, offering a potential for improvement of 40 percent in fuel consumption and 30 percent in power density; axicentrifugal compressor staging arrangements and uncooled radial flow turbines, offering the potential for a 40-percent improvement in efficiency for small gas turbines; powered-lift components (inlets, ducts, augmenting fans, ejectors) and control integration, providing significant improvements for advanced short takeoff and vertical landing vehicles; and the critical component data base needed for hypersonic propulsion. Increased emphasis on advanced propulsion concepts will enhance the technology development of four innovative configurations, offering the potential for high payoff improvements in future propulsion systems: high throughflow turbomachinery, offering a 20-percent range increase for a Mach 3 cruise mission; air

turboramjet cycle for extending variable cycle flexibility for the Mach 0 to 6 regime; variable geometry components, providing performance tailoring for multiple operating conditions with a 15- to 25-percent reduction in specific fuel consumption and 10- to 15-percent increase in thrust-to-weight ratio; and an off-axis, high-pressure core, offering the potential for a 20- to 30-percent increase in efficiency.

The materials and structures program will continue to develop advanced materials and innovative structural concepts aimed at reducing aircraft weight and cost. These include high-temperature aluminum alloys for subsonic and moderate supersonic speed aircraft, regenerative cooling of hypersonic aircraft, and deformable wing structures for high-performance aircraft. In addition, increased emphasis will be placed on developing high-temperature composites technology for use at up to 600 degrees Fahrenheit. The composites program will focus on the development of advanced materials, advanced fabrication methods that are especially tailored to take advantage of composite material characteristics, advanced structural concepts, and design and qualification test methods. Advanced structural concepts and fabrication methods will include filament winding and pultrusion techniques to reduce parts count for major structures and subsystems, while new design and qualification methods will reduce structural design and testing costs. These areas will be supported by continued development of advanced computational methods to reduce structural design time and minimize costly testing. Also during FY 1989, greater emphasis will be placed on analysis of large-scale airframe structures using advanced multiprocessor computers.

Research in information sciences will continue on concurrent processing for highly reliable and high-performance computer architectures which will be more immune to hardware and software failures. A family of parallel processing computers will be used to research novel concepts in parallel processors controlled by new software algorithms. Also, studies will continue to assess the reliability gain from formal specifications, software prototyping, computer-aided software engineering systems, software reuse, and formal verification. Support will be provided to NASA's computer networking system in order to increase the effectiveness and productivity of NASA's distributed computing resources.

In controls and guidance, the advanced transport systems research vehicle (B-737) has returned to flight research status after overhaul and upgrade of its avionics systems, and emphasis will be placed on flight evaluation of takeoff and landing performance monitoring, high-speed rollout and turnoff capacity improvements, and navigation systems for reduced airport congestion and delays. Increased emphasis will be placed on development of automation concepts leading to enhanced safety and productivity in the national airspace system. Adopting state-of-the-art space automation techniques and methods, evaluations will be conducted jointly with the Federal Aviation Administration at the Stapleton Airport in Denver, of an air traffic controller advisor and expert schedule advisor, which offer the promise for allowing reductions in controller workload and more efficient handing of air traffic. In FY 1989, research will continue on the detection, avoidance, and recovery from wind-shear encounters.

Human factors research will emphasize the development of methods for designing pilot decision aids and information transfer improvements in order to increase safety and reduce peak workload. To address the fact that over the last 30 years approximately 70 percent of the worldwide jet fleet accidents were caused by human error, the human factors research will be accelerated in areas directly related to aviation safety and automation. This research will emphasize the development and validation of methodologies for intelligent, error-tolerant systems; improved human/automation interfaces for increased situational awareness; and aircraft/active control technology integration. The goal of this activity is to substantially reduce the risk of human error.

Flight systems research will be directed toward the technology needs of aviation safety, flight test methodologies, and supporting research for high-performance aircraft. Research is being conducted to improve the understanding of the effects of weather and icing conditions on the safe operation of aircraft and rotorcraft and to develop the technologies which will improve the safety of future vehicles. Research will be conducted using the F-18 high angle-of-attack research aircraft to validate emerging experimental and computational methods for the prediction of high angle-of-attack aerodynamics, flight dynamics, and handling qualities.

Systems analysis research studies will focus on defining the research and technology requirements for advanced high-speed transport aircraft. Emphasis will be placed on assessing the impact of advanced technologies for reducing engine emissions, sonic boom, and airport noise. The goal of this research is to ensure that future high-speed civil transports will be environmentally compatible with respect to concerns about atmospheric ozone depletion and noise. Advanced supermaneuverability fighter configurations will be analyzed to determine the benefits of advanced technologies in aerodynamics, propulsion, materials, structures, and controls.

Advanced rotorcraft technology activities include airloads and active controls development for a potential 80 percent reduction in noise and vibration and high-speed configuration concepts for speeds of 400 knots and above.

High-performance flight research will continue to concentrate on the application of flight/propulsion controls integration for enhanced mission effectiveness, focused technology development of the most promising advanced short takeoff and vertical landing concepts, and the completion of technology validation flights of the X-29A forward swept wing aircraft. Flight tests of the high angle-of-attack research vehicle (HARV) will establish a flight-validated data base for the development and refinement of analytical, simulator, wind tunnel, and flight research design tools and test methods for the prediction of high angle-of-attack aerodynamics. Detailed design, fabrication, and flight qualification of a thrust vectoring control system will enable the HARV to conduct high angle-of-attack research in FY 1990 at the extreme portions of the flight envelope where future highly maneuverable aircraft will operate.

The advanced composite materials research will be directed toward exploiting new organic-composite materials for use up to

600 degrees Fahrenheit and advanced processing and fabrication concepts for low-cost composite structures. These advanced materials incorporated in innovative structures, such as geodesic fuselage panels and pultruded wing planks, will provide structural weight savings of 40 to 50 percent. Advanced analysis methods, including probabilistic modeling of composites for improved life prediction and analysis of composite failure mechanisms, will provide essential components of the technology required for the full use of composite materials in advanced aircraft.

Advanced turboprop systems technology efforts will continue to develop the underlying base of computational analysis capabilities and the experimental data base for high-speed (Mach 0.65 to 0.90) propellers. Emphasis will be placed on counter-rotating propeller aerodynamics, acoustics and aeroelastics, including aircraft installation interactions. The goal is to obtain cabin noise and vibration levels equivalent to, or less than, that of a modern turbofan-powered aircraft.

The general aviation/commuter engine research program will provide validated analytical data of the flow phenomena and heat transfer in small compressors, combustors, and turbines that offer the promise of a 40-percent increase in fuel efficiency and up to a 10-percent reduction in direct operating cost in small engines.

The advanced high-temperature engine materials program will focus on the development of metal matrix ceramic fibers and ceramic-ceramic composites. This includes the development of new fibers, matrices, and coatings. Chemical vapor deposition will be utilized to develop small-diameter silicon-carbide fibers that are stable to 3000 degrees Fahrenheit, and ceramic matrix composites will be fabricated that are stable to 2500 degrees Fahrenheit in oxygen. Higher temperature fibers and coatings will be developed for intermetallic and refractory metal matrix composites.

The numerical aerodynamic simulation (NAS) system is now operational. During the next year, the pathfinder high-speed processor number two will be integrated into the NAS system, giving a factor of four improvement in performance. This capability will allow for more detailed numerical simulation of complex flows providing, for example, improved aircraft performance through better propulsion/airframe integration optimization.

Research and Technology Base

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Fluid and thermal physics research and technology	$24,600,000	$26,500,000
Applied aerodynamics research and technology	52,800,000	64,300,000
Propulsion and power research and technology	45,800,000	70,100,000
Materials and structures research and technology	37,200,000	40,100,000
Information sciences research and technology	19,000,000	23,000,000
Controls and guidance research and technology	21,200,000	35,700,000
Human factors research and technology	20,600,000	19,700,000
Flight systems research and technology	24,800,000	28,800,000
Systems analysis	5,600,000	6,000,000
Total	251,600,000	314,200,000

Fluid and Thermal Physics Research and Technology

The objective of the fluid and thermal physics research and technology program is to advance the understanding of fundamental fluid mechanics phenomena and to develop efficient aerodynamic analytical tools. The research is directed primarily at external aerodynamics and includes efforts in fluid physics, computational fluid dynamics (CFD), CFD code validation, experimental aerodynamics, and viscous flow studies. CFD research is performed to increase the speed and efficiency of three-dimensional flow solvers and for the prediction and simulation of complex fluid flows over aircraft. The validation of prediction and simulation methods is accomplished by means of a coordinated experimental test program with particular focus on accurate three-dimensional turbulent models for attached or separated flows. This activity provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Experimental aerodynamics uses wind tunnel and flight testing to derive a data base for the evaluation of analysis methods and for the exploration of advanced aerodynamic configurations. Viscous flow research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag.

Substantial progress has been made in developing new, more efficient, and more accurate solution algorithms for complex viscous flows and in innovative gridding techniques to resolve the added geometrical complexity or realistic three-dimensional configurations. These new algorithms were tested for a variety of applications, including high angle-of-attack forebody flows, hypersonic vehicles, airfoil stall, engine exhaust jets interacting with ground crossflows, and separated flows over wings. The new gridding techniques were tested for three-dimensional geometries, such as civil transports and the Space Shuttle orbiter with solid rocket boosters. To assess the accuracy and reliability of these new techniques and codes, both computational studies and experimental validation activities are in progress.

Significant advances have been made in the enduring problem of understanding, predicting, and modeling the onset and structure of turbulence. First-of-a-kind simulations of late-stage transition to turbulence, turbulent separation, and turbulent heat transfer have generated previously unavailable, high-resolution data bases. To capitalize on the recent advances in supercomputers, experimental techniques and theoretical concepts, NASA and Stanford University jointly created the center for turbulence research (CTR). The CTR provides a synergistic environment for coordinated computational, experimental, and theoretical research on turbulence phys-

ics. Visiting participants include outstanding researchers from universities, government laboratories, and industry.

Critical investigations were identified to be conducted to generate the data for turbulence modeling and code validation. A three-dimensional orthogonal laser velocimeter (LV) has been installed for the basic aerodynamics research tunnel at Langley Research Center as part of the CFD validation program. In addition to the LV instrumentation, hot wire and total pressure surveys have been made to compare accuracies of different instrumentation systems. Vortex breakdown, a complex phenomenon which occurs on high-performance aircraft, is being studied to provide the data needed to validate the CFD codes which predict its onset.

Experimental and analytical aerodynamics research is conducted to identify and analyze innovative aerodynamic concepts and configurations. In experimental aerodynamics, Phase I of the Boeing 767 correlation model tests was completed in the National Transonic Facility (NTF). This model was previously tested in a number of NASA and industry conventional transonic wind tunnels so that the NTF experiment could provide calibration data for these facilities. A leading-edge vortex flap was successfully wind-tunnel tested on an F-106 model and demonstrated low-speed and transonic-speed maneuver improvements. Advanced low-speed and medium-speed, low-drag, benign-stall airfoils applicable to commuter and general aviation aircraft have been developed. High angle-of-attack flow separation control was successfully demonstrated through periodic velocity forcing techniques. A low-altitude unmanned research aircraft configuration was developed utilizing advanced airfoil technology. Such reconnaissance aircraft require special airfoil designs to maximize lift-to-drag ratios and range at low Reynolds numbers. An analytical method was derived for the analysis of Gortler instabilities on airfoils with variable curvature, pressure gradients, and Mach number. These instabilities, which are frequently curvature induced, can lead to premature boundary-layer transition. Juncture flow tests were performed in cooperation with the U.S. Navy for design of a submarine hull-appendage juncture.

Because of the high potential drag reduction payoff of laminar flows, viscous flow research efforts have focused on laminar flow control and natural laminar flow concepts which resulted in the completion of two notable flight tests. In the first, laminar flow control leading-edge systems were successfully tested on a Jetstar aircraft which simulated airline flight operations under varying weather conditions and flight scenarios. Additionally, experiments have been completed on a testbed F-14 research aircraft where natural laminar flow wing contours were tested at various sweep angles. The effects of cross-flow instabilities on boundary-layer transition and separation were determined. These tests, along with wind tunnel investigations and analytical techniques, are being performed to minimize the risk of applying laminar flow technology to transport aircraft. The investigation of complex viscous flow phenomena has been improved by the proof-of-concept testing of the holocinematographic velocimeter, which provides global tracking of fluid mechanisms. Passive friction techniques have been developed for flow separation control downstream of shock/boundary-layer interactions. Uncontrolled separation leads to unwanted increases in form drag. Supersonic viscous flow research has been initiated with preliminary flight experiments on determining the extent of natural laminar flow under actual flight conditions on existing aircraft. These tests provided initial data required to begin development of drag reduction concepts based on laminar flow control at supersonic speeds.

In FY 1989, the CFD program will capitalize on the recent increases in supercomputer memory and speed to investigate unsteady three-dimensional flows. This capability is required for the analysis of unsteady vortex breakdown, tip vortices, unsteady boundary-layer separation, jet impingement, and tail buffet effects. These physical phenomena are critical to the performance of vehicles which utilize thrust vectoring, high angle-of-attack maneuvers, and swept wing tips. Innovative grid techniques will be utilized to resolve complex three-dimensional flows and multiple bodies for use on the National Aero-Space Plane (NASP) configuration, separation of the solid rocket boosters from the space shuttle orbiter, and stores separation. In addition, the renewed emphasis on high-speed flows for supersonic and hypersonic vehicles, such as the NASP and high-speed civil transport, will be reflected in increased efforts in high-speed flow phenomena such as chemically reacting flows, real gas flows, rarified flows, and compressible transition and turbulence. Benchmark experiments will continue to be conducted for the acquisition of high-quality data bases as required for the validation of CFD codes.

The experimental aerodynamics research program will use wind tunnel, water tunnel, and flight experiments to complement the analytical aerodynamic developments for complex flows over aircraft components and configurations. Wing/airfoil optimization techniques will be extended from subsonic and transonic speeds to the supersonic regime. Panel aerodynamic methods will be tailored to analyze flows over an F-16 aircraft with tip missiles and under-the-wing fuel tanks, and the advanced turboprop. Advanced computational algorithms will be developed for exploring vortex interactions. Vortical flow aerodynamics plays a dominant role in fighter aircraft high angle-of-attack operation and includes some of the most complex phenomena in fluid mechanics. Cellular formation studies will be initiated for the derivation of separated flow control techniques. Laminar flow tests will be completed in the 8-foot transonic pressure tunnel, and this facility will be restored to its original configuration. This "work-horse" wind tunnel has been dedicated to laminar flow research for a number of years, but will now be utilized for other pressing research needs.

In FY 1989, the viscous flow program will emphasize the reduction of drag at supersonic speeds and the flight testing of a hybrid laminar flow system on a transport aircraft. The reduction of drag translates directly to fuel savings and increases aircraft range. Fundamental flow mechanisms investigations will include the study of turbulent-flow coherent structures and supersonic boundary-layer transition physics. Turbulent skin friction reduction devices, such as surface geometry modifiers, will be explored for the supersonic regime. Other supersonic drag reduction efforts will include supersonic laminar flow, utilizing leading-edge suction flow control, and wave drag research. Vorticity control concepts will be

investigated for reducing induced drag (drag due to lift) and for preventing flow separation. Hypersonic stability and boundary-layer transition analyses will be performed to derive transition prediction techniques. Predicting the location of boundary-layer transition is vital in the design of hypersonic vehicles such as the NASP. Hybrid laminar flow techniques, which combine wing leading-edge suction and innovative wing profile contouring, will be flight tested on a full-sized transport aircraft near the end of FY 1989. This research is a cooperative effort between NASA, U.S. Air Force, and industry.

Applied Aerodynamics Research and Technology

The objective of applied aerodynamics research and technology is to provide new, validated technology applicable to future U.S. military and civil aircraft from subsonic to hypersonic speeds. The approach is to conduct comprehensive ground and flight experiments involving realistic vehicle configurations and key configuration components. Such work is focused on technology areas expected to render major gains in advanced vehicle performance. Examples of potential gains include 40- to 60-percent gains in transport airplane cruise efficiency for subsonic, supersonic and hypersonic vehicles, a doubling of the productivity and agility of rotorcraft, and a doubling of the cruise and maneuver performance of high-performance airplanes. Products include new analytical and experimental methods needed in the design process and new aerodynamic concepts. This work covers the areas of aeroacoustics and the full spectrum of civil and military air vehicles, including rotary-wing and fixed-wing concepts. Recent progress in key program elements is summarized in the following paragraphs.

Test techniques and instrumentation research is performed to provide essential improvements in NASA's wind tunnel and flight testing capability. Classic limitations of wind-tunnel testing, such as wall and sting interference effects, are being eliminated by adaptive wall and magnetic suspension concepts being used and developed at Langley Research Center. Obtaining an accurate description of an unsteady fluid flow field requires the ability to take a "snapshot" of a large portion of the flow field—such capabilities are being developed and are referred to as global flow-field measurements where a number of parameters can be measured instantaneously over a large extent of the flow field. Another critical requirement in flow measurements used to check prediction methods is to perform the measurements in a nonintrusive manner and to obtain measurements at very high sample rates to describe rapidly changing flow parameters. Measuring turbulent flow fields has required the develpment of laser holographic sensing methods for both measurement and visualization; complementary, sophisticated, high-response sensors have been developed for measuring boundary-layer flows that exist very close to the surface of a flight vehicle. Nonintrusive laser velocimeter systems are being developed for in-flight measurement of wing flow fields. Providing accurate, nonintrusive, rapid-response measurement techniques is critical to achieving confident validation of predictive methods and the performance of new concepts.

Subsonic aerodynamic research has emphasized development of technology for induced drag reduction and separated flow control to reduce aircraft drag and improve stability and control. Novel approaches to achieving lower induced drag are being investigated in the form of unconventional wing planform shapes (crescent, for example) and sheared wingtip shapes. New nonplanar wing theories and wind tunnel tests are showing that these new wing shapes can yield efficiencies higher than originally thought possible, based on classical planar wing theory. Research continues with benchmark wind tunnel tests and radio-controlled model flight tests using sheared wingtip/crescent wing planform configurations to validate the nonplanar wingtip theory and to determine stability and control characteristics. Additional investigations are required to determine if the nonplanar wingtip theory applies to supersonic as well as subsonic flight. Flight tests are also being conducted to support industry applications of spin resistance technology to new aircraft designs.

Significant advancements have been made in recent years in the development of codes for application to the low-disk-loading rotors of conventional (helicopter, tilt rotor) and advanced rotorcraft. The codes include both fully analytical methods for component analysis and comprehensive semi-empirical methodologies for more comprehensive modeling of rotorcraft aerodynamics and dynamics. While the methodologies will continue to evolve, one of the most important needs for the near term is the experimental verification/validation of these methodologies. Preparations for major experimental activities have been completed, and these experiments will be the focus of the rotorcraft program in the next two years. These activities include both flight and wind tunnel programs, with primary emphasis on the investigation and measurement of unsteady airloads and the related acoustics and vibrations. Recent efforts to develop test hardware and instrumentation will come to fruition beginning in FY 1989. The availability of these experimental tools will enable a multipronged attack on the complex aerodynamic and dynamic environment affecting speed and maneuverability of rotorcraft configurations.

The high-performance (fighter/attack) vehicle technology program is focused in three key technology areas: (1) short takeoff and vertical landing (STOVL), (2) high angle-of-attack (post-stall) maneuverability, and (3) supersonic cruise and maneuver. In the STOVL arena, research is emphasizing powered-lift concepts for hovering, methods to predict the complex flow surrounding a hovering vehicle, and investigation of flight dynamics of transition between hover and forward flight. Studies have been completed to define the most promising STOVL vehicle concepts, and the key technologies needed are being worked. These STOVL technologies will be used to define the payoff of this capability in future supersonic fighter concepts when integrated with the other essential vehicle capabilities. In the area of high angle-of-attack, both new experimental and new analytical methods are being developed for the prediction and control of the separated and vortex flows which dominate this aircraft flight regime. One new concept for aerodynamic control of advanced fighters was successfully demonstrated on a flying model at the Langley Research Center; this concept for

control of the airplane forebody flow is being developed further in preparation for potential full-scale flight tests. These new capabilities will be applied to develop new vehicle and control concepts which will allow advanced, superior U.S. vehicles to push beyond the traditional stall barrier by virtue of increased stability and control. In the supersonic cruise arena, new nonlinear prediction and design methods for advanced airfoils and wing platforms are being developed to provide a doubling of cruise efficiency (including laminar flow) and a doubling of the sustained maneuverability of advanced fighters. New techniques have now been developed which allow the designer to rapidly and accurately define the complex shapes of advanced supersonic vehicles in forms needed to calculate the airplane aerodynamics. This technology will meet the current goals of the U.S. to develop more efficient and survivable supersonic vehicles.

In the area of aeroacoustics research, flight tests to verify and quantify the effects of acoustic fatigue loads on the aft structure of an F-15 aircraft were successfully completed at the Dryden Flight Research Facility. Various methods of decoupling the jet plume dynamics, and thus reducing the resonance effects in twin jet configurations, were also successfully demonstrated. Aircraft components with longer life will result from this work.

The development of advanced wind tunnel instrumentation will include the exploration of several new sensing techniques for supersonic and hypersonic flows. Emphasis is placed on these high-speed regimes to support the U.S. initiatives on supersonic and hypersonic vehicles. Concepts to be investigated include infrared boundary-layer transition visualization, micro-encapsulated liquid crystal methods for advanced flow visualization, and laser fluorescence for hypersonic flow sensing. Also, the development of laser velocimetry to obtain high-response measurements in supersonic shock flows will be pursued. Methods will be developed for three-dimensional adaptive-wall testing in the Langley Research Center 0.3-meter transonic cryogenic wind tunnel. A laser molecular velocimetry system capable of simultaneous measurements (essential to define realistic, time-dependent flows) of velocity, density, and temperature will be demonstrated in the supersonic unitary wind tunnel at the Langley Research Center. The capability to extract the hub impedance for rotorcraft configurations in flight and wind tunnel tests will be developed to allow comparison with predicted forces. These enhancements apply to all disciplines and vehicle types, but they are particularly critical for rotorcraft and other vertical/short takeoff and landing (V/STOL) configurations and for very high-speed supersonic/hypersonic vehicles. These configurations have extremely complex flows that must be carefully measured to extract the pertinent information.

In FY 1989, the emphasis of drag reduction technology will shift toward supersonic speeds. Theoretical and experimental investigations will be conducted to determine high angle-of-attack flutter and stability and control characteristics of sheared wingtip/crescent planform wing configurations. Separated flow control research will examine the formation and control of wing stall cells to provide a method to prevent asymmetric stalls and post-stall spins. Boundary-layer transition will be investigated in flight for all speed regimes, including extension to supersonic speeds; transition physics sensors will be developed; and manufacturing tolerances to enhance laminar flow will be determined to facilitate natural laminar flow applications by the aircraft industry. The validation of these new technologies may follow prior achievements such as winglets and supercritical wings into the commercial marketplace, enhancing the U.S. position in the manufacture of subsonic aircraft.

In FY 1989, major full-scale, experimental activities, aimed at verification and validation of advanced rotorcraft codes, will be conducted. Experimental flight and wind tunnel hardware, instrumentation, and data management capability, which have been under development for the past two years, will be available. The primary activity focuses on a joint Ames Research Center/Langley Research Center/Army/industry experimental flight investigation, with a highly instrumented UH-60 Black Hawk helicopter. The primary focus of this program will be on the validation of hybrid rotorcraft codes which combine comprehensive analyses of the entire rotorcraft with CFD codes for critical rotor azimuth positions for predicting rotor airloads and their resultant effects on aircraft vibration and acoustics. The UH-60 program is a comprehensive effort that will form the basis for much of the validation efforts. Model-scale rotor tests will be completed prior to the flight investigations, and full-scale wind tunnel tests of the rotor will be completed following the flight experiments to provide a complete data base. The UH-60 program will be augmented by specialized experiments for specific configurations and codes, including bearingless rotor configurations, tilt rotor airloads, aerodynamic interaction experiments, rotor/fuselage impedance experiments, and simulation experiments to upgrade mathematical models for piloted simulations. All of these experiments play a key role in the validation of the next generation of codes that will be critical for advanced rotorcraft design. Future commercial and military rotorcraft, optimized for noise, vibration, maneuverability, and performance goals, will result from these new methods.

High-performance research in the STOVL arena will include a technology program between the U.S. and Canada stressing the controls technology for powered lift and flight control integration, as well as wind tunnel tests of a full-scale advanced powered-lift fighter concept to validate the predicted performance. High angle-of-attack research will provide detailed analytical and experimental predictions of post-stall aerodynamics for validation against flight results obtained from the continuing tests of the NASA high angle-of-attack research vehicle (HARV), and new vortex control and vectoring concepts will be developed and explored in piloted simulations to quantify their ability to provide critically needed control power at high angle-of-attack conditions. Supersonic research will include the development of the vehicle mathematical modeling methods needed to apply new nonlinear aerodynamic analysis schemes to realistic, complex airplane configurations and experiments essential to validate the capabilities of these codes. Future fighter design efforts will depend heavily on such methods to accomplish the increasingly complex integrated fighter design process.

Also in FY 1989, the aeroacoustic research efforts will focus on developing and applying numerical techniques for predicting long-range propagation of low-frequency aircraft noise over realistic terrain features. These calculations and predictions will be verified and compared with long-range propagation experiments to be conducted at White Sands; results will lead to techniques for aircraft noise reduction. An additional focus of the FY 1989 aeroacoustics program will be on the coupling of high-frequency aeroacoustic loads with steady flight loads and thermal loads that will provide an integrated loads analysis to assist in verification of the vehicle's life cycle.

Propulsion and Power Research and Technology

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is being conducted in a wide variety of subsystems with applications ranging from the general aviation class through the hypersonic aerospace plane. Ongoing disciplinary research on instrumentation, controls, internal fluid mechanics, and aerothermodynamic concepts is providing the foundation necessary for continued advancements at the component and subsystem level. These research efforts will lead to high-payoff propulsion system improvements which have historically provided a major share of aircraft performance advances and also enabled new classes of vehicles.

The objectives of general aviation engine research are to achieve a fuel consumption reduction of 40 percent at cruise power, a power density increase of 30 percent at takeoff power, and multifuel capability for advanced intermittent combustion engine cycles. Research emphasis for stratified-charge rotary engines, which have now demonstrated multifuel capability, includes improved understanding of the combustion process that will enable improvements in engine performance and operating boundaries. As an initial step, an improved computer model of rotary engine flow fields has been developed through the use of detailed rig flow measurements. At a U.S. industry contractor, a single-rotor engine demonstrated improvements of 21 percent in specific fuel consumption and 12 percent in power density. In 1988, higher rate fuel-injection schemes will be tested for faster burn rates as a means to improve the fuel consumption.

For rotorcraft, the objective is to develop small gas turbine technology that enables up to a 40 percent reduction in fuel consumption. Scaling studies of small turbine engine components have been completed, and results used to identify the payoff areas for future research. A new small compressor test facility is now complete and enables the use of laser measurements to define critical flow-field physics. The large, low-speed centrifugal compressor facility is also now operational, and research testing will begin in FY 1988 to investigate boundary layers and secondary flows, and verify advanced three-dimensional viscous flow codes which will guide the improvements of high-pressure ratio per stage, high-efficiency turbomachinery.

For high-performance applications, the goal is to develop propulsion systems technology for powered lift and in-flight thrust vectoring that will lead to improved aircraft short takeoff and vertical landing, and also supermaneuvering capability. The full-scale powered-lift test rig is now operational at Lewis Research Center and was used in 1987 to evaluate the U.S./Canadian ejector concept to obtain total system performance and loss data. Additional testing of this ejector system and initial full-scale testing of one U.S. contractor's ejector system are both scheduled for FY 1988 to determine overall performance viability. Fabrication of a hot gas ingestion model was also completed and testing begun in the low-speed 9x15-foot wind tunnel at Lewis Research Center to determine the extent and effect of hot gas ingestion into the inlet during powered-lift operations. These latter results and additional configuration testing will verify hot gas injection computer codes that are currently under development. Short diffuser inlet testing will also be conducted in FY 1988 to determine performance potential at high angle-of-attack operation desired for supermaneuvering capability.

In supersonic cruise research, the objective is to develop technology for lightweight, efficient propulsion concepts for Mach 2 to 4 operating conditions. Research has been primarily focused on the analysis and experimental verification of the supersonic through-flow fan concept. This component technology offers the potential of 20-percent fuel savings compared to an advanced variable-cycle engine for a long-range supersonic transport-type aircraft. The design of a proof-of-concept fan stage and test rig has been completed using advanced three-dimensional Euler and Navier-Stokes codes. In FY 1988, the rig fabrication will be completed and initial testing of the supersonic inlet and downstream diffuser will be performed without the fan. Complementary research on innovative high-speed propulsion concepts will also be initiated through contracts with industry and academia.

Hypersonic propulsion research has as its objective the maturing of supersonic combustion technology and the study and development of propulsion concepts for high-speed cruise in the Mach 4 and above range. Testing of a Mach 5 small-scale inlet, using flow visualization, verified detrimental boundary-layer migration which had been analytically predicted, thereby guiding necessary incorporation of a bleed system prior to large-scale testing in FY 1988. Additional experimental efforts in FY 1988 include the evaluation of a scramjet module that reduces stresses in the walls of the combustor by transitioning from a two-dimensional inlet to an axisymmetric combustor, an oblique detonation wave concept test that offers significant supersonic combustor length reductions, and combustion contaminant testing to quantify both adverse and potentially advantageous impacts on the combustion process.

Instrumentation and control research is aimed at developing advanced high-temperature sensors and optical nonintrusive measurement systems for research applications and advanced engine sensors and controls for future propulsion systems. An advanced anemometer with the capability to measure detailed flow characteristics very near fixed surfaces has been used to measure near-

wall, boundary-layer flow in a turbine facility to verify advanced prediction codes. In the area of high-temperature electronics, progress continued on a silicon-carbide-based diode for 400°C applications, and the material antiphase boundaries were successfully eliminated to further improve silicon crystal quality and electronic characteristics. In FY 1988, a palladium-based 1000°C static strain gage for potential use in engine hot section research work will be demonstrated. A prototype fiber optic position sensor will also be tested in an aircraft turbine engine environment to demonstrate potential application in future fly-by-light systems. An initial advanced short takeoff and vertical landing (ASTOVL) linear control model will be completed and used to establish integrated control methodology concepts.

Internal computational fluid mechanics continues to be an increasingly important tool for understanding flow phenomena and as a basis for improved design capability in aeropropulsion systems. The objective is to develop advanced algorithms and methods for analysis of complex three-dimensional flows in high-speed inlets and nozzles, turbomachinery and chemically reacting flows, and to validate the analytical techniques with fundamental benchmark experiments. An explicit, unsteady quasi-three-dimensional viscous turbomachinery rotor and stator interaction code has been created and its predictive capabilities demonstrated. In FY 1988, a CFD code validation experimental data base, using the large, low-speed centrifugal compressor, will be created and used to compare the ability of the code to model important flow characteristics. Operational capability of a high-speed local area communications network linking additional special purpose internal fluid mechanics experimental and analytical computers to the Lewis Research Center computer system and the numerical aerodynamic simulation (NAS) system will also be completed.

General aviation engine research activities will continue to focus on advancing rotary engine technology. The structural viability of a lightweight rotor for improved rotary engine power density will be demonstrated through 100 hours or more of testing at speeds to 10,000 revolutions per minute. Analysis of the combustion process through advanced computer modeling will guide improvements in combustion efficiency to enable the fuel consumption goal.

Rotorcraft engine research efforts will continue to concentrate on developing an experimental data base using the large low-speed centrifugal rig, which will be used to validate analytical codes currently in development. Detailed measurements using laser anemometers of boundary layers developed on the rotor, secondary flows, and separated flow regions in both the rotor and diffuser, and the effect of tip clearance on the overall flow structure in the compressor, will be made for future integration with the compressibility measurements in the complementary small compressor test facility. Work will also be initiated on technology development of a small, compact, high-pressure-ratio core concept using close-coupled radial turbomachinery. Benefits of 20 to 30 percent improvement in thermal efficiency are projected, and the concept as conceived also may be integrated with large transport gas turbines for comparable payoffs.

High-performance aircraft research will include an evaluation of a complete computer simulation of a supersonic ASTOVL aircraft and propulsion system to identify the interactions of individual system response rate dynamics. Engine studies that define cycle performance parameters for a FY 1995 technology readiness date (2005 initial operating capability) will be completed, and the most promising of the ASTOVL propulsion schemes will be selected. The capability of a supersonic inlet to operate satisfactorily at extremely high angle of attack will also be demonstrated in a model test for verification of code predictions. To calibrate exhaust gas ingestion codes under development, the experimental data base will continue to be expanded for promising configurations and new concepts. Technology development on variable geometry components, such as inlets, nozzles, and internal flow control valves, which are critical to powered lift and supermaneuvering capability, will be significantly expanded. Projected performance benefits offered by these components include 25 percent subsonic and 15 percent supersonic fuel consumption reductions, and 15 percent increase in propulsion system thrust-to-weight ratio.

Supersonic cruise research will continue to focus on the supersonic throughflow fan concept. Tests will be completed on the full fan stage (with rotor) during FY 1989 and the results used to verify three-dimensional viscous analysis codes and help guide design refinements and the development of advanced off-design analysis codes. Systems studies will continue to define the critical technologies required for a propulsion system that incorporates a supersonic throughflow fan for high-speed applications. The ongoing work will be accelerated and expanded into the critical areas of airframe integrated inlets and nozzles, supersonic diffusers, compact high-work drive turbines, and lightweight high-temperature heat recovery systems necessary to bring an advanced high-speed propulsion system to fruition.

Hypersonic propulsion activities will continue with development of the analytical capabilities and supporting experimental data base for supersonic combustion and high-speed cruise systems. Code development will focus on the complex flow fields in scramjet combustors, variable geometry inlets and nozzles, and high-speed propulsion/airframe integration which must be understood to achieve system viability. Algorithms for high-speed flows (up to Mach 20) that reduce required computer time will be extended to three dimensions and will also include chemical heat release in order to accurately describe the total propulsion flow-field process. Advanced components to be used in development of a technology data base for improved airbreathing engine concepts will also be defined for future validation testing.

Advanced instrumentation and controls research will continue to be focused on both nonintrusive measurement of flow and high-temperature structural phenomena for code verification, as well as optical sensors and control methodology for propulsion system application. An analytical mechanistic model that predicts the epitaxial crystal growth of silicon carbide for high-temperature electronics will be created and verified to further enhance the repeatability and yield of the process. A four-spot laser anemometer for near-wall measurements will also be used to measure boundary-layer

flow to verify advanced codes now being developed. In the controls area, an initial analytical model of a reconfigurable control expert system will be completed and exercised to guide the development of intelligent fault-tolerant logic. Development of the ASTOVL linear control model and integrated control metholdogy concepts will also be continued to improve system logic based on predicted response rate interactions from the combined aircraft and propulsion system simulation.

Research emphasis in internal computational fluid mechanics will continue on advanced prediction capabilities for high-speed propulsion. For both existing codes and new codes under development, predictions of the aerodynamic flow field will be expanded to include both chemical reaction and heat transfer to yield the capability of describing the total process taking place within a propulsion system. A three-dimensional Navier-Stokes analytical code with predictive capability for high-speed aerodynamics and heat transfer in inlets, ducts, and nozzles will also be demonstrated. Work will be initiated for the demonstration of instrumentation and data acquisition systems necessary for making nonintrusive, three-component, unsteady velocity measurements in complex flow fields, including separated regions. Work will also begin on turbulent reacting shear-layer flow-fields validation experiments, with results used to determine the predictive accuracy of a three-dimensional Navier-Stokes code. Design of multistage axial research airfoils will also be completed for future testing in the large, low-speed test facility to complement the centrifugal compressor test data base now being developed.

Materials and Structures Research and Technology

The objective of the materials and structures research and technology program are to: (1) develop and characterize advanced metallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, durability, weight reduction of up to 40 percent, and reductions in aircraft life cycle cost. Areas of emphasis include high-temperature engine and airframe materials and structural concepts, composite materials application, life prediction, thermal and dynamic response including aeroelasticity, helicopter structural dynamics and airloads, and more accurate and efficient integrated design optimization methods for airframes and engines.

Research in turbine engine materials continues to create a strong technology base for ceramic materials applications up to 3000 degrees Fahrenheit with increased reliability and reproducibility. Toughened silicon-nitride ceramic composite materials with improved strength at high temperatures have been fabricated by a new slurry pressing processing method. The objective of the FY 1988 program is to identify critical processing variables controlling reliability, creep strength at elevated temperature, and toughening mechanisms for silicon-carbine and silicon-nitride ceramics. A major new emphasis on ceramic composite materials was initiated in FY 1988 as part of an advanced high-temperature engine materials program. The development of ceramic composites is expected to provide a materials system that is of sufficient strength and durability to have a wide range of design applications in advanced turbine engines, including high temperature blades and vanes.

In aircraft materials research, studies are being conducted in advanced composite materials to develop new, lightweight composites for high-temperature airframe and engine applications. A new thermoplastic polyimide, identified as LaRC-TPI, has been developed by Langley Research Center for use up to 450 degrees Fahrnheit with improved processability and high-temperature properties. This material is currently being evaluated by the airframe industry for potential future applications in advanced aircraft. Significant advances have been made in developing materials and processing methods for superplastic forming of aluminum alloys to achieve a 35 percent cost savings and 25 percent weight savings compared to conventional aluminum airframe construction. High-temperature intermetallic structures for airframe and propulsion systems have been fabricated using a new bonding process to demonstrate feasibility of lightweight structures for use up to 1800 degrees Fahrenheit. New processing methods for hot-forming, pultrusion and filament winding of composite airframe structures have been developed to demonstrate the potential for major reductions in fabrication cost of composite structures.

Computational structural mechanics (CSM), a major thrust in FY 1988, continues to focus on the development of advanced structural analysis and computational methods that exploit advances in computer hardware and software, such as multiple processors and parallel processing capability. CSM computational test models have proven to be an effective means to accelerate development of new computational methods and the exploitation of advanced computer technology. Advanced CSM methods are essential to permit efficient design and analysis of complex structural configurations and loading environments, such as composite structures, high-temperature structures, fluid-structure interaction and prediction of nonlinear structural response including post-buckling of airframe structures. CSM technology will be directed toward developing analysis methods for very large, complex structures requiring the latest and most powerful computer technology.

Research in aircraft structures emphasizes the development of design and analysis technology for efficient damage-tolerant advanced composite structural components and innovative structural concepts to achieve reductions in structural weight of 50 percent and cost reductions of at least 25 percent through low-cost fabrication methods. Thermomechanical structural analysis using probabilistic modeling concepts to predict reliability of engine structural components has been developed for high-temperature complex engine structures. Interdisciplinary design methods, including design optimization, will be developed and compared in a joint NASA/industry program to assess optimization methods for aeroelastic designs of advanced wing configurations. Analytical and experimental methods will be developed to predict structural loads due to intense acoustic radiation resulting from interaction of jet exhaust plumes. Significant accomplishments include the develop-

ment and evaluation of a filament-wound composite spar and a pultruded composite wing panel, evaluation of high-temperature properties of intermetallic structures for airframe and engine application, and performance and analysis of a crash dynamics test of composite fuselage structures.

In the aeroelasticity program, new and more efficient unsteady aerodynamic computational methods, with emphasis on transonic flow, have been developed and verified experimentally. A comprehensive transonic unsteady aerodynamics computer code for complete aircraft modeling has been released to the Department of Defense (DoD) and industry for evaluation. The FY 1988 objective is to complete the code verification for this flutter analysis capability for complete aircraft configurations. Actively controlled flexible-wing concepts will continue to be evaluated in the transonic dynamics tunnel to explore the potential for reducing the maneuver loads with at least 30 percent improved roll rates. Flexible-wing concepts can provide a major advance in future high-speed aircraft design through improved performance and reduced structural weight.

In rotorcraft research, analytical models of interactions between rotor vortex and rotating blades are being developed to predict airloads and acoustic levels generated in forward flight. Tests of blade-vortex interaction (BVI) are planned for an S-76 rotor in the NASA 40x80-foot wind tunnel. BVI noise reduction concepts will be explored by conducting definitive experiments in low-noise rotor systems in the transonic dynamics tunnel. Tilt rotor acoustic prediction methods will be validated by wind tunnel and flight test data to be acquired in FY 1988. Low-noise tail rotor designs and analytical models of main rotor/tail rotor noise interaction will be developed to provide a basis for advanced rotorcraft with reduced rotor noise.

Hypersonic research continues to explore innovative new materials and structures concepts for airframe and propulsion systems for advanced aerospace vehicles. Current research is directed toward development of new lightweight materials systems and structural concepts that will withstand the extreme high temperature and loads encountered in the hypersonic flight regime. Scramjet strut test specimens will begin with tunnel tests in FY 1988 to validate various structural concepts and materials systems for actively cooled structures. Hypersonic materials research on carbon-carbon fiber-reinforced material will be directed toward developing improved coating systems to reduce oxidation and on processing methods for improved thin gage high-temperature material properties. Carbon-carbon structural concepts for hypersonic control surfaces are being explored to determine the feasibility of using these composite systems for long-term applications. Analytical thermal/structural models will be developed to determine thermal effects on structural joints and stiffness, and an assessment of high-temperature effects on vehicle aeroelastic response will be made.

Research on materials will concentrate on advancing the understanding of material behavior, properties, microstructures, and processing parameters for advanced metallic, ceramic, polymer, and composite materials with primary emphasis on high-temperature application. New and tougher resin/fiber composites, high-temperature polyimides (700 degrees Fahrenheit), carbon-carbon composites, intermetallic aluminides, and aluminide matrix-silicon carbide composites will be developed. Work on powder metallurgy and weldable superplastic forming techniques for aluminum will continue with greater emphasis. Fundamental material behavior and processing techniques for ceramic materials will be pursued. Generalized, multiaxial constitutive models for composites will be developed for prediction of environmental effects, high-temperature cyclic damage, and loading rate dependence.

Composite materials and structures research will continue to focus on development of advanced cryogenic composite materials systems for airframe and engine applications as well as analysis methods for structural life prediction. Analytical and experimental studies will concentrate on understanding failure mechanisms and developing improved methods for analysis of complex composite structures. New structural concepts such as pultruded wing panels will be examined through structural tests to verify performance of low-cost composite structures and identify failure modes of complex skin-stiffened panels. A major program initiative in advanced composite materials is planned for FY 1989 to focus on development of new composite materials, innovative structural concepts and advanced fabrication methods that fully exploit the benefits of advanced composite materials. The composites base research and technology program will provide the fundamental foundation for understanding failure mechanisms and fiber/matrix interactions that will then establish a basis for the innovative structural concept design program.

The dynamics and aeroelasticity program will emphasize the development of improved analytical tools for predicting 3-D unsteady aerodynamic loads for transonic flow for total vehicle configurations. This 3-D analysis capability is needed to enable accurate prediction of flutter boundaries for complex aircraft configurations including effects of external stores. Propulsion aeroelasticity programs will focus on supersonic flow-through and counter-rotating turbomachinery research. New airfoil concepts, such as the flexible actively controlled wing that includes large-scale component development test and analysis verification, will be explored through wind tunnel testing to measure the expected reductions of up to 30 percent in maneuver loads and improved roll rates (30 percent) provided by this concept for high-performance aircraft applications.

Integrated analysis and design optimization efforts will concentrate on development of efficient methods in CSM for the analysis of complex aerospace vehicles and propulsion systems. The emphasis on innovative design concepts including minimum gage composite material systems for lightweight structurally efficient systems and the complex loads environment future aircraft vehicles experience requires a significant improvement in current structural analysis capability. Current analysis requirements are generally limited to linear elastic behavior but future missions and performance needs will require more detailed nonlinear structural prediction capability. Emphasis will be placed on nonlinear analysis of high-temperature engine structures, transient dynamics analysis of local/global airframe analysis and probabilistic analysis of complex engine components. Nonlinear analysis methods will be developed

for large displacement of postbuckled composite panels required for new innovative fuselage and wing structures. CSM analysis methods development will continue on concurrent computing methods using multiple and parallel processing to enable implementation of solution methods for complex 3-D structures that cannot be achieved on conventional serial processing computers. CSM research will focus on developing solution methods for large, complex, structural analysis problems requiring the newest most powerful computer technology. Design optimization research will concentrate on development and comparison of optimized aeroelastic wing configurations and analysis methods for high-performance aircraft. The overall objective is to develop the next generation of new analysis methods required to effectively design future airframe and propulsion systems subjected to the complex thermal, mechanical and acoustic loads environment future aircraft vehicles will experience.

Subsonic transport, commuter airplane, and general aviation aircraft research will be focused on developing analytical models and conducting experimental studies to improve aircraft ground operations and crashworthiness. Composite fuselage structures will be evaluated for crashworthiness in the NASA crash facility to examine energy-absorbing composite structural concepts. The NASA/U.S. tire industry modeling program will continue to develop models for tire wear including contact models for various tire configurations. Advanced tire testing on radial-ply tires for military and commercial aircraft and wear models will be developed to predict performance of aircraft tires and improve safe operations.

Rotorcraft research will continue to concentrate on developing experimental and analytical methods for airloads and structural dynamics analysis of rotor systems and airframes. In FY 1988, transonic dynamic wind tunnel tests will be completed on tapered rotor blades with advanced airfoil sections to develop improved performance rotors for advanced rotorcraft. Vibration, aeroelastic stability, and performance investigations of tailored bearingless rotors with advanced airfoil sections will be continued to develop advanced rotor structures with improved life and reduced structural noise. A comprehensive analysis code for prediction of full system helicopter noise (ROTONET) will be completed and transferred to industry.

Hypersonic materials and structures research will continue to be a major emphasis in FY 1989. Innovative concepts to enable future high-speed, high-temperature aerospace vehicles will continue to be developed. Integrated flow/thermal/structural analysis methods will be used for accurate mission loads prediction to aid the development of lightweight, efficient, and durable design of airframe and propulsion systems. New materials concepts for scramjet struts will be evaluated to determine the high-temperature performance of actively cooled hot structures. Additional focus will be on intermetallic composites and carbon-carbon reinforced materials; constitutive behavior and characterization of high-temperatures, lightweight composites; fabrication of intermetallic composites with low-density matrices; and oxidation-resistant and thermal barrier coatings. This will then provide the technology basis for development of design concepts for wing/fuselage structural configurations that are radically different than conventional skin/stringer/frame design concepts used today.

Information Sciences Research and Technology

The objectives of the information sciences research and technology program are to provide the fundamental capabilities to: (1) exploit advanced computer architectures to meet NASA's unique computing requirements, (2) increase the agency's ability to develop high-quality aerospace systems software, and (3) provide the advanced theory, concepts and capability to effectively use and manage aerospace information. Effective exploitation of computational modeling of physical processes, such as computational fluid dynamics (CFD), will be enabled through the development of a fundamental understanding of the relationship between physical algorithms and advanced parallel processing architectures. Research on the theoretical foundations for managing complex software systems and on the development and validation of reliable software is directed toward improving the quality and cost of complex mission-critical hardware and software.

Parallel processors offer the potential for enabling numerical simulation at affordable costs. Evaluating performance of parallel processors is an important problem to both computer system architects and application developers. A performance prediction method has been developed which is based on a graphical representation of the computational processes. This new method allows quantitative assessment of network queues, task residence times, and utilization of resources in a proposed concurrent processing system. These tools are expected to be useful in evaluating different concurrent architectures, and in the detection of bottlenecks in hardware and software, as well as in the comparison of task allocation and partitioning schemes.

A new concept in distributed operating systems has been developed this year. This distributed operating system is based on the concept of "objects," computer code or data, which users manipulate via "processes" and "transactions." The distributed operating system is operational on a cluster of VAX 750 computers. It provides the user with the capability to perform distributed computing tasks with no concern for machine boundaries.

The software automation generation and administration (SAGA) tool has been developed at the University of Illinois to improve the reliability and cost of mission-critical software. The SAGA software engineering environment supports the concepts of development by incremental refinement, executable specifications, and formal verification. The most promising software development methodologies are being incorporated in the NASA software acquisition life cycle and documentation standards which govern all NASA software projects.

The visusal comparison of experimental and computational results is an important problem to the field of computational fluid dynamics (CFD). A new technique has been developed to digitize and store experimental holographic interferogram data and to extract, scale, color code, and overlay computational density contours from a CFD program. Methods to effectively compare experimental and computational results will provide a better understanding of

the physics being investigated and contribute to the validation of CFD codes.

The high-speed mainframe computer networking subsystem continues to provide NASA aeronautical researchers remote access to the agency's mainframe computers. The system supports transmission rates up to 1.5 million bits per second from NASA's geographically distributed research centers.

Research on the use of novel parallel processors controlled by new algorithms for efficient numerical simulation will continue at the Research Institute for Advanced Computer Science (RIACS) located at Ames Reseach Center. A family of parallel processing computers will be utilized for this research, including a Sequent Balance, Intel Hypercube, Connection Machine 2, and Convex C1. Performance of special purpose CFD computers, including a systolic processor and the Navier-Stokes machine, will also be evaluated. These experimental parallel processors are comprised of a large number of very low-cost computers grouped to attack a computer problem, as opposed to the single very high-speed supercomputer approach typically employed. This research will address other aerospace applications of parallel processing including computational structural dynamics and vision research.

Research in sparse distributed memory, developed as a mathematical model of human long-term memory with the properties of associative recall, will continue. The ultimate capability of such a memory could include computer vision and natural language. A hardware simulator will be developed and evaluated in a number of aerospace application studies. One set of evaluations will include the study of how effectively the computer can be trained to recognize characters.

In the area of software engineering, studies will quantify the reliability gained from formal specification, software prototyping, computer-aided software engineering systems, software reuse, and formal verification. The approach of algorithm diversity appears promising and will be evaluated for a reasonably complex aeronautics control problem. The block grant for the Illinois Computing Laboratory for Aerospace Systems and Software will address characterization and evaluation of automated support tools for increased reliability in software specification and design.

NASA will continue to support the operation of the computer networking system to provide for the effective and productive use of NASA's distributed computing resources. NASA will continue to work through the Federal Coordinating Council on Science, Engineering and Technology to coordinate national access to high-performance computers.

Controls and Guidance Research and Technology

The controls and guidance research and technology program will provide a technology base supporting future aircraft designs which will be capable of safer and more efficient operation and will have greatly expanded flight envelopes. In order to provide this technology base, the specific objectives of the controls and guidance program are: (1) exploit emerging controls, guidance, and artificial intelligence technologies for the development of advanced automation concepts; (2) development of highly reliable system architectures and validation methods leading to flight-crucial systems; (3) development of sensors for airborne wind shear detection and flight management avoidance techniques; (4) development of advanced control, guidance and display theories, concepts, and analysis methods; and (5) development of new methodologies for achieving multidisciplinary integration.

Knowledge-based control and guidance concepts have been shown to be feasible for both improving system performance and for improving crew-vehicle interface. Extensive simulation studies examining advanced time-based traffic management concepts were conducted and a preliminary series of flight tests was completed. The results of these tests indicate more accurate arrival times can be achieved, leading to airport capacity increases. A controller advisor and expert system schedule advisor have been evaluated in air traffic control simulations by Federal Aviation Administration (FAA) controllers in preparation for upcoming flight evaluations at Denver. The use of data link for the automated transmission of flight clearances has also been evaluated in simulation. These automation aids will improve controller workload in peak traffic situations. Concepts for automated, real-time mission planning have been identified and are being evaluated for application to rotorcraft all-weather, nap-of-the-earth flight.

A candidate system architecture for highly reliable, integrated airframe/propulsion control systems for high-performance aircraft has been established. Advanced analytical and experimental validation methodologies are being used to assess the reliability and performance of this architecture which will enable more efficient and higher performance in future aircraft. Lightning characterization studies resulted in the definition of lightning wave forms which have been adapted as a Society of Automotive Engineers (SAE) standard for evaluating the effect of lightning on avionic systems. Initial planning for a research program to develop validation and verification methods for knowledge-based systems is underway. These methodologies will be required for the flight-critical application of future knowledge-based expert systems.

An analytical wind shear model has been developed, validated, and transferred to industry for use n simulation studies and in evaluating candidate detection and warning system characteristics. Design requirements for an experimental doppler radar wind shear sensor have been defined and the flight experiment plan developed. Sensor technology to be used with an aircraft hazard index for determining the severity of wind shear in front of the aircraft was developed, evaluated, and transferred to industry. Energy-based guidance techniques for wind shear recovery were developed and evaluated in simulation.

Innovative flight test techniques for the real-time evaluation of in-flight stability levels were developed and utilized in the X-29 flight test program, resulting in greatly reduced costs and flight test time. A study was completed which identified deficiencies in control power which exist for a class of generic hypersonic aircraft. Innovative approaches to overcome these deficiencies through the use of thrust modulation, pop-out surfaces, and other new types of force generators are being explored. A high-fidelity fighter simulation model, incorporating nonlinear, unsteady aerodynamics, struc-

tural dynamics, and thrust vectoring, has been developed for use in exploring advanced multidisciplinary concepts for supermaneuverable aircraft.

Beginning in FY 1989, approximately $10 million for operations and maintenance of simulation facilities at the Ames Research Center has been realigned to this program from human factors research and technology to more appropriately reflect the contributions of these facilities to this discipline.

Increased emphasis will be placed on development of automation concepts leading to enhanced safety and productivity in the national airspace system. Flight evaluations of the controller advisor and expert schedule advisor will be conducted jointly with the FAA at Denver's Stapleton Airport, allowing reductions in controller workload and more efficient handling of air traffic. Also in cooperation with the FAA, the feasibility of using advanced display concepts and operational procedures for close-spaced parallel and converging runways will be evaluated in flight at the Raleigh-Durham Airport. If successful, these tests could lead to an increased number of operations under instrument meteorological conditions at a number of major airports. Full mission simulations incorporating near- and far-field planning and advanced control and guidance concepts enabling rotocraft nap-of-the-earth flight in all weather conditions will be conducted.

Experimental validation of methodologies for predicting effects of lightning on aircraft avionics will be conducted in Langley Research Center's avionics integration research laboratory (AIRLAB), utilizing a digital jet engine controller. An analytical program allowing the prediction of lightning interactions with aircraft systems will be made available to industry through the Computer Software Management Information Center (COSMIC). Increased emphasis will be placed on the development of validation methods for flight-crucial systems. These methods will be required prior to in-flight use of expert systems requiring high levels of reliability.

In FY 1989, development of the experimental radar scatterometer for flight evaluation of airborne wind shear sensing will be initiated. Adaptive guidance algorithms for the avoidance of, and recovery from, wind shear encounters will be evaluated in simulation studies.

Emphasis in guidance and display technology will be placed on improving the situational awareness of the flight crew. Materials and fabrication techniques enabling practical-sized, color, thin-film electroluminescent displays will be evaluated. Investigations of alternate formats and crew input-output techniques for a large-screen "whole-flight-deck" display concept will be conducted. Control algorithms leading to greatly enhanced maneuverability will be evaluated in a wind tunnel test of an advanced fighter design featuring a highly flexible, lightweight, wing design.

Human Factors Research and Technology

The objective of the aeronautical human factors research and technology program is to provide the capability to design effective crew-cockpit systems using advanced cockpit automation technologies which will properly integrate the diverse systems, operators, and procedures within the mission requirements and environment. This is necessary for safety, productivity, efficiency, and increased effectiveness in advanced commerical and military aircraft, rotorcraft, and the national aero-space plane (NSAP) program. Human capabilities and limitations of crew personnel and their interactions with systems, components, procedures, and flight requirements are determined and refined in order to delineate guidelines. These guidelines provide the roadmap to understand how to integrate the crew with automation technologies in the cockpit. There are four areas of emphasis: (1) flight management, (2) human engineering methods, (3) rotorcraft, and (4) subsonic transports.

In the flight management research program, automation devices currently in use in cockpits were evaluated to determine the extent of situational awareness maintained by the flight crews. An expert system, called Faultfinder, was developed and evaluated to provide early detection of engine failures and recommended alternatives for safe flight operations.

The effects of wind shear were quantified and piloting techniques for recovery and escape evaluated by simulation. This information resulted in the development and verification of a wind shear hazard index which provides a standard by which wind shear at different sites and under different conditions can be evaluated. A full-mission simulation of the FAA traffic alert and collision avoidance system (TCAS) was conducted using pilot evaluation. A comprehensive set of conflict scenarios was investigated in a safe, controlled, but realistic, research setting. The initial research results demonstrated significant potential for increased safety in flight, and also identified additional areas of study to eliminate other problems in operational conditions.

Human factors research to support advanced military and civilian rotorcraft has resulted in a mission-oriented aircrew/aircraft integration simulation capability. This system allows rapid cockpit reconfiguration by the analyst at his/her desk to assess different combinations of personnel (anthropometric values), advanced displays and controls, and mission requirements. Night vision requirements for rotorcraft crews were translated into specific flight procedures to overcome existing problems in night operations. Both in-flight tests and simulator tests were conducted to support these procedures.

Beginning in FY 1989, approximately $10 million for operations and maintenance of simulation facilities at the Ames Research Center has been realigned from this program to controls and guidance research and technology to more appropriately reflect disciplinary support of this activity.

A new program initiative in human factors will begin as part of a special effort in aeronautical safety. Two purposes are to provide: (1) increased emphasis on optimal integration of humans and automated systems to reduce threats to aviation safety and (2) decision aids and flight crew/air traffic control (ATC) system support systems, especially for contingency operation. Research in the human factors program will continue to serve NASA's needs for identification of the effects of automation technologies in the cockpit. Development of design principles for the human-automation interfaces in intelligent, error-tolerant flight systems is a major focus. Pilot simulations to evaluate the onboard engine fault monitoring and

diagnosis expert system, Faultfinder, will be conducted to qualify the benefits and to examine crew interface. The evaluation of new, improved strategies and procedures will be continued in order to verify automated flight decks and their usefulness and safety aspects in maintenance of full situational awareness.

Application of human performance measurement methods to high-risk rotorcraft flight environments and missions will continue, and results will be applied to police and medical evacuation rotorcraft operations. The computer-based rotorcraft aircrew/aircraft integration analytical tool will be expanded to support the predictive design and human engineering of Army rotorcraft cockpit systems.

Evaluation of human factors issues in operational use of TCAS will continue with particular attention to TCAS involved and excessive altitude deviations which could prove problematic. Aviation safety reporting system research activities will continue to examine incidents involving operational errors in the ATC system, pilot deviations and near mid-air collisions, and air carrier operations impacted by minimum equipment list issues. In-flight data collection and pilot simulation studies will be conducted to establish certification criteria for long-haul transport operations.

Flight Systems Research and Technology

The objective of the flight systems research and technology program is to provide the necessary research and technology development for an improved and validated base of advanced technology for application by industry to future generations of the entire spectrum of aircraft. In many cases, joint funding is provided by NASA, the Department of Defense (DoD), and the Federal Aviation Administration (FAA). The program is organized into the following categories: (1) aviation safety; (2) flight instrumentation and test techniques; (3) fighter/attack aircraft; and (4) flight support. The activities within this program encompass advanced engineering techniques and the establishment of the feasibility of concepts to ensure rapid application of promising new technology essential to meeting one or more of the following goals: (1) reducing aircraft accidents resulting from weather effects (heavy rain and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of needed information; and (3) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high angle-of-attack (up to 90 degrees) flight conditions and vertial landing capability.

The objectives of the activities in aviation safety are to provide a better understanding of aeronautical safety hazards and their consequences and to provide criteria for design of aircraft systems and operating techniques. The present effort involves the development of analytical models to predict ice accretion and its effects on aircraft handling qualities and airfoil performance for both rotary- and fixed-wing aircraft and development of ice protection concepts.

During FY 1988, the test of the composite wing section with an intercalated graphite thermal deicing system is being conducted in Lewis Research Center's icing research tunnel. In addition, a flight test program investigating the effects of artificial ice shapes on aircraft stability and control is being conducted. A design report on the electromagnetic impulse deicer system will also be published. In the area of heavy rains, a full-scale wing section is being tested using the aircraft landing dynamics facility with a spray rig assembly straddling the track. The test data will be used to assess the aerodynamic performance penalties due to heavy rain effects.

The objectives of the flight instrumentation and test techniques activity are to improve flight test efficiency and information accuracy by using innovative techniques and devices to obtain needed data.

The objectives of the fighter/attack aircraft activities are: (1) to refine and validate aerodynamic predictive tools at high angle-of-attack flight conditions and demonstrate the performance benefits and utility of propulsive flight control and (2) to develop efficient concepts for advanced short takeoff and vertical landing aircraft. A technology development program for advanced short takeoff and vertical landing (ASTOVL) aircraft is being conducted under a memorandum of understanding with the United Kingdom, DoD, and NASA. A series of propulsive-lift concepts has been studied and assessed to determine which of the most promising concepts should be pursued into detailed technology development/validation phases. The objective of this collaborative program is to bring the most critical ASTOVL technologies to a state of readiness by the mid-1990's.

The objectives of the flight support program are to provide a variety of support services to flight research projects using standard aircraft for chase, airspeed calibration, remotely piloted research vehicle air drops, and flight crew readiness training. Replacement of the aging F-104 high-performance support aircraft at the Dryden Flight Research Facility with Navy-loaned full-scale development F-18 aircraft is continuing.

In FY 1989, the aviation safety program will emphasize coordinated wind tunnel and analytical investigations of the effects of ice accretion on rotary-wing aircraft performance and handling qualities. Data from the full-scale wing section tested in the aircraft landing dynamics facility will be available. This wing section will have been propelled along a track through an overhead water spray system simulating heavy rain. This data base will yield an understanding of the effects of heavy rain on aerodynamic performance.

Wind tunnel and analytical research will be conducted to investigate the potential benefits and the aerodynamic, propulsion system, and structural interactions resulting from multiaxis thrust vectoring at high angle of attack. Simulator and design studies will be completed to establish a data base for potential integration of aerodynamic and propulsive flight controls on the NASA F-18 high angle-of-attack research vehicle. In the U.S./United Kingdom ASTOVL program, activities will be initiated on the most promising aircraft concepts identified by the design studies completed in FY 1988.

During FY 1989, in the flight instrumentation and test techniques area, a flight test of the basic computer module for an advanced airborne information management system will be conducted. Also, an advanced flight test instrumentation package for measurement of pressures, temperatures, and aircraft motions will be assembled using newly developed sensors and systems.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft. These high-performance support vehicles will be flown as chase aircraft in support of research aircraft described under high-performance aircraft systems technology (X-29A, F-15, F-18, YAV-8B) and rotorcraft systems technology (X-wing, XV-15 tilt rotor). Also included during this period will be specialized training for critical personnel, as well as maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

Systems Analysis

The objectives of the systems analysis effort are to identify and quantify the impact of emerging technologies in aerodynamics, materials, structures, propulsion, and systems that can lead to new plateaus or major improvements in civil or military aircraft of the future, create new markets, reduce noise and environmental impact, and provide potential new economic benefits. Conceptual designs are performed incorporating new technologies, and sensitivity analysis and tradeoff studies are conducted to quantify the benefits of the emerging technologies.

Systems analysis studies of transport aircraft concentrated on the impact of ultra high-bypass propulsion systems for improving the efficiency of large (500-passenger) long-range transport aircraft. These propulsion systems offer the potential of reducing fuel usage by 20 to 25 percent compared to conventional turbofan engines. Also, the benefits are being assessed for the application of superconductivity to general aviation, commuter, and subsonic transport propulsion and control systems. If electric motors and generators can be made to be very lightweight and powerful through the use of superconductivity, the conventional propulsion and control system could be revolutionized.

In FY 1988, systems analysis for rotorcraft is concentrating on advanced configurations and propulsion systems for high-speed tilt rotors and helicopters. High-speed rotorcraft has the potential application in the civil market to efficiently transport passengers between the downtown city and remote airports and, in the military market, to transport both troops and equipment to remote battle locations and to perform air combat missions. Computer conceptual design codes are being improved so that the benefits of new technologies to alternative high-speed rotorcraft configurations can be quantified. These codes have been and will continue to be used both by NASA and the Army as part of the V-22 joint technology assessment study.

A major study effort is in progress to identify the most promising vehicle and propulsion system concepts for high-speed civil transportation (from Mach 2.0 up to Mach 25). The studies show that commercial supersonic passenger transportation can be economically viable for a 300-passenger, 6500-nautical-mile high-speed civil transport. Also, the studies show that these advanced vehicle concepts could only be enabled by the development of advanced technologies. The studies, performed by two major aircraft manufacturers with propulsion systems manufacturers as subcontractors, address advanced vehicle concepts enabled by emerging technologies, including those from the national aero-space plane (NASP) program. Sensitivity studies are in progress to assess the benefits and technical risk of configuration options in terms of civil airline operations. To augment the contractual studies, in-house studies are being performed in the following key opportunity and problem areas: sonic boom, community noise, environmental impact, airframe propulsion integration, and fuels. In FY 1988, the concept feasibility is being developed and potential benefits assessed for an advanced supersonic throughflow fan engine capable of powering a supersonic civil transport. The concept has the potential of a 12-percent efficiency improvement over a conventional turbofan engine for this application.

Systems analysis for high-performance aircraft in FY 1988 focuses on advanced short takeoff and vertical landing (ASTOVL) aircraft. As part of a cooperative U.S./United Kingdom program, five conceptual configurations developed by contractual studies have been normalized for evaluation, and the down-selection is in progress. The focus for the technology development will be on the selected configuration. Preliminary investigations are in progress for the potential aeropropulsion application of superconductivity to highly maneuverable fighter aircraft. These concepts offer the potential of having remote electric propulsion systems for active aircraft control and enhanced maneuverability.

In FY 1989, studies to identify specific high-payoff technologies and associated benefits for ultra-high-bypass engines suitable for large long-range transport application will continue. By incorporating advanced technologies in the core of these propulsion systems, their fuel efficiency can be further improved by at least 25 percent.

Systems studies for rotorcraft will continue to focus on the high-speed regime. Two major contractual studies are planned. These studies will provide direction and research focus toward high-payoff technology areas for rotorcraft capable of high subsonic cruise speeds, quiet and efficient hover, and economic viability. Helicopter, tilt rotor, X-wing, stowed rotor and other unique concepts will be assessed. Efficient, high-speed and low-noise rotorcraft have many applications to civil transportation for solving such problems as air and ground congestion and to the military for enabling new combat strategies and missions. The studies will identify new and emerging technologies to enable low-noise configurations, advanced propulsion systems, automated single-pilot operation, and advanced composites and structures concepts. Computer codes used in the conceptual design process will continue to be updated with new technologies data for the credible prediction of the performance, weight, cost, and other characteristics of advanced rotorcraft concepts.

The high-speed civil transportation studies with the two major airframe manufacturers will continue through FY 1989. The studies are focused to assess the impact of advanced technologies on the most promising, economically viable concepts. The in-house systems analysis efforts are concentrating on assessing the benefits that advanced technologies have on reducing the airport noise which high-speed transports create, and the sonic boom levels for overland supersonic flight, as well as assessing the impact a fleet of high-speed civil transports would have on the earth's atmosphere. Atmospheric models will be utilized to determine the impact of aircraft emis-

sions on the earth's stratospheric ozone layer. Also, studies will be performed addressing cycle and noise suppression concepts for reducing community noise. A variable-sweep wing configuration will be evaluated for reducing the engine power required for landings, thus reducing ocmmunity noise, and for increasing fuel efficiency at subsonic cruise speed. By wind tunnel testing of advance high-speed transport configurations, sensitivity studies will be performed to assess the effect aircraft configuration has on sonic boom over pressure levels and signature characteristics. A high-speed transport with supersonic overland operational capability would be much more economically attractive to the airlines. Studies are being initiated to determine the public acceptability of sonic boom over pressures and the sensitivity of this acceptability to the signature. In-house conceptual designs will be performed for two concept vehicles, one that has a cruise speed of Mach 3 and the other that has a cruise speed of Mach 4. These designs will focus on key opportunity and problem areas, such as propulsion/airframe integration including inlets and nozzles, supersonic laminar flow, advanced materials and structural concepts, thermal management, and advanced wing planforms.

In FY 1989, high-performance aircraft systems analysis will focus on new capabilities enabled by key technology developments in high-thrust propulsion systems for supermaneuverable ASTOVL and conventional takeoff and landing fighter aircraft. Performance evaluation criteria will be established for assessing advanced configurations. Improved high-thrust engine models will be developed for assessing the impact of advanced technologies. Studies will continue to assess the advantages of advanced thrust vectoring technology and superconductivity technology to supermaneuverability.

Systems Technology Programs

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Materials and structures systems technology	$8,800,000	29,200,000
Rotorcraft systems technology	4,600,000	4,800,000
High-performance aircraft systems technology	12,800,000	11,000,000
Advanced propulsion systems technology	18,000,000	14,000,000
Numerical aerodynamic simulation	39,000,000	41,000,000
Total	83,200,000	100,000,000

Materials and Structures Systems Technology

The objective of the materials and structures systems technology program is to develop advanced materials and structural concepts for future advanced aircraft propulsion systems and primary structures.

In FY 1988, the turbine engine hot section technology element and the ceramics for turbine engines element were combined and augmented to form the advanced high-temperature engine materials technology program. The programs were combined to focus their efforts on developing fundamental technology for revolutionary advances in high-temperature materials for advanced propulsion systems. The objective of the advanced high-temperature materials research is to develop very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life, hot-section components which can endure sustained operation without cooling air and thus enable significantly higher fuel efficiency. Key to these applications are materials capable of operating at much higher temperature and strength levels than now possible. These advanced materials will provide for a significant decrease in weight, while allowing an increase in maximum operating temperature and an extension of life. Existing materials currently in use, such as titanium alloys and nickel-base superalloys, offer only minor potential gains in performance. The candidate advanced materials include ceramics and ceramic matrix composites, metal matrix composites, intermetallic matrix composites, polymer composites and carbon-carbon composites. Advanced materials such as these are vital to attaining higher turbine inlet temperatures for sustained supersonic cruise, higher thrust-to-weight engines for advanced high-performance concepts, and engine hot-section components without cooling air for greater fuel efficiency. In addition, analytical codes to conduct design, predict life and establish failure mechanisms will be developed to enable effective utilization of these new classes of materials by engine manufacturers.

In FY 1988, techniques and methodologies to fabricate and test revolutionary new materials, such as metal matrix and ceramic matrix composites, were developed. Also, work in several supporting technologies, including high-temperature sensor development, nondestructive evaluation, and loads definition, was pursued. Techniques to optimize the fabrication of silicon-carbide/intermetallic alloy composites were developed and introduced into laboratory practice. An initial data base compilation on the high-temperature oxidation characteristics of candidate alloys for metal matrix composites was completed. Initial efforts were conducted to produce, by chemical vapor deposition, ceramic matrix composites containing silicon-carbide fibers to enhance resistance to sudden brittle failure. Progress was made in developing resins capable of oxidative stability at 700 degrees Fahrenheit and above. Novel test methods were developed for measuring elevated-temperature tensile, fatigue and fracture characteristics of metal matrix and ceramic matrix composites.

The objective of the advanced composite materials systems technology program is to develop advanced materials and innovative structural concepts to fully exploit the benefits of advanced composite materials for cost-effective primary structures for future aircraft applications. The program objectives will be accomplished through materials development, design and fabrication of innovative structural concepts, structural analysis and improved life prediction methods, and demonstration of improved structural performance through subscale and full-scale tests of critical components representative of advanced composite airframe structures.

Composite replacements for conventional metallic structures have demonstrated that organic-matrix composites can reduce airframe structural weight for primary structures on fighter aircraft and helicopters, as well as medium primary and secondary struc-

tures on transport aircraft. These first-generation applications have demonstrated the potential for composite materials, but the full benefits of advanced materials and new design and fabrication concepts have not yet been realized. It was determined that the full potential of 40- to 50-percent weight reduction and 25-percent cost reduction can be obtained by incorporating new materials in optimally designed composite structures that are both structurally efficient and more cost effective than current metallic or state-of-the-art composite structures. To achieve these objectives, a major advanced composite materials research program, building on current NASA and DOD research, is planned for FY 1989. This program will focus on developing advanced toughened thermoset and thermoplastic composite materials; new structural concepts using cost-effective fabrication techniques such as advanced thermoforming, multidirectional weaving, pultrusion, filament winding, and advanced fiber placement techniques; analysis, design and test methodologies to validate structural concepts; and analysis of failure mechanisms and methods for extending subscale laboratory tests to prediction of full-scale composite structural performance.

For FY 1989, advanced high-temperature engine materials research will emphasize fiber development, composite mechanics, and interfaces. Strong, stiff, lightweight reinforcement fibers, which are capable of maintaining chemical stability and mechanical properties at elevated temperatures, are a central issue to this entire program. To date, much emphasis has been placed on silicon-carbide fibers. Research will be pursued to develop small-diameter silicon-carbide fibers, as well as additional candidate fibers. This will include the development of processes for fiber fabrication and a comprehensive determination of fiber properties. The mechanical behavior and failure mechanisms of composite materials under the combined influences of stress (both static and cyclic) and elevated-temperature environment are highly complex and incompletely understood. Work in this area will be pursued at both the micro- and macro-mechanical levels. Time-dependent, visco-elastic effects, such as creep and creep-fatigue interactions, will be included. New concepts in damage mechanics will be pursued, including both analytical and experimental approaches. The characteristics and behavior of fiber/matrix interfaces can dominate the overall performance of composite materials at elevated temperature. The mechanical strength and environmental resistance of interfaces can exert disproportionate effects on composite strength and durability. Fundamental understanding of elevated-temperature interface behavior under severe oxidizing conditions in metal, intermetallic and ceramic composites will be pursued. In addition, other areas of emphasis will include the development of mechanical testing and environmental durability experimental capabilities for temperatures of 3000 degrees Fahrenheit and above, and development of metal-ceramic and ceramic-ceramic joining methods.

During 1988, advanced composite materials and structures research in the Research and Technology Base will focus on developing fundamental technology for application of composites to primary airframe structures. This research will be directed toward exploiting new organic-composite materials for use up to 600 degrees Fahrenheit and advanced processing and fabrication concepts for low-cost composite structures. These advanced materials incorporated in innovative structures, such as geodesic fuselage panels and pultruded wing planks, will provide structural weight savings of 40 to 50 percent. Advanced analysis methods including probabilistic modeling of composites for improved life prediction and analysis of composite failure mechanisms will provide essential components of the technology required for the full use of composite materials in advanced aircraft. The composite materials and structures technology developed in the research and technology base in FY 1988 will form the basis for the expanded program effort planned in the FY 1989 systems technology program. This research will focus on developing and demonstrating in the laboratory advanced structural concepts for wing and fuselage primary structures using new composite materials and will include in-house structural test validation to provide the confidence essential for use of composite materials in future aircraft systems.

Rotorcraft Systems Technology

The rotorcraft systems technology program consists of interrelated research on three fronts: (1) completion of noise prediction and reduction in cooperation with industry, (2) increased focus on technology for high-speed rotorcraft, and (3) completion of the flight research on the X-wing concept under a joint program with the Defense Advanced Research Projects Agency (DARPA).

In the noise research focus, the NASA/American Helicopter Society (AHS) cooperative program with industry concludes with the final release to industry of the NASA-developed comprehensive noise prediction code called ROTONET. Validation of the code with industry will determine if the prediction accuracy goal of ± 1.5 decibels for flyover noise was met. Final tasks under this program are the design of a low-noise rotor using conventional techniques and two innovative approaches: a radical planform concept (in small-scale testing) and a low-noise airfoil (in full-scale testing). Several noise sources that dominate in approach and takeoff have proved difficult to model and will be addressed in the research and technology base activities.

In high-speed rotorcraft research, there is an increased activity for tilt rotor technology and a new look at other, higher speed designs. The advanced composite blades for the XV-15 tilt rotor research aircraft are in flight testing to evaluate their promise for increased maneuverability, lower noise, and more efficient performance. Download reduction and a large-scale wind tunnel test of the rotor and wing of the Navy V-22 Osprey tilt rotor are being completed in cooperation with the Navy.

In the jont DARPA/NASA rotor systems research aircraft (RSRA)/X-wing rotor investigation, the goal is to investigate a stoppable circulation-control rotor concept which could increase the operational capability for future rotorcraft into the high subsonic flight regime. The prime objectives of this test program are to provide baseline technology, to generate engineering development design criteria, to acquire flight test data on the x-wing rotor system with stopped rotor and no blowing and with stopped rotor and manually controlled blowing, and to continue wind tunnel testing of the powered scale model through stopped-rotor blowing. Spe-

cial areas to be investigated are performance, aeroelastic stability, and rotor control characteristics of the X-wing rotor and control system. The aircraft, cleared to begin flight testing, has successfully completed high-speed taxi tests. A series of flight test will be conducted in FY 1988 to include tests with the rotor blades in a stopped/fixed configuration.

In FY 1989, the program will increase the effort on high-speed rotocraft. In noise technology, with the completion of the NASA/AHS noise program, the emphasis will shift to in-house acoustics research for military application and specific issues for high-speed rotorcraft designs. Far-field propagation and detection prediction are two military acoustics activities to be investigated. In addition, prediction of tilt rotor noise will be validated in all flight modes in order to understand the source phenomena and potential areas for reduction.

In other tilt rotor activities, the potential for active control, drag reduction, and improved performance will be investigated in the wind tunnel and in flight. A pressure-instrumented blade for the XV-15 will be manufactured to obtain the needed data base for the validation of methodoligies that are applicable to tilt rotor unique regimes. Cooperative efforts will also take place with the FAA for civil certification issues and with the Navy for V-22 tilt rotor technology assistance. The immense payoff of this technology for the nation through civil application is recognized in the government and by the industry and regional transportation authorities. The NASA technology program will help ensure the successful introduction of the tilt rotor to commercial service to meet urgent air traffic congestion reduction needs. In higher speed rotorcraft efforts, an X-wing model will be tested at transonic speeds to determine its maximum speed potential.

In FY 1989, the RSRA/X-wing research program will be concluded. The completion of the flight tests of a full-scale X-wing rotor will provide the data base for determining the next step in the development of this technology which offers significant potential for high-speed rotorcraft application.

High-Performance Aircraft Systems Technology

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research tests of advanced aircraft concepts and systems.

The F-18 high angle-of-attack research vehicle has been modified to a research configuration with the goal of obtaining a flight-validated data base for the design of highly maneuverable aircraft. Initial flight tests are focusing on the measurement of high angle-of-attack aerodynamics for correlation with wind tunnel and analytical predictions. For the NASA/Air Force advanced fighter technology integration (AFTI) F-111 mission adaptive wing (MAW) program, aircraft performance flights with the manual control modes of the mission adaptive wing system operational have been completed, and an industry workshop has been held to report the results. An 8 to 20 percent improvement has been obtained in the lift-to-drag ratio of the variable camber MAW wing compared to the basic F-111 wing configuration. This translates into significant performance benefits with both range and maneuverability improvement payoffs. Flight testing of the automatic camber control modes has been initiated. For the F-15 highly integrated digital electronics control (HIDEC) project, which builds on the capability developed during the digital electronic engines control (DEEC) and F-100 engine model derivative programs, flight tests of the adaptive engine control system (ADECS) were completed showing 15 to 25 percent improvement in overall aircraft performance. Work has been initiated on the performance-seeking-control (PSC) system development which will greatly improve the practicality of implementing the ADECS technology on various engine configurations without the necessity of obtaining a specific model of engine performance characteristics for early application. Final development of the F-106 vortex flap assembly has been completed, and the system has been installed and readied for test flight. The first flight will take place in FY 1988 to validate the predicted improvements in aircraft takeoff, landing, and maneuvering flight performance. Flight research utilizing a YAV-8B Harrier testbed is continuing to obtain validation of wind tunnel, analytical, and simulator predictions of vertical/short takeoff and landing aircraft aerodynamic, propulsion, and control characteristics. The NASA/DARPA X-29A forward swept wing flight demonstration program successfully completed envelope expansion flights which included evaluation of an enhanced flight control system and loads evaluations at elevated "g" levels. Results from the flight tests were presented to industry and DoD at several on-site workshops, with over 800 people in attendance. Results were well received as being applicable and timely to ongoing activities within the aerospace community.

The objective of the joint NASA/Navy oblique wing research aircraft program was to establish a flight-validated data base for application of the technology to future civil and military aircraft. This effort is being terminated in FY 1988 due to withdrawal of Navy funding.

In FY 1988, the turbine engine hot section technology element and the ceramics for turbine engines element were combined and augmented to form the advanced high temperature engine materials technology program in the advanced propulsion systems technology program. In FY 1989, the advanced high temperature engine materials program has been transferred to the reestablished materials and structure systems technology program to more appropriately group and manage systems technology efforts in that area.

The flight research activity in FY 1989 will involve several high-performance aircraft tests designed to investigate advanced concepts. Several projects will continue their flight phases during this period. Flight research on X-29 aircraft number one, including evaluation of buffet characteristics, performance evaluation and characterization of structural dynamics, will be completed in late FY 1988 and reported to industry through workshops and symposia in FY 1989. High angle-of-attack testing on X-29 aircraft number

two will be carried out primarily in support of DoD requirements in this area. Design of a performance-seeking-control system, including hardware and software, that will enhance performance improvements already demonstrated by the F-15 HIDEC, will be completed, and initial ground tests conducted prior to flight test evaluation on the F-15 HIDEC research vehicle. Flight tests of a self-repairing flight control system design, developed jointly with the Air Force to improve system failure detection and reliability, will also be tested on the F-15 aircraft during this period. Modification of the F-18 high angle-of-attack research aircraft will be initiated for installation of turning vanes and flight cntrols to permit thrust vectoring at high angles of attack. Results of the AFTI/F-111 MAW flight test program, having been completed in FY 1988, will be presented to the industry and DoD agencies in FY 1989 through workshops and symposia.

Advanced Propulsion Systems Technology

The objective of the advanced propulsion systems technology program is to explore and exploit advanced technology concepts for future aircraft propulsion systems in high-payoff areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology analytical and experimental data base necessary for achieving the concept's full potential. Information on aerodynamic performance, aeroelastic stability, and acoustic environment obtained from small-scale wind tunnels will be used for verification of analysis codes and also to support the gathering and analysis of experimental data under actual flight conditions using aircraft testbeds. During last year, the nine-foot-diameter large-scale advanced propeller and propulsion system was installed on the propfan test assessment (PTA) aircraft and structural, aeroelastic, and acoustic performance verified for propellers at large scale during flight tests. Good quality data have been acquired and indicate structural and acoustic levels better than, or at least equal to, predicted values. A high-aspect-ratio, contoured, nacelle-powered, semispan model was tested in a wind tunnel to gather detailed aerodynamic data behind the propeller to aid in the analysis of the large-scale results. The development and application of advanced analytical codes, such as Euler and Navier-Stokes, to the analysis and design of an integrated turboprop system were continued. Experimental installation aerodynamics wind tunnel research was also continued on a variety of turboprop and airframe configurations, including single- and counter-rotation propellers using wing- and aft-airframe mounts.

In the general aviation/commuter engine systems technology program, the objectives are to raise the performance level of small turbine engines to approximately that of large transport turbine engines, and to enable a 10-percent reduction in direct operating cost. The work continues to be focused on providing a detailed understanding of the design parameters that affect performance at the component level. Small engine component technology studies have been completed and provide a prioritized technology development plan. From these studies, it was determined that high-temperature materials, such as ceramics for the hot section, improved aerodynamics of components, and advanced cycles, including waste heat recovery, have the potential of reducing fuel use by 20 to 50 percent, with a corresponding reduction in direct operating costs of 12 to 20 percent for applications using small engines. The experimental evaluation of an advanced ceramic matrix combustor liner was completed, and full analysis of the data will be accomplished in FY 1988. Ceramics offer the potential of eliminating cooling requirements for combustor liners, thus increasing engine cycle efficiency. During FY 1988, the new small turbine facility, which is now operational, will be used to evaluate turbine performance penalties associated with inlet boundary-layer size and blade surface finish.

In FY 1989, advanced turboprop systems research will continue to emphasize source noise, cabin environment, turboprop and airframe installation aerodynamics, and the development of advanced aerodynamic and structural analysis techniques for both single- and counter-rotation propellers. The results of the flight test of the large-scale advanced propeller will be fully analyzed and compared to small-scale results to confirm scaling techniques for structures, aerodyanmics, aeroelastics, propeller source noise, and untreated cabin environment. The combination of aerodynamics and aeroacoustic analysis will continue in order to accurately predict the source noise of the complex shapes and multitude of configurations available for counter-rotation propellers. Experimental installation aerodynamics wind tunnel research will continue on a variety of turboprop and airframe configurations, including single- and counter-rotation and wing and aft mounts. These experimental results will be used to verify Euler and Navier-Stokes analysis codes for predicting aircraft flow fields. Advanced propeller research will include code development and verification using three-dimensional steady and unsteady transonic methods that consider counter-rotation interaction and evaluation of advanced concepts such as swirl recovery vanes and ultra-high-bypass-ratio ducted propellers, offering weight, noise, performance, and aircraft installation tradeoffs.

The general aviation/commuter engine technology effort will continue to demonstrate component improvements through the practical application of validated analysis codes that will enable high-performance small engine systems. Advanced turbine technology will continue to be emphasized in FY 1989 with the experimental evaluation of a cooled, high-work radial turbine and a mixed-flow turbine. Radial turbines offer very high work capability per stage, and successful cooling of small radial rotors has the potential to yield a very high-power compact turbine that can be used in high-pressure-ratio engines to provide system efficiency improvements of 15 to 25 percent. In another approach, the need for cooling can be potentially eliminated by using high-temperature materials, such as ceramics, although ceramics have not as yet proven strong enough to be used in a radial turbine. A compromise would be a mixed-flow turbine with almost as high work per stage, while significantly reducing stress levels. A mixed-flow metal turbine rotor will be used to evaluate the maximum stress levels during rig tests in preparation for fabrication and test of a ceramic rotor at a

future date. Modifications to the combustion research test rig will also be completed in preparation of testing the ceramic matrix liner to higher temperature levels for further thermal efficiency increases.

Numerical Aerodynamic Simulation (NAS)

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the nation's capabilities in computational fluid dynamics (CFD) and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. Ongoing research and technology base efforts in computational aerodynamics are benefiting significantly from the advanced computational capabilities to be provided by the NAS program. This program provides the computational capabilities required to obtain solutions to problems which are currently intractable. The combination of the NAS and CFD programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations and enabling the prediction of performance of complex aircraft geometries. To meet this goal, the NAS program is pursuing the following objectives: (1) acquire pathfinding, state-of-the-art high-speed processors; (2) provide a uniform, user-friendly system with equivalent capabilities for local and remote users; (3) provide an auxiliary processing center for secure processing; (4) investigate and incorporate parallel architecture machines into future generations of NAS; (5) provide a hardware and software development environment for prototyping and testing of computers, networks, storage devices, workstations, and graphic output devices; and (6) continue to research and develop an increasingly sophisticated system of hardware/software tools and environment to assist the user in performing CFD tasks and to improve productivity.

Since NAS is both a development and operational system, two high-speed processors are necessary. The first high-speed processor (HSP-1), a Cray 2 supercomputer, has been integrated into the system in the NAS facility. In FY 1988, a memory upgrade was acquired for the Cray 2 which provided a 20-percent performance increase. The second high-speed processor (HSP-2) will be acquired and delivered in FY 1989. One processor will be devoted exclusively to production computing. The second, newer and more powerful processor, will be integrated into the system, while software for production use is being developed. When a new supercomputer becomes available with over four times the performance of HSP-2, that machine will be acquired as HSP-3. To make room for more advanced processors, HSP-1 will be replaced by HSP-3, when HSP-3 is fully integrated into the NAS system.

The NAS system provides the UNIX operating system on all levels of the processing system from the supercomputer to the workstation. With support from the NAS program, UNIX has become the defacto standard operating system for supercomputer centers. With high-speed communication links to remote users, remote users are provided an environment which is equal to local on-site users. The NAS system is currently supporting over 700 users on 203 projects at over 70 sites.

An applied research and advanced development program has been initiated to support the pathfinding goal for NAS. As part of this program, an advanced development laboratory, an advanced architecture study, and a CFD workbench project have been formed. This program will provide the capability to evaluate commercial products, to provide industry with requirements for future products, and to design new systems and software to support new architecture machines.

FY 1989 will be an important year in the development of the NAS system. The second high-speed processor will be integrated into the NAS system. This event had slipped due to unavailability of a supercomputer meeting the HSP-2 requirements. With HSP-2 integrated into the system, secure processing will be available while users have access to the other high-speed processor.

With the second processor, the number of users and projects supported by NAS will increase accordingly. Support processing will be upgraded to satisfy the additional requirements of the system. Mass storage continues to be a primary concern for computer systems. The NAS program will double the mass storage capacity in late FY 1989 and efforts with industry on developing more capable systems are being pursued.

10. TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

FY 1989 NASA REQUEST, $84,400,000

FY 1989 AUTHORIZATION, $84,400,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Transatmospheric Research and Technology:	
Estimated fiscal year 1988	$52,500,000
Authorization fiscal year 1989	84,400,000

NASA requested $84,400,000 for Transatmospheric Research and Technology in Fiscal Year 1989. This amount is NASA's contribution to a joint NASA/DOD research project to develop the technology for and prove the feasibility of an aerospaceplane, capable of extended hypersonic cruise in the upper atmosphere or single-state-to-orbit operation. The Committee recommends the request.

The project consists of two phases. The first phase began during FY 86 and is scheduled to continue to the end of FY 90. Its purpose is to mature the various propulsion and airframe technologies to a point where a decision can be made to proceed with the second phase, a flight test program, lasting about five years. The project is being managed by a joint program office, headed by the Air Force and with membership from the Navy, Strategic Defense Initiative Organization, Defense Advanced Research Projects Agency, and NASA.

The Committee strongly supports the Aeronautics research project as a necessary precursor to potential applications, such as a follow-on to the Space Shuttle, which will be needed in the late 1990's. Furthermore, the Committee believes the scientific fallout, in areas such as high temperature materials and cryogenic fuels production and use, will pay huge dividends, not only in terms of continued U.S. leadership in both space and aeronautics, but in many other fields.

The Committee recommends for FY 89, $84,400,000; for FY 90, $149,400,000; and for FY 91, $99,300,000.

The National Aero-Space Plane (NASP) program is a joint effort between NASA and the Department of Defense to accelerate the development of critical enabling technologies for a revolutionary class of hypersonic/transatmospheric vehicles. Such vehicles could be capable of taking off from and landing on conventional runways, using airbreathing propulsion up to, or near, orbital speed, and providing rapid and lower cost access to space. The program will accelerate the development and validation of key technologies through application of analytical prediction methods coupled with testing in ground-based facilities. The critical technologies being pursued in the current phase of the program include efficient airbreathing propulsion systems, with emphasis on scramjet performance that provides the necessary thrust from takeoff to near orbital speeds; reusable thermal structures that can withstand repeated combinations of extreme peak heating and significant long-duration heat loads; and complete integration of the propulsion system with the airframe for a minimum weight system wth good performance throughout a broad range of accelerating, cruising, and maneuvering flight conditions. A necessary precursor to the development and flight validation of an experimental vehicle (X-30), these technologies will form the critical data base required for design and integration of complex propulsion and structural systems into a vehicle configuration capable of transatmospheric flight.

This program is an outgrowth of the ongoing aeronautics and space research and technology programs. It is a multicenter effort (Ames, Langley, and Lewis) directed at generating the technologies required to provide the variety of options afforded by airbreathing transatmospheric vehicles. The opportunities for exploiting this regime for advancement of national interests are broadly recognized—including launch vehicles, hypersonic transports, and military applications.

The FY 1989 NASP activities will emphasize extensive detailed design, component fabrication, and tests by the engine and airframe contractors, as well as continued refinement of the supporting technology maturation effort in preparation for the decision on whether to proceed with development of the X-30 research vehicle.

The engine contractors will continue to refine their concepts to achieve the performance required to accomplish the X-30 mission goals. Emphasis will be on integration with the vehicle configurations being developed by the airframe contractors, since the desired performance depends critically on the integrated propulsion-airframe system. A major effort will be extensive ground testing of the contractors' near full-scale modules to a simulated flight speed of Mach 8. The tests are essential for building confidence in engine operation under as realistic a set of conditions as possible. These tests will include evaluation of component performance under severe environmental conditions. Hydrogen-cooled engine components, for example, will be evaluated under Mach 25 heating conditions to validate predicted operation and lifetime. Successful demonstration of engine performance in the ground facilities to Mach 8 and computational fluid dynamics (CFD) analyses of engine performance at higher Mach numbers are critical to the X-30 decision.

The airframe contractors will further develop their preferred configurations, using data from the engine contractors. Emphasis will be on increasing the performance of the integrated propulsion-airframe system, reducing drag through detailed CFD analyses, and reducing weight through careful evaluation of advanced structural designs. Significant activities will include development, fabrication, and test of large-scale sections of the hydrogen tank and thermal protection system to validate analytical predictions of systems performance; large-scale advanced materials panels with the necessary joints, fasteners, and gap seals to develop realistic weights for vehicle designs; full-scale nose, engine strut, and wing leading-edge models to evaluate survivability in simulated flight thermal conditions between 4000 and 6000 degrees Fahrenheit; and full-scale fuselage sections and wing/fuselage attachments to evaluate vehicle structural integrity. Control system designs will be developed and evaluated for control of complex, integrated vehicle systems under simulated flight conditions. Subsequent predictions of overall vehicle performance based on these data are critical inputs to the decision to build the X-30 research vehicle.

The technology maturation effort will continue to focus on critical disciplines as an underpinning of the engine and airframe efforts. The technology maturation activities concentrate on four key objectives: (a) an airbreathing propulsion system with high specific impulse; (b) vehicle structural weight improvement with reusability and durability over a wide temperature range; (c) integrated systems and subsystems in aeropropulsion, thermal management controls, etc.; and (d) sound design and analysis tools based on advanced computational methods fully verified by test. Significant activities will include integration of finite-rate air and hydrogen reactions into three-dimensional Navier-Stokes computer codes for complex geometries to allow for accurate prediction of flow fields; investigation and prediction of laminar-to-turbulent flow transition using advanced computational techniques and a low-turbulence wind tunnel modified to conduct hypersonics flow experiments to permit accurate prediction of thermal heating loads in flight; detailed real-gas validation of CFD codes by advanced test facilities to predict external flows, inlet flows, and combustor/nozzle flows for more realistic prediction of engine performance; and continued development and evaluation of advanced metal matrix composite materials to provide the lightweight structures needed to meet X-30 performance goals. The major effort to scale up and characterize advanced lightweight, high-temperature materials in a cooperative effort with contractors begun in FY 1988 will be significantly expanded in FY 1989.

11. SPACE RESEARCH AND TECHNOLOGY

FY 1989 NASA REQUEST, $390,900,000

FY 1989 AUTHORIZATION, $

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Research and technology base	$108,400,000	
Civil space technology initiative (CSTI) program	115,200,000	
Pathfinder program	0	
Total	223,600,000	

The overall goal of the space research and technology program is to provide advanced technologies that ensure continued U.S. leadership in space to meet national needs. Achieving this goal requires a commitment to provide a broad base of advanced technology for vehicle and subsystem concepts, components, devices, and software; to develop technical strengths in the engineering disciplines within the agency, industry, and academia; and to perform critical technology demonstrations that facilitates the transfer of new technology to future space missions with a high level of confidence.

The research and technology base program provides the wellspring of innovative and fundamental research for future NASA and other civil space missions. Within this program, high-leverage technological advances and concepts are, if successful, brought to the level of demonstrating proof of principle. This program is in effect a seedbed for generating the more highly mission-focused technology programs. The Civil Space Technology Initiative (CSTI) program is a mission-focused program that consists of major technology thrusts to enhance Earth-to-orbit transportation, improve operational capabilities at low Earth orbit for enhancing the effectiveness of Shuttle/Space Station, and provide increased capabilities to conduct Earth-orbital science programs. The Pathfinder program provides those emerging and innovative technologies required to enable a broad set of future space exploration missions. Depending on future decisions, such missions could include a return to the Moon to build an outpost, and both autonomous and piloted missions to Mars and other destinations in the solar system. Proof-of-concept testing for mission-critical engineering designs will be an important product of the CSTI and Pathfinder programs and will directly support the continuing evolution and maturation of mission plans. In support of the objective of encouraging the development of engineering and research capabilities in the academic sector, the university activities have been combined into a separate focused budget line item which includes the space engineering research center program, the university system design program, and university innovative research.

In FY 1989, the space research and technology program will be significantly augmented to provide a greater emphasis on focused technology (CSTI and Pathfinder) and university space research programs. The research and technology base program will shift emphasis to explore newly emerging areas that offer longer range, high-leverage program benefits. The university space research program includes augmentation and expansion of the university engineering research centers and the university advanced design effort. Development of the concepts and plans for an expanded in-space research and demonstration program will be pursued. The following describes in greater depth the planned FY 1989 activities.

The aerothermodynamics program provides the basis for fundamental understanding and prediction of the combined effects of heat transfer and aerodynamics on vehicles during ascent and entry. This activity is enabling to the successful development and design of advanced aerospace vehicles. Current program emphasis is on development and validation of computational fluid dynamics codes that incorporate real-gas and nonequilibrium effects to more accurately predict performance of aeroassisted orbital transfer vehicles.

The space energy conversion program provides the fundamental understanding and technology basis for the development of future space power systems ranging from relatively low power levels required for spacecraft to high-capacity, nonnuclear power for large space systems. Photovoltaic power technology will focus on improving the efficiency and reducing the degradation rate of photovoltaic cells through improved designs and materials. Technologies for lightweight deployment systems, reduced weight substrates, and ultrathin cover glass are being developed. Higher energy chemistry and improved battery designs are being developed to provide improvements in the energy density and life of storage systems. The goal is to improve the total system (photovoltaic and storage) performance to permit a 50 percent increase in payload weight. Research continues on fuel cells for application at higher power levels (greater than 25 kilowatts) where they offer significant potential weight advantages. New conversion catalyst materials and designs are being developed to achieve reduced system weight and increase life. Technologies for high-efficiency thermal-to-electric conversion, high-temperature thermal storage, and lightweight high-concentration-ratio solar collectors are being developed for solar dynamic systems. The goal of these technologies is to provide a 25 percent reduction in collector area and a substantial reduction in weight over current high-capacity systems.

The propulsion technology program focuses on key lifetime and performance issues associated with space propulsion systems. Variable-flow turbomachinery, enhanced heat transfer combustors, and high-expansion-ratio nozzle rotorcraft for space-baseable orbit transfer vehicles will be investigated. The ultimate benefit will be to reduce substantially the cost of space operations by reducing the amount of mass required to be transported to Earth orbit. In addition, the potential of very high-energy-density propellant combinations, such as liquid oxygen with metalized fuels, will be assessed for Earth-to-orbit propulsion systems. For ascent vehicle operations, candidate propulsion systems that can operate efficiently

with propellants produced in situ on Mars or on the Moon will be identified and their performance and operational capabilities explored to greatly reduce Earth launch requirements. Research on auxiliary propulsion will develop concepts for control of an evolutionary space station and space vehicles which operate with mixtures of gaseous oxygen and hydrogen derived from electrolytic systems. Electric propulsion technology will address fundamental issues governing thruster life, performance, and weight through improved inert gas ionization processes and cathode materials and designs.

The materials and structures program will focus on extended space durability, structures for lightweight vehicles, and concepts to enable the development of large space structures. The dimensional stability and durability of metal-matrix, carbon-carbon and graphite-epoxy composites will be evaluated for long-term service life in both low-Earth-orbit and geosynchronous-Earth-orbit environments. The approach will include both the development of computational chemistry methods to describe atomic oxygen interactions and accelerated testing methods. Structural concepts will be developed incorporating mechanisms to adjust stiffness, damping, and shape in order to enable construction of large high-precision space structures. Hot structures for integral cryogenic tankage will be pursued, and toughened ceramic thermal protection systems will be developed.

Space data and communications research will be directed toward increasing traveling wave tube efficiencies, developing and packaging monolithic microwave integrated circuit components, refining 20/30 gigahertz antenna technology, and advancing electro-optic research aimed at laser communications.

Areas addressed by the information sciences program include computer sciences, sensors, and photonics. In the computer science area, emphasis will continue to be placed on concurrent processing for improved physical simulations and visualization of scientific data. Sensor research will concentrate on the use of artificial intelligence techniques in autonomous onboard data analysis. Investigation of new materials, devices, and analytical models leading to the development of improved sensor systems will continue. In the area of photonics, research will focus on improved photonic materials and devices for use in real-time computer vision systems and very low-cost, wide-bandwidth signal analysis.

Controls and guidance research will support the implementation of future advanced Earth-to-orbit transportation systems, aeromaneuvering vehicles, and interplanetary space travel. Particular emphasis is placed on real-time, fault-tolerant distributed control architectures and system autonomy in the real-time environment of a maneuvering vehicle. The development of analytical tools and techniques for the precision pointing and control of large flexible spacecraft and the control of extremely large flexible transportation vehicles is a principal research focus.

Space human factors research includes development of advanced concepts and hardware for extravehicular activity, such as hard space suits, and development of highly integrated displays and controls to support telepresence and astronaut and crew performance.

Space flight research includes the continued development of orbiter experiments to use the shuttle as a research testbed vehicle. The in-space technology experiments program was expanded to define and develop seven flight experiments selected from 58 NASA in-house generated proposals. The program was also expanded further by the selection of 41 externally sponsored flight technology experiments from 231 university and industry proposals.

The systems analysis area will focus on the identification of high-leverage technologies for future space missions.

The objective of the university space research program is to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program. It is an integral part of the strategy to rebuild the space research and technology base. The program responds to remedy the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program elements include the university space engineering research program that supports interdisciplinary research centers, the university innovative research program which provides grants to individuals with outstanding credentials, and the university advanced space design program which funds advanced systems study courses at the senior and graduate levels.

The objective of the Civil Space Technology Initiative (CSTI) program, begun in FY 1988, is focused on research in technologies to enable reliable and lower cost access to space and to support space operations and science missions. The CSTI program is a positive first step to restore the agency's technical strength and provide options for high-priority civil space goals of the future. The research is targeted at opportunities with clearly defined end objectives to validate technology advances. Three broad categories—transporation, operations, and science technology—are supported.

Automation and robotics is directed at developing and demonstrating the technology to enable intelligent autonomous systems and telerobotics applications to space and autonomous ground systems. Propulsion includes Earth-to-orbit propulsion that will provide the experimental data base and test environment to verify the models needed for the design and development of advanced, reusable, and high-performance propulsion systems and also booster technology that will develop alternate propulsion concepts for the Shuttle booster with higher performance and a safe-abort option. Vehicle-oriented technology is focused on an aeroassist flight experiment that will provide critical design and environmental technologies for an aerobrake orbital transfer vehicle. Information technology is directed at developing the high rate/high capacity data technology for onboard real-time data processors and storage systems with up to ten times increase in data rates and 1000 times increase in storage capacity and at providing new sensor technologies for Earth observation and space science. Large structures and control includes a series of in-space experiments to provide fundamental data on structural dynamics and control of a very large, flexible structure to enable development of lower weight, more stable, space structures while technology will be developed for a precision segmented reflector to enable the design of large, high-

precision, orbiting astronomical instruments for making deep space observations in the submillimeter portion of the spectrum. Power technology is focused on advanced technology development efforts to increase nuclear system conversion efficiency fivefold to meet the long-duration, high-capacity power requirements for future space initiatives. The Committee is particularly interested in the Sterling Space Power Program and encourages its support.

Project Pathfinder is an important new program, through which NASA will develop a broad set of technologies to enable future space missions. Project Pathfinder is the critical next step, augmenting CSTI, in strengthening the technology foundation that supports the civil space program and the nation's technology leadership. Moreover, Pathfinder is an essential prerequisite to any later decision by the nation's leadership to go forward with ambitious civil space missions, such as an outpost on the Moon. Until key technologies are developed, these ambitious civil space missions will always remain 10–20 years in the future. Pathfinder will provide the technology required for the future robotic exploration of the solar system, an outpost on the Moon, a piloted mission to Mars, and advanced Earth orbserving missions and Earth orbit operations. Project Pathfinder addresses technologies in the areas of: space transporation and operations, in our ability to live and work productively in space, and for exploration. Through these program thrusts, and a strong partnership between NASA, industry, and universities, Pathfinder will push American space technology forward in the coming decade, as the Apollo program did during the 1960's.

The technologies included in the exploration element are related to the gathering of scientific knowledge and technical understanding at mission sites on the Moon and Mars. Specific objectives will provide the capabilities needed to precede pilot flights to Mars and for the construction of a lunar outpost. The space operations element deals primarily with the lunar outpost, with piloted missions to Mars, and with operations in Earth orbit. For lunar and Mars missions, this program will address critical technologies for preparing to depart Earth orbit, for performing mission tasks on arrival at surface sites, and for safe return from the Moon or Mars. For Earth orbit operations, this program will greatly extend our capability to maintain an infrastructure and to support major new science missions. Specific objectives include extensive capabilities for in situ materials processing, fabrications and assembly, and repair of massive and complex systems in Earth orbit and at lunar and Martian orbits and surfaces. The humans-in-space program will address the technology for making it feasible and productive to send astronauts on lengthy missions. Specific objectives include improving astronaut productivity, maintenance of health, and minimal or no dependence on resupply of expendables. The transfer vehicle element will support transportation to and from geostationary Earth orbit, the Moon, Mars, and other planets. Specific objectives include significant reduction in the mass that missions require to be launched into low Earth orbit and in transit, as well as reduction in the time required for transit. The mission studies element will (starting with the exploration scenarios identified in the report entitled "Leadership and America's Future in Space") identify,

define, and analyze future space missions. These studies will lead to continuing refinement of the Pathfinder program to ensure that critical, long-lead technologies are receiving proper attention.

Research and Technology Base

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Aerothermodynamics research and technology	$10,300,000	$11,500,000
Space energy conversion research and technology	12,500,000	13,800,000
Propulsion research and technology	13,300,000	19,700,000
Materials and structures research and technology	15,900,000	17,500,000
Space data and communications research and technology	7,900,000	9,300,000
Information sciences research and technology	7,700,000	9,000,000
Controls and guidance research and technology	5,500,000	6,700,000
Human factors research and technology	4,200,000	5,300,000
Space flight research and technology	21,400,000	18,100,000
Systems analysis	5,700,000	6,900,000
University space research	4,000,000	16,300,000
Total	108,400,000	134,100,000

Aerothermodynamics Research and Technology

Future aerospace vehicles, such as aeroassist orbit transfer vehicles (AOTV), the aerospace plane, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in both rarefied and continuum flow flight regimes. The design of these vehicles presents formidable performance prediction challenges. To meet these challenges, the aerothermodynamics program is pursuing the following objectives: (1) development and application of advanced computational methods and numerical techniques covering the entire spectrum of continuum, transitional, and rarefied flows; (2) development of accurate and detailed real-gas chemistry and high-speed turbulent flow models and the efficient integration of these models with standard computational flow codes; (3) establishment of a high-quality ground and flight experimental data base for code validation and verification; (4) direct correlation and comparison of computations with available ground and flight data; (5) establishment of a detailed aerothermal loads data base and development of fully integrated analysis techniques; and (6) enhancement of engineering design codes and advanced configuration analysis capability to support rapid evaluation of future vehicle/mission concepts.

Progress continues to be made on the direct simulation Monte Carlo techniques to better understand and predict the complex flow problems associated with aerospace vehicles operating in the rarefied or noncontinuum flow regime. During FY 1988, stagnation point and axisymmetric body solutions, including global radiative heating, temperature, and electron number density, were obtained for the aeroassist flight experiment (AFE) reentry trajectory.

The ability to efficiently and accurately simulate chemically reacting flows is critical to the successful design and optimization of proposed hypersonic vehicles. Toward this end, a two-dimensional equilibrium real-gas code has been developed, and this first-order inviscid code has successfully computed a number of flow fields. This code allows accurate, simplified analyses of a wide range of internal and external flows about advanced space transportation vehicles. Numerical results for Mach 20 real-gas flow over a hemisphere compared well with results obtained from other methods. The code has also been used to compute equilibrium flow through a hypersonic inlet and supersonic flow about a missile with exhaust plume.

The computational analysis capability for the AFE has been expanded to include predictions of flight aerodynamic coefficients, forebody pressure distributions, and Mach 10 heating distributions using the high angle-of-attack inviscid solver code coupled to a three-dimensional boundary-layer code. These calculations are critical to finalizing the design for the AFE. At the other end of the lift/drag spectrum, a preliminary analysis of a hypersonic slender body configuration has been completed using a three-dimensional viscous shock-layer code. This calculation was able to isolate and quantify the effects that variations in nose bluntness and angle of attack have on laminar and turbulent heating.

Complementary to the development of computational fluid dynamics codes and numerical simulation capability is the requirement to establish a high-quality aerothermodynamics experimental data base applicable to a wide range of vehicles and flow conditions. In FY 1988, wind tunnel tests conducted in the hypersonic facilities complex at the Langley Research Center provided detailed aerodynamic performance data on both U.S. and foreign space transportation systems. This included critical information on pitch and yaw stability and control limits. Complete force, moment, and pressure distributions for the baseline AFE configuration were also obtained. These are being compared with the latest computational calculations to verify present performance predictions.

During the past year, a Shuttle ascent abort study was undertaken to evaluate the feasibility of safe aerodynamic separation of the orbiter from the lower stack (external tank and solid rocket boosters) from lift-off through solid rocket booster staging. A vital part of this study involved single- and two-body wind tunnel tests which provided the detailed interference aerodynamics data. While these tests were able to establish the preliminary feasibility of various separation options, they also confirmed the highly complex and nonlinear nature of the localized air flow which cannot be accurately predicted or simulated by current computational techniques.

An ongoing activity to improve and verify the aeroheating predictions of current engineering design codes has been successfully completed. Flight test data, benchmark computational codes, and wind tunnel tests were compared with engineering code predictions relative to nose bluntness and angle-of-attack effects, gas chemistry (real versus perfect gas), and turbulence heating methods. These codes have been verified and were successfully used in the downselect process of the National Aero-Space Plane program.

In the area of aerothermal loads, the first operation of a fully integrated flow thermal-structural analysis technique was accomplished. Excellent agreement between theory and experiment was found for a blunt leading-edge case. As a companion activity, an experimental study of shock wave interference heating (compression wave impinging on a bow shock) on a cylindrical leading edge was completed in the Calspan Corporation's 48-inch and 96-inch shock tunnels. Analysis of these results indicates a tenfold increase in heating rate for the shock-shock condition versus the undisturbed, no-shock impingement case.

The FY 1989 program in computational methods will emphasize techniques for efficient coupling of real-gas chemistry to Navier-Stokes flow codes. This will involve the development of more sophisticated chemistry models and more robust and computationally efficient solution algorithms. A second area of emphasis will be continued development of user-friendly two-dimensional and three-dimensional adaptive grid generation techniques, which can be applied to a variety of flow fields and configurations (i.e., plumes/nozzles, cowlip, inlets, forebody, and base flows). These improved capabilities will permit more accurate simulation of continuum flow about advanced space transportation vehicles under ascent and entry conditions.

In the area of direct simulation techniques, focus will be given to developing a highly efficient particle kinetic simulation method. Unlike the Monte Carlo approach, this method restricts or limits the allowable energy and momentum states that can result from a collision of two ideal diatomic molecules. Therefore, it is not as computationally intensive as the Monte Carlo method and will be better suited to predicting transitional and near-continuum flows. This capability will allow for the inclusion of more complete physics resulting in more accurate simulations, as well as enabling rapid parametric studies of maneuvering vehicle trajectories in the upper atmosphere.

Continuing the efforts to expand the current aerothermodynamic ground test data base, emphasis will be given to code calibration and validation experiments and, in particular, to simulating nonequilibrium flows through the initiation of a series of high-velocity tests on slender conical bodies. To this end, plans to establish a high-enthalpy/high-velocity ballistic range facility and to further develop nonintrusive diagnostic techniques for hypersonic flows will be actively pursued to enable realistic hypersonic experimentation.

Aerothermal loads research efforts will concentrate on completing shock-on-lip tests to providing understanding of leading-edge sweep and multiple shock effects on hypersonic inlet heat transfer in order to facilitate structural analysis and design. In FY 1989, a more complete validation of the integrated flow-thermal-structural analysis technique will be accomplished utilizing the complete experimental data set obtained in past Langley Research Center and Calspan Corporation wind tunnel and shock tube tests. The calibration of the glow-thermal-structural integrated analysis code will provide the first ever integrated analysis for high-speed aerodynamics/aerothermodynamics/structure interactions.

Space Energy Conversion Research and Technology

The objective of this program is to develop technology alternatives that improve performance, reliability, and cost effectiveness of space power for manned space operations, as well as autonomous Earth-orbiting and planetary exploration spacecraft. To meet the challenge, greater than 50 percent improvements and increased life potential are being sought in alternative solar power generation components, energy storage systems, electrical power management and distribution, as well as the thermal management systems. For spacecraft photovoltaic technologies, the goal is to improve the total system performance enough to permit a 50 percent increase in payload mass while not increase the spacecraft's overall mass.

Recently, two significant advances were made in photovoltaic cell technology. Over 18 percent efficiency was demonstrated in an indium phosphide solar cell. This measurement, when combined with data indicating that indium phosphide should be more resistant to space radiation than any other material, shows real promise, for the first time, of using photovoltaics in high radiation environments such as extended missions in the Earth's radiation belts. Using prismatic solar cell covers, which direct incident sunlight away from electrodes to active areas of the cell, gallium arsenide (GaAS) concentrator cells set an efficiency record of over 22 percent. This result demonstrates the promise of substantial reductions in array areas. Electrochemistry research has identified a relationship between electrolyte concentration and cycle life of nickel-hydrogen batteries which provides sufficent cell life to meet the Space Station cycle life goal. Other improved nickel-hydrogen technology components that will further extend life and improve cell reliability were verified and provided to battery cell manufacturers for consideration in their space station cell designs. Feasibility investigations have identified promising cathode, electrolyte materials and processes suitable for long-life (10 years), higher energy density (100 watt-hours/kilograms), secondary lithium cells for application to mass-critical planetary spacecraft. An advanced hydrogen-oxygen regenerative fuel cell system investigation to establish life-performance interrelationships and system weight tradeoffs was initiated to identify the technology payoff benefit areas and to guide the critical technology efforts.

In the power management and distribution area, installation and initial full-power operational testing of a 20-kilohertz, 1000-kilowatt component test facility was completed. A major technology achievement during this period has been the development, maturation, and acceptance of the 20-kilohertz power management and distribution system as the Space Station baseline. The benefits include very low electromagnetic interference, 50 percent reduction in weight, 7 percent increase in end-to-end efficiency, increased crew safety, and compatibility with any energy source.

The feasibility of a high-efficiency, thin-film alkaline metal thermal electric conversion (AMTEC) system electrode has been demonstrated at representative cycle temperatures. A power flux of 0.6 watts/centimeter squared was achieved with a thin-film molybdenum electrode. AMTEC is an alternate static conversion concept that potentially could achieve system efficiency on the order of 20 percent, as compared to efficiencies of approximately 6 percent for other static conversion systems. It is suitable for application with chemical, solar, and nuclear heat sources.

In FY 1989, the space energy conversion research and technology program will continue to extend the fundamental understanding of energy conversion systems and to develop technology options for future space missions with power levels ranging from hundreds of watts for small planetary spacecraft to many kilowatts for large space platforms and manned spacecraft and bases. Energy conversion research includes solar and nuclear power generation systems, energy storage systems, power management, and thermal transport and heat rejection.

For spacecraft photovoltaic technologies, fabrication of a prototype advanced array will be completed and engineering tests initiated to demonstrate 300 watts/kilogram array components. This is a fivefold improvement over today's state of the art. Efforts will be made to combine future thin-film cells, such as amorphous silicon, with optimized blankets and deployment mechanisms to attain even higher specific power. Work begun in FY 1986 continues on mitigating the effect of low-intensity, low-temperature degradation of silicon solar cells to lead to a cell capable of efficient operation in Jupiter orbit. Research and technology efforts with thin-film indium phosphide cells are expected to culminate in a manufacturing design. Space environmental effects experimental work to understand and reduce the damaging effects of space radiation is continuing.

Component level testing of solar dynamic concentrator concepts will be completed, and performance testing of several concentrator designs under various conditions of sunlight and pointing will be initiated. Thermal energy storage materials will be formulated and evaluated to establish heat of fusion, thermal conductivity, and coefficients of thermal expansion. Materials with high thermal conductivity and high heat of fusion are needed to develop efficient and lightweight thermal energy storage systems and receivers. A low coefficient of thermal expansion is needed to reduce failures due to cyclic fatigue. In FY 1989, selection of concentrator, receiver, and thermal storage concepts for integration into a high-temperature, high-concentration ratio and long-life solar dynamic system is to be accomplished. AMTEC electrode life of 1000 hours will be demonstrated.

Laboratory experiments to develop a fundamental understanding of the chemical mechanisms governing the cycle life of lithium secondary (rechargeable) cells will be conducted. Assessments of the performance and life potential of high-temperature sodium sulphur cells will be initiated. Both lithium and sodium batteries are of interest because of their high-energy densities (100 watt-hours/kilogram). However, both suffer from problems of insufficient cycle life and reliability. In some applications the sodium-sulphur may not be able to meet environmental (vibration, shock, etc.) constraints. Technology efforts will address these issues. University efforts will continue to develop improved catalytic materials and electrode designs for regenerative fuel cells.

Experimental and analytical efforts to study droplet formation, heat transfer mechanisms and zero-gravity phase change, and fluid

flow phenomena will be conducted to evaluate materials and designs and develop the required technology base for advanced radiator concepts that will allow the large amounts of heat generated by high-power level systems to be dissipated. High-frequency power system designs and components will be developed to reduce the weight, increase the life, and meet the space radiation and temperature constraints. Experimental power systems, biased to simulate space charging effects, will be tested in vacuum chambers to determine the possible detrimental effects of high-voltage arcing and to develop designs which will be suitable for use in civil missions.

Propulsion Research and Technology

The objectives of the propulsion research and technology program are to develop a fundamental understanding of the chemical and physical processes that occur in space propulsion systems, to develop and validate accurate analytical simulations of those processes, to identify and evaluate advanced higher thermal and mechanical load-resistant materials, and to evaluate the potential benefits and feasibility of advanced concepts that will improve our propulsion capabilities well beyond those that are achievable with today's operational systems. Depending upon the application, the thrust range of these chemical and electric propulsion systems varies from millions of pounds to millipounds. Included are propulsion systems for Earth-to-orbit (ETO) vehicles, orbit-to-orbit transfer vehicles (near Earth and planetary transfer), planetary orbit insertion, lander, ascent, and Earth return vehicles. Also included is Earth-orbiting satellite auxiliary propulsion needed for such functions as attitude control and station keeping. Finally, a part of the program is dedicated to the identification and evaluation of very high-energy advanced propulsion concepts that, if proven feasible and ultimately practical, would provide a quantum leap in propulsion capabilities that could be applied to a number of the above applications. The propulsion technology advances being pursued in support of future vehicle and spacecraft design concepts will greatly enhance our ability to perform these missions with increased capability and at greatly reduced cost.

ETO propulsion technology is directed toward advanced concepts that offer significantly increased propulsion system density impulse characteristics (i.e., increased propellant density while a high level of engine specific impulse is maintained). This combination results in the smallest vehicle size and dry weight (thus, reduced cost) for any given payload delivery capability. Recent studies conducted to evaluate a number of candidate high-density impulse propulsion approaches identified metallized gelled fuels, such as hydrocarbon and aluminum, as the most promising approach. Suspending small particles of metal in the fuel greatly increases its mass with a minimum increase in volume. Current efforts are being directed toward developing techniques for creating stable metallized fuel gels, and the successful gelling of hydrocarbon/aluminum has been demonstrated. Another effort in the ETO area is focused on developing a fundamental understanding of combustion instabilities, including combustion response characteristics, combustor acoustic characteristics, triggering mechanisms, resonance-avoidance techniques, stability aid devices, etc. The work is aimed at the oxygen/hydrocarbon propellants generally used in booster stages, but the analytical techniques developed will be generic to other propellant combinations and beneficial to all future propulsion systems. To date, experimental testing with liquid oxygen/methane has demonstrated that a fuel temperature ramping technique developed with hydrogen is also valid for methane. Efforts to understand and model the basic physics of combustion instabilities and to define experimental verification techniques have been initiated.

One other area of interest in ETO technology involves the evaluation of very high-temperature materials (up to 4000 degrees Fahrenheit), such as rhenium/iridium, for use as combustor inner liners. The ability of an inner liner to operate at these temperatures would greatly reduce heat transfer through the combustor, which will ease the regenerative cooling problem and allow higher combustion pressure operation, resulting in much higher engine performance. Design configurations utilizing these high temperature materials in conjunction with transpiration cooling have been generated, and plans for the fabrication and test of these designs are being developed.

Efforts are also being directed toward demonstrating the performance characteristics of propulsion systems designed to operate with propellants derived from lunar and planetary resources. Studies have been conducted to identify resources available at Mars and on the Moon that could be used for rocket propellants. It has been determined that both oxygen and aluminum can be extracted from the lunar soil, and that both oxygen and carbon monoxide can be obtained from the carbon dioxide in the Martian atmosphere. Combustion devices which could generate chemical energy through the reaction of these resources are currently in design. In both cases, using in situ derived propellants for ascent from either the lunar or Martian surface will have a pronounced effect on mission costs, since these propellants would otherwise have to be carried all the way from Earth to the lunar or Martian surface for use in the ascent propulsion systems.

The orbit transfer propulsion technology program will provide the design and analysis tools needed for the future design and development of reusable, space-based, high-performance, throttleable, oxygen/hydrogen expander cycle engines. These next-generation high-capability space engines will be used for highly efficient orbital transfer from low Earth orbit to geosynchronous Earth orbit and to lunar and planetary transfer trajectories. They will also be used for lunar and planetary landers, where high performance over a wide throttling range is of paramount importance for efficient propellant utilization during hovering and landing operations. Advanced expander cycle engine concepts that will provide the needed capabilities have been developed and key technologies identified, including those that will allow the expander cycle engine to be maintained and operated in low Earth orbit. Key technologies include enhanced heat transfer combustor designs that will provide greater turbine drive energy, hence higher combustion pressure operation, and the development of small high-speed turbopumps that can provide high-efficiency operation over a wide flow range (for throttling). In addition, integrated health monitoring and control systems need to be developed to permit automated in-space servic-

ing, as well as fault-tolerant flight operations. Laboratory-scale and bench-type experiments have successfully demonstrated enhanced heat transfer combustor and critical turbomachinery subcomponent designs. In addition, overall health monitoring/control systems have been configured and needed control components and diagnostic sensors identified. Design and analysis tools, as well as materials and fabrication techniques for component level hardware designs, have been developed. Efforts in the chemical transfer element funded in the Pathfinder program will be directed toward the design, fabrication, and verification testing of full-scale components and leading ultimately to an integrated component test capability needed to verify component performance, operation, and predicted interactions at the engine system level.

Auxiliary or low-thrust propulsion technology is directed toward improved capabilities in resistojets, arcjets, ion thrusters, magnetoplasmadynamic (MPD) thrusters, and long-life, efficient gaseous and storable liquid chemical propellant rockets. Two of the recent technology products of this program have been selected for the Space Station baseline design. One is a 25-pound-thrust gaseous hydrogen/oxgen thruster that has operated for over 20 hours without degradation. This thruster will be combined with an electrolysis unit to turn surplus Station water into propellants to provide orbit control and station maneuvers. The other is a multipropellant resistojet that will operate with the anticipated waste gases from the Space Station to both aid in drag makeup and dispose of the gases, so that they do not have to be returned to Earth. An engineering model of the resistojet has completed over 2000 hours of operation without a problem. Another technology transfer item is the selection for planned future solar system exploration projects of the iridium-coated rhenium chamber which adds 10 percent to performance from storable bipropellants by operating uncooled at up to 4300 degrees Fahrenheit. Since the future spacecraft would be more than 70 percent propellant by weight, this 10 percent improvement means hundreds of pounds of added payload. During 1987, a 5-pound rhenium thruster attained an operating time of 12 hours, and a 100-pound unit was made and tested indicating a need for a better injector spray pattern and an improved internal coating procedure. An arcjet thruster, operating at 1 kilowatt (kw) level with hydrazine byproducts, has operated successfully for over 750 hours in two-hour-long pluses followed by cooling, simulating the operational mode of a thruster on a geosynchronous Earth orbit (GEO) communications satellite during 15 years of operation. This test proved that a startup problem which badly eroded the central electrode has been solved. The impulse level of the arcjet is 450 seconds, 50 percent higher than the best system now operating with hydrazine. The potential saving in control propellant is enough to add 2 or 3 years to the life of a GEO satellite. A joint program has been initiated with a satellite manufacturing company to include a pair of arcjets on a future GEO satellite to verify performance and to investigate interference with communications during arcjet operation. Thirty centimeter (cm)-diameter ion engines have been operating for hour-long periods in vacuum chambers at ever-increasing power levels. Redesign has allowed more than 20 kw to be processed by this engine, originally designed for 3 kw. More power per engine means fewer engines for future megawatt flights and better reliability. A pair of 30-cm ion engines has been operated as a system to investigate control problems and possible simplifications, such as common power supplies and beam neutralizers. A 50 cm-diameter ion engine has been designed and is in construction. This size could be operated at 100 kw with over 70 percent efficiency. MPD thruster work has been scaling up in anticipation of Pathfinder applications. Megawatt-level pulse work continues at Princeton University. Meanwhile, sustained operation tests at levels of 40 kw for 20 minutes and 70 kw for several minutes have been attained with acceptable electrode erosion. An increase to 100 kw at the Jet Propulsion Laboratory is planned to better understand the critical electrode erosion problem that still limits life.

Advanced propulsion concepts studies continue to investigate promising capabilities not yet within our reach. Efforts include determining the critical research needs for antimatter propulsion and the selection of critical experiments, evaluating the status of fusion propulsion and selecting possible applications to NASA missions, and appraising the ram cannon and railguns. A magnetically confined microwave-induced plasma experiment has been initiated at the Massachusetts Institute of Technology as the first experimental effort under the advanced concepts program.

In the ETO propulsion program, efforts will continue toward developing techniques for creating stable gelled metallized fuels. Experimental efforts aimed at understanding and modeling combustion and heat transfer characteristics of oxygen/metallized fuel reactions will be initiated. Efforts aimed at developing an experimental data base for validating combustion instability analyses will be initiated. The evaluation of very high-temperature materials (4000 degrees Fahrenheit) as potential combustor inner liners will move toward the fabrication and test of alternate design approaches. Propulsion concepts designed to operate with propellants derived in situ on the Martian and lunar surfaces will be generated, test hardware fabricated, and experimental efforts initiated.

In FY 1989, the orbit transfer propulsion program will focus on developing design concepts, improving analytical techniques, and evaluating advanced technologies for high-pressure combustors, turbomachinery, and health monitor/control systems that will provide the basis for the design and development of advanced components for breadboard testing and evaluation.

The high-temperature iridium-coated rhenium engine technology program will be completed, resulting in design criteria and fabrication procedures that will allow initiation of 100-pound thruster development. Characterization of arcjet designs and systems will be completed with long-life tests (900 hours), vibration testing, and operation at conditions above and below nominal and with plume and electrical interference measurements. The test units for flight on a communications satellite will be fabricated and installed. The 50 cm-diameter ion engine will be operated to develop more design data points for the operations model and to determine the power limits and operating efficiency. A new large vacuum chamber will be completed, allowing continuous operation of 100 kw electric thrusters, both ion and MPD. Experiments will be performed to add an externally induced magnetic field to the field which is self-

induced in an MPD thruster to determine whether efficiency can be increased above the current estimate of 35–50 percent. A low-thrust chemcial propulsion test stand with very accurate measurement equipment will become available, allowing verification of small, low Reynolds number flow models and a better understanding of the basic physics and combustion in small thrusters.

Advanced propulsion concept studies will continue toward the objective of identifying the most fruitful areas for agency interest and the critical experiments necessary to prove their potential. The magnetically confined, microwave-induced plasma experiment at the Massachusetts Institute of Technology will be in the final stage of fabrication and preparing for test initiation.

Materials and Structures Research and Technology

The objective of the materials and structures program is to provide technology that will enable the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, efficiency, durability, and economy. Major technical areas of emphasis in materials include fundamental understanding of the properties and behavior of advanced space materials; characterization of the long-duration space environmental effects on space materials; development of computational chemistry to predict fundamental physical properties of materials and their interaction with the space environment; development of advanced space-durable materials for structures, propulsion and power systems; and development of ceramic, metallic, and advanced carbon-carbon thermal protection systems. Structures technology focuses on the development of erectable and deployable structural concepts; methods for in-space construction, monitoring, and repair of large complex structures; dynamics of flexible structures and concepts for active configuration control and vibration suppression; new structural concepts for active cooling of hot structures and cryogenic tanks for advanced Earth-to-orbit rocket propulsion systems, hypersonic vehicles, and orbital transfer vehicles; and efficient analysis and design methodology for advanced space structures, including multidisciplinary analysis and optimization.

Activities in the materials program are focused on understanding the fundamental effects of the space and reentry environment on materials and developing advanced materials with significantly improved durability. The primary environmental effects of concern are atomic oxygen, radiation, thermal cycling, and debris impact. Atomic oxygen is the dominant factor in low Earth orbit and can reduce the useful lifetime of polymer coatings, lubricants, and lightweight polymer composites to a few years. In geosynchronous orbit, radiation and thermal cycling are the major concerns. In both cases, temperature variations affect the short-term and long-term dimensional stability of most materials. Impact from small debris particles (one millimeter to one centimeter) is becoming a more serious problem in low Earth orbit, requiring the development of new lightweight shielding materials and concepts. High temperature from frictional heating is the main concern during reentry, though catalytic reactions between rarefied gases and the hot surfaces of the thermal protection system can significantly increase the heating rate. Recent accomplishments have identified thermal protection materials and coatings that can minimize this effect. Advances in computational chemistry have demonstrated the potential to predict the catalytic heating effect and have recently demonstrated the ability to predict certain complex, high-temperature, molecular atmospheric interactions. These same methods are being used successfully to predict the interaction of hydrogen with metals and to predict the structure of clusters of metal atoms. These predictions are being validated by data from tests conducted especially to confirm computational methods. Similarly, a special test series is being conducted to evaluate the ability of ground-based test methods to predict the effects of atomic oxygen on space materials. This program began in FY 1987. During FY 1988, the atomic oxygen beam facility at the Jet Propulsion Laboratory will be fully characterized and calibrated. Also, real-time reaction products and the velocity distribution of the fast oxygen atom interactions with space materials were determined, which will provide the basis for improved test methods. New polymers for films and composites, based on fluorocarbon chemistry, are showing significantly improved atomic oxygen durability relative to hydrocarbons. Recent experimental work in this general area has determined the combined effects of thermal cycling and atmosphere on composite tubes. The capability to combine a thin 2-mil outer aluminum foil to graphite epoxy composite tubes was demonstrated and provides a validated approach for development of the Space Station core truss members. The outer aluminum foil provides a barrier for atomic oxygen protection and, by using an anodizing process, the spectral characteristics of the surface can be tailored for thermal control requirements. Also, methods to predict the damage (crater size) from debris impact have been developed along with concepts for improved impact resistance using composite materials. During FY 1988, a model will be developed to predict hypervelocity impact damage to graphite-epoxy composites.

The program in advanced space structures is directed toward methods to build large structures in space and to predict and control their behavior. This includes concepts for lightweight tight-locking joints and methods to maintain dimensionally precise configurations. It is closely coordinated with the large space structures and control element of CSTI but is directed toward basic methodology rather than applied technology. Erectable and deployable concepts are being developed to build large two-dimensional and three-dimensional structures in space. The 5-meter erectable truss concept for the baseline Space Station configuration came largely from this fundamental research program. The development of the baseline Space Station erectable joint concept was completed and includes a dual locking feature to prevent accidental unlatching of the core truss members. Also, a greater emphasis has been placed on automated in-space construction methods. This has led to the development of a concept for a mobile remote manipulator system to enable rapid construction and easy expansion of the space station. Prototype versions built and tested in the natural buoyancy facilities at Johnson Space Center and Marshall Space Flight Center will be completed during FY 1988.

In the area of dynamics of flexible structures, accurate methods have been developed and validated to experimentally determine the fundamental stiffness and damping characteristics of complex structures with closely spaced or clustered natural frequencies using relatively sparse test data. In particular, these methods require much less data than currently established methods and quantify damping properties more accurately. They are very applicable to truss-like structures which display frequency clustering and can be very difficult to analyze accurately. A concept also has been developed to control the dynamic motion of flexible structures by placing actuators at the base of the structure with distributed sensors along the structure. Computationally, an advanced capability has been developed to predict the nonlinear dynamics of multibody structures, and multidisciplinary analysis and optimization methods were used to develop a new concept for the Shuttle solid rocket motor field joint and to redesign the external tank attachment ring. During FY 1988, a large amplitude, transient dynamics code for flexible three-dimensional structures will be completed and validated. This will provide the capability to analyze large motions and deployment dynamics of large spacecraft systems.

The area of aerothermal structures is currently focused on developing lightweight, multiwall cryogenic tanks for reusable space transportation systems and advanced thermal protection systems (TPS). A new tankage concept has been developed weighing about three pounds per square foot, and a new lightweight ceramic TPS has been developed with greatly increased structural durability. The brittle nature of advanced ceramic TPS is its primary drawback, and a new surface coating approach has increased fracture toughness of current Shuttle TPS by a factor of ten. Also, analytical methods were developed and validated to predict the interaction of a shock wave impinging on a blunt leading edge at high Mach numbers. This phenomenon, which can increase local heat generation by a factor of ten, is a potential problem in very high-speed vehicles. During this past year, the accuracy of this analytical capability was validated over a range of applications by test data.

The space materials and structures program in hypersonics includes development of high-temperature metallics, intermetallics, and metal matrix composites; coatings for surface protection and thermal control; advanced joining and bonding methods for hot structures, including integral structure/cryogenic tank concepts; and minimum-gage, oxidation-protected, carbon-carbon materials. A new carbon-carbon research facility has been established at Langley Research Center to develop oxidation-resistant materials. During FY 1988, layered titanium TPS for use up to 900 degrees Fahrenheit will be fabricated and tested for cryogenic tank applications.

In FY 1989, the materials program will continue to focus on the effects of the space environment and on developing more durable materials. A strong emphasis will be placed on using accelerated testing methods to validate new materials. In particular, materials development will concentrate on developing polymers for protective films and composite matrices with 20- to 30-year life on orbit. Work will continue to develop improved protective metallic coatings, which can offer protection from atomic oxygen and micrometeorites, and significantly enhance dimensional stability. Low thermal expansion resins, ceramic fiber composites, and tailored surface treatment to optimize radiative properties also will be studied as ways to maintain dimensional stability. This factor will become more important as larger structures are built in space with stringent requirements to act as a stable platform for scientific experiments and astronomical observations. Computational chemistry will place more emphasis on describing combustion kinetics and atomic oxygen interactions with polymers and on predicting properties of large atomic clusters (approximating pure bulk properties). Areas which will start receiving greater emphasis are high-temperature materials for space power and propulsion and materials and shielding concepts for protection from space debris. Strong candidate materials for all three areas are metal-matrix, ceramic-matrix, and carbon-carbon composites.

The program in advanced space structures will continue to develop erectable/deployable concepts for large two-dimensional and three-dimensional structures with a strong emphasis on automated construction methods. However, new design concepts including understanding of joint effects will be developed for precision structures with requirements for high dimensional tolerance and precise pointing, slewing, and tracking capacity. This emphasis is consistent with the space materials program and the large structures and control element of CSTI. A supporting effort will be the development of efficient and accurate methods for multidisciplinary analysis and optimization for this class of structures. The area of dynamics of flexible structures will continue to develop analytical and experimental dynamic characterization methods and will focus on the concept of "smart" structures as a means for control. This involves the development of structural elements which sense vibration and distortion, either by internal or external sensor devices, and respond with the aid of embedded integral actuators in a manner which opposes the disturbance. Piezoelectrically activated structures will be developed to explore concepts of this type. Components will be designed, fabricated, and tested to demonstrate "smart" structures capabilities for vibration suppression or load alleviation. A goal of at least 25 percent improvement in structural damping using "smart" structural components will enable efficient performance gains not achievable with current technology. The focused control/structure interaction technology program, conducted under the large structures and control element of CSTI, will benefit from and be closely coordinated with this research and technology base activity.

The aerothermal materials and structures activity will continue development and testing of lightweight cryogenic tank concepts and advanced ceramic TPS with higher temperature capability (approximately 3000 degrees Fahrenheit) and high structural strength. Design and analysis emphasis will be placed on validating design concepts for curved tank structures. Curvature causes more severe realistic thermal stresses such that concepts for flat panels may not be suitable for complex shapes. Integral and separate cryogenic tank subscale components will be fabricated and tested to validate design concepts for advanced thermal protection systems and struc-

tural integrity. Ceramic composite TPS design concepts including advanced fabrication methods using improved multiaxis weaving will be continued in FY 1989. The goal of improving transverse mechanical properties by at least 50 percent will be emphasized which will then enable effective use of ceramic composites as both structural components and TPS. Here, as well, curved TPS ceramic-ceramic concepts will be fabricated and validated using arc jet tests required to achieve the high-heating rate environments for hot structures. These activities will be supported by a strong program in analytical and experimental methods to predict aerothermal loads. An increasing part of this activity will be extensive testing of hot structures, includng cryogenic tankage concepts.

The effort in space-related hypersonics will emphasize generic concepts for lightweight structures with complex shapes, including novel concepts for areas of extreme heating, such as leading edges and nose caps. One concept currently under study, in small scale, is a spinning leading edge. Advanced joining and shaping methods will be studied for thin-guage sheet and multiwall concepts, again emphasizing curved complex surfaces. Work also will continue on carbon-carbon materials including methods to improve transverse properties. Various coating concepts will be explored to improve oxidation resistance of advanced carbon-carbon composites. Small-scale components will be fabricated and tested under simulated service environments up to 3000 degrees Fahrenheit to assess the potential for carbon-carbon high-temperature structures for hypersonic vehicles.

Space Data and Communications Research and Technology

The space data and communications research and technology program is directed toward developing advanced ability to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

In the area of advanced data systems, an erasable programmable read-only memory based on the Hopfield model of neural networks was demonstrated. Materials for a variable-strength reversible synaptic connection have been evaluated. These neural memory systems have the potential to replicate the capability of the human mind for pattern recognition and deductive reasoning and will serve as hardware-based natural intelligence machines and smart knowledge bases for space applications such as robotics. The implementation of an integrated software development environment was demonstrated, and the system design was expanded to include software experience from successful programs. An advanced software life-cycle simulation development was applied to a model of the Space Station software development environment. These tools are intended to provide software managers with critical tools for evaluation of software development cost and schedule.

The communications effort is directed toward maintaining the research and technology base to enable reliable, ultra-high-rate communication links for future NASA missions. An engineering model of a 5.5-watt X-band solid-state power amplifier using gallium arsenide materials technology has been developed with greater than 30 percent efficiency. Two such models, successfully tested in a vacuum environment, have been integrated to produce more than 10 watts of radio-frequency power. A program combining existing structural and thermal computer codes and geometrical optics/aperture integration codes has been developed to enable the prediction of the far-field performance of complex dual-reflector antenna systems. A procedure has been developed for determining the amplitude and phase excitation coefficients for an array transmit or receive feed which will allow on-orbit compensation for degradation in performance due to antenna distortions. This technology may alleviate the need for more complex and costly antenna shape control. In the area of optical communications, a high-power diffraction-limited aluminum gallium arsenide semiconductor diode laser with a channel substrate planar structure has yielded less than 1/30th wave phase-front error and has demonstrated over 15,000 hours lifetime at 50 milliwatts output power. Finally, two highly efficient 200-milliwatt semiconductor diode laser arrays were employed to pump a niodynium-doped yttrium-aluminum garnet laser yielding 120 milliwatts of continuous output power. This represents significant increases in both power and reliability and comes much closer to meeting projected requirements for space applications than previous lasers. Long-life space qualifiable lasers are critical to practical space optical communications.

To enable an erasable neural network memory, the design of reversible synapses will be optimized; test structures and devices will be fabricated; and a study of advanced neural network applications will be initiated. A generic software life-cycle model will be validated by application to a number of NASA-managed software projects. The initial version of the software management environment will be applied to management and acquisition of software systems, and the knowledge base and tools will be validated and expanded toward meeting the objective of providing a complete and integrated set of tools and measures for management and acquisition of major software systems. Funding will be provided to continue support for the software engineering research center at the University of Houston at Clear Lake for continued research in Ada software development, integration, and validation for embedded and distributed systems.

In FY 1989, work will focus on the technology to develop more efficient, lighter, and smaller deep space communications. The Ka-band (32 gigahertz) promises significant improvements in these areas. Research will continue on the development of an efficient Ka-band spacecraft solid-state power amplifier. At the same time, this will enable efficient power combining and electronic beam steering with the use of monolithic microwave integrated circuits in the transmit and receive modules. Phased-array feed codes will be applied to the 15-meter hoop column antenna to evaluate their potential for compensibility for reflector distortion. The techniques will be essential for large radiometric antennas for Earth remote-sensing applications. In the area of optical commnications, research will continue on the development of laser arrays using the distributed-feedback structure with the advantage of single-frequency operation under conditions of high speed modulation. Coherent laser arrays allow the combining of low-power, solid-state, laser diodes into a high-power, high-data-rate optical communication transmitter. For deep space communications applications, high peak power

laser output pulses are required. Since holmium-doped yttrium-lithium fluoride has a fluorescence lifetime 60 times longer than niodynium-doped yttrium-aluminum garnet, these materials offer the potential of greatly increased peak powers. Research will continue on semiconductor diode array pumping of this longer life laser material.

Information Sciences Research and Technology

The objective of the information sciences research and technology program is to provide new concepts, techniques, system algorithms and architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In the information sciences area, the distributed access view integrated data base (DAVID) system software has been built and tested to provide scientific users a transparent access to space data stored in dissimilar data bases. In addition, design and detailed software specifications for a library layer on top of the DAVID system have been successfully completed. Refinements to the initial prototype version of the hyperspectral image analysis expert system have been completed. This tool suppports the heavy software analysis requirement presented by the data generated by imaging spectrometer instruments. In the concurrent processing research area, five algorithms were successfully run on the massively parallel processor. One algorithm used in the study of climatology executed 4,000 times faster than conventional virtual address computers.

In the sensing area, two focal plane deep diode X-ray imaging detectors have been fabricated and are undergoing tests. They provide high-resolution (250 electron volt) imaging capability in the 1 to 130 kilovolt x-ray energy range and have the potential of providing better spatial and energy resolution than a charged-coupled device and calorimeter instruments. High-purity mercury iodide crystals for application as an x-ray spectrometer detector have been shown to have an energy resolution of less than 400 electron volts. Electron property measurements of liquid phase epitaxy grown mercury/zinc/telluride (HgZnTe) material have yielded superior carrier mobilities and lifetimes of 2670 nanoseconds to make it superior to mercury/cadmium/telluride as a detector material. This new material offers the promise of low-cost, highly reliable far-infrared sensors with reduced transmitter output energy requirements and reduced telescope size.

In the area of photonics, a new theoretical mathematical technique for the construction of matched spatial filters has been developed which will enable the identification of multiple objects in a viewed scene irrespective of the objects' scale, orientation, and aspect angle. For the first time, these filters have been demonstrated in an optical correlator at video rates of 30 frames per second, a significant step toward real-time correlation vision systems. A prototype acousto-optical spectrum analysis system has accomplished coarse grain resolution producing a thousand frequency bins. This system allows rapid, low-cost analysis of radio frequency signals.

A high priority item for infrared astronomy research is to develop an ideal detector which can detect the arrival of a single signal photon in a "nearly noiseless" fashion. Research will continue on the following detectors that have the potential to fulfill this goal. The deep diodie X-ray detector array will undergo further testing to delineate the mechanism for variations in pixel response and resolution. A large-area, high-resolution mercury iodide detector will be construed and the design of improved detector/preamplifier electronics will be completed. Experiments will continue on mercury/zinc/telluride, in particular on the possibility that it has a longer wavelength cutoff than mercury/cadmium/telluride. Recent experiments on a solid-state photomultiplier for infrared astronomy applications indicate that this device may have quantum efficiencies of over 30 percent, fast response, and low dark current. The avalanche mechanism of carrier gain multiplication will be investigated; models of device noise will be developed; and experiments will be done on the output pulse shape. Besides detectors, solid-state lasers must also be researched for improved power performance and new lasing wavelengths for in situ sensing of planetary atmosphere and surfaces. To rapidly study possible candidate laser materials, fibers of these materials will be grown and fabricated. An analytic model describing absorption due to laser-induced emission, affected by the length of the fiber from excitation to emission, has been developed in order to study the spectroscopy of these materials. These models allow the early analysis of a complete laser system to guide the development and transfer of new laser materials.

In the area of photonics, one of the objectives is to provide real-time computer vision which requires research to increase the speed of the optical devices. The matched spatial filter component research will be dedicated to improving device size, contrast, and speed. New solid-state materials with large electrooptical coefficients will be investigated for use with spatial light modulators. A second objective is to provide very low-cost signal analysis for applications such as the microwave observing project which needs to scan a large number of frequencies with ultra-high resolution in order to detect signals from other planets. The acousto-optical spectrum analyzer research will be directed toward increasing frequency resolution by employing two-dimensional charge-coupled imaging arrays whose output can be digitized in real time and further processed by digital electronics.

Controls and Guidance Research and Technology

The goals of the controls and guidance research and technology program are to develop and validate advanced control synthesis techniques for large, flexible, loosely coupled structures; to establish analytical and design tools attendant to such developments; to provide the basis for onboard guidance, navigation, and control techniques for future space transportation systems; and to define and develop methodologies for the design and validation of highly reliable advanced flight-crucial controllers. The emphasis is placed on establishing analytical tools for the control of both large space structures and space transportation systems and testing these tools in high-fidelity computer simulations and, where applicable, in ground and flight tests.

One focus of the work for the past year has been the development of mathematical techniques for analyzing and controlling large, lightweight, flexible structures, such as space station and large space antennas. This multidisciplinary research, done in collaboration with the materials and structures research and technology program, emphasizes control techniques. Large flexible structures that will be used in space are not easily characterized by the linear models frequently used for structural analysis and control design. Accurate mathematical descriptions are required for control design because of the lack of structural stiffness of these structures. Slewing control laws have been developed using nonlinear models which are more difficult to analyze than the linear models, but which provide much higher fidelity mathematical description of real space hardware. The vertical beam/antenna configuration at the Marshall Space Flight Center has been used to validate three new control concepts based on multiple sensors and actuators which show promise for use in large antennas and the Space Station. The use of fiber-optic sensors and piezoelectric actuators that are continuously distributed throughout the structure has been demonstrated on a generic large space structure test article. These extremely lightweight elements will greatly reduce the complexity of sensor and actuator systems. A breadboard has been designed and fabricated for a three-dimensional spatial high-accuracy position encoding sensor. This technology is essential for the real-time shape identification of large space structures that must maintain precise surface accuracy. The fiber-optic gyro shows promise of significantly reducing the cost, complexity, and power demand while increasing the usable lifetime of rotation sensors for spacecraft. Significant progress is being made in replacing the electrical components in these devices with lightweight, low-power optical components and in reducing these optical components to the microchip level. A 3-component optical chip for a fiber-optic rotation sensor has been evaluated and the preliminary demonstration of an 8-component optical chip version has been completed.

In the space transportation technology area, control laws have been developed for aerodynamically assisted orbit transfers using trajectories that skip through the upper atmosphere, and these have been tested in computer simulations. This type of trajectory will be required for vehicles returning from lunar or Mars missions. Computer simulations for testing onboard, real-time guidance logic for aeroassisted space vehicles have been developed and interfaced with more complete mission simulations using a program that optimizes space trajectories. These simulations are required for comparing various approaches for guidance, navigation and control in a realistic mission environment.

Research in the space controls and guidance area will continue to emphasize development of theoretical tools for identification and control of large flexible space structures and for guidance and control of space transportation systems. Advanced laws for the identification and control of large space structures will be tested using ground-based facilities at the various NASA centers to determine which approaches can be effectively applied to the real structures, such as space station and large deployable reflectors. Research and testing will continue into the application of distributed fiber-optic sensors and actuators to more complex space structures in order to reduce the complexity and weight of systems required for structural control. The sensor will be evaluated for real-time position sensing in three dimensions and for simultaneous tracking of a number of different targets to simulate the task of tracking the precise position of a large space antenna. The fiber-optic rotation sensor will be tested using an 8-component version of the optical chip in order to further reduce the weight and complexity of the final optical gyro.

In the area of space transportation technology, the emphasis will remain on the development of algorithms for onboard real-time guidance and control for the purpose of reducing the operational costs associated with space missions. This emphasis is also imperative for the vehicles, such as aeroassist orbital transfer vehicles and the National Aero-Space Plane, which have special requirements for autonomous guidance, control, and mission planning. Guidance algorithms for ascent and abort will be developed in order to reduce operational costs and increase system reliability for new vehicles such as the advanced launch system (ALS). Technologies for validation of flight software and hardware using state-of-the-art fault-tolerant computers will be developed using a systematic approach that takes advantage of advanced information processing architectures.

Human Factors Research and Technology

The objectives of the space human factors research and technology program are to provide a technology base for intelligent operator interfaces, especially with autonomous subsystems, and to develop a new generation of high-performance space suits, gloves, and tools/end effectors to meet the requirements of advanced space missions. Development of guidelines for man-machine interfaces in space, computer-generated models of human performance in weightless conditions, and unique means for collection of human performance data in weightless conditions are included in these objectives. This reserach is focused on the space station and other manned missions now being planned which will involve more autonomous operation to reduce the cost of ground support. The technology base is intended to provide increased productivity, efficiency, and safety in complex manned operations within auotmated onboard systems and extravehicular activity (EVA) environments. Two key areas of human factors reserach are crew-station design and extravehicular activity.

Crew-station research focuses on: (1) development of integrated operator-interface technology for the supervision of space subsystems, (2) development of human-computer interface technology, including guidelines for effective three-dimensional interactive visual and aural displays, (3) providing a data base and standards of human capabilities and limitations in the space environment, and (4) development of a technology for autonomous vision and other perceptual systems to be used in space operations and maintenance.

Extravehicular activity research builds on progress made in the design, testing, and operational evaluation for an advanced hard space suit (AX-5). The utility of advanced gloves, tools, and end ef-

fectors for EVA activities is being determined through tests in special buoyant facilities for space assembly and construction tasks.

Research in crew-station operations has included: (1) applied studies of crew operations for docking maneuvers with Shuttle models, (2) analysis of astronaut operational procedures in the space workstation, and (3) identificaiton of window requirements. An anthropometric, computer-based model was developed, providing the capability to simulate human performance in the weightless environment. A number of vision studies were performed to determine and verify algorithms of retinal sampling and color coding to allow the analytical evaluation of alternate crew-station approaches. Characteristics of visual displays and computer-generated graphics that automatically capture the operator's attention were analyzed and documented to identify the better methods to use in the design of operator displays. An ongoing project to develop a workstation in which the operator, through use of a helmet with controlled audio and video input, is made to think he is in a computer-generated environment has been demonstrated. This virtual workstation capability can allow the crew to have a natural interaction with complex operational tasks which may be performed miles away from the crew's location in either a training or actual situation.

Operational experience of NASA personnel who have been involved in designing and piloting spacecraft provides an important base of information and insights relative to lessons learned. This information is being collected and organized as a data base and will be used to avoid repetition of errors and to increase the quality of the human interface. The National Research Council, National Academy of Sciences, completed an analysis of human factors needs for advanced space missions, especially those associated with the Space Station. The report was published in August 1987 and provided specific research recommendations for man-in-space operations, habitation, and productivity in unique and inhospitable environments. This study will serve as a guide to selecting our future research activities.

Research to achieve safe and productive EVA operations continues. A helmet mounted display was developed to assist the astronaut during EVA operations by making it easy for him/her to view data needed in the EVA task and to increase productivity. Test and evaluation of the AX-5 hard suit in the Ames Research Center's neutral buoyancy test facility provided a strong astronaut endorsement of the high-pressure (eight pounds per square inch) hard-suit concept. New tasks included development of a three-point body restraint system for use in EVA operations.

Evaluation of realistic, but simulated, Space Station proximity operations will be continued. Among the important topics for research are the effects of intense sunlight or darkness on visual displays and on workspace layout, including windows, other displays, and simulated operational capabilities in place. This will allow realistic workload levels to be imposed on the operators in order to evaluate operational methods and procedures. Advances in the virtual workstation will allow realistic test and information management capabilities and control of robotic operations. This effort will include assessment of three-dimensional virtual visual and auditory displays. Tests of previously developed vision and image coding methods and methods for attracting human attention to one item in preference to others will provide a baseline for advanced test and evaluation of new interfaces used in Space Station operations.

The interaction of the astronaut and his/her EVA suit will be evaluated by a series of tests on the ground, in simulated weightlessness, and under weightless conditions. Important tasks to be evaluated include astronaut strength capabilities and requirements during EVA and under weightless conditions, the relation between EVA suit design features and EVA operational maintenance requirements, and astronaut training.

Research recommended in the National Academy of Sciences report on space human factors will be reviewed with the goal of putting increased emphasis in three important research problem areas: (1) human supervision and control of autonomous space systems, (2) teamwork and interaction between automated systems/robotic systems and humans, and (3) the appropriate use of expert systems for aiding space operations and maintenance. These areas provide both the biggest challenge for humans in space operations and the largest payoff in increased productivity, safety, and effectiveness.

Space Flight Research and Technology

The objective of this program is to provide research-quality flight data supportive of ground-based research and technology efforts for the development of future space systems and operations. Data obtained from this effort support the development and verification of analytical theories and verification of ground facility performance, test methods, and techniques. This program encompasses the design, development and flight test of experiments, and the development of special purpose, reusable, flight research facilities for use in space.

Cryogenic fluid management flight experiment concepts which will provide a basic understanding of the storage, acquisition, and transfer of cryogenic fluids in the near-zero gravity environment have been formulated for flight. In FY 1988, three parallel feasiblity study contracts were awarded to examine both of these concepts in greater detail. Additionally, in the supporting ground-based program, a contract will be awarded for a liquid hydrogen flowmeter and for the design and qualification of a fail-safe valve to control the flow of hydrogen between the tanks of the flight experiment. Individual computer codes, such as that for the heat exchanger, will be incorporated into a master program which will have a preprocessor menu for easy access to its use.

In the orbiter experiments program, the Shuttle upper atmosphere mass spectrometer (SUMS), Shuttle entry air data system (SEADS), Shuttle infrared leeside temperature sensor (SILTS), and the high-resolution accelerometer package (HiRAP), which characterize the aerodynamic/aerothermodynamic environment, will be recertified and reinstalled on OV-102. The design and fabrication of the advanced ceramic thermal protection system (ACTPS) materials experiment, which provides actual flight data on durable high-performance material concepts, will be completed. Fabrication will be completed on the orbital acceleration research experiment

(OARE), which will provide data to evaluate aerodynamics induced decelerations in the free molecular flow flight regimes at orbital altitude and during entry.

The space technology experiments platform (STEP) is being developed as a cost-effective, reusable payload/experiment support system for interfacing with the Space Shuttle systems. In FY 1987, fabrication of the payload integration hardware was completed. The development of the platform avionics interface systems will continue through FY 1988.

The industry/university in-space technology experiments program (outreach) was initiated in FY 1986 to stimulate the aerospace community through the utilization of Space Shuttle and Space Station for advancing the total U.S. technology inventory. The initial selection of 41 potential flight experiments was completed in FY 1987, and contracts for definition and development will be awarded in FY 1988. Critical space technology requirements for future U.S. missions will be identified at a workshop in FY 1988.

The NASA in-space technology experiments program (inreach) was initiated in FY 1986 to stimulate flight validation of advanced space technologies being developed in the NASA research and technology ground-based facilities. Seven potential flight experiments were selected in FY 1987 for development and are planned to culminate in space flight tests during the early 1990's.

The light detection and ranging (LIDAR) in-space technology experiment (LITE), being developed to evaluate the capability of making measurements of aerosols and other atmospheric parameters from a spaceborne platform, has completed the fabrication and testing of a prototype laser transmitter module. These tests have verified the laser architecture and the power and beam quality that allows flight design to proceed. In addition, the protoflight development of the boresight assembly, telescope support structure, and the aft optics system has been completed. Systems design of the experiment will be completed and parts fabrication initiated.

The long-duration exposure facility (LDEF) awaits retrieval by the Shuttle and subsequent data analysis. Also, the ion auxiliary propulsion system remains in flight-ready status for flight on an Air Force satellite. Fabrication and flight certification have been completed on the heat-pipe radiator experiment which is awaiting an early Shuttle flight.

For the cryogenic fluid management program, development of the liquid hydrogen and gaseous flow meters and the cryogenic relief valves will be completed.

Under the orbiter experiments program, flight testing for SUMS, SEADS, SILTS, and HiRAP will begin in early FY 1989. Two flights for each of these experiments are scheduled. Additionally, installation of the remaining experiments, orbital acceleration research experiment (OARE), aerothermal instrumentation package (AIP), tile gap heating experiment (TGHE), catalytic surface effects (CSE), and the advanced ceramic thermal protection system (ACTPS), will be accomplished on OV-102 for flight beginning in mid-1989. Analysis of the data from these experiments will occur throughout the year. STEP will continue with the development and ground testing of the platform and avionics system.

The second solicitation in the in-space experiments program (outreach and inreach) will be initiated for critical space technology flight experiments. These experiments utilizing Space Shuttle and Space Station are an integral element in regaining U.S. leadership in space technology development.

Experiment assembly and certification testing for LIDAR LITE will be conducted during FY 1989.

Systems Analysis

The objectives of the systems analysis program are to identify technology requirements for prescribed mission concepts and opportunities for enabling new and improved concepts; to integrate these into a comprehensive technology set of planning options; and to generate candidate plans to develop these technologies in a timely manner. Close coordination with the Offices of Space Flight, Space Science and Applications, Space Operations, Space Station, and Exploration and other users is maintained to ensure proper understanding of missions and to gain assistance in prioritization of enabling and high-leverage technologies. This analysis program is directed at the system-focused areas of space transportation, spacecraft, and large space systems and at emerging, new, mission concepts and mission-enabling technologies.

Spacecraft systems analysis is contrated in five science and applications areas: astrophysics, space physics, Earth science, communications, and solar system exploration. In FY 1988, efforts to understand the critical technologies associated with geosynchronous Earth science observations and tethered upper atmospheric satellites will be continued. A comprehensive series of studies on the technologies required for a Mars surface sample return mission is being completed. A second Mars rover workshop was held to establish future directions of the automation and robotics program. Detailed analyses of technology tradeoffs for the Mars rover sample return (MRSR) orbital spacecraft have been initiated. Working through the spacecraft 2000 government/industry steering group, a joint strategic plan was developed for future spacecraft technology development, and definition of a spacecraft experiments testbed was continued.

The space transportation systems analyses are focused on advanced Earth to orbit (ETO) vehicles, aeroassist orbit transfer vehicles (AOTV), and advanced space transportation systems conceptual design and analysis methods. Studies and analyses focus on the generic architecture from the ongoing space transportation architecture studies (STAS). The ETO studies include the technology to support a second-generation fully reusable piloted vehicle, and advanced heavy-lift launch vehicle, and very advanced (post-2010) future space transportation systems. The ETO studies also include the definition of nonintrusive flight instrumentation and measurements applicable across the speed range during ascent and entry of an ETO vehicle.

Three specific study areas constitute the large space systems analysis program: (1) systems analysis methods, to develop and maintain advanced analytic simulation/emulation computer-based capabilities for determining the operational characteristics of large space systems, predicting nominal and worst-case failure modes,

and identifying critical system/subsystem interfaces; (2) future space systems, to address mission and system requirements and to identify their associated technology needs and trends; and (3) in-space research and technology experiments planning, using the Shuttle and Space Station as a laboratory facility. Analysis activities continue to examine the technology implications for designing a lunar base with emphasis on power systems and habitat facilities. Also, the definition of support hardware necessary to use the Space Station for in-space research and technology experiments is being completed. Specific efforts continue to develop generic space system models to permit the conduct of sensitivity trade studies incorporating advanced technology concepts and options. Additional tasks are investigating advanced power system technology for evolutionary space stations and a lunar base, low-gravity structures for the Moon, propellant and oxygen production from lunar oxides and Martian permafrost and atmosphere, and food production and enhanced human capability for extended space missions. FY 1988 activity includes the preliminary definition of experiment support equipment for an aggressive in-space experiments program in the technical areas of fluids, power, environmental effects, and structures and control.

In FY 1989, many of the long-range efforts currently underway will be continued. These efforts will have substantial impact on the development of future CSTI and Pathfinder technology program elements, as well as on identifying thrusts for the research and technology base and the evolving flight experiments program.

For spacecraft systems, the Mars rover studies will be completed, and emphasis will be directed toward the study of other human expansion precursor missions and an outer planet science station study. A focused study effort will examine the technology planning options for more extensive exploration of planet Earth. Within the astrophysics focus, activities will center on the techonology requirements for interferometic observatories across a range of wavelengths. The definition study of a space flight testbed for validating governent and industry technology development will be completed. Work will be initiated to synthesize the analytical techniques developed for past studies into a general purpose spacecraft systems analysis capabililty.

The transportation systems analysis effort will continue the definition of key areas for technology growth in orbit transfer vehicles and advanced systems for delivery of payloads to low Earth orbit. The analyses will focus on concepts and technologies requirements for a lunar orbit transfer vehicle, a heavy-lift launch vehicle, and the shuttle replacement. The continued development of design and analysis tools and the technology base for advanced transportation vehicles will enable the development of economical space systems in the future.

In large space systems, the transition of the systems analysis focus from the initial space station to an expanded mission perspective, including the evolutionary space stations, lunar bases, and long-duration manned space trips, will be continued. The primary thrust of the extended perspective is to ensure that the research and technology base program is structured to enable and support the needs of these missions in the turn-of-the-century time frame.

Additionally, the FY 1989 program will continue to include planning for the use of the Space Station as a facility to support research and technology.

In FY 1989, an added program element will address studies and analysis of opportunity-oriented technologies and their impact on enabling new mission/system capabilities. These studies will explore the potential applications of emerging, high-leverage technologies such as superconductivity, antimatter, and high-level machine learning to the formulation of new or improved system concepts. Detection of extrasolar planetary systems is a mission concept that could be enabled by technological innovation and/or breakthrough.

University Space Research

The objective of the university space research program is to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program, and this program is an integral part of the strategy to rebuild the space research and technology base. The program responds to the need to remedy the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program utilizes technical advisors at NASA centers to foster collaborative arrangements, exchange of personnel, and the sharing of facilities between NASA and the universities. The program elements include the university space engineering research program that supports interdisciplinary research centers; the university innovative research program, providing grants to individuals with outstanding credentials; and the university advanced space design program, which funds advanced systems study courses at the senior and graduate levels.

The university space engineering research program is designed to advance the traditional engineering disciplines applicable to space and bring together the knowledge, methodologies, and engineering tools needed to advance future space systems. The research centers promote the kind of multidisciplinary teamwork that systems technological problems demand and bring individuals from a wide range of engineering and scientific fields into a single research structure. These partnerships provide the universities with a broader charter for independent research and enable new mission concepts and ideas that might alter NASA's own visions of the civil space program. In the summer of 1987, the Office of Aeronautics and Space Technology issued a notice calling for proposals by November 1987. A total of 115 proposals were submitted and 310 evaluators were selected from NASA, industry, universities, and other government agencies to conduct the evaluation process.

The objective of the university innovative research program is to sponsor individual research on highly innovative space technology concepts directed toward far-term mission use. The grants will be awarded to persons who have a demonstrated record of performance in generating and validating innovative concepts. Selection of grantees will be made through a competitive evaluation conducted by a peer review selection panel. The grants to innovative researchers are for a three-year duration, with one-year awards and two

annual renewal options. Each grant requires a center-designated person to serve as technical advisor for the research activity. Eventually 20 or more small ($100 thousand/year order of magnitude) individual research grants will be awarded.

The objectives of the university advanced design program are to foster engineering design education in the universities and to supplement NASA's in-house efforts in advanced planning for space systems design. Expanding from the original 9 to a total of 25 universities cooperating with 8 NASA installations in 1988, the advanced design program continues to mature and strengthen. The study topics include potential missions which could be undertaken during a 20–30 year period, beginning with the space station initial operating configuration scheduled for the mid-1990's. During FY 1988, design studies for both manned and unmanned endeavors included a lunar storage and transfer system, variable artificial gravity facility for the Space Station, ram accelerator direct launch system for space cargo, long-term space habitat, construction equipment for lunar base, and a Mars oxygen processor demonstration unit. The university advanced design program has been an effective mechanism for integrating the educational objectives of the university community with the advanced engineering design interest of NASA.

The FY 1989 university space research program will be augmented to enable an increased number of universities and academic researchers to participate effectively in the program.

In FY 1988, the program funding will permit establishment of eight research centers. The FY 1989 program funding is required to continue the support of the incumbent centers, as well as to expand the number of centers. The enthusiastic response from universities, both in number and in the quality of the proposals, demonstrates the timeliness and perceived value of the program. Many excellent proposals will not be funded in FY 1988. The augmented program will allow NASA to expand university participation, achieving a better technical balance and a broader geographic involvement, and to more fully satisfy program goals.

It is intended to continue funding, as planned, those eminent researchers selected in FY 1988 to participate in the university space innovative research program and to continue to add on a quarterly basis additional three-year grantees. The total number of grants is planned to reach a level of approximately 20 during FY 1989. Grant additions will continue in future years, with some rollover of grantees occurring at the lapse of their three-year grant periods. The university space design program will continue during FY 1989 and will seek to become more effectively coupled to the NASA future missions activities, particularly with the space exploration program studies efforts. There will also be an attempt to increase the interactions and cooperative efforts between universities so that related studies can be coupled for a more effective program. Semiannual conferences will be continued to promote these interactions.

Civil Space Technology Initiative (CSTI) Program

Fiscal Years 1988 and 1989 Funding Levels

	Estimated fiscal year 1988	Authorization fiscal year 1989
Automation and robotics	$25,100,000	$25,900,000
Propulsion	23,800,000	46,700,000
Vehicle	15,000,000	28,000,000
Information technology	16,500,000	17,100,000
Large structures and control	22,000,000	25,100,000
High capacity power	12,800,000	14,000,000
Total	115,200,000	156,800,000

The Civil Space Technology Initiative (CSTI) is developing the technologies to enable reliable and lower cost access to space and to support enhanced space operations and science missions. Support for future space transportation systems includes: autonomous systems research for prelaunch and postlaunch operations; reusable, high-performance engines for next-generation launch vehicles; and a flight demonstration of aerobraking for orbit transfer vehicles. Future Earth-orbiting operations and science missions will be enhanced through an expanded effort in automation and robotics; technology to significantly increase data processing and storage capabilities; ground and in-space experiments to expand the design data base for very large, flexible structures; and technology for high-capacity nuclear power conversion systems. New sensor technologies and capabilities to deploy large, extremely precise surfaces will further enhance Earth and deep space observation.

Automation and Robotics

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. The goal of the robotics element is to evolve the capability for remote space operations from the current level of teleoperation (direct human control) of a single crane-like arm, through the telerobotic operation (human supervisory control) of dexterous multiarmed manipulators, to the robotic operation (human task-level control) of multiple intelligent manipulators. The goal of the autonomous systems element is the use of artificial intelligence technology to effect the reduction of manpower involved in ground control; automation of control of subsystems aboard the Space Station, spacecraft, and space transportation vehicles; and elimination of astronaut time spent performing housekeeping functions.

The robotics element consists of a sequence of evolutionary demonstrations, together with five core technology elements: sensing and perception, control execution, task planning and reasoning, operator interface, and systems architecture and integration. In FY 1988, the telerobotic demonstration facility, which consists of a two-arm manipulator, a third arm with a vision system, and a suspended spacecraft (Solar Max) model, completed its first demonstration

task. Using machine vision and integrated position/force control, a spacecraft rotating at two revolutions per minute (RPM) was captured without having a preprogrammed spatial trajectory. Several scientific achievements were accomplished in the core technology areas. In sensing and perception, a machine vision system demonstrated its capability to identify and track a satellite spinning at 15 RPM with labeled vertices (i.e., lit with light-emitting diodes) and at 9 RPM with unlabeled vertices. This capability will be required for robotic capture of spinning satellites for retrieval and servicing. In the area of operation interface, it was demonstrated that the assembly concept for construction of erectable space structures (ACCESS) could be assembled using teleoperation in a one-gravity environment. Another space structure, the erectable assembly structures experiment (EASE), was actually assembled by the beam assembly teleoperator (BAT) in the zero-gravity simulation of the neutral buoyancy test facility at the Marshall Space Flight Center. These telerobotic assembly tasks establish the feasibility of telerobotic assembly in space. When the robots become operational on the Space Station, they will dramatically decrease the required amount of astronaut time spent doing time-intensive, expensive, and potentially dangerous extravehicular activity. In the area of control execution, much more precise manipulation of a single workpiece required for complex assembly and servicing applications, was achieved through coordinated hybrid position/force control of two arms.

The autonomous systems element is composed of a sequence of evolutionary demonstrations using Space Station, a set of operational demonstrations using Shuttle and spacecraft, and research elements in the following core technology areas: planning and reasoning, control execution, operator interface, and systems architecture and integration. This program is closely coordinated with that of the Defense Advanced Research Projects Agency (DARPA), assuring that relevant technologies in the DARPA strategic computing initiative are fully leveraged.

In the evolutionary demonstrations for Space Station, all preparations were completed for the initial test of the expert system for control of the thermal control subsystem. This system incorporates capabilities for fault diagnosis of a majority of failure modes, real-time control and reconfiguration, and incipient failure prevention through trend analysis of the Space Station's thermal control system. This capability, when operational, will increase the Space Station scientific throughput by allowing the astronauts to spend their extremely valuable workhours on scientific experiments rather than on mundane housekeeping functions. In the operations demonstrations, one expert system has been developed for monitoring and making recommendations on management of Space Shuttle communications, and another has been developed for autonomous control and diagnostics of the Space Shuttle's environmental control system during launch processing. In the core technology program, an expert automation classification (AUTOCLASS) system has been developed which through deduction automatically learns the most probable set of subclasses of a data base. Such a system will help scientists who are studying large data bases, such as the infrared astronomical satellite data base, by automatically breaking down the entire data base into smaller sets of highly similar data vectors. For example, (AUTOCLASS) has provided the indication that there are more classes of heavenly bodies than astronomers previously recognized. In control execution, a mathematical theory is being developed to integrate artificial intelligence and conventional control system design methodologies. In systems architecture and integration, preliminary performance tests have been completed for an advanced very large-scale integration (VLSI) space-qualifiable symbolic processor developed under this program.

In robotics, development and advancing technologies are described by a sequence of evolutionary ground demonstrations scheduled through 1996. In FY 1989, the telerobot demonstration facility at the Ames Research Center will perform its first test in which all of its subsystems (artificial intelligence, run-time control, sensing and perception, operator control, and manipulation and control mechanization) are implemented. The task will be to remove and replace a module in the spacecraft mockup. This will be the first implementation of the concept of traded control in which the automatic control system and the human operator can pass control smoothly to each other during the task. Since all existing remote manipulators are either robotic or teleoperator in nature, this will be the first time the integration of the two has ever taken place. Further demonstrations will take place in 1993 and 1996. The 1993 demonstration will incorporate automated replanning for error conditions. The 1996 demonstration will extend repair tasks to include cutting and fabrication.

Research and development in each of the five robotics core technology areas will continue. In task planning, artificial intelligence techniques will be used to develop telerobot arm movement sequences and trajectories to provide more precise and more rapid positioning. In operator interface, development of virtual workstation concepts will continue to focus on the telepresence aspect of the operator control station. In sensing and perception, the machine vision system will be extended to include tracking with partial occlusion, which may occur in real applications, and a 160-module vision system will be developed. In control execution, algorithms will be developed for control of robot arms with redundant links, i.e., with more than six degrees of freedom, thus allowing the same end-effector position to be achieved using different configurations of the arm. In the area of systems integration and architecture, a new grant made to Carnegie Mellon University in FY 1988 will develop a working model of a planetary rover.

Integration of advancing technologies in the automation element is also described by a sequence of evolutionary ground demonstrations through 1996. The first demonstration (in FY 1988) will be of the expert system for control of the Space Station thermal system and will be tested on the thermal testbed at Johnson Space Center. It will be rule-based for control of a single subsystem in which reasoning is limited to standard procedures, and knowledge of the task world is complete and unambiguous. The second demonstration (in 1989) will be of a model-based expert system for coordinated control of multiple subsystems, and it will be capable of reasoning about nonstandard procedures.

The expert system for monitoring of Shuttle communications will be tested during the next Shuttle flight, where it will operate in parallel with the human controllers who will have actual control. The expert system for control of the environmental control system during launch processing actually will be used during the next Shuttle launch. This will be the world's first operational use of artificial intelligence in a space mission. In core technology, the following actions will occur: (1) In planning and reasoning, the classification system findings will be evaluated by astronomers, and development of a generic tool for very complex scheduling problems will be developed; (2) in control execution, the development of methods for integrating artificial intelligence and conventional tools for control system design will continue; and (3) in systems architecture, a brassboard system of the complete space-qualifiable symbolic processor, including system software, will be developed.

Propulsion

The objective of the CSTI propulsion program is to provide a validated design and analysis capability that can be applied to the design and development of advanced propulsion systems for future low-cost reusable Earth-to-orbit (ETO) vehicles and recoverable boosters.

The ETO propulsion technology program will validate advanced design concepts and analytical techniques that have been developed with laboratory-scale, subscale, and rig test hardware through the design, fabrication, and test of large-scale component technology hardware. The technology hardware will be highly instrumented and will be capable of varying operating conditions over a wide range, in order to provide a broad experimental data base with which to validate analytical codes and evaluate new design concepts. Typical components include large-scale combustors and gas generators and high-pressure turbopumps designed for efficient performance over long operating times. Being able to operate at a high combustion pressure provides the opportunity to optimize engine performance, weight, and size for specific vehicle designs. For this reason, most of the effort will be related to high-pressure systems. Accurate modeling of combustion performance, stability, and heat transfer, as well as turbopump hot gas flows, bearing thermal and mechanical characteristics and rotor dynamics, will provide the design and analysis tools needed to develop long-life reusable engine components with accurately defined design margins and performance capabilities.

Candidate propellant combinations include oxygen/hydrogen (at Space Shuttle main engine (SSME) and oxygen-rich mixture ratios) and oxygen/hydrocarbons. The program includes the SSME testbed engine which will be used to verify the performance of advanced technology components in a system-level environment, including advanced bearings, hollow and single-crystal turbine blades, and diagnostic instrumentation.

In the development of advanced design concepts and analytical techniques, significant progress has been made in a number of areas. A thermal model under development for cryogenic bearings was used to predict bearing temperatures as a function of speed, load, and coolant flow and was validated with data obtained in a bearing tester. Results indicate that two-phase flow may be occurring in the SSME pump bearings, and based on this analysis, the cooling flow is being increased. The use of powder metallurgy gives promise of longer life bearings based on the results of rolling contact fatigue testing. This processing technique will be used in the fabrication of new ball bearings for evaluation in the bearing tester. Using a new measurement technique, bearing materials auto-ignition temperatures have turned out to be lower than expected based on classical test procedures. This is due to internal endothermic and exothermic reactions that have been masked in previous testing. In the future, the bearing thermal model will be used to provide adequate temperature margins relative to the newly established auto-ignition temperatures. Advanced single-crystal hollow turbine blades have been evaluated in a burner test rig and show promise of extending blade life up to 30 times that expected with currently used directionally solidified materials. A method of detecting engine anomalies by viewing the exhaust plume with a spectrometer has been developed and has been used to detect degrading bearing materials in the plume. Eventually, with further development, the instrument will be reliable enough for active engine shutdown in real time. Both a fiber-optic deflectometer for measuring bearing wear and an optical pyrometer for detecting turbine blade temperature anomalies have been demonstrated in the laboratory, and design efforts have been initiated for installing these diagnostic sensors in the Space Shuttle main engine pumps for evaluation in the technology testbed.

In the liquid oxygen (LOX)/hydrocarbon combustion area, carbon deposition characteristics of RP-1, propane, and methane at mixture ratios commensurate with gas generator turbine drive operating conditions have shown that methane appears to have the cleanest combustion process at the combustion temperatures of interest. Efforts have been initiated to design and fabricate large-scale LOX/hydrocarbon combustor hardware that will be used to validate combustion performance, stability, and heat transfer analytical models developed in the subscale hardware test program over the past several years. In addition, the procurement of highly instrumented large-scale technology turbopumps for in-house testing to validate turbine stage performance codes, hot gas flow codes, rotor dynamic codes, and advanced design concepts, including new shaft bearing suspension systems, has been initiated.

The booster technology program will investigate alternate propulsion concepts for the Space Shuttle booster, both solid-liquid hybrid boosters and pressure-fed bipropellant liquid boosters. Performance models will be generated and verified with data from a number of static firings with increasing size. Thrust levels of up to a million pounds will be considered. A single system will be selected for large-scale demonstration of performance and safe abort capability. There has been limited experience with either booster system to date. Hybrid firings have not exceeded 75,000 pounds of thrust and pressure-fed systems have not exceeded 250,000 pounds. There has been no technology effort with either system for booster applications for several years.

In FY 1989, the CSTI Earth-to-orbit propulsion program will continue to conduct LOX/hydrocarbon specific technology tasks to

verify high-pressure ignition, combustion performance and stability, heat transfer and cooling, and will begin the design and fabrication of appropriate large-scale technology turbopumps. Models and design concepts developed in the subscale research and technology base program will be used for the design of the large-scale hardware.

The Space Shuttle main engine testbed effort will include the final assembly of the testbed engine and the initial hot-fire operations utilizing the newly activated S1C test stand at the Marshall Space Flight Center. Research-quality diagnostic instrumentation, including selected advanced technology sensors, will be installed and calibrated. Advanced technology components (turbine blades, diagnostic sensors) will be prepared for installation for the second hot-fire test sequence.

For the hybrid booster system, FY 1989 efforts include evaluating candidate fuels, establishing burning characteristics, evaluating propellant configurations, selecting an oxidizer pump concept, evaluating spray concepts, and establishing the mechanisms for a safe abort option. For pressure-fed liqiuid booster systems, tasks include propellant selection, combustion stability characterization, pressurization systems, design, nozzle size and number optimization, and structural design and material evaluation. Both systems will enter the mid-size hardware fabrication and test phase in FY 1989.

Vehicle

The aeroassist flight experiment (AFE) will investigate the critical vehicle design and environmental technologies applicable to the design of the aeroassist orbital transfer vehicle. Aerodynamic braking maneuvers, which occur in the upper regions of the Earth's atmosphere at or near geosynchronous return velocities, produce aerothermodynamic environments that cannot be simulated in ground facilities or modeled using existing analytical techniques. It is necessary, therefore, to obtain critical aerodynamic and aerothermodynamic data from flight experiments. The technologies that will benefit from the AFE are categorized into environmental and vehicle design technologies. The environmental technologies include nonequilibrium heating (radiative and convective), wall catalysis, and real-gas aerodynamics. Vehicle design technologies involve thermal protection materials, structural loads, avionics, and guidance and control. Design technologies are strongly influenced by the variations associated with the upper atmosphere.

The technology data base developed by the AFE will enable the use of aeroassist in conjunction with an orbital transfer vehicle to achieve minimum fuel expenditure in a return to low Earth orbit from a high energy orbit, such as geosynchronous. Application of the aeroassist or aerobrake concept to the orbit transfer vehicle on return to low Earth orbit has the potential for increasing the payload by a factor of two.

In FY 1988, wind tunnel and arcjet tests will be performed to support the establishment of the AFE aerodynamic and aerothermodynamic design requirements. Experiment feasibility studies will be completed, instruments will be selected, preliminary design will begin, and procurement for the propulsion system and the thermal protection system tiles will be initiated.

In FY 1989, the preliminary design of the AFE spacecraft and associated ground and airborne support hardware will be completed and final design initiated. Component structural testing on the aerobrake will begin. Software simulations will be conducted to evaluate guidance and navigation control schemes. Wind tunnel and arcjet testing will be continued to support the design data base for the AFE. Additionally, mission requirements will be defined and a preliminary mission operation timeline prepared.

Information Technology

The objective of the information technology program is to discover, invent, and develop new materials, devices, components, and systems that will enable active and passive detection and imaging of electromagnetic radiation and subsequent data storage systems for space missions in the next century. Of special importance are tunable laser sources and millimeter wave sensors for both active and passive remote sensing of the Earth's atmosphere and surface.

Passive remote sensing in the relatively unexplored submillimeter portion of the electromagnetic spectrum relies on space-qualifiable heterodyne detection systems employing a local oscillator and mixers. The programmatic goal is to develop oscillators with frequencies of up to 1.5 terahertz allowing detection of the lowest wavelengths of interest from stellar sources. The world's first fundamental solid-state oscillator for use in submillimeter heterodyne detectors will be demonstrating useful power levels at 200 gigahertz (GHz), and frequency multiplying by tripling 67 GHz to 201 GHz. Small-area superconducting-insulating-superconducting (SIS) junctions made of niobium nitride with magnesium-oxide insulating layers are demonstrating nonlinear characteristics necessary for a successful submillimeter detector mixer. Research is continuing on scaling this device to higher frequencies. At the same time, new mixers are being developed that can detect very low light levels and whose electronic noise levels are less than the theoretical limit. A mercury/cadmium/telluride photodiode mixer employing a novel interdigitated electrode concept will be successfully operated at a wavelength of 28 micrometers with 2 percent efficiencies over a 500-megahertz (MHz) bandwidth. These devices will allow astrophysics observations in the far infrared spectrum. Because of limited life and reliability, the cooling of spacecraft detectors to low temperatures with current refrigerators has been a problem for system design engineers. In collaboration with the National Bureau of Standards, a single-stage pulse tube refrigerator has been built and will be successfully demonstrated by producing 12 watts of cooling at 80 degrees Kelvin, thus demonstrating the feasibility of this inherently reliable technology.

Current lasers lack the degree of reliability, tunability, efficiency, and frequency purity required for space operation. A solid-state titanium-doped sapphire laser has been used to demonstrate, in the laboratory, amplification by a factor of 2, injection locking turning, and generation of picometer pulses. This will meet projected requirements for tunability, efficiency, and frequency purity. Additional work will be directed toward reliability and long lifetime requirements. LIDAR remote sensing of the earth's atmosphere requires lasers with wavelengths of 2–3 micrometers to detect meth-

ane. Research to develop a holmium-doped yttrium-aluminum garnet laser in the 2–3 micron wavelength range was initiated with a design where only the laser cavity needed cryogenic operation. Finally, an autotracking second harmonic generator has been integrated with a vibronic alexandrite laser leading to improved detection and quantification of numerous tropospheric trace species and pollutants.

In the area of onboard processors, a 4-element parallel processor is being successfully demonstrated, applying the evolving 1750A very high-speed circuit technology to the development of a new generation of high-speed general processors. The concept for an expandable flight optical disk recorder/controller was developed based on drive modules comprised of two 14-inch counter-rotating disks and a modular controller concept. A controller architecture is being initiated which allows expandability to a tera (10^{12}) bit capacity with error coding/correction, onboard data formatting, and in-flight reconfigurability.

A breadboard optical disk system demonstrated the write, read, and erase capability with the magneto-optical technology, including the necessary 14-inch media laser devices and electro-optical system. The erasable optical disk system and media were developed through a multiagency consortium of which NASA is a major partner. An 8-bit slice general processor, utilizing gallium arsenide technology, is being developed during FY 1988. This processor technology, integrated in a system with a controller enabling bitslice and pipeline computer operations, will achieve operational speeds required by imaging preprocessors (e.g., 5×10^9 operations per second). A study to evaluate the applications of onboard processing digital synthetic aperture radar (SAR) data was completed and resulted in a patent application and design architecture which provides for significant power and mass reduction for future SAR flight missions.

The next major thrust in science instrumentation is submillimeter heterodyne detectors utilizing coherent detection principles and concepts with simultaneous spatial array imaging capabilities. This notion will greatly enhance the future scientific instrument throughput by at least two orders of magnitude in these wavelengths. Research efforts will proceed in three technically deficient areas: direct detectors and heterodyne frequency sources (local oscillators), frequency mixers, and quasi-optical components for the submillimeter portion of the electromagnetic spectrum. In the local oscillator area, research will continue to focus on the development and evaluation of novel backward wave oscillator tubes employing electronic microfabrication techniques, quantum well semiconducted oscillators and frequency multipliers, and submillimeter lasers sources. In the mixer area, work will continue on SIS as well as Schottky diode mixers. In the quasi-optical area, exciting concepts on coupling the SIS mixer arrays with planar antenna structures and possibly integrated lenses will be pursued. Finally, since a majority of these components will need to be cooled to low temperatures, a concomitant effort will be dedicated to cooler or refrigerator technology to enable and extend sensor system performance and life.

In the active remote sensing area, the research effort will be focused on the necessary technology to implement solid-state laser systems for future missions. Future science-sensing active instruments will require semiconductor laser array pumping, new solid-state laser crystal materials, and efficient frequency doubling and tripling materials, with system efficiencies of 5 percent and reliabilities of 3 years, respectively. To enable this, research will be focused on new electro-optic materials including the chromium-based compounds, alexandrite, emerald, sapphire, and possibly diamond. The emphasis will be on achieving adequate heat dissipation, frequency stability, and spectral purity.

The high rate/capacity data effort is directed at efficient and timely collection, extraction, manipulation, and utilization of space-derived data. A new generation of data and information systems will be developed to enable smart sensors to maximize information return from future space missions and increase scientific productivity. In addition, onboard processing and storage will enable the compression of data into more useful information at the source of the space data. Work will continue on the modification of the 4-processor very high-speed integrated circuit (VHSIC) breadboard. Test software written in Ada will be developed for measurement of multiprocessor efficiency and demonstration of system fault tolerance. The development of an optical disk controller and a brassboard optical disk buffer module will be initiated. The gallium arsenide processor and controller will be integrated to implement to space data compression algorithm designed to operate at a 200-MHz clock speed. A preliminary design of a single-azimuth processing channel for the onboard digital SAR processor will be implemented with discrete components in a developmental testbed environment. The preliminary design of a very large-scale integrated circuit chip for implementation of the azimuth correlator function will be accomplished.

Large Structures and Control

The objective of the large structures and control element of CSTI is to develop integrated structures and control technology to enable the development of large flexible structures and high-precision structures to meet long-range requirements for complex multibody platforms, spacecraft, and large scientific instruments. Past and current systems, including the space station, have been designed so that on-orbit stability, control, structural integrity, and performance could be assured by analysis and ground-based testing. Future systems will be very large and flexible and possibly require extreme precision (e.g., a large lightweight telescope); therefore, current design and test methodology will be inadequate to assure on-orbit performance. In particularly, gravity loading on earth can significantly affect structural natural frequencies and damping of large flexible structures, and the dynamics of an onboard control system can interact with the dynamics of the structure leading to uncontrollable, or even unstable, motion.

In 1985, the control of flexible structures (COFS) program was initiated, consisting of two key thrusts: (1) a fundamental research and technology program to develop integrated control structures interaction (CSI) technology as an approach to the multidiscipli-

nary analysis, design, and testing of large flexible structures, and (2) a progressive series of Shuttle-based flight experiments to provide a data base for CSI technology development and to validate new methods and concepts. The series of flight experiments, designated COFS I and II, would begin with a simple beam truss, scheduled for 1991, and end with a multibody experiment. In addition, a scale model of The Space Station, COFS III, was planned to compare ground-based predictions with in-space measurements.

During FY 1987, a 20-meter ground test version of the 60-meter flight article was delivered to NASA for testing. Also, a guest investigator program was developed to enable universities and industry to participate in the flight test program. However, cost and schedule problems led to cancellation of the contract for the flight article. As a result, the FY 1988 program plan was revised in order to consider several options for comparable flight experiments that could still meet the FY 1991 schedule and provide valuable CSI data. A basis for these options is to use existing hardware rather than develop the more specialized hardware as had been the course under the original plan.

During FY 1988, an experiment will be selected to meet the 1991 schedule, consistent with the existing COFS budget, and development of the test article configuration will begin. Also, a comprehensive ground-based CSI program is being developed consisting of advanced analysis, design, and test methods and concepts for controlling structural response through a robust global control system and through "smart" structures having controllable stiffness and damping.

The second part of the large structures and control element, precision segmented reflectors, began in FY 1988. It addresses the requirements of advanced, orbiting, scientific instruments (such as the proposed 20-meter large deployable reflector) to have large, extremely precise surfaces on the order of 1-micron average roughness. Such systems would be too large to be placed in orbit by a single launch vehicle. They will also have to be very lightweight to avoid excessive launch costs. Consequently, reflecting surfaces, supporting structures, and appendages (such as a floppy sun shade) will have to be constructed in space, and precise alignment and vibration suppression will be accomplished largely by active control concepts. The technology developed under this activity will be validated/demonstrated at the end of FY 1991 in a multi-panel testbed system. Major accomplishments for FY 1988 will be the design of a multipanel alignment control system, conceptual development of an erectable/deployable backup truss structure, and fabrication of a 1-meter reflecting panel with 10-micron surface accuracy.

During FY 1989, the revised COFS I structural flight hardware will be developed in preparation for a 1991 space experiment (requiring a 1990 delivery to Kennedy Space Center). Control sensors and actuators will be integrated into the structure, and ground tests will be conducted to establish control/structure response characteristics and for comparison with analytical predictions.

The CSI technology activity will continue to develop integrated control/structure analysis and design methodology and test methodology focused on selected structures, including the COFS I flight article. This will be a multicenter activity involving Langley Research Center, Marshall Space Flight Center, Goddard Space Flight Center, and the Jet Propulsion Laboratory and will be directed toward developing a NASA-wide approach to accelerate the design, development, and qualification of future large space structures. During FY 1989, a global control concept and piezoelectrically activated structural members will be developed and demonstrated to control shape and dynamic characteristics of large flexible structures. Also, analytical and ground test methods will be validated for predicting the on-orbit characteristics of flexible structures, including the COFS I flight article, and a COFS III generic pathfinder model will be developed.

The precision segmented reflector activity will develop a component-level system to control panel alignment, and a control law will be demonstrated by simulation. Several 1-meter honeycomb construction reflector panels will be fabricated with 3-micron surface accuracy, demonstrating both precision and reproducibility. Also, an initial erectable/deployable backup truss design having millimeter-level precision will be fabricated and demonstrated.

High Capacity Power

The objective of this program is to develop the technology base for a nuclear power system capable of supplying high-capacity, long-life power for potential future sustained lunar and planetary base operations and any future evolutionary developments to the space station, and to supply power to electric propulsion systems for interplanetary cargo transfer vehicles. This is a joint activity with the Department of Energy (DOE) and the Department of Defense (DOD). The NASA program emphasis is on thermal-to-electric conversion, heat rejection, and power management and distribution subsystems. Higher conversion efficiencies in conjunction with improved thermal and power management and distribution systems materials and design innovations can enable a fivefold increase in the electrical power that can be delivered from the available thermal output of the SP-100 reactor, while more than doubling the system power-to-weight ratio. In FY 1988, NASA will support the joint-agency SP-100 ground engineering systems (GES) program to maintain the momentum of this priority national ongoing activity. The space nuclear reactor technology being validated in the SP-100 GES demonstration program is an essential first step in the process that will lead to the successful development of high-capacity power systems. Revised plans were generated that essentially delayed startup and/or completion in the out-years of selected activities. Realignment to increase the NASA contribution for SP-100 in this CSTI high-capacity power program has resulted in a scale down of the FY 1988 advanced conversion technology activity. In FY 1989, the NASA contribution for SP-100 is budgeted in the operations technology element of Pathfinder.

Dynamic conversion system technology with thermal-to-electric conversion efficiency of at least 25 percent has been demonstrated in a 25-kilowatt electric (kwe) initial demonstrator engine. Tests of the 12.5 kwe free-piston Stirling engine configuration with advanced heat transport and bearing components are underway to evaluate performance and endurance characteristics. The ultimate goal is a refractory metal Stirling engine that will be capable of op-

erating at 1300 degrees Kelvin (K) delivered by the reactor thermal source. As an intermediate step, a full-scale Stirling space engine is being designed to be fabricated of superalloy material for tests to be conducted at 1050 degrees K to investigate critical performance and reliability issues. In the thermoelectric static converter area, laboratory characterization of potentially stable, higher efficiency silicon germanium/gallium arsenide phosphide (GAP) junction materials has been concluded. Improvement over the baseline silicon germanium material is two- to threefold in terms of couple efficiency. The technology target of the silicon germanium thermoelectric effort is to achieve a figure of merit of greater than 1.0, as compared to the current level of 0.7. Material characterization and development of several even higher efficiency rare earth chalcognide junction material candidates (potentially providing a figure of merit as high as 1.4) have been completed with establishment of respective physical, thermal, and electrical properties.

Alternate waste heat radiator concept studies have been initiated to identify promising candidates. In parallel with this activity, supporting research and technology efforts in heat pipe modeling and analyses were conducted. New high-temperature composite materials were developed, manufactured, and characterized in this period. Tungsten fiber-reinforced niobium composites and also graphite fiber-reinforced copper composites exhibited improved creep strength at the high temperatures of interest, resulting in potential mass savings on the order of 10 percent. Joining and fabricating techniques for high-temperature intermetallic compounds used in building thermal systems were developed. Techniques have also been developed to texture the surfaces of these materials to achieve thermal emittance greater than 0.8 at 1300 degrees K.

Tests are continuing with a new family of semiconductors based on silicon, deep injection, double-dopant materials which result in inherently high tolerance to high levels of radiation exposure. Two orders of magnitude improvement in radiation tolerance over current systems at increased operating temperatures (400–500 degrees Centigrade range) have been measured. In addition, laboratory-scale demonstrations of advanced switches, inverters, converters, and distribution concepts were initiated. Fault-survivable power distribution concepts are being defined and assessed in this latter activity.

During FY 1989, preliminary design of the Stirling space engine will be completed. After design review and approval, the detailed design efforts for the test engine(s) will be initiated, as well as test planning. N-leg silicon-germanium/GAP material characterization and development, increasing the figure of merit to 0.85 for the thermoelectric converter, will be nearing completion. The program has optimized the thermal and electronic properties of the N-type thermoelectric converters. Research on P-leg configurations with similar materials will continue.

The waste-heat radiator configuration is the major mass contributor in the high-capacity power system. Advanced radiator concept definition studies will have been completed. Parallel studies of selected concepts will be initiated addressing feasibility assessment at the component level. Technology development efforts for the power management and distribution system components will be increased, and a definition and assessment effort directed at fault-survivable power system concepts will be initiated in FY 1989. Research and technology tasks addressing the space environmental effects and interactions will also be conducted.

Pathfinder Program

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Exploration technology	0	$17,000,000
Operations technology	0	41,000,000
Humans-in-space technology	0	13,000,000
Transfer vehicle technology	0	14,000,000
Mission studies	0	15,000,000
Total	0	100,000,000

Project Pathfinder is an important new program through which NASA will develop a broad set of technologies that will enable decisions on future space missions. Project Pathfinder is the critical next step, augmenting CSTI, in strengthening the technology foundation of the civil space program and the nation's technology leadership. Moreover, Pathfinder is an essential prerequisite to any future decision by the nation's leadership to go forward with ambitious civil space missions. Pathfinder is organized into four technology areas: exploration, operations, humans-in-space, and transfer vehicles. In addition, mission studies will be conducted to support the detailed formulation of mission requirements and technology options. The technologies included in the exploration element are related to the gathering of scientific knowledge and technical understanding at mission sites on the Moon and Mars. The space operations element will address critical technologies for in-situ materials processing, fabrication, and assembly and repair of massive and complex systems in Earth orbit and at lunar and Martian orbits and surfaces. The humans-in-space program will address the technology for improving astronaut productivity, maintenance or health, and minimal or no dependence on resupply of expendables. The transfer vehicle element will support transportation to and from geostationary Earth orbit, the Moon, Mars, and other planets.

Exploration Technology

In the expoloration technology area, development of the critical technologies necessary for the gathering of scientific knowledge and engineering understanding at mission sites on the Moon, Mars, and other planets in the solar system will be initiated. Specific objectives include the capabilities for robotic exploration missions ultimately capable of autonomous surface exploration; site characterization; and sample collection, analysis, and return. This capability would enable the resolution of many scientific questions related to the geology, biology, and surface chemistry of sites without an in situ human presence. It would also greatly augment the capabilities of humans when they eventually are on site. Also to be initiated is

the development of specialized surface power systems that are capable of providing the power requirements necessary for sortie, piloted missions, and for the interim period while base power systems are being established. All systems will be required to survive exposure to the extreme dust and temperature environments of the Moon and Mars. Optical communications technology will be developed to support the high-volume high-rate information transfer that is associated with both the high levels of surface activity and the collection of extensive scientific and engineering data.

The essential technologies for the future robotics and piloted exploration of the solar system are grouped into four spearate elements: planetary rover; sample acquisition, analysis, and preservation; surface power; and optical communications. The planetary rover elements will focus on the development and integrated testing of technologies for mobility, navigation, site identification, and portable power. The sample acquisition, analysis, and preservation element will focus on the methodology for sample identification and selection, chemical and physical analysis, the development of special tools for sample acquisition, and sample preservation techniques. The surface power element will perform research leading to high power-to-weight, photovoltaic arrays, and regenerative fuel cells that are resistant to the dust, chemical reactants, and temperature environments ambient to the Moon and Mars. Optical communications hardware will be developed to support a subsequent flight demonstration at interplanetrary distances.

In 1989, the planetary rover element will be focused on designing the local navigation and mobility testbeds and awarding contracts for their implementation; selecting and developing the technologies to be incorporated into the testbeds; and carrying out the second year of a university grant for rover development activity. The preliminary testbed objectives will include semi-autonomous traversal of a simulated Martian terrain using stereo correlation and onboard planning; evaluation of a demonstration of autonomus control of multiple arms; and fabrication of the university rover including integrated planning and perception. In addition, integrated rover power systems architectures will be demonstrated. These proof-of-concept demonstrations will enable decisions on projects targeted for the late 1990's. In the late 1990's, all critical technologies will be integrated into a testbed for demonstration of a full planetary rover capability.

Technology for sample acquisition, analysis, and preservation has not advanced very much since the Apollo and Viking missions. In FY 1989, work will be initiated to define systems requirements for sample detection/imaging/handling, physical/chemical analysis, and preservation/containment/transporting. Consideration will be given to an optimum division of tasks between the rover and the lander, Specialized tools will be developed for surface and subsurface sample collection. Baseline development will be initiated in the areas of terrain imaging, elemental analysis, water detection, minerology, volatile analysis, meteorology, and geophysics. Systems will be made rugged to survive the accidental impacts and extended exposure to harsh environments, yet also be compact and lightweight. Concepts will be developed for sample containers to preserve returned samples in pristine condition. These activities will be performed in close cooperation with the planetary rover development and will be integrated into the rover testbed.

The surface power element will develop technology required for short-term and storage to enable human lunar surface operations prior to startup of main base power and Mars surface operations during one-month human visits. Potential candidates for the 25-kilowatt system include amorphous silicon and gallium arsenide photovoltaic systems. They will be compared as candidates for the energy generation system. Both candidates will be designed, fabricated, and tested with the goal of achieving 300 watts/kilogram. A regenerative fuel cell with minimum structure, higher operating efficiency, improved cell separators, and solid electrolyte will demonstrate a goal of 1000 watt-hours per kilogram. The power subsystems will be demonstrated in a flight test and a substantial life test in a simulated Mars environment.

Optical communications will reduce the size of transmitter/receiver antennas by over a factor of 10, offer multigigabit per-second data rates, high-reliability solid-state components, and high directivity with reduced interference problems and power requirements. The program will develop optical communications technology for NASA-unique mission application. Work will begin on the necessary components to build an experimental package that could increase the data return from a potential mission to Saturn by two orders of magnitude. The optical communications element will be focused in FY 1989 on a systems study of an optical transceiver terminal for inclusion onboard the Shuttle. The transceiver will be the low Earth orbit link for a space-to-ground laser experiment to demonstrate the necessary technology for a deep space mission.

Operations Technology

The space operations thrust will provide the critical technologies required for logistical support of human activities. For Earth orbit operations, this program will greatly extend our capabilities to maintain the infrastructure and to support major new science missions. For lunar and Mars missions, the critical technologies for preparing to depart Earth orbit, for performing tasks on lunar or Martian surface sites, and for safe return to Earth from those sites will be addressed. The specific program objectives include developing the capability for in-situ lunar materials utilization, development of technology for advanced on-orbit operations, and the development of nuclear power for transportation and sustained lunar and planetary operations. Critical issues, such as the extent to which manned activities can be self-sustaining through processing of extraterrestrial materials, will determine the course of space exploration. The elements of the program include autonomous rendezvous and docking technology, resource processing pilot plant research, in-space assembly and construction, cryogenic fluid depot technology, and space nuclear power technology.

The autonomous rendezvous and docking program will develop the necessary strategies, sensors, and guidance software required for such operations in both earth and planetary orbits. In FY 1989, rendezvous and docking requirements for a variety of vehicles will be identified and coordinated. The most suitable strategies, trajectories, and guidance schemes for each mission will be determined

and simulated. The laser docking sensor will be improved and will be compared with comepting radar and video technologies. Work will begin on technology for a long-range sensor for a possible future Mars mission.

The resource processing pilot plant element will develop basic technologies to utilize extraterrestrial materials. In particular, it will focus on the methodology for production of oxygen, metals, and construction materials from lunar raw materials. During FY 1989, the program will be initiated by identifying and evaluating material collection and separation and production processes. Such processes will be evaluated based on their energy efficiency, complexity, and initial and life cycle costs.

The in-space assembly and construction element will focus on methods that will enable large, complex structures to be built in space. This will include methods to precisely manipulate large objects using lightweight flexible arms and to hold them close together; to weld or bond structural members; and methods to construct large surfaces and enclosed volumes. The FY 1989 focus will be on the analytical and experimental evaluation of high-capacity joint concepts, automated methods for producing structural welds and bonds, and methods to manipulate large masses precisely by means of rigid robotic arms.

An important aspect of the permanently manned space infrastructure is the capability to refuel on orbit. The cryogenic fluid depot element of the program will validate the data base for design of such a depot which will include liquid production, conditioning, storage, and transfer. Basic technologies of the component subsystems will be initiated. Development of flowmeters for liquid and gaseous hydrogen and development of cryogenic relief valuves will be completed. Validation of the integrated analytical model of the fluid depot in Earth gravity will begin.

Space nuclear power technology is being developed under the tri-agency (NASA/DOD/DOE) SP-100 program, which includes performance test, life models, and accelerated tests to validate life models of a nuclear reactor ground engineering system. In FY 1989, emphasis will be placed on the continuing development of fuel pellets and cladding materials for the nuclear reactor, the electromagnetic pump for the liquid lithium coolant, thermoelectric couples for the energy conversion, and heat pipes for the radiator.

Humans-in-Space Technology

The objectives of this portion of the Pathfinder program are to enable: (1) on-demand, extended surface extravehicular activity (EVA) with mobility, dexterity, simple servicing and maintenance, and long-life systems; (2) productive cognitive and physical performance over long self-sufficient missions in different gravity environments and with protection from space radiation; and (3) self-sufficiency and significant reduction in life-support expendable weight and transport requirements for long missions (greater than one year). Existing technologies for these functions cannot be scaled to meet human performance and life-support requirements over long, self-sufficient missions. Furthermore, technology identification and advancement cannot effectively proceed without the determination of human performance and support requirements. This program will be conducted jointly with the Office of Space Science and Applications (OSSA). OSSA will determine the biomedical requirements and implement the life sciences portion of the program.

The objective of the EVA/suit program is to provide technology for a highly mobile, lightweight, rugged pressure suit and portable life support system that will allow safe and efficient EVA work during planetary missions. The system concept includes five major research areas: suit concept and space serviceability; portable life support system (PLSS) concept with a regenerable air and thermal capability; human performance models, including task and information requirements, personal hygiene, microbial growth control and human comfort requirements; mechanical, electrical, and power components, such as joints, bearings, seals, lighting, ventilation, and mobile power supply capabilities; and tools, gloves, and end effectors for mobility and maneuverability requirements. Advanced orbital suit designs and test prototypes currently offer promise of high working pressure and modular design; however, EVA suits and systems for lunar and Mars missions must address a different set of working requirements. Concepts and technology must be developed for in-transit/surface suit compatibility, reduced weight of the PLSS, simple and expeditious regenerability of the PLSS, materials and joint resistance to surface dust abrasion and corrosion, simple serviceability, and extended-duration mobility concepts.

The objectives of the human performance program are to determine human capabilities, limitations, and adaptability for individual and group work during long-duration missions and to develop supporting human-machine interface technologies. The program consists of seven subelements: (1) physical performance model; (2) cognitive performance model and human-machine interface; (3) teamwork model; (4) application of computer-aided design tools to develop vehicle designs for crew habitability and space radiation protection; (5) small group behavioral model and analysis of simulated mission environments and authentic analog environments (e.g., Antarctica and North Sea platforms); (6) artificial gravity effects on human physiology and physical and cognitive performance; and, (7) space radiation protection requirements, materials, and vehicle configurations. The program supports determination of performance factors and requirements, and development of strategies, technologies, and procedures that will meet these requirements and accommodate the effects of weightlessness and gravity readaptation on human performance. Prior research established that highly automated, confined, or remote environments induce poor productivity, human error, and other unproductive behaviors. A systematic collection and evaluation of experiences from astronauts and cosmonauts was initated in FY 1988 to provide a human performance data base, including effects of prolonged weightlessness, isolation, social withdrawal, sleep disturbances, and other behavioral and social problems. Some experiments reveal deleterious effects on human perceptual processes due to artificial rotational gravity. Research results from human factors studies of strength capabilities and limitations in weightless conditions provided insights on human performance useful for the design of crew stations and crew tasks. Performance of small groups has identified important varia-

bles associated with leadership effectiveness, group cohesion, and performance under stressful conditions (i.e., decision-making under uncertainty).

The objective of the closed-loop life support program is to provide a high degree of closure in the crew life support system for long-duration space missions to provide air revitalization, water reclamation, and waste treatment. Based on physical and chemical processes, highly efficient subsystems will be developed and integrated into a total life support system which will minimize the requirements for stored consumables and spares and eliminate the need for resupply. In the past, the physical-chemical life support research and technology program was focused on providing the air revitalization and water reclamation systems for use in low Earth orbit and, most recently, for Space Station. The life support system proposed for the Space Station will include an air revitalization system which is largely a closed system and partial water reclamation from wash water and urine. All wastes and trash will be transported back to Earth for disposal. Food, spares, and make-up oxygen and water will be resupplied to the Station on a periodic basis. Much longer duration missions in which resupply will not be frequent or practical will require signficant technological improvements. To date, all physical-chemical life support subsystems, including subsystem integration, have been developed experimentally. Work has been initated to begin the analysis and simulation modeling of physical-chemical processes for air, water, and waste treatment subsystems to guide selection of candidate processes prior to experimental evaluation. To date, no U.S. manned space flights have depended on onboard plants or biological subsystems for life support. The current research program dealing with controlled ecological systems has focused on the growth dynamics and support requirements of candidate plant systems and on demonstrating a proof-of-concept system which would then permit both specific applications of biological subsystems to be examined and a realistically sized breadboard closed-loop system to be designed. In this program, the feasibility of biologically based systems will be examined for enabling such functions as habitability enhancement, waste processing, food production, and oxygen/carbon dioxide/water exchange. As appropriate, biological subsystems will be integrated with physical-chemical subsystems to evaluate biologically based closed-loop systems.

The FY 1989 effort will provide EVA systems concepts and reliable forecasts of the technology needed for high-pressure, high-mobility, readily serviceable suits, and compact fully regenerable PLSS capable of sustaining an astronaut in healthy and comfortable conditions for many hours during planetary EVA. Four major milestones are projected: (1) development of an EVA systems concept compatible for both in-transit and surface use; (2) identification of surface suit components, including task, information, and biomedical requirements affecting suit design; (3) identification of portable life support system requirements; and, (4) definition of requirements for surface mobility and dexterity. Early identification of materials for lightweight, rugged abrasion/corrosion-resistant suits and design of a fully dexterous hybrid glove are planned. Automated and/or simplified servicing concepts for maintenance and quality control of the suit will be pursued. Efficient materials and processes for the provision of breathable air, removal of carbon dioxide from expired air, and the onboard regeneration of the removal subsystem will be identified. Development of the EVA display and control system concepts to allow the suited astronaut to manage the unique planetary information and to carry out surface operations safely and easily will be initiated.

Development of working models of physical, cognitive, psychosocial teamwork performance will be initiated, and studies of small isolated groups who perform mission-equivalent tasks will be started to provide mission and system designers with preliminary data on human performance. Strategies for applying to and integrating models of human performance and behavior into design guidelines will be developed, including the identification of system and technology requirements for computer-aided design. Preliminary system definition and technology requirements for space radiation protection and for rotating systems to produce artificial gravity will be identified. Ground-based experiments and studies of zero-gravity countermeasures will be started, using bed rest, water immersion, and slow-rotation rooms. A program will be preliminarily defined for on-orbit experimental validation of ground-based predictions of human performance in these environments.

In FY 1989, subsystem models of some physical-chemical life support processes will be available, although not completely validated. Efforts to analytically model candidate processes for waste treatment and reclamation of water from wastes will begin. Experiments to provide data to validate the subsystem models will be defined. These models will be used for selecting candidate air, water, and waste processes for further development and integration into a breadboard life support system. Revolutionary advances in technologies for portable life support subsystems for EVA will continue to be pursued to obtain maximum performance of the air revitalization and water removal systems at minimum volume, weight, and power levels.

An initial reference concept of a biologically based controlled ecological system will be used with proof-of-concept test results to develop strategies for research, in-space validation, and envolving operational use of biological subsystems to fulfill human support functions.

Transfer Vehicle Technology

Transfer vehicle technology addresses reusable transportation to and from geostationary Earth orbit, the Moon, Mars, and other destinations in the solar system. This thrust provides the technologies for a significant reduction in mission costs by reducing the mass required to be launched into low Earth orbit and in transit, as well as reductions in the transit time. The broad objectives toward these goals include research into higher performance, reusable, reliable, space-based transfer vehicles that have low operational cost. The efforts which support the objectives include chemical transfer propulsion, chemical vehicle propulsion, high-energy aerobraking, autonomous lander, and fault-tolerant systems technology.

The objective of the chemical transfer propulsion technology element is to provide demonstrated advanced design concepts and

validated analytical techniques that will allow the design and development of advanced expander cycle liquid oxygen (LOX)/hydrogen engines capable of meeting the demanding requirements of Mars and lunar transfer and lander vehicles. Capabilities include high performance to reduce the quantity of propellant required to perform transfer and lander missions, reusability to reduce mission costs, and space-basing to eliminate the need for returning vehicles to earth after every mission for refueling, inspection, checkout, and relaunch. This class of engine can provide the deep throttling capability required for Mars and lunar hovering and landing. Critical technologies include long-life heat-transfer combustor designs, development of turbomachinery technologies that will provide high efficiencies over a wide flow range of operating conditions, integrated diagnostic sensors, and tehnologies for enabling space-based maintainability and automated operations. To date, design approaches that will achieve these technology advances have been identified in the research and technology base program and demonstrated in laboratory and rig testing.

The cargo vehicle propulsion technology element addresses extremely efficient electric propulsion (specific impulse 10 times better than the best chemical). Use of an electric propulsion system and a megawatt-level nuclear power source could save the expense of up to 4 expendable launch vehicles per mission. The best electric thruster candidates are ion and magnetoplasmadynamic (MPD) propulsion systems. Small ion systems have been tested. Larger size, higher power units will minimize the number of components and increase reliability for megawatt-level systems. MPD systems are at an earlier technology state, but offer the ability to process high power in a small thruster with a very simple design. MPD units have had limited testing. Erosion of the central electrode during MPD operation is a serious problem needing study.

The high-energy aerobraking element develops aerobraking/aeromaneuvering technology that will enable lightweight, space-based orbital transfer vehicles for future planetary missions. Critical technologies to be addressed include examining and defining the effects that long-term exposure to the space environment will have on the thermal protection system. Designs that will accommodate very high velocity and enthalpy flow conditions must be developed. The ability to handle "new" atmospheric constituents must be developed through gas chemistry models which will provide accurate prediction of aerodynamic and aerothermal loads in the Martian environment. High-speed Earth and Mars entry conditions must be better defined and understood. Finally, fault-tolerant, real-time adaptive guidance, navigation, and control systems must be defined and developed.

The autonomous lander element provides the technology to safely land, without real-time human control, a planetary exploration spacecraft close to an intended target even though the target includes surface hazards such as slopes and rocks. This capability is needed to improve the operational reliability of robotic missions where the round-trip communication time prevents remote human control of landing and where scientifically interesting areas are expected to be hazardous. It will also be important for landings of unpiloted supply spacecraft that form part of any further piloted Mars mission or lunar base supply operation and as a crew aid during piloted landings.

The fault-tolerant systems element will rely heavily on, and provide a major advance in, the technology of photonics. Photonics has the potential to surpass electronics in important areas of computation. The high throughput of analog photonic data processing reflects the enormous information capacity of light waves and the inherently concurrent nature of wavefront operations. Photonic flight systems will be more fault-tolerant and reliable than comparable electronic systems; will have fewer discrete active components and physical interconnections; and their architectures will be inherently more resistant to single-component failures. The goal of the program is to provide photonic or hybrid photonic/electronic components and sub-systems and overall system architectures that, for selected flight data-system functions important to missions that require one or more supercomputers of the Cray class (1 to 10 billion operations per second), can deliver a substantial savings (10 to 50 percent) in weight, volume, and power over all electronic systems with significant increases in reliability.

The chemical transfer propulsion effort will apply the design concepts and analytical methods developed to date in the base program to the design of full-scale enhanced heat transfer combustors, variable-flow turbo-pumps, and controls. Appropriate diagnostic sensors will be incorporated into the component hardware. Component performance and operation, including the diagnostic sensors, will be demonstrated initially. The components will be developed for assembly into an integrated component test configuration to validate high-pressure expander cycle engine performance and operation. Ultimately, the engine will evolve to a near prototype configuration in which fault-tolerant engine operation will be demonstrated, and component design margins will be established.

Technology for MPD systems will be emphasized in the cargo vehicle element. Megawatt pulse testing will be continued with emphasis on understanding the cathode erosion that occurs at very high current flow. The power level of the sustained MPD operation will be raised to 100,000 watts to more nearly simulate high-power operation, and equipment to operate at 250,000 watts will be designed and installed. Externally applied magnetic fields will be imposed on an MPD unit to determine whether this field, added to the self-induced magnetic field, may raise the thrust efficiency above the current 35–50 percent. The 50-cm-diameter ion system will be assembled and operated at increasing power levels up to 100,000 watts. An operational model will be developed to allow prediction of performance under all conditions and to predict the operating life of the various subsystems in order to direct further technology development. A pair of 30-cm ion thrusters, integrated into a prototype of a flight system, will be operated to begin to learn system characteristics.

Initial designs of power supply and management systems will be made and tested under operating conditions including exposure to the type of radiation caused by nuclear power sources.

The initial focus of high-energy aerobraking will be on improving CFF codes for prediction and characterization of the aerodynamic and aeroheating loads for Mars entry and very high-velocity earth

reentry conditions. Studies will be initiated to begin the evaluation and selection process for advanced thermal protection materials and designs. New and advanced control algorithms for fault-tolerant guidance and control systems with the ability to adjust in "real time" to atmospheric uncertainties will be developed. In addition, overall vehicle configuration and system design will be analyzed.

Initial work in the autonomous lander element will focus on an unpiloted landing on Mars. An approach to terminal hazard detection will be demonstrated via simulation, capable of detecting hazards in the size range of 0.25–1 meter at a range of 1–5 kilometers during the final 30 to 60 seconds of landing. The necessary prototype instrument development will have been successfully completed in parallel. Approaches to be considered will be based on state-of-the-art image analysis and will include those that use intensity information from passive devices, such as a camera, as well as those that use range information from active devices, such as a scanning laser or millimeter wave radar.

The fault-tolerant systems element will research and develop breadboard photonics processors to perform necessary functions for future NASA missions. A breadboard robotic vision system capable of quickly recognizing new images in real time will be built. Component technology work will produce spatial light modulator test samples with improved, faster, information-shaping characteristics. Special analyzers will be built and tested in the laboratory, reducing by up to several orders of magnitude the quantity of support electronics needed.

Mission Studies

Using the exploration scenarios identified in Dr. Sally Ride's report, *Leadership and America's Future in Space,* as a starting point, the mission studies will: (1) identify other viable scenarios to be considered; (2) develop a more detailed definition of each of the candidate scenarios; (3) conduct trades and analyses of the scenarios to begin the process of narrowing down viable and desirable candidates; and, (4) identify the prerequisites (technology, infrastructure, and precursor missions) for conducting such missions. Of particular criticality are the long-lead technologies and infrastructure elements. Special emphasis studies will be conducted to investigate the high-leverage elements to identify the high-payoff options and critical technologies associated with these elements. These missions studies will serve to continually refine the Pathfinder technology program, ensuring that the critical and enabling technologies are receiving proper attention.

During FY 1988, an in-house team was assembled to initially manage and develop the process and the initial data base. This team will conduct a search for all viable scenarios and perform the initial screening and consolidation of these scenarios.

Two-year parallel contracts of the more viable scenarios will be conducted focusing on conceptual design and definition studies. FY 1989 will be the first year of these contracts. These parallel studies will define end-to-end mission scenarios and perform first-order systems trades, including mission unique funcions, infrastructure (transportation, Space Station, and operating systems), and prerequisites (technology, science research, and precursors). In addition to the current infrastructure and programs of NASA, including planetary surface systems, planetary space transfer systems, human systems, and planetary lunar orbital modes, there will be studies concentrating on the more detailed definition of unique systems and functions.

Finally, special emphasis studies will be developed through academia, industry, and other government agencies for definition of critical issues. Included will be identification and development of potential innovations, as well as detailed assessments of known problem areas such as: (1) initiative cost analysis methodology, (2) in-situ resource utilization, (3) lunar resource processing analysis techniques, (4) space cryogenic reliquification systems, (5) on-orbit assembly feasibility, and (6) artificial gravity systems.

12. SAFETY, RELIABILITY AND QUALITY ASSURANCE

FY 1989 NASA REQUEST, $22,400,000

FY 1989 AUTHORIZATION, $22,400,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Safety, reliability and quality assurance:	
Estimated fiscal year 1988	$14,100,000
Authorization fiscal year 1989	22,400,000

The Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) program supports NASA's overall goals through activities in safety, reliability, quality assurance, maintainability, systems engineering, and program practices through independent assessment activities which reduce program risk. Specific objectives of the program are to:

—Identify and provide independent assessment of issues that have potential impact on mission success.
—Support in-depth reviews, studies and analyses of issues and problems for readiness to launch.
—Conduct major tests and provide a viable problem reporting, corrective action, and trend analysis program throughout NASA.
—Perform radiation characterization on emerging technologies and complement the Air Force program for testing on-orbit radiation effects.
—Upgrade existing software standards, guidebooks, and training; and identify software management product assurance and automated work stations.
—Develop product assurance methodology for procuring reliable, custom large scale integrated (LSI) and very large scale integrated (VLSI) circuit components.
—Upgrade technology and emphasize the safety, reliability and performance of NASA's aerospace battery power systems.
—Plan, document, and establish policy for a NASA wide SRM&QA Information System.
—Increase the safety of high hazard operations and develop safety risk management policy and guidance for all NASA programs.
—Support industrial, aviation, fire protection, and ground operations safety activities.

—Provide policies, procedures and surveillance for all agency safety, quality, maintainability, and reliability activities.

In concert with the NASA Centers and industry, efforts continue in the areas of materials treatments and processes; integrated circuit product assurance; microcircuit radiation effects evaluation; aerospace and system safety related matters; and other areas in support of NASA-wide programs. The Non-Destructive Evaluation (NDE) Program places special emphasis on developing NDE techniques for assessing the quality of Solid Rocket Motors. Development of qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors is being promoted. The Software Management and Assurance Program will continue to develop standards, specialized training, distributed software, corporate memory data bases, and guidebooks to facilitate improved software business practices. A Maintainability Program has been formalized and a study completed resulting in the definition of maintainability requirements appropriate for NASA programs.

In response to the findings and recommendations contained in the Report of the Presidential Commission on the Space Shuttle Challenger Accident (Rogers' Commission), a system has been developed to address the reporting and documentation of significant problems, assessment of problem resolutions, and analysis of trends. Goals have been defined for the system to achieve.

The NASA Safety Program is focused on developing specific programmatic system safety management procedures and providing independent system safety reviews at Headquarters. The program will conduct assessments and develop requirements for hazardous systems such as radio frequency interference, ionizing radiation, toxic chemicals and propellants, and propulsion, ordnance and electrical systems. The assessment of Space Transportation System (STS) Safety Management procedures and the development of specific programmatic system safety procedures will be completed in FY 1989. System safety management procedures for Level I independent safety reviews, hazard analyses procedures and prioritization methods, system safety methodology development for flight critical software, and safety risk acceptance criteria recommendations are underway.

In FY 1989, the SRM&QA program will continue to conduct activities in support of the objectives of the Agency. This funding level will provide for enhanced capabilities which will implement the reporting and documentation of significant problems, assess problem resolutions and analyze trends, and other safety systems as required. The Agency will develop a data base of failures, anomalies, and unsatisfactory conditions for analysis and assessment of remedial and preventive actions. Trend analysis of flight and critical ground hardware problems will be conducted, as well as for certain generic program hardware.

Problem reporting requirements, hazards analysis, and failure modes and effects analyses, accessible through an Agency-wide tracking and reporting system, will continue to be supported in the STS program through the Program Compliance Assessment Status System (PCASS) effort. PCASS will provide commonality throughout the STS program and NASA centers. The Intercenter Problem Reporting and Corrective Action (PRACA) data base for non-conformance data will be established. The NASA Headquarters SRM&QA management information center will be linked to both the Intercenter PRACA and the PCASS systems. A NASA wide SRM&QA information system will be established. This system will control the proliferation of data bases, assure appropriate informational content and provide standardized access and reporting throughout the Agency.

Integrated engineering standards and practices will be implemented and a data base brought on-line. Standards for fracture control, atmosphere, and environment programs will be expanded. Emphasis will be placed on updating and consolidating engineering standards for use in space station development. Engineering policies and standards for system engineering, configuration management, and drawings will be developed.

The Aerospace Flight Battery Systems program will provide a better understanding of critical performance parameters; provide improved capability of existing chemistry applications, and test and evaluate newly developed chemistry applications for flight.

The NASA safety program will increase the safety of hazardous operations, develop a better understanding of the failure modes of highly stressed wind tunnel components and pressure systems, and quantify the hazard potential of new, exotic propellants, existing cryogenic propellants, and new composite materials. Policies, procedures, practices, regulations, guidelines, and directives will continue to be developed. Independent assessments of hazardous systems such as radio frequency, ionizing radiation, toxic chemical and propellant, propulsion, ordnance, and electrical systems will be continued.

The Independent Systems Assurance Assessments program will develop between use of numerical techniques for reliability analysis and risk assessment.

The Non-Destructive Evaluation (NDE) measurement assurance program will continue to provide state-of-the-art quantitative advanced inspection techniques for solid rocket motors, composites and ceramics and will explore inspection techniques such as microfocus x-ray, fiber optics, acoustic emission, computer tomography, and laser thermography.

13. TRACKING AND DATA ADVANCED SYSTEMS

FY 1989 NASA REQUEST, $18,800,000

FY 1989 AUTHORIZATION, $18,800,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Tracking and data advanced systems:	
Estimated fiscal year 1988	$17,900,000
Authorization fiscal year 1989	18,800,000

The objective of the Advanced Systems Program is to perform studies and provide for the development of tracking and data systems and techniques required to obtain new, higher performance tracking and data handling capabilities that will address planned future mission requirements and also improve the cost effective-

ness and reliability needed for overall support of the total mix of spaceflight missions.

This activity is a small but vital part of the total Space Tracking and Data Systems Program. Advanced programs continue to focus on assessing and making use of technological advances in telecommunications, electronic micro-circuitry and the computer sciences. Such effort is essential for the cost-effective application of new technology and for planning future support capabilities. Ongoing work includes the investigation of the total data transfer and processing needs of upcoming missions and studies of ground systems and telecommunication links to determine design approaches, and overall tradeoffs for the lowest life cycle costs to support future space missions.

Activities planned for FY 1989 include efforts to obtain location accuracies at the decimeter level for Earth-orbiting spacecraft which would make possible a new class of high precision Earth observatory missions on the Shuttle, Space Station and on free-flying spacecraft. The techniques being analyzed for particular application include the Department of Defense's Global Positioning System and the use of Very Long Baseline Interferometry. Work will continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nano-radians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible. Studies will continue on ground-based navigation strategies, analyses, and demonstrations for Galileo, Ulysses, Mars Observer.

Efforts to improve communications between the ground and spacecraft will continue in such areas as the use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; development of a K-Band terminal for TDRSS-user spacecraft; and antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by increasing the amount and quality of the data returned. Optical tracking and communications technology to meet telecommunications needs in the decades ahead will also be investigated both for its cost-performance advantages over microwave technology and for its potential in space data relay applications.

The use of high density magnetic tape and optical disk storage with automated quality control of recorded data is being investigated to meet future high-rate image data processing requirements as the data handled from Earth-orbital missions increases from a current peak of 50 megabits per second to the TDRSS design limit of 300 megabits per second. These future requirements result from high resolution sensors, such as multispectral scanners and synthetic aperture radars, which will be capable of transmitting more data than previous scanning and radar instruments. New techniques and systems will be developed for the transfer and processing of these high data rates. These developments include new techniques for signal coding and decoding of data; optical disk buffering and storage to handle TDRS data transfer rates; automated distribution and processing of high volume data, improved man-machine interfaces, and a communications network using an optimal mix of fiber optics, satellites, and local area networks to distribute data to processing center and users.

Investigations will continue on achieving a more efficient operation of the mission control facilities and providing for the necessary real-time interaction between the spacecraft experimenters and their experiments. Other investigations are being carried out in the area of expert systems applications, greater use of distributed command terminals, and the performance of orbit and attitude computations on board the spacecraft.

SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS

FY 1989 NASA REQUEST, $4,841,200,000

FY 1989 AUTHORIZATION, $4,841,200,000

FY 1990 AUTHORIZATION, $5,379,000,000

FY 1991 AUTHORIZATION, $5,261,000,000

SUMMARY

		Estimated fiscal year 1988	Authorization fiscal year 1989	Authorization fiscal year 1990	Authorization fiscal year 1991	Page No.
1	Shuttle production and operational capability	$1,088,300,000	$1,400,500,000	$1,468,000,000	$1,571,000,000	252
2	Space transportation operations	1,838,000,000	2,405,400,000	2,721,000,000	2,522,000,000	259
3	Space and ground networks, communications and data systems	884,400,000	1,035,300,000	1,190,000,000	1,168,000,000	266
	Total	3,810,700,000	4,841,200,000	5,379,000,000	5,261,000,000	

1. SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

FY 1989 NASA REQUEST, $1,400,500,000

FY 1989 AUTHORIZATION, $1,400,500,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Orbiter operational capability	$328,600,000	$320,000,000
Launch and mission support	164,800,000	343,700,000
Propulsion systems	594,900,000	711,800,000
Changes and systems upgrading	25,000,0000	
Total	1,088,300,000	1,400,500,000

The objectives of this program are to provide for the completion of the modifications required to return the Space Transportation System to a safe flight status, the completion of the national fleet of Shuttle orbiters, including building a replacement orbiter for the *Challenger*; the development and production of the propulsion system; the development of launch site capabilities; and the potential changes and upgrading of the Space Transportation System (STS). Also included is the development of the Extended Duration Orbiter (EDO) and the Advanced Solid Rocket Motor (ASRM).

With the loss of *Challenger* in January 1986, the orbiter fleet was reduced to three vehicles until a replacement orbiter, which was approved by Congress in 1986, can be delivered. The current orbiter fleet includes *Columbia*, the orbiter developed and flown on four test and evaluation flights, and two orbiters of a lighter-weight configuration, *Discovery* and *Atlantis*. The budget provides funding for necessary improvements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. In addition, the provisioning of orbiter spares at the Kennedy Space Center is an ongoing activity for the initial lay-in of spaces to support the flight rate buildup. The EDO development is also included to increase on-orbit stay time in order to improve the Shuttle capability to support payload requirements.

Launch and Mission Support provides for the required investment in Launch Operations and Flight Operations capability to meet STS program objectives, which include returning safely to flight and supporting the flight rate. At KSC, the second line of facilities allow simultaneous processing and checkout of orbiters and associated flight hardware from landing through launch. At JSC, mission support provides collateral hardware, principally the extravehicular maneuvering units (EMU) while mission operations capability provides for improvements in the flight support system. The flight support systems funded by this budget include training and carrier aircraft, additional landing aids and runway end barriers at the primary and contingency landing sites, and replacement/upgrade of equipment in the mission support complex such as the Shuttle Mission Simulator and the Mission Control Center.

Propulsion systems provide for the production of the Space Shuttle Main Engines (SSME) and the development of the capability to

support operational requirements established for the SSME, SRB, and ET. The SSME program includes: production of main engines necessary for the orbiter fleet and to establish a spares inventory, ground testing in support of engine development, anomaly resolution, and product improvement and advanced development efforts to improve operating margins.

The SRB production and capability development activities include: the reclamation of production vertification and 51-L configuration solid propellant motors; investigation of returned flight hardware; procurement of contamination control tooling and equipment to support flight rate; and selected studies to continue investigative, analytical, and problem solving activities. The development of an ASRM is included in this budget.

Changes and Systems Upgrading provides funding for potential changes and system modifications as well as unanticipated new requirements not covered in the budget estimates for the above activities and other program elements.

ORBITER OPERATIONAL CAPABILITY

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Orbiter	$206,700,000	$191,000,000
Systems integration	34,000,000	17,700,000
Orbiter spares	87,900,000	111,300,000
Total	328,600,000	320,000,000

Our primary objective is to continue return of the three orbiter fleet to safe flight status in FY 1988. This will provide safe and reliable access to space for NASA, the Department of Defense and certain domestic and international users of space. In support of this objective, orbiter production activities include the necessary safety modifications identified by the Rogers Commission and the post-Challenger accident review process and the development and installation of necessary hardware, software and procedural modifications. Also, work continues on improvements to achieve greater operational capabilities, reduce operational costs, and meet system requirements. These improvements include upgrading the general purpose computers (GPC), inertial measurement units (IMU), auxiliary power units (APU), and provision of a crew escape system during Orbiter controlled gliding flight. The brake and the nose wheel steering systems are undergoing modifications to improve landing performance. In concert with these major improvements to the hardware, there are modifications to the flight and ground software. In addition to these system changes, there are numerous mission and modification kits requested for specific flights and payloads. Also included will be the work necessary to continue work on an extended duration orbiter (EDO) capability.

The structural spares program initiated in FY 1983 provided the foundation for the production of a replacement orbiter with a delivery date planned for mid-1991. A new set of structural spares will be initiated in FY 1989. This new effort will sustain the capability to produce another vehicle in addition to providing additional spares for inventory. Structural assemblies include the wings, aft thrust structure, engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

The procurement and fabrication of the orbiter spares inventory is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A logistics depot has been established at KSC for repair and maintenance of orbiter parts. The on-site depot will reduce repair costs and shorten turnaround time. The depot is currently repairing and maintaining minor line replaceable (LRU) and shop replaceable units (SRU) and is scheduled to transition to major repair activity and become fully operational by FY 1991.

Orbiter funds provide for the procurement of a logistics capability including an inventory of spares to support operations requirements, the continuation of previously approved systems improvement programs, necessary safety modifications identified as a result of the Challenger accident review process, initiating the manufacture of a replacement set of structural spares, and the engineering analysis and integration support for the flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, the on-board flight software, and implementation of a crew escape system during orbiter controlled gliding flight. Starting in FY 1989, work on the Extended Duration Orbiter (EDO) will be continued under the orbiter program. In FY 1988, Congress appropriated funds in Research and Development to initiate the EDO.

The orbiter logistics capability program in FY 1989 is continuing the lay-in of LRU's, SRU's, and repair parts to support the flight rate buildup. The funding covers flight hardware spares, ground equipment spares, scheduling, provisioning documentation, and maintenance training. In addition, funding is included to provide maintenance test equipment and special test equipment for the centralized depot and selected vendor repair sites.

The development, qualification and production of flight units for an improved auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will continue. The improved APU will have longer life and higher reliability and will require substantially less ground servicing. This configuration will preclude recurrence of problems which have occurred on prior flights such as the formation of wax due to the mixing of lube oil and fuel. The new GPC will add memory and increase operating speed in order to avoid the operational limitations of the current hardware and will result in a more reliable system.

The orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, as well as procuring orbiter support items and capability changes to the on-board flight software. Continuing development of the capabilities of the on-board primary and backup flight software is necessary due to expanding safety requirements and system capabilities.

The EDO provides for the development of a cryogenic pallet kit to extend the on-orbit stay time from 7-10 to 14-16 days in order to provide significantly greater time for payloads to complete their mission objectives. The crygenic pallet will accommodate four tank sets to supply the fuel cells with additional reactants needed to generate electrical power for the added time on-orbit. The program should be completed in FY 1992 with the modification of an existing orbiter.

Launch and Mission Support

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Launch site equipment	$54,400,000	$142,000,000
Mission support capability	32,700,000	93,500,000
Mission operations capability	77,700,000	108,200,000
Total	164,800,000	343,700,000

This activity supports the development of launch and mission support capabilities, principally at the Johnson Space Center (JSC) and Kennedy Space Center (KSC). The first line of facilities at KSC was developed during the DDT&E program to support launch processing and checkout of one Shuttle vehicle through launch. A "second line" of facilities is provided in the launch site equipment budget to support processing and checkout of up to three orbiters in flow and to sustain the operational launches at KSC. Second line facilities already operational include the second launch pad, the second high bay of the orbiter processing facility, the second mobile launch platform, and two additional high bay areas in the vehicle assembly building. The third mobile launch platform will be completed in FY 1989. The orbiter modification and refurbishment facility (OMRF) will have safing and deservicing capability.

Funding has been included for upgrading landing aids for end of mission and contingency/abort landing sites. Capability improvements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. Funding for a pre-flight adaptor trainer has also been added to help prepare the crews for a weightless environment. Consistent with the recommendations of the Rogers Commission, improvements in simulation training including new host computers and interface hardware are being made. Critical improvements in simulation fidelity will be accommodated with the expanded capacity of the new hardware. Reliability required for the longer integrated simulations and associated maintenance cost will also be substantially improved with these replacements. Other activities include implementing required modification and upgrades on the T-38 proficiency aircraft and procuring a fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft. Procurement of extravehicular mobility units and associated improvements are also included.

In FY 1989, Launch Site Equipment includes activities to improve the capability to support the flight rate requirements at KSC. These include a digital internal communications system with associated fiber optics cabling, safing and deservicing equipment for installation into the orbiter modification and refurbishment facility, replacement equipment for the launch processing system, extension of the launch equipment test facility (LETF), and installation of equipment at the contingency landing sites. The third mobile launcher platform previously scheduled for readiness in September 1986, has been delayed until FY 1989 consistent with the adjusted flight rate requirements. Identification, replacement and upgrading of obsolete ground processing and support equipment will be accomplished.

Mission support capability requirements continue to establish an inventory of crew equipment, principally extravehicular mobility units (EMU), to support the flight rate. STS operations effectiveness work and other support functions continue to support STS program-wide requirements including flight safety, mission success, and rate capability.

Mission operations capability funding in FY 1989 provides for completion of replacement of the host computers, selected critical items for the Shuttle training simulators and replacement of ADP and other hardware in the Mission Control Center. Continuing projects include improvements to weather prediction, information handling, mission control systems, and contingency landing sites. Also included is the continued development of a preflight adaptor trainer to prepare the crew for a gravity-free environment and procurement of the fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft.

Propulsion Systems

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Main engine	$382,200,000	$511,800,000
Solid rocket booster	179,200,000	193,000,000
External tank	33,500,000	7,000,000
Total	594,900,000	711,800,000

Propulsion Systems provides for the production of the Space Shuttle Main Engines (SSME), the implementation of the capability to support operational requirements, and anomaly resolution for the SSME, Solid Rocket Booster (SRB), and External Tank (ET). The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spare engines, ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes the reclamation and refurbishment of hardware produced prior to the Challenger accident, continued replacement of reuseable hardware lost during the 51-L failure and subsequent ground testing of the SRB redesign, continuation of test data analyses and evaluation, completion of SRM tooling modifications, procurement of transportation

equipment to support the projected flight rate, and development of the Advanced Solid Rocket Motor. Engineering analysis and modification of booster hardware for certification of a 20 flight reuse capability will continue in FY 1989. Systems support primarily provides for support to the testing of the SSME in the main propulsion test article configuration.

The SSME program has been structured into three major elements under Shuttle Production and Operational Capability: (1) flight engine; (2) development engine; and (3) advanced development. The total SSME experience now exceeds 1,400 tests, totaling approximately 320,000 seconds of test and flight time. This experience includes 285 tests, exceeding 62,208 seconds of operation, at the full power level (FPL).

The flight engine activity includes the production of new engines, retrofit of improved hardware into the fleet, and anomaly resolution activity.

The development engine activity provides for the hardware, propellants, and support for testing, and for testing, and for the development, certification, and flight certification extension of improved hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as improved blades and bearings. The NSTL B-1 test stand for single engine test has been added to the program to meet expanded ground test requirements.

In light of the Challenger accident, the SSME program has delayed all activities associated with the operational use of FPL (109%). Single engine testing at these levels has continued to demonstrate margin and safety for the life certification extension test program. In addition, testing is required to demonstrate capability to support extreme abort modes which require operation at FPL. The NSTL main propulsion test stand capability is being maintained for the FPL test of three clustered engines. This test will provide for a verification of the main propulsion system operations at full power level using the main propulsion system test hardware mounted in the aft end of the simulated orbiter.

The advanced development element includes the alternate turbopump program and the technology test bed. An alternate source for high pressure turbopumps was selected in August 1986. These alternate pumps will be designed for greater reliability, safety margin, and lower operational costs. The technology test bed will provide an independent means to evaluate the technical advances arising from the development program, the alternate pump effort, and the OAST Space Research and Technology program.

The redesign of the SRB to resolve deficiencies in the previous design will be completed through certification and reflight in FY 1988. Assessment of flight data, including analysis and evaluation, will be continuing in FY 1989. There will be a continuing activity to improve tooling and procedures to enhance process control and product quality. Reclamation of reuseable SRM hardware produced prior to the Challenger accident will be accomplished through static firing and refurbishment. Refurbishment of the case hardware will include modification to the redesigned configuration.

Funding for the FY 1989 budget is based upon resumption of the flight program in the late summer of 1988 and the design, test, and certification of the propulsion hardware for flight. Return to flight activities include a complete reassessment of the program and recertification of all flight hardware to assure compliance with flight requirements. The SSME program will continue production of flight hardware and the development programs including necessary improvements to the current configuration and the alternate turbopump programs. The SRB FY 1989 funding will primarily focus upon continued evaluation and analysis of flight data to thoroughly assess the redesign. Modification of booster hardware necessary to obtain 20 flight reuse capability will continue as well. The External Tank program supports the production of tanks with required off-the-shelf equipment.

The Advanced Solid Rocket Motor (ASRM) project is intended to enhance the flight safety, reliability and performance of the Space Shuttle fleet. The ASRM will not be subject to the constraints of maximum utilization of existing hardware that limited changes on the recent SRM design activities. The ASRM may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins. Production processes will be examined to utilize the latest applicable technology and process automation to enhance reproducibility and reliability.

During the ASRM definition studies, now being conducted, the contractors will perform preliminary designs on a segmented motor and monolithic motor. Also, they will provide design data on a modern, automated production facility to maximize material and process controls for enhanced reliability. An additional objective of the ASRM is to achieve increase payload capability. The definition studies will examine achieving this objective with the requirement that there be no compromise to flight safety and reliability, and that the impact to other Shuttle elements be held to an absolute minimum.

The Request for Proposal (RFP) for the development phase will be issued at or near the end of the definition studies. One contractor is to be selected for development, and the contract start is anticipated during the first half of FY 1989. The development program is anticipated to extend for 4 to 5 years with the first flight in early 1994. The development period is based on the original SRM development. The scope of the development will include modification or acquisition of facilities, the development and test of the new design and production of verification units. The ASRM development is comparable in scope and complexity to that of the SRM, and the technological base is greater than that at the start of the SRM project.

The asbestos-free insulation development program previously included as a separate development will be incorporated into the scope of the ASRM development. This requirement is driven by environmental and production safety concerns rather than by technical or performance issues. Costly duplications of qualification tests can be avoided by incorporating this effort into the overall ASRM effort. However, is the ASRM is not approved or the existing asbestos-based insulation production is stopped before the ASRM is available, the separate development will have to be reinstated.

CHANGES AND SYSTEMS UPGRADING

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Changes and systems upgrading:	
Estimated fiscal year 1988	0
Authorization fiscal year 1989	$25,000,000

Management, technical flight experience, and cost reviews of the Shuttle program have stressed the need for providing an allowance for changes and modification which inevitably are required in a large, complex, and technically demanding space system.

The Changes and Systems Upgrading budget provides for potential changes to improve system reliability, safety and performance.

The funding for FY 1989 will provide for those changes which are considered to have highest priority. The objectives are to improve reliability, increase operating safety margins, and reduce costs.

2. SPACE TRANSPORTATION OPERATIONS

FY 1989 NASA REQUEST, $2,405,400,000

FY 1989 AUTHORIZATION, $2,405,400,000

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Flight operations	$583,600,000	$660,100,000
Flight hardware	776,600,000	1,035,200,000
Launch and landing operations	449,800,000	514,600,000
Expendable launch vehicles and services	28,000,000	195,500,000
Total	1,838,000,000	2,405,400,000

Space Transportation Operations provides launch services to NASA payloads utilizing a mixed fleet approach of the Shuttle and Expendable Launch Vehicles. Launch services are also provided, on a reimbursable basis to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle program launch schedule is based on a resumption of flight activity in late summer 1988 with one flight in FY 1988, seven in FY 1989, and ten in FY 1990. The ELV planning reflects use of a mix of launch systems based on individual payload requirements.

The Space Shuttle has demonstrated a broad range of capabilities including deployment of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Spacelab systems, and extravehicular activity operations. These capabilities provide a unique opportunity to enhance the scientific return of many payloads and the Shuttle will remain the mainstay of NASA's launch capability. The major program elements of Shuttle Operations are Flight Operations, Flight Hardware and Launch and Landing Operations. These elements provide for the standard service operation of the Shuttle including pre-flight preparation activities, procurement and refurbishment of flight hardware and maintenance and operation of equipment and facilities necessary to support all phases of the Shuttle flight process.

The Flight Operations activity is divided into three major elements: mission support, integration, and support. Mission support includes training, flight operations activities and a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes launch support services and sustaining engineering for orbiter systems, cargo analytical integration, and systems integration. The support element includes systems support activity at JSC such as aircraft operations, engineering support, and support to the NSTS program office. Shuttle system support at Headquarters and the Goddard Space Flight Center is also included.

The Flight Hardware program element provides for: the procurement of external tanks (ET) and solid rocket booster (SRB) hardware including motors, booster hardware, and propellants; spare components and flight support for the Space Shuttle Main Engine (SSME); orbiter spares; ET disconnects, logistics support for the ET, SRB, and SSME flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, subsystems and additional ground testing of the redesigned Solid Rocket Motor (SRM) necessary to sustain and verify the production of elements in a manner consistent with the flight rate requirements.

Launch and Landing Operations provides for the pre-launch preparation, liquid propellants, launch, and landing operations of the Shuttle and its cargo. Total funding requirements for Shuttle Operations are offset by reimbursements for Shuttle launch services received from other U.S. Government, commercial, and international users to support the operations requirements of the Space Shuttle. There are currently no planned reimbursable funds for Shuttle Operations in FY 1988. It is anticipated that reimbursable funding will resume in FY 1989 and increase as the Shuttle flight rate builds up.

The Expendable Launch Vehicles/Mixed fleet plan was initiated in FY 1987 as a result of an assessment of NASA's space transportation requirements after the Challenger accident. This assessment showed that U.S. Civil Government spacecraft be launched on a mixed fleet in order to provide increased access to space, to assure continutity of space operations and to enhance mission flexibility. The missions currently planned for launch on ELV's are selected high priority missions previously manifested on the Space Shuttle for west coast launches and selected east coast launches which do not require the Shuttle's unique capabilities and can transition to ELV's without significant impact to the Spacecraft.

FLIGHT OPERATIONS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Mission support	$193,200,000	$215,400,000
Integration	226,800,000	264,100,000
Support	163,600,000	180,600,000
Total	583,600,000	660,100,000

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of pre-flight planning, crew training, and operations control activities. The planning activities range from the development of operational concepts and techniques to detailed systems operational procedures and checklists. Tasks include flight planning, preparation of systems and software handbooks, flight rules, detailed crew activity plans and procedures, development and implementation of the mission control center (MCC) and network system requirements for each flight, and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight as well as support to the crew training simulations and flight techniques. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed in the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems. Also included are the maintenance and operation of critical mission support facilities including the mission control center, flight simulators, crew training, and flight software reconfiguration and recertification facilities.

Integration includes orbiter sustaining engineering, payload integration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. The orbiter sustaining engineering provides all prime contractor engineering activities necessary to re-qualify the orbiter for flight including FMEA/CIL, design changes and certification reviews. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter.

Support includes base operations support to Shuttle operations and systems level support at the manned space flight centers. Base operations support provides for operation and maintenance of aircraft for flight training, crew proficiency and the ferry requirements; engineering and supporting activities for the orbiter, crew equipment, and flight operations systems; and support to the NSTS program office.

Currently, the resources for Flight Operations are focused upon preparing for resumption of flight, fixing a backlog of system discrepancies and incorporating a large number of changes to ground systems hardware, software, and procedures including those resulting from the ongoing process of analysis and decision-making in the wake of the Challenger accident. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are critical to the safe operation of the Shuttle and significant emphasis is being placed on insuring that the flight products and crew training satisfies revised and more stringent operational requirements.

The Flight Operations portion of the Shuttle Operations budget continues to support that activity predominately associated with the effort at JSC to plan for and conduct STS missions from launch to landing. The functions are essentially the same as in the past: to maintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; to maintain and operate aircraft for proficiency, training and orbiter ferry requirements and to perform analyses of and conduct of the mission planning necessary for each mission.

It also includes the sustaining engineering required to integrate all flight and ground elements and to assure systems safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and verification of interfaces; and support of crew operations and training programs. Orbiter engineering manpower continues the required support of procedure and hardware modifications resulting from the FMEA/CIL reviews, in addition to the sustaining engineering activities that ensure maintainability, reliability, and anomaly resolution during operations.

FLIGHT HARDWARE

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Orbiter	$280,900,000	$339,400,000
Solid rocket booster	205,600,000	382,500,000
External tank	290,100,000	313,300,000
Total	776,600,000	1,035,200,000

The Flight Hardware program element provides for the procurement of External Tanks (ET), the manufacturing and refurbishment of Solid Rocket Booster (SRB) hardware and motors; and operational support to the Orbiter including orbiter spares, ET disconnects, spare components and flight support for the Main Engines (SSME) and maintenance and refurbishment of flight crew equipment. Included in the funding request for tanks and boosters are the long lead raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain a smooth and efficient buildup of the pro-

duction capability. Included also are static test firings of two production type motors a year in order to continue verification and analysis of the SRM redesign. In the ET, production continues at a minimum level of activity necessary to retain manufacturing capability. The Orbiter line element includes Orbiter spares for replenishment of line and shop replaceable units, the manpower for supporting the logistics operation, and the repair capability for flight hardware. SSME includes component and engine overhauls, flight support, and procurement of replacement spare parts. Also included in flight hardware are replaceable spares, field support, and maintenance of crew-related equipment. Some examples of orbiter spare equipment are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to pre-flight training and flight usage of the extravehicular maneuvering unit, emergency portable oxygen systems, radiation instrumentation, survival radios, closed-circuit television cameras, medical support, and food and other galley-related items.

Requirements for Orbiter flight spares, crew equipment spares, and logistics are based on projected flight rates, maintenance schedules, operational usage, repair times, and lead times to procure or repair flight hardware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the Orbiter, extravehicular maneuvering unit and other crew equipment. The flight equipment processing contract (FEPC) which was initiated during FY 1986 is continuing its buildup to full capability to support the projected flight rates. Main Engine hardware provides for manufacturing and delivery of overhauled engines, engine component spares and flight support. Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and fabrication of units which will be flown during FY 1989, as well as the support of the production of units which will be flown thereafter. Additionally, two static firing tests of the redesigned SRM will be conducted to monitor the consistency of production characteristics.

Launch and Landing Operations

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Launch operations	$402,700,000	$456,600,000
Payload and launch support	47,100,000	58,000,000
Total	449,800,000	$514,600,000

Launch and Landing Operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the processing facilities at KSC. Standard service processing and preparation of payloads as they are integrated into the orbiter are also funded by this category as is procurement of liquid propellants for launch and base support. Support to landing operations at KSC and contingency sites, as required, is also provided.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off. Support is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation, and inventory management.

Support to Shuttle processing is provided by the Base Operations Contractor or (BOC). The BOC is responsible for operations support functions such as propellants and life support, railroad maintenance, pressure vessels, Shuttle landing facility, and facility and equipment modifications.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports Shuttle processing as an on-line element of the launch processing system; range support provided by the DOD; Shuttle related data management functions such as work control and test procedures; and purchase of equipment, supplies and services not procured under the Shuttle Processing Contractor.

The Payload and Ground Operations Contract (PGOC) is the major contract for the payload processing activities. In Shuttle Operations, the PGOC contractor provides the standard service processing of all STS payloads into an integrated cargo prior to loading into the Shuttle. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

Launch operations funding in FY 1989 provides for manpower and support services necessary for processing launches from KSC. This includes manpower to assemble the SRB's, mate the boosters and tanks, process the orbiter, mate the orbiter to the integrated SRB's and tank, process and checkout integrated flight elements through launch, retrieve the SRB's for refurbishment, and support landing of the orbiter either at KSC or at a contingency landing site when required. Funding also supports the manpower required for sustaining engineering, spares provisioning, logistics, launch processing system operation and maintenance, and maintenance/modification of all other Shuttle-related ground support equipment and facilities. Flight safety will continue to be emphasized through testing, engineering and quality control.

Payload and launch support funding provides propellants for launch operations and base support, and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment (such as cargo integration test equipment and multi-mission payload support equipment) and to the payload support areas including the Vertical Processing Facility, Operations and Checkout building, and cargo hazardous servicing facilities. Support required for maintaining the Dryden Flight Research Facility as a contingency landing site is also included.

EXPENDABLE LAUNCH VEHICLES AND SERVICES

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

Expendable launch vehicles and services:	
Estimated fiscal year 1988	$28,000,000
Authorization fiscal year 1989	195,000,000

The Expendable Launch Vehicles/Mixed Fleet plan, initiated in 1987, provides launch services for selected NASA payloads not requiring the Space Shuttle's unique capability. Four performance classes of expendable vehicles are planned in the mixed fleet. A small class capable of launching payloads up to 1,000 lbs into low Earth orbit; a medium class capable of launching payloads up to 10,000 lbs into orbit; an intermediate class capable of launching payloads up to 30,000 lbs and a large class capable of launching payloads of 40,000 lbs or more. NASA plans to utilize competition where possible in the acquisition of expendable launch vehicle sevices in these performance classes to accommodate a range of spacecraft requirements in FY 1992 and beyond. In the interim, NASA will acquire expendable launch vehicle services for selected high priority missions previously manifested on the Space Shuttle consistent with the Competition in Contracting Act (CICA). In this interim period, two Delta II launches, one for the Roentgen Satellite (ROSAT) and one for the Extreme Ultraviolet Explorer (EUVE) are being acquired through the Department of Defense (DOD). DOD has also been requested to provide a Titan IV vehicle to be available in 1991 to provide a back-up for either the Magellan, Galileo and Ulysses planetary missions presently manifested on the Shuttle. Titan III vehicles are being evaluated for launch of the TDRS-F and Mars Observer spacecraft in the 1991-92 time period. In addition, discussions are in progress to obtain Atlas/Centaur launch services for the Combined Release and Radiation Effects Satellite (CRRES) as part of a barter in exchange for residential hardware from previous programs. Assuming that CRRES is launched on this vehicle, several of the planned experiments which could not be accommodated on Atlas/Centaur would be launched on Scout vehicles.

Funds provided in FY 1988 are being utilized for procurement the Delta II launch vehicles from the DOD for the ROSAT and EUVE missions. In addition, a Delta vehicle is being prepared for the Cosmic Background Explorer (COBE) mission using funds reimbursed by DOD for residual hardware.

Funds are required for continuation of launch vehicle procurements through the DOD for the ROSAT and the EUVE missions. In addition, funding is required to initiate work on the Titan III, Titan IV, Atlas/Centaur and Scout launches described above. Funding is required for medium class vehicles for the Geotail and Wind spacecraft of the Global Geospace Science project. Procurement of launch services for small class vehicles in support of Science & Application missions, planned to be launched at a rate of two per year, will be initiated with these funds.

3. SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

FY 1989 NASA REQUEST, $1,035,300,000

FY 1989 AUTHORIZATION, $1,035,300,000

FISCAL YEARS 1988 and 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Space network	$435,700,000	$538,900,000
Ground networks	232,200,000	248,100,000
Communications and data systems	216,500,000	248,300,000
Total	884,400,000	1,035,300,000

The purpose of this program is to provide vital tracking telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations engaged in space research.

Support is provided for Earth orbital, planetary and solar system exploration missions, research aircraft, sounding rockets and balloons. Included in Earth orbital support are the Space Shuttle, Spacelabs, and scientific and applications missions. The various types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space; (b) acquisition of scientific and space applications data from on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions from space vehicles; (e) transmission of commands from ground stations to the spacecraft; (f) communications with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions and for executing the critical decisions which must be made to assure the success of these missions.

Tracking and acquisition of data for the space projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by the first of three tracking and data relay satellites in geosynchronous orbit working with a highly specialized ground station. Ground facilities are interconnected by terrestrial and communications satellite circuits linking the spacecraft and their control centers for execution of the missions.

To meet the support requirements levied by the wide variety and large number of flight projects, NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network including the Tracking and

Data Relay Satellite System (TDRSS), which will provide all low Earth orbital mission support when it becomes fully operational.

The STDN will provide Earth orbital support until the TDRSS becomes operational. At that time the STDN phasedown will continue with the closure of several ground stations. The DSN, under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, higly elliptical, and planetary and solar system exploration mssions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Highly specialized computation facilities provide real-time information for mission control; and process into meaningful form the large amounts of scientific, applications, and engineering data which is collected from flight projects. In addition, instrumentation facilities provide support for sounding rocket launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications appropriation includes the Space Network, Ground Networks, and Communications and Data Systems elements of the program, and provides funding for: (a) TDRSS operations, spacecraft production, and launch support; (b) operations and maintenance of the tracking, data acquisition, mission control, data processing, and communications facilities; and (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project requirements.

SPACE NETWORK

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Tracking and data relay satellite system (TDRSS)	$318,900,000	$313,800,000
Space network operations	42,700,000	46,700,000
Systems engineering and support	26,700,000	25,600,000
TDRS replacement spacecraft	35,800,000	78,800,000
Second TDRSS ground terminal (STGT)	7,600,000	70,000,000
Advanced TDRS	4,000,000	4,000,000
Total	435,700,000	538,900,000

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary tracking, telemetry, command, and communications services to low Earth orbital spacecraft. The TDRSS, when fully operational, will consist of a three satellite constellation, including an on-orbit spare, in geostationary orbit and ground facilities located at White Sands, New Mexico. From the White Sands location, satellite and ground communication links interconnect the NASA elements of the network and any remotely located user facilities.

The FY 1989 request includes funding for: repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands complex and other NASA elements of the network; support activities such as systems engineering, documentation and mission planning; equipment modification and replacement; analytical studies to define the spacecraft required for the next generation TDRSS; the development and integration of an additional spacecraft to replace the TDRSS lost in the Challenger accident; and the implementation of a second ground terminal at White Sands.

Tracking and Data Relay Satellite System (TDRSS)

The Tracking and Data Relay Satellite System's (TDRSS) objective is to provide communications services between spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from user satellites and relay these communications to the ground via the White Sands facilities which are interconnected with the other elements of the network. From their position in geostationary orbit, the TDRS's can provide nearly a six-fold increase in the orbital coverage provided by ground tracking stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

The TDRS-1 was launched in April 1983, and since that time it has supported Shuttle missions, including Spacelabs, and free flyer satellite missions such as the Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesopheric Explorer (SME). The TDRS-2 was destroyed during the Challenger accident in January 1986. The four remaining spacecraft are undergoing modifications to be compatible with Shuttle safety requirements and are in various stages of construction, assembly and retesting. It is anticipated that the launch of the next TDRS will be on the first Shuttle mission when flights resume. The third TDRS had been scheduled for launch in the first quarter of 1989. The launch date is currently under review pending determination of the Shuttle manifest. Once these two spacecraft have been successfully launched, the system achieves full operational status, TDRS-1 will become the on-orbit spare.

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to Space Communications Company (SCC), the owner-operator of the TDRSS, for program development. Under the terms of the loan agreement and assignment, NASA repays these loans directly to the FFB. In addition, NASA will make payments to SCC for the operation and maintenance of the White Sands complex and for satellite construction and launch support provided during the year.

Of the amount requested in FY 1989, approximately $227 million is for the FFB loan repayments. The remainder of the request is for continuing spacecraft construction, modification, test, storage, and assembly, launch related costs, and operation and maintenance of the White Sands Ground Terminal.

Space Network Operations

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems and facilities which, when combined with TDRSS, provide a full array of reliable tracking, telemetry, command, and communications services to user spacecraft in low Earth orbit. Each of these key NASA network elements are designed to function as an inte-

grated operative system and perform specific functions for the Space Network.

The NASA Ground Terminal (NGT) monitors TDRSS performance, provides fault isolation monitoring for the network, and serves as the communications interface between White Sands and all other user facilities. The Network Control Center (NCC) manages and schedules TDRSS services for all user spacecraft, and the Flight Dynamics Facility (FDF) provides orbit determination, trajectory analysis, and position location for flight missions supported by the space network and for selected missions supported by the ground networks.

The overall system has provided services to a variety of missions and effort is continuing to achieve an operational configuration that will be capable of supporting an expanded workload in the early 1990's.

The funding request provides for services to operate network facilities 24 hours a day, seven days per week, and for related hardware and software maintenance. Funding is also provided for a variety of support activities such as operational analysis, mission planning, simulations, user compatibility testing, and documentation.

Systems Engineering and Support

The objective of Systems Engineering and Support is to provide the engineering services and hardware required to sustain and modify the NASA elements of the Space Network. Engineering services are supplied primarily through support service contracts.

Preparations continue to assure ground system readiness for the resumption of Shuttle flights including the upcoming TDRS launches and for full network operation once the TDRSS is operational. There is ongoing activity to sustain system reliability for current users and preparations are underway to meet the support requirements of upcoming missions such as the Hubble Space Telescope.

Funds are requested to provide systems engineering, hardware and software maintenance, sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Funds are also requested for continued software development and ongoing hardware implementation, replacement and modification for the NCC.

TDRS Replacement Spacecraft

A contract has been awarded to TRW, the sub-contractor for the TDRSS space segment, to provide a replacement spacecraft and long-lead parts for an optional spacecraft. The replacement for the TDRS-2 spacecraft lost with the *Challenger* will maintain the TDRSS until the late 1990's when the Advanced TDRS is planned to become available. The option provides protection against unforeseen launch or deployment failures. Preliminary design studies identified parts and components no longer available and recommended limited design changes to increase spacecraft safety and reliability. The design objective is to provide a satellite functionally identical to the current satellites and fully compatible with the existing system.

The requested funding will provide for continuation of the construction phase of the program. This phase will include completing all design activities culminating with critical design review in the second quarter of FY 1989. In addition, fabrication of the spacecraft bus and payload hardware will continue, specifically including the spacecraft structure and control systems, antennas, traveling wave tube amplifiers, and signal processing sub-systems.

Second TDRSS Ground Terminal (STGT)

The objective of this program is to provide a backup to the existing ground terminal at White Sands, New Mexico, to insure continuity of service and to minimize the potential loss of critical space assets, including data. The existing terminal is a single point of failure for the entire Space Network, and a catastrophic failure of this terminal could result in a nearly complete loss of NASA communications and data gathering capabilities for earth orbiting missions. In addition, the present terminal has experienced temporary service outages due to equipment failure which could have been avoided with a backup terminal.

Due to the aging of equipment, replacement of major subsystems and components in the existing terminal will eventually be required, necessitating an alternate means of conducting network operations while the replacement activity is underway. The addition of a second ground terminal will provide the necessary alternative means for continuing operational support while the existing terminal is down during the replacement.

Because the design of the current terminal is limited to full operation of two TDRS spacecraft, a second terminal will also provide the additional flexibility to operate more spacecraft if, as anticipated, mission requirements exceed current capabilities in the mid-1990's.

A competitive award for two design study contracts was made in May 1987. A competitive award to a single contractor for implementation is planned for early FY 1989. Funding for the initiation of the implementation phase for the development of hardware and software is included in this request.

Advanced TDRS

The objective of the program is to develop and competitively procure technologically advanced satellites to sustain Space Network operations. By the mid-1990's, the stock of ground spare spacecraft for the Tracking and Data Relay Satellite System (TDRSS) is expected to be exhausted. The ATDRS will provide the capability to extend network service into the 21st century and to accommodate the future mission requirements projected for this era. Initial low level studies have been initiated and will be completed by mid-FY 1989. In late FY 1989, definition activities will commence.

Requested funding is required to complete the initial studies and to begin competitive definition activities.

GROUND NETWORKS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Spaceflight tracking and data network systems implementation	$3,200,000	$6,200,000
Spaceflight tracking and data network operations	70,100,000	65,700,000
Deep space network systems implementation	46,200,000	50,100,000
Deep space network operations	88,000,000	99,000,000
Aeronautics, balloons, and sounding rocket support systems implementation	8,200,000	9,300,000
Aeronautics, balloons, and sounding rocket support operations	16,500,000	17,800,000
Total	232,200,000	248,100,000

The Ground Networks provide support to three broad categories of missions: Earth orbital spaceflight; planetary and solar system exploration; and aeronautics, balloons and sounding rockets. Earth orbital support is provided primarily by the Spaceflight Tracking and Data Network (STDN), a network of eight geographically dispersed ground stations. The Deep Space Network, with ground stations located at three sites approximately 120 degrees apart in longitude, provides support to the planetary and solar system exploration missions as well as Earth orbital missions not compatible with TDRSS. Aeronautics, balloons and sounding rocket research is supported by specially instrumented ranges as well as mobile systems.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities as required to support new missions. The workload in FY 1989 will include support to the Space Shuttle, the Voyager–2 encounter with the planet Neptune, and the Magellan spacecraft launch. Magellan will perform radar imaging of Venus during 1990. Preparations will be underway for the future Galileo, Ulysses, and Mars Observer planetary encounter missions, and the Global Geospace Science (GGS) mission. Ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM) will continue to receive Ground Networks and/or Space Network support. Aircraft test programs will also be supported.

Spaceflight Tracking and Data Network Systems Implementation

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement of hardware and attendant engineering services to sustain, modify, and replace existing network capabilities to ensure reliable tracking, command and data acquisition support to NASA's spaceflight missions.

The FY 1989 request includes funds for replacement of obsolete and difficult-to-maintain equipment at certain tracking stations and other network facilities. The funds requested also provide for the procurement of major subsystem spares, the replacement of older test equipment, and minor equipment modifications resulting from changes in support requirements.

Funds are also required to upgrade equipment systems and subsystems at those facilities to be retained after TDRSS is operational. These facilities include the Merritt Island, Florida, and Bermuda STDN stations which provide prelaunch, launch, and Shuttle landing support, as well as limited orbital support. Also included is the orbital tracking facility at the Wallops Flight Facility.

Spaceflight Tracking and Data Network Operations

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support NASA's Earth orbiting spaceflight missions, including the Space Shuttle. This network also provices launch support to NASA planetary missions, and on a reimbursable basis, spaceflight missions of other United States government agencies (NOAA and DOD) and other nations.

The STDN presently consists of eight geographically dispersed ground stations. They are located at: Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Dakar, Senegal; Bermuda; Santiago, Chile; and Yarragadee, Australia. Each of these stations, with the exception of Yarragadee, have the capability to electronically track spacecraft, send commands for spacecraft and experiment control purposes, and receive and display engineering and scientific data from the spacecraft. In the case of manned flights, they also maintain voice communications for crew operations and safety and other project-related purposes. The Yarragadee, Australia station provides only air-to-ground voice communication with the Space Shuttle astronauts.

The STDN will undergo a highly significant change from its current configuration when the Space Network achieves operational status. At that time, six STDN stations will cease operations and either close or be transferred to other organizations. These stations are Ascension Island; Guam; Hawaii; Santiago, Chile; Dakar, Senegal; and Yarragadee, Australia. The two remaining stations at Merritt Island, Florida, and Bermuda will provide prelaunch, launch, and Shuttle landing support as well as limited orbital support.

The FY 1989 funding request provides for a full year of operation of the eight STDN stations. In addition to the costs of operating the eight STDN stations, the request includes funding for logistics support, network planning, scheduling, control center operations, engineering, documentation, and software programming support. Logistics support funded under this program is provided to a variety of users such as the Deep Space Network, NASA Communications Network, Wallops Flight Facility, and spacecraft control centers at Goddard Space Flight Center (GSFC).

Deep Space Network Systems Implementation

The primary role of the Deep Space Network (DSN) is to provide the communication link between each of NASA's planetary and interplanetary spacecraft and the Earth. The DSN is responsible for receiving science and engineering data and providing the navigation, command and control capabilities from the ground to a wide variety of spacecraft across distances ranging from hundreds

to over 6 billion kilometers from Earth. The DSN also has support responsibilities for some spacecraft in Earth orbit that are not supportable by the TDRSS.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in an array to receive the extremely weak radio signals. The antennas use ultrasensitive, cryogenically-cooled receivers and powerful transmitters. Extremely stable hydrogen maser time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the DSN Complexes and the Network Operations Control Center.

Since Magellan and Galileo, both planned for launch in 1989, are the first spacecraft to receive the higher X-band frequency, the Deep Space Network is being equipped to transmit commands in this frequency range. Initially, the 34-meter antennas in California, Spain and Australia will have this capability. Not only will Galileo utilize this new frequency for spacecraft telecommunications, but it will also use a new precision tracking capability to perform experiments designed to detect perturbations in the gravity field caused by collapsing quasars. Since other deep space missions such as Mars Observer, with a planned 1992 launch will also utilize X-band, it is planned to implement this capability on most of the remaining antennas in the DSN by FY 1992.

The four major objectives for the DSN in the late 1980's are as follows: (1) to provide communications channels to scientific spacecraft at ever-increasing distances and to provide the capability to receive images at these great distances; (2) to increase the frequency range and data rate capability of the ground network to accommodate new deep space mission requirements; (3) to provide support for a new set of spacecraft which will include non-TDRSS compatible, highly elliptical Earth orbiters, and synchronous Earth orbital missions; and (4) to provide the improved navigation capabilities required for precise spacecraft targeting and probe delivery.

These objectives continue to represent a significant challenge to the DSN. The most distant planetary encounter will be with Neptune by Voyager-2 in August 1989. This encounter will occur some 4.5 billion kilometers from Earth. At that time, Voyager-2 is expected to transmit the first high resolution images ever received from a spacecraft at that distance. To meet the challenge, an expansion of the 65-meter antennas to 70-meters will be completed by mid-1988. This expansion, along with multiple antenna arraying (signal combining) of DSN antennas and non-NASA radiotelescopes in New Mexico and Australia, will provide the increased signal capturing capability for our first look at Neptune. This technique was previously used successfully by the Canberra-Parkes, Australia array during the Voyager encounters with Saturn and Uranus.

The Magellan spacecraft is planned for launch in April 1989 and will be placed in orbit around Venus during July 1990. Radar mapping of Venus will be performed over the course of one Venusian year. Atmospheric dynamics of the Venusian atmosphere will also be measured.

The Deep Space Network will also support the two landers of the U.S.S.R.'s Phobos mission in FY 1989. This Soviet mission consists of two spacecraft, each of which will place a lander on the Martian moon Phobos. Future deep space missions to be supported by the DSN include Galileo, Ulysses, and Mars Observer.

Funding in the FY 1989 request provides for continuing the evolution of the DSN, taking advantage of the latest technologies to meet increasingly complex support requirements. Included are new capabilities needed to meet the more stringent navigation and spacecraft-ground telecommunications requirements.

Funds are included in the FY 1989 budget to implement the new capabilities required for the Magellan and Mars Observer missions. These capabilities include telemetry system modifications to handle the high data rates and extensive changes to the receiver system required by spacecraft signal dynamics. Funds have also been included to support the microwave observing project which will analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy.

The band transmission capability being implemented at the new 34-meter sites requires modifications to the antenna feed systems and the addition of a transmitter to the antennas which are currently in a "listen only" configuration. Extensive improvements to the ground tracking systems are required in FY 1989 to provide the navigation accuracy necessary for the Galileo probe release. This mission event requires that the position of the spacecraft be precisely known in order that the probe, when released, will follow the correct ballistic trajectory into the Jovian atmosphere.

Work will continue in FY 1989 in preparation for the Voyager-2 spacecraft encounter with Neptune in August 1989. This activity consists of implementation of a X-band receive capability for the Very Large Array radiotelescope at Socorro, New Mexico (which will be arrayed with Goldstone, California antennas) and the 64-meter radio telescope antenna at Parkes, Australia (which will be arrayed with the DSN antennas at Canberra, Australia).

This program also includes funds for sustaining activity in the DSN such as reliability modifications, operations improvements, and replacement of obsolete equipment at the three DSN complex signal processing centers and at the Network Control Center at Pasadena, California.

Deep Space Network Operations

The three Deep Space Network (DSN) complex locations—Goldstone, California; Canberra, Australia; and Madrid, Spain—are approximately 120 degrees apart in longitude to permit continuous viewing of planetary spacecraft. After completion of the project in FY 1988 to expand the diameter of the 65-meter antennas to 70 meters, each complex will have four antennas: one 70-meter, two 34-meter and one 26-meter. A centralized network control center is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California.

The Voyager-2 spacecraft encounter with Uranus in January 1986 provided the first detailed information on that distant planet. Voyager-1 is now nearly 5 billion kilometers from Earth on a trajectory that will take it out of the solar system. The Pioneer-10 spacecraft is beyond the orbit of Neptune, and is the first man-made object to leave the solar system. It now takes eleven and one-

half hours for a radio signal, traveling at the speed of light, to make the round trip between Earth and Pioneer-10. The Pioneer-11 spacecraft, some 3.8 billion kilometers from Earth, continues to be tracked. The Pioneer-6 through 8 spacecraft are provided support periodically, and especially during solar conjunctions and gravity wave experiments.

The DSN facilities are also used for ground based measurements in support of experiments in planetary radar mapping and in the field of radio astronomy. The ultrasensitive network antennas are being used in an attempt to learn more about pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena.

The DSN operations funding provides for the maintenance and operation of network facilities and the support and engineering effort required for continuing operation of the network. The expected DSN workload in FY 1989 consists of support for the Voyager-2 spacecraft and its encounter with Neptune, Voyager-1, the six ongoing Pioneer spacecraft (Pioneer-6, 7, 8, 10, 11 and Pioneer-Venus), Magellan, Phobos, preparations for Galileo launch, Active Magnetopheric Particle Tracer Explorer, International Cometary Explorer, Nimbus-7, and Dynamics Explorer. The DSN will also provide emergency and backup support for the Space Shuttle, TDRSS and Hubble Space Telescope.

Aeronautics, Balloons, and Sounding Rocket Support Systems Implementation

The facilities of the Aeronautics, Balloon and Sounding Rocket (AB&SR) Program encompass the ground support capabilities required to capture the scientific and engineering data from aircraft, balloons, sounding rockets and some Earth orbiting vehicles engaged in scientific research. The primary fixed facilities are located at the Wallops Flight Facility (WFF), the Ames Research Center (ARC) and the Dryden Flight Research Facility (DFRF).

The Wallops Flight Facility, under the management of Goddard Space Flight Center (GSFC), operates an extensive range at Wallops Island, Virginia, which supports aeronautics research as well as sounding rocket and small weather balloon launches. In 1986, a capability was established at WRR to provide tracking and data acquisition support to certain Earth orbiting satellites to supplement the capabilities of the Spaceflight Tracking and Data Network (STDN). WFF also manages the operation of off-site ranges located at the White Sands Missile Range, New Mexico; Poker Flats Research Range, Alaska; and the National Scientific Balloon Facility, at Palestine, Texas. Mobile campaigns for balloon and sounding rocket launches are conducted at various sites throughout the world.

The ranges at Moffett Field, Crows Landing and the Dryden Flight Research Facility (DFRF), are under the management of ARC and are configured to support aeronautics research. The DFRF has the additional capability to support shuttle landings.

The AB&SR system implementation program is directed primarily at the systematic replacement of obsolete systems and the upgrade of these facilities to assure reliable support to NASA's research programs.

The aeronautical research efforts and scientific experiments using sounding rockets and balloons are programs of a continuing nature which generally require a relatively constant level of support. Support for these programs requires fixed and mobile instrumentation systems which include radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, test and calibration equipment routinely replaced, and equipment refurbished or modified to assure reliable support.

Aeronautics, Balloons, and Sounding Rocket Support Operations

The operations element of the AB&SR Program includes the operations and maintenance of ground-based instrumentation systems, both fixed and mobile, under the management of the Ames Research Center (ARC) and the Goddard Space Flight Center (GSFC). These facilities support NASA aeronautics, sub-orbital, and a limited number of Earth orbit research programs. Funding provides for services and consumable supplies required to operate and maintain the radar, telemetry, data acquisition, data processing, data display, communications and special purpose optical equipment essential to the conduct of these research programs.

The aeronautical test ranges at the Dryden Flight Research Facility (DFRF) and the Moffett Field Flight Complex (MFFC), under the auspices of the Ames Research Center, maintain an active schedule of aeronautics research support. During FY 1987, more than 1450 missions were conducted at DFRF and MFFC. Programs supported by the ranges encompassed a wide variety of activities including revolutionary aircraft configurations, advanced technologies, high performance aircraft, highly integrated control systems and powered lift technologies.

The GSFC activities support aeronautics programs as well as sounding rocket, balloon and Earth orbiting satellite programs at the Wallops Flight Facility (WFF). During 1987, approximately 220 aeronautics missions were supported at the WFF covering such programs as heavy payload mid-air retrieval systems development, XV-15 Aircraft Noise Program, runway friction testing, microwave landing system operations testing, storm hazards research, and the general aviation light aircraft thruster research program.

The sounding rocket program at the WFF conducted approximately 120 launches in FY 1987, which included 29 of the larger rockets with major scientific payloads. The remainder were the smaller meterorological and special purpose rockets supporting a variety of research programs. The balloon program had 200 launches during FY 1987, including 41 large balloons with major scientific payloads. Earth orbiting satellites supported included International Ultraviolet Explorer, Interplanetary Monitoring Platform-8, and Nimbus-7.

The funding estimate for FY 1989 is based on a relatively constant level of mission support activity. Operations, maintenance, logistical support and technical services for the ground-based fixed and mobile instrumentation systems will be continued in support of the ongoing sounding rocket, balloon, Earth orbiting satellite and aeronautical research programs.

COMMUNICATIONS AND DATA SYSTEMS

FISCAL YEARS 1988 AND 1989 FUNDING LEVELS

	Estimated fiscal year 1988	Authorization fiscal year 1989
Communication systems implementation	$6,300,000	$12,100,000
Communication operations	109,500,000	116,300,000
Mission facilities	11,500,000	8,800,000
Mission operations	25,000,000	32,000,000
Data processing systems implementation	21,500,000	25,800,000
Data processing operations	42,700,000	53,300,000
Total	216,500,000	248,300,000

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support.

Communication circuits and services provide for the transmission of data among the remote tracking and data acquisition facilities, launch areas, and the mission control centers. Real-time information is crucial to determine the condition of the spacecraft and payloads for the generation of spacecraft and payload control demands. Data received from the various spacecraft must be processed into a usable form for spacecraft monitoring in the control centers and before the transfer of data to the experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects, and international cooperative efforts.

Major activities underway include: implementing necessary changes to the Hubble Space Telescope mission control and data capture system, and mission control and data processing capabilities required to support upcoming missions such as Gamma Ray Observatory (GRO), Spacelabs, Upper Atmosphere Research Satellite (UARS), Global Geospace Science (GGS) and Advanced X-ray Astronomy Facility (AXAF). In addition, studies are continuing to evaluate Space Station support requirements.

Communication Systems Implementation

The objective of the Communications Systems Implementation program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data. NASCOM interconnects the tracking and data acquisition facilities which support all flight projects; it also links such facilities as launch areas, test sites, and mission control centers.

The major effort being initiated in NASCOM is the planning, engineering, and equipment acquisition required to tie together the existing TDRSS ground terminal at White Sands, New Mexico, with the Second TDRSS Ground Terminal. This requires an integrated communications capability for the control and transfer of data between the two facilities. The secondary effort under way is the equipment acquisition to upgrade the Deep Space Network's ground communications data handling capability at Madrid, Spain; Tidbinbilla, Australia; and the Jet Propulsion Laboratory.

The FY 1989 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and provide for the engineering and equipment acquisition to support the Second TDRSS Ground Terminal at White Sands. Efforts will continue at the Goddard Space Flight Center (GSFC) on the implementation of the new voice intercom system for all the Payload Operations Control Centers. Funding will also provide for the ground communications data handling capability required in the Deep Space Network to support the increased data rates of the Magellan, Galileo, and Ulysses satellites.

Communication Operations

NASA's global Communications Network (NASCOM) interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. Also, NASCOM links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at JPL and Madrid. The NASA flight projects require the transfer of data between the mission control centers and the sites because of the need for real time control of spacecraft and on-board experiments. In addition, there are requirements to provide experiment data expeditiously to users for analysis.

NASA's Program Support Communications Network (PSCN) interconnects the NASA Centers, Headquarters, and major contractor locations through leased voice, data and wide-band circuits for the transfer of programmatic and scientific information. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

The FY 1989 funding requirements for the Communications Operations program will provide the circuits and service required to operate and maintain the NASA Global Communications Network. International communications satellites and cables will continue to provide digital wideband services to all the overseas tracking stations. Domestic satellite systems and terrestrial networks will continue to service the continental United States stations. With the reactivation of the Shuttle network and the trend toward fiber optic systems, there will be a dramatic increase in the use of digital technology in NASCOM with a corresponding decrease in the use of analog technology. Funding increases will be required to simultaneously support the Shuttle and the deep space projects with wideband data links to the Deep Space Network stations in Spain and Australia.

Funds are included for Program Support Communications network (PSCN) which provide for the circuits and facilities for programmatic operations such as data transmission and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1989, funds are required to operate and maintain the PSCN hardware and wideband satellite and terrestrial circuits at all NASA locations and selected contractor sites. The network will support all

NASA programs and projects such as the Shuttle, Hubble Space Telescope, and Space Station. Beginning in FY 1989, the PSCN backbone circuits, which support all programs, will be funded by the Office of Space Operations and the individual program offices will fund additive unique tail circuit requirements.

Mission Facilities

The Mission Facilities Implementation Program provides the capabilities needed for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments are carried out via the Payload Operations Control Centers (POCC's) and related mission support systems.

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and the transmission of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is under development to control the Hubble Space Telescope scheduled for launch in mid-FY 1989. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning/Command Management System to schedule spacecraft support and generate command sequences for transmission to the spacecraft by the POCC's.

The FY 1989 funding requirements will provide for Hubble Space Telescope prelaunch systems testing and software development. This software will control the accurate pointing of the telescope and determine the on-orbit power consumption and thermal gradients of the spacecraft subsystems and scientific instruments.

In addition, FY 1989 funds are included for modifications to the existing Multi-Satellite Operations Control Center (MSOCC) for control of the Gamma Ray Observatory (GRO), Cosmic Background Explorer (COBE), Upper Atmosphere Research Satellite (UARS), Extreme Ultra-Violet Explorer (EUVE), and various Shuttle attached payloads. In FY 1989, control center modifications will be underway which permit spacecraft payload operations from user facilities. This new concept, which is planned for use with Space Station, will provide operational efficiencies for experimenters.

Mission Operations

The Mission Operations program in FY 1989 will provide for the operation of the five Payload Operations Control Centers (POCC's) and the related software and support services necessary for the monitoring and control of eight in-orbit spacecraft and pre-launch preparations for five spacecraft.

The POCC's, which are the control facilities for spacecraft-payload operations, have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data and for sending commands to the spacecraft. Commands transmitted to the spacecraft include both emergency commands resulting from decisions made by the spacecraft analysts and preplanned command sequences generated in advance to carry out the mission objectives. Each POCC is operated 24 hours per day, 7 days a week in mission support. For Shuttle launches with attached payloads, having GSFC responsibility, there is a specialized GSFC Shuttle Payload Interface Facility (SPIF) which processes and provides for the display of Shuttle-unique data that is necessary for payload control.

The FY 1989 budget request includes funds to operate the POCC's and supporting facilities for control of on-orbit missions and to develop control center software to support upcoming missions. In FY 1989, the new Hubble Space Telescope POCC will be in the final stages of spacecraft and ground systems testing in preparation for a late FY 1989 launch, followed by a period of on-orbit checkout of the new telescope observatory. A major activity that will be conducted in this facility is the operational checkout and calibration of the total ground system, the spacecraft and its scientific instruments. Also in FY 1989, software development activities will continue for the GRO, UARS, EUVE, and AXAF missions. POCC software for mission control to the COBE will also be completed to support a mid-FY 1989 launch.

Data Processing Systems Implementation

The Data Processing Systems Implementation program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC). These systems support both the operational and payload requirements of flight missions. To meet operational requirements, these systems determine spacecraft attitude and orbit and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data from science and applications experiments for subsequent transfer to the experimenters for analysis.

Major computation capabilities include the Flight Dynamics Facility which performs the real-time attitude, orbit computation and flight maneuver control functions and the Mission Operations and Data Systems Information Network (MODSIN). In addition, there are four major systems for processing payload data: (1) the Telemetry On-Line Processing System (TELOPS) which routinely supports a number of earth-orbiting spacecraft; (2) the Image Processing Facility (IPF) which generates products for Nimbus-7; (3) the Spacelab Data Processing Facility (SLDPF) which has provided support to the Spacelab missions and the Shuttle Imaging Radar-B experiment; and (4) the Hubble Space Telescope Data Capture Facility (HSTDCF) which will capture, process, and forward to the Science Institute Facility the packetized telemetry data from the Hubble Space Telescope spacecraft.

Significant activities in this program continue at GSFC to keep the large systems viable and responsive to project support requirements. Implementation continues on new systems to process data from the Gamma Ray Observatory (GRO) and the Upper Atmosphere Research Satellite (UARS) missions.

Also included is the improvement in the test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced Systems Program. Promising technologies for application to future support will be investigated in the areas of remote payload operation and control, expert systems, high speed data processing, high level languages, and very large scale integration (VLSI).

The FY 1989 budget request will provide continued funding for improvements in the existing computation systems at GSFC which provide real-time support to NASA spacecraft. Funding is also included for initial development of the MODSIN Host system and initial cost-benefit study to determine the life-cycle cost effectiveness of integrating and improving the orbit and attitude large applications software programs. In addition, the request provides for the improvement and upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation.

The FY 1989 budget request includes funds to continue the upgrade of the existing TELOPS system in order to develop a generic time division multiplexed (TDM) system for processing data. The Upper Atmosphere Research Satellite (UARS), will be the first user. The handling of UARS data will serve as a baseline for providing such support to other users allowing for trade-offs between development costs and support risks for future missions. Funds are also requested for upgrading the data processing capabilities at GSFC to facilitate the exchange of data within the data processing complex and with other mission support facilities.

There is a continuing requirement to procure and maintain an adequate supply of unique spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration. Funds are included in the request for continuing the evaluation of Space Station support requirements and the capabilities needed to meet the requirements. In FY 1989, a systems definition study will be initiated for the Customer Data and Operations Systems (CDOS) which will provide preliminary design and specifications.

Data Processing Operations

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to the experimenters. This transformation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small Explorer satellites to complex imaging-type satellites such as Nimbus.

In addition to the actual processing of data, upcoming projects require extensive pre-launch orbit analysis including spacecraft position and attitude predictions. Analyses are also required to develop operational sequences, procedures and optimization of systems resources and look angles for maximum science data return during the actual operation of these complex spacecraft.

Telemetry data is the primary product of spacecraft, and it is through reduction and analysis of this data by the experimenters that the planned objectives are achieved. Data is processed to separate the information obtained from various scientific experiments aboard the spacecraft, consolidate information for each experimenter, determine spacecraft attitude, and correlate these measurements with spacecraft position data. Four facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS) facility, the Spacelab Data Processing Facility (SLDPF), and the Hubble Space Telescope Data Capture Facility (HSTDCF) have been established at the Goddard Space Flight Center to preprocess different types of raw experimental data. Sustained operations of these facilities is needed to support the on-going spacecraft in-orbit.

The IPF, initially established to handle image data from the Landsat-1 satellite, has supported Landsat-2 and Landsat-3 and presently is processing data from the Nimbus-7 mission. The Nimbus-7 mission support will end in late FY 1988. However, retroactive Nimbus-7 data processing is anticipated to last through FY 1989. The TELOPS handles satellite non-image data which is received in a digital form from the tracking stations via NASCOM. It is capable of electronically storing large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility management, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operation of the SLDPF is included along with software development and maintenance required for attitude determination, flight maneuvers, mission simulations, and Mission Operations and Data Systems Information Network (MODSIN).

The FY 1989 budget request provides for operation of the various computation and data processing facilities including the SLDPF which requires maintenance of unique hardware and software for Spacelab and Dedicated Discipline Laboratory (DDL) missions.

Application software development, prototyping, and system testing activities are continuing. Additional activity in support of such upcoming space science and applications missions as Cosmic Background Explorer, Gamma Ray Observatory, Shuttle Attached Payloads, Upper Atmosphere Research Satellite, and Extreme Ultraviolet Explorer is also planned. For on-orbit spacecraft, software development and maintenance is required on a continuing basis in order to perform flight control maneuver operations and for the data processing activities.

CONSTRUCTION OF FACILITIES

FY 1989 NASA REQUEST, $285,100,000

FY 1989 AUTHORIZATION, $285,100,000

FY 1990 AUTHORIZATION, $341,100,000

FY 1991 AUTHORIZATION, $401,100,000

The Construction of Facilities (CoF) appropriation contractual services for the repair, rehabilitation and modification of existing facilities, the construction of new facilities; the acquisition of related facility equipment; the design of facilities projects; and advance planning related to future facilities needs.

The funds requested for FY 1989 provide for the continuation of prior year endeavors in meeting the facilities requirements for the Space Flight and Space Station programs; initiation of a structured multi-year effort to restore and modernize NASA's aeronautical research and development facilities; repair, rehabilitation and modification of other facilities to maintain, upgrade and improve the usefulness of the NASA physical plant; minor construction of new facilities, facility planning and design activities, and environmental compliance and restoration.

The projects and amounts in the budget estimates reflect Space Station and Space Flight requirements that are time-sensitive to meet specific program objectives. Other program requirements for 1989 include construction of an auxiliary chiller facility at the Johnson Space Center, modifications to the X-Ray Calibration Facility to support the Advanced X-Ray Astrophysics Facility Program at the Marshall Space Flight Center, modernization of the Space Environment Simulator at the Jet Propulsion Laboratory, projects to repair, restore and modernize NASA's aeronautical research and development facilities at Ames, Lewis, and Langley Research Centers, and refurbishment of the Electric Power Laboratory at the Lewis Research Center.

The FY 1988 program continues to meet the objectives of preserving and enhancing the capabilities and usefulness of existing facilities and ensuring safe, economical and efficient use of the NASA physical plant. This request continues the necessary rehabilitation and modification program begun in prior years and continues a repair program. The purpose of the repair program is to restore facilities to a condition substantially equivalent to their originally designed capability. The minor construction program continues to provide a means to accomplish smaller facility projects which accommodate changes in technical and institutional requirements. The Environmental Compliance and Restoration Program

will ensure that statutory environmental requirements will be met and any necessary remedial action promptly taken.

Funds requested for facility planning and design cover advance planning and design requirements for potential future projects, master planning, facilities studies, engineering reports and studies and the preparation of facility project design drawings and bid specifications.

With regard to aeronautical facilities, the Committee notes that many of NASA's wind tunnels are old, having been constructed in the 1940's and 50's. Furthermore, the rate of investment in rehabilitation and modernization has been about one percent of the replacement value per year, compared with the industry standard of about five percent. The result is a potentially serious situation involving structural failures, long testing delays, and safety problems. A particularly serious example is the 12-Foot High-Pressure Tunnel at Ames, which has been decertified because of numerous cracks in the pressure shell, a limitation that its many industrial and military users find intolerable. Because of this, Congress increased NASA's original FY 88 request for Construction of Facilities by $16 million to begin rehabilitation of the 12-foot tunnel.

NASA commissioned a special task force to make a comprehensive assessment of the state of health of its major wind tunnels. The task force found a total of 19 wind tunnels that are in need of rehabilitation and modernization, and recommended a 5-year, $260 million program. The FY 89 request for $63.8 million represents the first year of this plan, aimed at rehabilitating the 12-foot at Ames, the 10 × 10-foot at Lewis, and the hypersonic complex at Langley.

The Committee believes NASA's wind tunnels are a national asset critical to maintaining preeminence in aviation and strongly supports the need to refurbish them. For construction of aeronautical facilities, the Committee recommends for FY 89, $63,800,000; for FY 90, $76,100,000; for FY 91, $121,100,000.

The total budget authority requested for FY 1989 is $285,100,000, with estimated outlays of $178,000,000.

Project	Authorization fiscal year 1989	Page No.
Construction of Space Station Processing Facility (KSC)	15,000,000	285
Modifications of Process Technology Facility for Space Station (MSFC)	3,700,000	286
Construction of Addition for Space Systems Automated Integration and Assembly Facility (JSC)	9,200,000	286
Replacement of High Pressure Gas Storage Vessels (NSTL)	3,500,000	287
Increase Chiller Capacity, LC-39 Utility Annex (KSC)	2,300,000	287
Rehabilitation of PAD A, Launch Complex 39 (KSC)	4,600,000	288
Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility (JSC)	4,900,000	288
Modifications for Advanced Engine Development, Test Stand 116 (MSFC)	13,500,000	289
Modifications to Orbiter Modification and Refurbishment Facility (OMRF) for Safing and Deservicing (KSC)	2,800,000	290
Construction of National Resource Protection (Various Locations)	2,600,000	290
Construction of Auxiliary Chiller Facility (JSC)	7,800,000	291
Modifications to the X-Ray Calibration Facility (XRCF) (MSFC)	11,400,000	291

Project	Authorization fiscal year 1989	Page No.
Modernization of Space Environment Simulator (GSFC)	2,800,000	292
Modifications for Utility Reliability (GSFC)	3,100,000	293
Refurbishment of 25-Foot Space Simulator (JPL)	12,000,000	294
Repair and Modernization of the 12-Foot Pressure Wind Tunnel (ARC)	36,500,000	295
Rehabilitation and Modifications to 10x10 Supersonic Wind Tunnel (LaRC)	14,500,000	296
Refurbishment of Hypersonic Facilities Complex (LaRC)	12,800,000	288
Refurbishment of Electric Power Laboratory (LRC)	6,100,000	299
Repair of facilities at various locations, not in excess of $750,000 per project	27,000,000	300
Rehabilitation and modification of facilities at various locations not in excess of $750,000 per project	34,000,000	301
Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project	9,000,000	302
Facility planning and design	20,000,000	303
Environmental compliance and restoration program	26,000,000	303
Total	285,100,000	

1. CONSTRUCTION OF SPACE STATION PROCESSING FACILITY, JOHN F. KENNEDY SPACE CENTER, $15,000,000

This project provides for the initial increment of construction of the space Station Processing Facility (SSPF) for the prelaunch and post-landing nonhazardous processing of the various Space Station elements.*

Prelaunch processing is necessary to inspect and verify space Station elements, to ensure that these elements are properly configured for launch, to verify element-to-element interfaces, to perform final prelaunch servicing, and to verify on the ground, to the extent practicable, the capability of the elements and systems to function as planned in orbit. The final processing operation in this facility will be to install the element in the KSC Shuttle payload canister for transportation to the launch pad. The need for processing will continue during the operational phase of the Space Station, as certain elements will be regularly returned from orbit for refurbishment, retrofitting, and resupply. After studies and analysis of the processing requirements, that the most cost-effective manner to provide nonhazardous processing of Station elements was to build a new facility. Use of the existing Operations and Checkout Building was not suitable due to its configuration and continuing requirement for Spacelab and other programs.

The Space Station Processing Facility will enclose a total gross area of 297,000 square feet and has a permanent staff of over 900 civil service, contractor, user, and international personnel. It will include approximately 73,000 square feet of high bay and intermediate bay floor space for parallel processing of eight space Station (SS) elements in a class 100K clean, controlled environment. Operations support areas for schedule and quality control (QC), shop supervision, documentation and control will be included. laboratories, office space, and cafeteria will also be included.

* Total cost Over 3 Years $68.7 million.

A second increment will be included in the FY 1990 budget request for approximately $31 million and a third increment in the FY 1991 budget for $22.7 million, will be required to complete this project.

2. MODIFICATIONS OF PROCESS TECHNOLOGY FACILITY FOR SPACE STATION, GEORGE C. MARSHALL SPACE FLIGHT CENTER, $3,700,000

This project provides for the development of new productivity techniques for Space Station which is to remain in orbit for many years and on-orbit repair to damaged hardware will be required. Therefore, the development of special equipment, tools, materials, and techniques in a vacuum to measure the effectiveness of each application for space use is necessary. A 10-foot by 15-foot working diameter walk-in vacuum chamber, robotic water jet, and composite test component areas will be provided for development and testing of potential space assembly processing and repair activities.

The manned Space Station is being developed to remain in orbit for approximately 20 years and will require on-orbit repair of damaged hardware. Development of the required special repair equipment must include testing in a vacuum. Robotized electron beam welding, cutting, soldering, and metal spray coating will be developed and demonstrated. A means of managing debris generated by this process will be studied. The Space Station, with twice the volume of Skylab and more than 1,000 linear feet of seal application, has a specified leak rate of 5.0lbs/day versus 22.5 calculated for Skylab, given the same pressure. Accordingly, initial priority will be placed on verification of seal concepts and leak rates. The vacuum chamber is also needed to develop adhesives, and coatings for Space Station module repair and refurbishment work. Candidate materials will be tested for outgassing, flammability, toxicity, bonding strength, and sealing efficiency.

This project upgrades the existing Process Technology Facility, Building 4707. Work includes 4,000 square feet of space with the installation of a 10-foot by 15-foot diameter Vacuum Chamber, a clean room of 1,500 square feet, control room, and instrumentation.

Equipment to be funded with R&D resources will consist of a 10 KW laser welding and heat-treating system, 10-foot by 8-foot diameter auto clave, artificial intelligence system, and microvax computer at an estimated cost of $2,700,000.

3. CONSTRUCTION OF ADDITION FOR SPACE SYSTEMS AUTOMATED INTEGRATION AND ASSEMBLY FACILITY, LYNDON B. JOHNSON SPACE CENTER, $9,200,000

This project provides for construction of an addition to the east end of the Systems Integration and Mockup Laboratory to support development, testing and flight qualification of integrated component assembly/attachment hardware and other mechanisms for the Space Station. This 47,000-square-foot addition will accommodate simulators, associated support equipment, and personnel used in simulation testing of manual and automated construction techniques and hardware.

The high-bay addition will provide space for a large stationary six-degree-of-freedom simulator, two portable six-degree-of-freedom simulators, a 40- by 40-foot air-bearing floor, and a static test area

for various space Station structures. The three-story laboratory addition is required for a technician work and staging area, test and applications computing support, techniques development laboratories, transient engineering support space, and mechanical equipment associated with the total project.

Noncollateral equipmenmt such as a six-degree-of-freedom motion simulator, computers and miscellaneous test equipment estimated to cost $2,500,000, will be provided from R&D resources.

4. REPLACEMENT OF HIGH PRESSURE GAS STORAGE VESSELS, NATIONAL SPACE TECHNOLOGY LABORATORIES, $3,500,000 *

This project will replace deteriorated high-Pressure Gas Storage Vessels in the "B" Test Complex that are used to furnish gases for the Space Shuttle Main Engine (SSME) Testing Program at NSTL. Existing gas storage vessels have been removed from service or are operating on safety standards waivers requiring pressure derating. One 1,500–CF GN_2 storage vessel and one 600–CF of GH_2 storage vessel will be replaced with two 750–CF and one 600–CF high-pressure gas storage vessels.

Safety standards require that these vessels be derated below the originally designed maximum allowable working pressure or be removed from service.

The Test Complex Pressure Vessels were fabricated in 1964 and have been in continuous service since that time. These vessels are used for storage of gases up to 6,000 psig. The vessels, of laminated construction, are fabricated from HS–1A (T–1) steel. The properties of this steel make it highly susceptible to hydrogen embrittlement and stress corrosion cracking and require replacement at this time.

The work includes procurement of two 750–CF GN_2 vessels with a maximum allowable working pressure of up to 6,500 psig; one 600–CF GH_2 vessel, with a maximum allowable pressure of 4,500 psig; installation of a vessel support structure; modification of interconnecting piping; and chemical cleaning and testing of the vessels and modified system.

There will be a future requirement to replace the remaining 1,500–CF GN_2 vessel that has been downrated because of deterioration at an estimated cost of $3,000,000.

5. INCREASE CHILLER CAPACITY, LC–39 UTILITY ANNEX, JOHN F. KENNEDY SPACE CENTER, $2,300,000

This project will add a fifth water chiller to the Vehicle Assembly Building (VAB) Utility Annex and Launch Complex 39. Growth in cooling requirements coming from the activation of several new facilities will require an additional "on-line" chiller in 1990.

This project is required to provide the necessary cooling for Shuttle processing activities in the VAB, Launch Control Center (LCC), Orbiter Processing Facility (OPF), OPF Annex, Orbiter Modification and Refurbishment Facility (OMRF), and Thermal Protection System (TPS) Facility in 1990 and following years. Projected cooling requirements will exceed the present capability and an additional 2,500-ton refrigeration unit will be required to support Shuttle processing and launch.

The needed fifth chiller will allow adequate backup cooling in this highly critical system to ensure launch support with no effect on launch activities or schedules.

6. REHABILITATION OF PAD A, LAUNCH COMPLEX 39, JOHN F. KENNEDY SPACE CENTER, $4,600,000

This project provides for the rehabilitation of LC–39, Pad A Fixed Service Structure (FSS) elevators and replacement of the Payload Changeout Room (PCR) wall panels to enhance personnei accommodations, Shuttle systems, and payloads safety at the launch site.

The rehabilitations provided by this project directly affect KSC's capability to launch the Shuttle, process payloads, and ensure personnel safety at LC–39, Launch Pad A. Rehabilitation of the Fixed Service Structure elevators eliminates a potential unsafe condition. The elevator system was relocated from the Apollo Launch Umbilical Tower and has been in service since 1965. Exposure to the salt environment, launch environment, and Solid Rocket Booster exhaust residue has damaged the system beyond economical repair. Rehabilitation of the Payload Changeout Room side walls 1 and 4 are required to preclude contamination of payloads during processing. The type of insulation used inside the existing panels is damaged during launch due to severe vibration and insulation particles are expelled into the PCR requiring extensive decontamination before a new payload can be placed inside.

The two FSS elevator cabs, rails and support structures will be replaced. The elevator shaft doors and elevator system controls will be replaced or repaired as required. New elevators will be designed which will better withstand the severe launch environment. The PCR Side 1 and Side 4 wall panels will be removed and replaced with new panels. Additional structural bracing will be installed similar to Pad B.

7. REFURBISH ATMOSPHERIC REENTRY MATERIALS AND STRUCTURES EVALUATION FACILITY, LYNDON B. JOHNSON SPACE CENTER, $4,900,000

This project replaces one of the two test positions in the 10-Mw Atmospheric Reentry Materials and Structures Evaluation Facility (ARMSEF), Building 222, used for testing and evaluation of the Space Shuttle orbiter thermal protection system (TPS). The work includes replacing a 20-year-old deteriorated test chamber, diffuser, and boiler system. The new equipment will include the test capability to develop, evaluate, and certify thermal protection systems for application on aero-assisted orbital transfer vehicles.

The ARMSEF was the lead facility for the selection and initial testing of Shuttle Oribter TPS and presently uses both of its test chambers to support the resolution of Shuttle TPS flight anomalies and ongoing TPS engineering. Because of reduced diffuser capability, the test chamber has been derated from its full 10-Mw capability to 5-Mw. The boilers which supply steam to the ejector system are also constantly leaking because of age. This project will replace one test chamber, diffuser, and associated boilers so that the test position can be restored to its full 10-Mw capability. Also provided

* Total project cost of 2 years $6.5 million.

is a new contoured channel nozzle and new cross-tie vacuum ducting to link test chambers at Test Position (TP) #1 and (TP) #2 to a single existing steam ejector vacuum pumping system. This project also provides a new 80,000-pound-per-hour saturated steam boiler to replace two failing boilers. The refurbished test position will continue to support Shuttle TPS engineering, but will also have the capability to develop and certify TPS for the aeroassisted orbital transfer vehicles.

8. MODIFICATIONS FOR ADVANCED ENGINE DEVELOPMENT, TEST STAND 116, GEORGE C. MARSHALL SPACE FLIGHT CENTER, $13,500,000

This project provids for modifications to Test Stand 116 to test the components of a new advanced liquid oxygen-hydrocarbon 750,000-pound thrust engine. The objective of this testing is to establish and verify new propulsion technology at the component level such as the main combustion chamber (MCC), gas generators (GG) and preburners (PB). This will enable an optimum design of components that will lead to assembly of new full-scale advanced test engines. This is a technology development effort in direct support of the Civil Space Technology initiative efforts to develop higher-performance engines for future NASA use. The technology development efforts will also have application to the Advanced Launch System (ALS), Space Transportation Booster Engine (STBE), and Space Transportation Main Engine (STME).

The initial development activities of an advanced oxygen-hydrocarbon booster engine are in the initial planning phases. Difficulties with injector development have historically been much more severe with hydrocarbon fuels than with hydrogen. This has been especially true from the standpoint of combustion instability. It is essential that the advanced oxygen-hydrocarbon engine programs have available pressure-fed test facilities for injector and combustion stability work prior to pump-fed engine testing. Testing of key components, such as the main combustion chamber (MCC), will be tested at three levels with the two lower thrust levels being scaled-down versions of the MCC. The test levels which are needed are (1) injector and combustion chamber performance and heat transfer testing at a thrust level of 40,000–70,000 pounds, (2) dynamic stability testing of two-dimensional combustion chambers at approximately 250,000 pounds of thrust, and (3) full-size combustion chamber stability testing at approximately 750,000 pounds of thrust. The capability for test level (1) currently exists at Test Stand 116 and this data is being forwarded to the advanced engine development contractors. This test position is the most complete and most flexible pressure-fed facility in the country, but it is limited in thrust level to approximately 70,000 pounds. Existing large, high-pressure tanks at the facility provide an excellent base for uprating to 750,000 pounds of thrust.

Work includes constructing a 250/750-pound thrust structure, a new 225-square foot static input unit reinforced concrete structure for the new and relocated controls and instrumentation, a 20-foot by 40-foot addition to test stand support Building 4539, an addition to the blockhouse (Building 4541), and interior modification to Building 4583. Mechanical work includes installing GFE pressure vessels, relocating existing pressure vessels, installing a new burn stack for methane disposal, constructing a new 15,000 psig methane gas-generating facility and upgrading various buildings and related mechanical and electrical systems.

Equipment to be funded from R&D resources will be test specific pressure vessels, engine instrumentation and control systems, high-pressure pumps and vaporizers, and liquid high-pressure lines from the run tanks to the thrust structure, with an estimated cost of $13,800,000.

9. MODIFICATIONS TO ORBITER MODIFICATION AND REFURBISHMENT FACILITY (OMRF) FOR SAFING AND DESERVICING, JOHN F. KENNEDY SPACE CENTER, $2,800,000

This project provides orbiter safing and deservicing capability in the Orbiter Modification and Refurbishment Facility (OMRF). This capability will allow returning orbiters to be safed and deserviced without disrupting orbiters being processed for launch in the Orbiter Processing Facility (OPF).

Upon returning from a space mission, an orbiter must undergo immediate safing, maintenance, and checkout before it can begin processing for reuse. Currently, processing orbiters for reuse is totally performed in the OPF and includes such major on-line operations as draining and purging all fuel systems, removing ordinance and all other hazardous elements, removing payloads brought back from space, inspecting the payload bay and crew cabin, repairing and replacing damaged components, and refurbishing the thermal protection system. Currently, the OMRF provides an off-line facility for performing major modifications and refurbishment. It was not provided with safing and deservicing capabilities. With current facilities, an orbiter being processed in the OPF for reuse must be temporarily removed so that immediately required safing and deservicing operations can be performed on a returning orbiter. This disruption causes a 9-day delay in orbiter processing.

This project includes hydrogen, oxygen, nitrogen and helium systems, hydraulics and ground coolant piping.

10. CONSTRUCTION OF NATIONAL RESOURCE PROTECTION, VARIOUS INSTALLATIONS, $2,600,000

This project provides security protection for Space Transportation System (STS) and related facilities which have been designated a vital national resource at the John F. Kennedy Space Center (KSC) and Dryden Flight Research Facility (DFRF). This protection includes constructing fencing, guardhouses, and perimeter lighting to protect all designated vital STS assets against sabotage, damage, and theft.

Presidential Decision Memorandum Number 37 (National Space Policy, 1978), Presidential Directive/NSC, Number 42 (Civil and Further National Space Policy, (1978), and National Security Decision Directive Number 42 (National Space Policy, July 4, 1982) contain policy designating space systems and support systems as vital national resources. This designation specifically referenced the Space Transportation System (STS), and required that the survivability of the STS be assured in order to be available for military, scientific, and research uses.

This project provides for construction of seven-foot-high double chainlink fencing, 3-strand barbed wire, concertina wire, automatic gates, guardhouses, perimeter lighting, and all electrical work needed to support the lighting, guardhouses, and automatic gates. Facilities to be protected by this project are Pad B at Launch Complex 39 (KSC), Orbiter Processing Facility (KSC), Vehicle Assembly Building/Launch Control Center (KSC), Shuttle Mate-Demate Structure (DFRF), Shuttle Hangar (DFRF), and other smaller Shuttle facilities (DFRF). These facilities have been classified as category "A" which, if lost, could cause the loss of an orbiter or crew or would result in an STS program delay greater than 6 months.

11. CONSTRUCTION OF AUXILIARY CHILLER FACILITY, LYNDON B. JOHNSON SPACE CENTER, $7,800,000

This project provides for the construction of a new 6,000 square foot auxiliary chilled water generating facility. Two 2,000-ton electrically driven chillers are required to accommodate increasing demand from existing facilities and new floor space that will be added at the JSC main site through the early 1990's.

JSC's chilled water usage has been increasing steadily over the past several years, primarily because of the installation of additional and more powerful computing equipment. Daily chilled water requirements temporarily exceeded the Center's operating capacity of 10,000 tons during the summer of 1985 and will permanently exceed it in 1988. Projected chilled water requirements growth indicates that the Center's total operational capacity of 12,000 tons will be permanently exceeded by the end of 1989.

The age and condition of the existing chillers contribute to the shortfall. The seven 2,000-ton chillers in the central plant have been in operation approximately 25 years. Due to the increasing load and the frequent need for chiller maintenance, reliable operation of the needed number of chillers cannot be assured. The new 4,000-ton chilled water production facility provided by this project will accommodate the increasing cooling needs and provide backup and permit overhaul of the existing chillers.

The facility building will contain two 2,000-ton electrically driven chillers. Included are the installation of new chilled water pumps, cooling water pumps, piping, cooling towers, transformers, and metal-clad switchgear with vacuum breakers to power the new chillers. The work also will include installing new 1,200-ampere 15-kV breakers in the site substation and new feeders to the new chiller plant.

12. MODIFICATIONS TO THE X-RAY CALIBRATION FACILITY (XRCF), GEORGE C. MARSHALL SPACE FLIGHT CENTER, $11,400,000

This project will modify the XRCF instrument chamber in Bldg. 4708 to accommodate the extended focal length of the x-ray mirror assemblies for the Advanced X-ray Astrophysics Facility (AXAF). The instrument chamber building and associated clean room will be enlarged and the control room relocated. The AXAF is one of NASA's series of "Great Observatories in Space" and will provide for long-term study of deep space x-ray emissions. The AXAF is a Space Science and Applications new start planned for FY 1989 and this facility is essential to supporting this program.

The modifications to the XRCF are required for the ground testing and calibration of the performance of the High Resolution Mirror Assembly (HRMA) and instrumentation. Such testing is mandatory for evaluation of the x-ray reflection efficiency and resolution of individual mirrors; for calibration and final alignment testing; for functional testing to determine final performance; and to calibrate x-ray instrumentation necessary for the development of the computer software required for the interpretation and analysis of the scientific and engineering data generated by the spacecraft. The instruments involved in this program must be tested in a facility with a long evacuated path length to provide a nearly parallel beam of radiation similar to that arriving from deep space which can be used for testing, calibration, and alignment. The most practical means for testing is to provide a nearly parallel beam of radiation using a long distance between the radiation source and exposing the instruments to only a very narrow angle of the x-rays arriving from the source. Since radiation at x-ray lengths is heavily attenuated in air, the path length of the radiation must be evacuated. Additional uses for the facility will be for calibration of rocket payloads for extreme ultraviolet and x-ray experiments, star tracker evaluations and calibrations, and the enlarged instrument chamber will provide an in-house capability at MSFC for performing thermal vacuum tests on payloads flown in the Shuttle cargo bay.

Modifications to the ORCF include the following:

1. Lengthen the instrument chamber and provide an internal 360° liquid nitrogen (LN_2) cooled shroud to provide a test volume approximately 18-foot-long to accommodate the AXAF spacecraft.
2. Increase the size of the instrument chamber building to accommodate the requirements in item 1. The existing class 10,000 clean room will be enlarged accordingly.
3. Relocate the existing 1,000 feet of 3-foot-diameter guide tube. Insert an additional 400 feet of a 5-foot-diameter and 300 feet of 4-foot-diameter guide tube between the instrument chamber and the relocated 3-foot-diameter guide tube section for a total length of 1,700 feet.
4. Provide a new x-ray source building at the west end of the guide tube and relocated the existing x-ray source and alignment source.
5. Provide new control consoles and equipment for the enlarged facilities.

Equipment to be funded with R&D resources will consist of an optical bench and associated electrical/mechanical figures with an estimated cost of $6,000,000.

13. MODERNIZATION OF SPACE ENVIRONMENT SIMULATOR, GODDARD SPACE FLIGHT CENTER, $2,800,000

This project provides for modernizing the Space Environment Simulator (SES) located in Building 10 and upgrading the vacuum pumping system from oil diffusion to cryogenic vacuum pumps. This will eliminate the risk of oil contamination of payloads during testing. For the last 25 years, the SES has been a key element in Goddard spacecraft development capability and must be modern-

ized to meet the testing needs of spacecraft being developed and planned for the future.

The SES is a 27-foot by 40-foot thermal vacuum chamber used for systems-level thermal testing of both engineering and flight hardware. The current pumping system is 25 years old and uses 17 oil diffusion pumps to attain high vacuum. These pumps pose an inherent risk of oil backstreaming into the chamber test space. Contamination of the vacuum chamber by diffusion pump oil degrades instrument sensitivity particulary in the ultraviolet spectral ranges. Contamination of optical surfaces is difficult to clean because cleaning methods tend to further degrade the optical surfaces. There have been several incidents where diffusion pump oil has backstreamed into the chamber onto flight hardware. Newer types of spacecraft contain significantly more sensitive instruments than those of older spacecraft. Presently, testing must be compromised by not including contamination-sensitive instruments during the system thermal test. The proposed modification would eliminate this risk and the risks and costs of otherwise unnecessary disassembly and reassembly of spacecraft by replacing the obsolete diffusion pumps with state-of-the-art cryogenic pumps and a turbomolecular pump.

Proposed work for this project includes the replacement of seventeen 32-inch oil diffusion pumps with eight 48-inch cryogenic pumps of equal or greater volumetric capacity so as to maintain the 1×10^{-6} torr operating level of the simulator. Two mechanical pumps will be provided for initial stage roughing of cryopumps. A turbomolecular pump with its dedicated mechanical roughing pump will be included to handle non-condensed gases such as helium and hydrogen.

14. MODIFICATIONS FOR UTILITY RELIABILITY, GODDARD SPACE FLIGHT CENTER, $3,100,000

This project provides for increased reliability of the Goddard Space Flight Center (GSFC) chilled water and electrical distribution systems which support communications and control of the Tracking and Data Relay Satellite System, Shuttle flights, major science and application satellites and DOD missions. The present system provides emergency backup electrical power for critical equipment but no backup for cooling of the same equipment. The result is that a short-term electrical failure shuts down the electronic equipment because of overheating even though a limited amount of emergency electrical power is still available. This project will provide short-term backup for the cooling systems to allow the safing of satellites and the orderly shutdown of control and communication equipment.

In the Tracking and Data Relay Satellite System (TDRSS), and Space Shuttle era, the demands on the system have again taken a significant increase causing the GSFC communications and control complex to operate 24 hours a day. This operation has become extremely critical to TDRSS support of major satellite, Shuttle flights, and certain DOD payloads. In order to keep pace with the rise in demand for services, new computers and communications equipment have been added or have replaced older models. Facilities to support this equipment have also been constructed. This includes chillers for increased chilled water distribution necessary to cool the electronic equipment. But, secondary (or backup) utility systems especially for cooling were not included. No additional backup diesel generators have been added since 1965. The result is that there is no backup power capability to fully operate the existing cooling system during electrical power shortages. While critical electronic equipment is supported by uninterruptable power supplies (UPS) for 15 minutes, without cooling, computer spaces overheat and require operating equipment to be shut down within 5 minutes after the electric power fails. It is essentially impossible to put all electronic and computer equipment and spacecraft into a "safe" mode within these 5 minutes and this causes abrupt cessation of satellite control and data handling. By providing uninterrupted air-conditioning support for at least 15 minutes, this project will provide adequate protection against short-term failures which are the most likely to occur.

Small emergency power plants will be provided to operate chilled water pumps, critical air handlers, booster pumps and controls. Automatic values also will be installed in the chilled water distribution system for isolation of critical areas. A 100,000-gallon chilled water reservoir will be constructed to provide 15-minute (minimum) cooling.

15. REFURBISHMENT OF 25-FOOT SPACE SIMULTOR, JET PROPULSION LABORATORY, $12,000,000

This project will refurbish the 25-foot Space Simulator, Building 150, by resurfacing the 23-foot diameter solar simulator collimating mirror, replacing the existing power supply rectifiers of the solar simulation system, and replacing the obsolete oil diffusion pumps with new cryogenic pumps. The space simulator chamber has been used on Mariners, Viking, Voyager, IRAS and Galileo.

The collimating mirror is the largest optical element of the solar simulator system, and was fabricated in 1965. Future planetary exploration projects will utilize its test capability. The condition of the mirror's nickel substrate has deteriorated over the years so that the specified test intensity of the solar beam cannot be maintained. The mirror surface has deteriorated to where the reflectivity is less than 50 percent. Some isolated areas are currently producing only 12-percent reflectance. Corrosion pits and bubbles have appeared across the entire nickel surface. The original simulator's capability of 2.0 solar constants intensity has deteriorated to only 1.0 solar constants. If this deterioration is allowed to continue, the chamber will become inoperable and future flight projects cannot be tested.

This project will refurbish the 25-foot Space Simulator, Building 150, by resurfacing the 23-foot diameter solar simulator collimating mirror, replacing the existing power supply rectifiers of the solar simulation system, converting the oil diffusion pumping system to a new cryogenic and turbo-molecular system and updating the corresponding section of the central console. The 23-foot diameter mirror will be removed from the space simulator chamber. The reflector aluminum, and electrolytic nickel supporting surfaces will be stripped off, the surface of the mirror will be reground by a specificially fabricated machine, then plated with electroless nickel

and polished. After the mirror is reinstalled in the simulator chamber, the surface will be aluminized. The deteriorating power supply rectifiers of the solar simulation system will be replaced with new high-efficiency rectifiers. Approximately 111 old rectifiers serving 37 existing lamp assemblies will be replaced with 37 individual rectifiers (plus spares). The existing electrical control and power distribution systems will also be modified and updated to suit the new rectifiers' requirements as well as to meet stricter specifications for spacecraft testing. This project also includes replacement of all ten oil diffusion pumps of the space simulator chamber with ten new cryogenic pumps installed in existing ports. Two new turbo pumps will also be installed. The present housing over the diffusion pumps will be enlarged and heightened to permit installation, containment, and maintenance of the new pumps and cryogenic elements.

16. REPAIR AND MODERNIZATION OF THE 12-FOOT PRESSURE WIND TUNNEL, AMES RESEARCH CENTER, $36,500,000*

This project provides the initial construction increment for the repair and modernization of the 12-Foot Pressure Wind Tunnel. The total project will return the tunnel to its original operating capability of six atmospheres, and upgrade the facility to modern standards for increased reliability and productivity. The facility is required to support the Nation's rapidly expanding requirements for low speed, low turbulence level, high quality flow, and high Reynolds Number aeronautics testing. This increment of construction includes the replacement of the pressure vessel shell and supports and provides a test section isolation system which will allow model access without depressurization of the tunnel circuit. Additional items of work will provide new model supports, modernized controls and automation, a new model preparation areas, new tunnel internal airstream cooling, and increased main drive power. This major repair and modernization project is the initial project of a comprehensive and concepted Aeronautical Facilities Revitalization Plan that is being implemented to restore and modernize the NASA key facilities that are crucial to maintaining U.S. competitiveness in aeronautical research and development. The total program is being phased over a 5-year timeframe with three major projects included in FY 1989.

The 12-Foot Pressure Wind Tunnel is a significant subsonic pressure wind tunnel which has provided critical high Reynolds Number test capability to NASA, DoD, and the U.S. aircraft industry since 1946. The tunnel has an exceptionally low free stream turbulence level, high quality flow, wide range of flight regimes, and large test section capability for high fidelity models. Since 1965, essentially every military aircraft and civil transport has been tested in the 12-Foot Pressure Wind Tunnel. The discovery of severe, unrepairable weld defects forced the derating of the tunnel from six to one atmospheres of pressure in September 1986 to preclude the possibility of a catastrophic failure. Without repair of the pressure shell to restore the six atmosphere pressure operation, the 12-Foot Pressure Wind Tunnel cannot be used to provide critical high angle of attack, high lift, and laminar flow data for the development of the Nation's advanced military and commercial aircraft. The 12-Foot Pressure Wind Tunnel is a high-demand facility with tests typically scheduled 8 to 16 months in advance with two-shifts-per-day operation. During its operation, the productivity was severely limited because the entire tunnel circuit had to be depressurized for model changes or adjustments. In addition, the inability to assemble, check out, and calibrate models outside the test section and the use of outdated and obsolete model support systems and controls severely hampered and limited efficient utilization of the tunnel. The modernization portion of this project will result in a significant increase in productivity with installation of a test section pressure isolation system, a modern measurement and automation system, and dedicated model preparation and calibration areas.

This project provides for the installation of a new spherical rotating test section plenum to provide pressure isolation for improved model access. Additionally, this increment will start the repair and modernization of the model handling systems and supports; main drive power increase from 12,000 hp to 15,000 hp; a new solid state speed control; enhanced Mach Number and Reynolds Number control by modifying the countervate, inlet guide vane and main drive speed controls; and installing a new internal radiator for airstream cooling. Installation of modern tunnel automation and system controls will be started to provide state-of-the-art feed-back and distributed control of all systems from one central control location. The tunnel support building will be modified to include a second story addition. Two new model preparation rooms will be provided to allow buildup and checkout of models prior to installation. The existing control room will be modernized to include raised computer flooring, visual access to the model staging area, human factors-engineered control consoles, lighting, power, and air-condition as required. A new computer support room, and technical shops with supporting utilities will also be included.

To complete this project, a follow-on increment will be included in the FY 1990 budget for approximately $16.3 million.

17. REHABILITATION AND MODIFICATIONS TO 10×10 SUPERSONIC WIND TUNNEL, LEWIS RESEARCH CENTER, $14,500,000

This project provides for the rehabilitation and modification of the 10×10-Ft. Supersonic Wind Tunnel (SWT) in order to improve productivity and ensure future reliability and capability. This facility, built in 1955, is used for a wide variety of propulsion and non-propulsion-related research; including testing of actual new aircraft propulsion systems, new propulsion system concepts, new inlet/engine integration concepts, advanced inlets and nozzles, and advanced aircraft configurations. This project will provide a new model buildup/calibration/checkout area; rewind and rehabilitate the drive motors; provide new drive motor controls, and new wind tunnel controls; and rehabilitate and automate the existing air dryer. This project also will repair the tunnel expansion joints, rehabilitate the main drive compressor, and install a new roll/pitch capability to the existing model support. This major rehabilitation and upgrade project is a key element of the NASA Aeronautical Facilities Revitalization Plan for restoring and modernizing our

*Total cost over 2 years is $52.8 million.

basic facility capabilities for aeronautical research, technology development and testing.

The 10×10 SWT is the only NASA unitary plan wind tunnel having propulsion capability with a speed greater than Mach 2.0. It is one of only two large propulsion facilities in the free world, but is the only tunnel that can operate in an open circuit mode without the need of a scoop system to collect combustion products. Testing in this facility is varied and includes operating aircraft engines (turbojets, turbofans); propulsion concepts such as turbo-props, advanced inlets and nozzles for a range of applications; performing engine/inlet compatibility concepts, and advanced aerodynamic aircraft concepts and configurations. Rehabilitation and modifications are now required to restore and modernize major systems, and to improve productivity by adding modern real-time feedback controls for automated tunnel operation and by construction of a model calibration and checkout area to reduce tunnel downtime for model installation and checkout. The 10×10 SWT will be used as an integral and critical component for testing in support of several multiagency programs in developing and verifying new, previously unexplored technologies. For example, the National Aerospace Plans (NASP) program will involve the development of an advanced airbreathing propulsion system with capabilities far beyond any current system. Research will be performed to examine boundary layer effects, bleed effects, and variable geometry concepts. New nozzle geometries will be tested, as well as full engine module performance, component interactions, propulsion mode transitions, controls, and dynamics. Another use of the 10×10 SWT will be testing of the Advanced Tactical Fighter (ATF). In addition, new aircraft, configurations will be tested to examine airframe aerodynamics as it effects the inlet, engine, and nozzle performance, and to help determine the optimum propulsion system location. A critical item of work in this project is rewinding the tunnel drive motors. The drive motor control systems must also be replaced. These original systems designed in the early 1950's are based on vacuum tube technology. In some cases, replacement parts are no longer available. The Air Dryer is also outmoded and in need of replacement. The basic wind tunnel control system is outdated, extremely slow and needs modernizing. The new system will be a state-of-the-art distributed control system and that will significantly improve energy efficiency and productivity. New model calibration areas are also needed to improve productivity. These new areas will permit an estimated 40 percent increase in tunnel testing capability, since calibration and checkout will be performed outside of the test section.

This project includes:

a. Rewinding of seven large tunnel drive motors and stators. Four 37,500 HP motors are located in the main drive system (Building No. 90) and three 33,000 HP are located in the secondary drive system (Building No. 87).

b. Replacement of the speed control system and subsystems in the main drive (Building No. 90) and secondary drive (Building No. 87) with modern electrical devices.

c. Installation of new tunnel control system to automate and integrate tunnel operation. The systems to be automated include strut and sting, compressors 1 and 2, coolers 1 and 2, flexible wall, second throat, air heater, tunnel pressure, fuel, 3,000 psi air, and routing valve control.

d. The air dryer reactivation system will be automated to permit hands-off operation during times of non-interference with other tunnel functions. The air dryer burner systems will be updated to meet current safety codes. Thirty-year old starters for combustion air and cooling flows will be replaced.

e. Two model preparation and calibration areas will be provided in Building 113.

f. Numerous metal seals and joints around the tunnel loop will be weld repaired, and flexible seals and joints will be replaced.

h. A new foll/pitch control device will be installed on the model support system.

18. REFURBISHMENT OF HYPERSONIC FACILITIES COMPLEX, LANGLEY RESEARCH CENTER, $12,800,000

This project refurbishes the Hypersonic Facilities Complex (HFC) by replacing worn-out and obsolete components to improve reliability, flow quality and productivity of the many small-scale facilities. This refurbishment and upgrade project is a key element of the NASA Aeronautics Facilities Revitalization Plan for restoring and modernizing our basic facility capabilities for aeronautical research, technology development and testing.

The Hypersonic Facilities Complex (HFC) includes a number of wind tunnel facilities for performing hypersonic aerodynamic and aerothermodynamic research. This complex provides a test capability for conceptual development and evaluation, optimization analysis, and configuration studies of space vehicles. The research facilities in the HFC were developed in the late 1950's and early 1960's for hypersonic and hypervelocity testing. Since that time, the HFC has been in continous operation with a supporting technical staff. Now, some critical components are worn out and must be replaced. Some equipment has become obsolete and must be modified to increase productivity and improve tunnel flow characteristics. The HFC utilizes small blowdown tunnels which employ inexpensive models to perform in a broad spectrum of operating conditions in terms of Mach Number, Reynolds Number, ratio of specific heat, and hypersonic viscous interaction parameters. Refurbishment of the HFC is needed to support continued development of the aeorthermodynamic technology data base for such programs as the National Aero-Space Plane (NASP) and Aeroassisted Orbital Transfer Vehicle (AOTV). Hypersonic Propulsion Test Cells 1 and 2 are facilities for small-scale, high-run-frequency scramjet research. They support research in combustor design, fuel injector configurations, ignition, flameholding, hypersonic inlet performance, and complete subscale engine performance. The cells provide an environment for testing with liquid hydrogen and hydrocarbon fuels. Their present primary limitation is the exhaust system. The new 70-foot vacuum sphere will provide the needed reduced back pressure capability, allowing Mach 4 to 6 testing with altitude simulation from 50,000 to 100,000 feet.

This project will refurbish wind-tunnel facilities in the HFC and increase vacuum pumping capability for air and nitrogen systems supporting these facilities. Vacuum systems for the Building 1247 complex will be upgraded by the installation of a new pumping system to reduce pump downtime, provide longer run times, greater productivity, and increased reliability. Modifications to the Hypersonic Helium Tunnel in Building 1247B include a higher capacity helium heater, a new Mach 20 nozzle, and a flow field survey probe. Modifications to the Hypersonic Nitrogen Tunnel include a pressure/temperature control system, high pressure nitrogen system, filter system, and the control room. Modifications to the Mach 8 Variable Density Tunnel include a new nozzle, replacement air supply system, a new in-line filter, and upgraded control room. Modification to the High Reynolds Number Mach 6 Tunnel include a new model support system for increased productivity, installation of a flow field survey system, and the control room. Modification of the 31-inch Mach 10 Tunnel, Building 1251, will provide a new nozzle throat section and an in-line filter to reduce the flow contamination level, flow field survey system, pitot probe system, a schlieren system, and angle-of-attack drive system. Modification of the Hypersonic CF4 tunnel in Building 1275 will provide a new refrigeration system for CF4 (tetrafluoromethane) recovery, flow field survey probe, filter system, injected probe system, and lead bath heater bundles. Modifications to the Hypersonic Propulsion Test Cells 1 and 2 in Building 1221 will provide for increased facility capability and productivity by the installation of a new vacuum system. Included are a 70-foot vacuum sphere, cooling system, multi-stage steam ejector and related controls.

19. REFURBISHMENT OF ELECTRIC POWER LABORATORY, LEWIS RESEARCH CENTER, $6,100,000

This project will refurbish one vacuum chamber (Tank 5) in the Electric Power Laboratory (EPL), Building 301, to improve productivity and reactive a second, existing large vacuum chamber (Tank 6) to provide additional capability for research, technology development on power sources, conversion systems, thermal management and electric propulsion; and to test large space systems under simulated thermal/vacuum conditions.

Availability of two fully functional, large vacuum chambers in the EPL is mandatory to successfully support ongoing space research and technology and development programs sponsored by NASA/OAST, DOD, and others. Major efforts in Advanced SP-100 space nuclear reactor, Advanced Solar Dynamics, Thermal Management and Space Station power require large volume chambers with thermal high vacuum environments. Other programs, including environmental interactions, space tether, and electric propulsion basic research and technology and development for Space Station, require extremely high pumping speeds. The increased workloads now require that the large vacuum chamber, Tank 6, be refurbished. This facility does not have LN_2 cold walls, and, therefore, no large chamber thermal vacuum test capability. Also, numerous failures have occurred in the 30-year pumping trains and the existing instrumentation and controls.

This project will provide for the modification of two existing large space environment chambers, installation of new model preparation and assembly areas, and modification of the facility support systems. Tank 6 will be restored to a fully operational condition by removal of mercury contamination, replacing diffusion pump cold traps, mechanical vacuum pumps, piping and valves. New LN_2 cryopanels will be installed in both vacuum chambers.

20. REPAIR OF FACILITIES, NOT IN EXCESS OF $750,000, PER PROJECT, $27,000,000, VARIOUS LOCATIONS

These resources will provide for large repairs to facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in the request are those facility repair needs FY 1989 that can be foreseen at the time of the submission of these estimates, and are not to exceed $750,000 per project. The thrust of this program is to restore facilities or components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. The request includes the substanitally equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. This work also includes major preventive measures which are normally accomplished on a cyclic schedule of greater than 1 year.

A major portion of the agency's facilities exceeds 25 years in age, and increases in repair requirements are to be expected. Maintenance and repair costs for mechanical and electrical systems in a typical building are almost three times higher during the 16- to 30-year period of a building's life than they are during the intitial 15 years. Many electrical and mechanical components reach the end of their serviceable or economic life at about the 15- to 20-year point, and should be replaced in the interest of long-term economy. Continued piecemeal reapir of these components is usually more costly in the long-run than replacement at the end of the economic life of the original components. Approximately 75 percent of NASA's physical plant is in the 16- to 30-year old category. A major thrust of this repair program, along with the rehabilitation and modification programs, is to preserve the capabilities of the agency's $4.0 billion physical plant. An analysis of each project clearly indicates that this work must be addressed and progressively accomplished. Otherwise, risks are increased and future costs of the specific work will be greater. More importantly, there will be increased breakdowns interruption of critical operations, and costly unscheduled repairs required. This program includes only facility repair work having an estimated cost not in excess of $750,000 per project. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance and repair activities. Repair projects estimated to cost more than $750,000 are included as separate discrete projects in the budget request.

SUMMARY—REPAIR

Summary of project amounts by location:	*Amount*
Ames Research Center	$1,945,000
Dryden Flight Research Center	995,000
Goddard Space Flight Center	2,010,000

Jet Propulsion Laboratory	1,520,000
Johnson Space Center	2,590,000
Kennedy Space Center	3,450,000
Langley Research Center	3,270,000
Lewis Research Center	3,400,000
Marshall Space Flight Center	1,680,000
Michoud Assembly Facility	1,330,000
National Space Technology Laboratories	1,415,000
Wallops Flight Facility	1,930,000
Various Locations	200,000
Miscellaneous Projects Not Exceeding $150,000 Each	1,265,000
Total	27,000,000

21. REHABILITATION AND MODIFICATION OF FACILITIES, NOT IN EXCESS OF $750,000 PER PROJECT, VARIOUS LOCATIONS, $34,000,000

These resources will provide for the rehabilitation and modification of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in this request are those facility rehabilitation and modification needs for FY 1989 that have been fully identified at the time of the submission of these estimates and are estimated not to exceed $750,000 per project. The purpose of this program may include some restoration of current functional capability but also includes enhancement of the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability.

Based on the initial investment costs, the NASA Capital Type Property totals approximately $7.7 billion (September 30, 1986), of which the physical plant comprises some $4.0 billion. A continuing program of rehabilitation and modification of these facilities is required to accomplish the following:

a. Protect the capital investment in these facilities by minimizing the cumulative effects of wear and deterioration.

b. Ensure that these facilities are continuously available and that they operate at peak efficiency.

c. Improve the capabilities and usefulness of these facilities and thereby mitigate the effects of obsolescence.

d. Provide a better and safer environment for all personnel.

This program includes only facility rehabilitation and modification work having an estimated cost not in excess of $750,000. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance or by related routine facility work efforts that are provided for in other than CoF estimates.

Proposed rehabilitation and modification projects for FY 1989 totaling $34,000,000 are described under *"Project Cost Estimate."* The total program of $34,000,000 has been distilled from requests of approximately $58,000,000 and represents only a modest request in relation in the backlog of this type of work. Based on relative urgency and expected return on investment, the projects which comprise this request are the highest priority requirements. Deferral of this mission-essential work would adversely impact the availability of critical facilities, program schedules, and energy conservation objectives. Only this projects estimated to cost less than $150,000 have not been individually described or identified by center. The total cost of these miscellaneous projects is $1,410,000.

SUMMARY—REHABILITATION AND MODIFICATION

Summary of project amounts by location:	*Amount*
Ames Research Center	$1,690,000
Dryden Flight Research Center	390,000
Goddard Space Flight Center	3,010,000
Jet Propulsion Laboratory	2,010,000
Johnson Space Center	3,175,000
Kennedy Space Center	4,150,000
Langley Research Center	3,215,000
Lewis Research Center	3,800,000
Marshall Space Flight Center	3,560,000
Michoud Assembly Facility	2,010,000
National Space Technology Laboratories	1,910,000
Wallops Flight Facility	1,710,000
Various Locations	1,960,000
Miscellaneous Projects Not Exceeding $150,000 Each	1,410,000
Total	34,000,000

22. MINOR CONSTRUCTION OF NEW FACILITIES AND ADDITIONS TO EXISTING FACILITIES, NOT IN EXCESS OF $500,000 PER PROJECT, VARIOUS LOCATIONS, $9,000,000

These resources will provide for minor facility construction at NASA field installations and Government-owned industrial plants supporting NASA activities. Each project included in this program is estimated to cost not more than $500,000 and involves either the construction of new facilities or additions to facilities. The FY 1989 request of $9,000,000 will improve the usefulness of NASA's physical plant by changing the utilization of or augmenting the capabilities of various facilities. Included in this request are those programmatic and institutional projects that are essential to the accomplishment of mission objectives.

The configuration of NASA's physical plant necessarily must respond to changes in utilization and adaptations required by changes in technology or in mission needs. Demands are generated by research, development, test, and similar activities. Specific justification for each minor construction project is provided under *"Project Cost Estimate."*

Included in the FY 1989 minor construction program are those facility projects for institutional or technical facility needs which could be fully identified at the time of submission of this budget estimate. Items of work totalling $9,000,000 are included in this resource request and have been distilled from a list totalling over $15,000,000. Projects were selected on the basis of the relative urgency of each item and the expected return on the investment. Only those projects estimated to cost less than $150,000 have not been individually described or identified by center. The total cost of these miscellaneous projects is $225,000. During the course of the year, rearrangement of priorities may require changes in some of the items to be accomplished. Such changes will be accommodated within the resources allocated.

SUMMARY—MINOR CONSTRUCTION

Summary of project amounts by location:	*Amount*
Ames Research Center	$450,000
Dryden Flight Research Facility	485,000
Goddard Space Flight Center	480,000
Jet Propulsion Laboratory	950,000

Johnson Space Center	830,000
Kennedy Space Center	1,460,000
Langley Research Center	975,000
Lewis Research Center	930,000
Marshall Space Flight Center	725,000
National Space Technology Laboratories	760,000
Wallops Flight Facility	730,000
Miscellaneous Projects Not Exceeding $150,000 Each	225,000
Total	9,000,000

23. FACILITY PLANNING AND DESIGN, $20,000,000

The funds requested in this estimate are required to provide for the following advance planning and design activities related to facilities activities and projects:

a. The accomplishment of necessary development and master planning for field installations and, where not otherwise provided for, the provision of continuing engineering support and special engineering management and other services.

b. The preparation of preliminary engineering reports, cost estimates, and design and construction schedules.

c. The preparation of final construction plans, specifications, and associated cost estimates and schedules required to implement construction projects.

d. The accomplishment of facilities siting and other investigations, studies and reports, where not otherwise provided for.

Regular requirements encompass the basic purposes outlined above. The "other requirements," while also in support of "regular" purposes, cover those special needs related to large, complex projects or specific programs considered to represent high potential future construction requirements for which early definition is essential. The large projects require more planning and longer lead time. Much of this planning must be completed prior to inclusion of the project in a budget request.

SUMMARY—FACILITY PLANNING AND DESIGN

	Amount
Regular Requirements:	
Master Planning	$450,000
Sustaining Engineering Support	1,600,000
Preliminary Engineering Reports and Related Special Engineering Support	3,000,000
Final Design	6,950,000
Other Requirements:	
Space Flight Facility Planning and Design	2,800,000
Payload Facility Planning and Design	400,000
Space Station Facilities Planning and Design	4,800,000
Total	20,000,000

24. ENVIRONMENTAL COMPLIANCE AND RESTORATION PROGRAM, VARIOUS LOCATIONS, $26,000,000

These resources will provide for studies, assessments, design, and remedial projects for environmental compliance and restoration measures at NASA field installations and Government-owned industrial plants supporting NASA activities. The purpose of this program is to enable compliance with mandatory statutory environmental requirements and standards. The resources authorized and appropriated pursuant to this program may not be applied to other activities. The program includes such measures as studies or assessments to determine current status and options for remedial action, environmental restoration, hazardous waste removal and disposal, cleanup and closures, and removal of unsafe buildings and debris.

Proposed environmental compliance and restoration projects for fiscal year 1989 total $26,000,000. This program represents only a modest request in relation to total requirements for environmental compliance and restoration that must be implemented within three to four years. Based on relative urgency and potential health hazards, the following listed projects are the highest priority requirements and are currently planned for accomplishment in FY 1989. Deferral of these necessary remedial measures would make it impossible for NASA to comply with environmental law and will cause shutdown of critical NASA operations by individual state or Federal environmental authorities. Studies, assessments, and design costs are approximately $2,110,000. Projects estimated to cost less than $150,000 have not been described or identified by specific location. The estimated cost of these projects is $795,000. For those projects greater than $150,000, the following broad categories of effort will be undertaken in Fiscal Year 1989. As studies, assessments, and designs progress, it is expected that priorities may change and revisions of the activities and projects may be necessary.

	Amount
a. Air Pollution Abatement and Asbestos Management	$5,125,000
b. Rehabilitation/Replacement of PCB Transformers	9,900,000
c. Hazardous Waste Monitoring and Control	5,470,000
d. Replacement of Underground Storage Tanks	2,100,000
e. Solid Wastes Disposal Facility Upgrade	500,000

ENVIRONMENTAL COMPLIANCE AND RESTORATION

	Amount
Summary of project amounts by location:	
Ames Research Center	$1,400,000
Dryden Flight Research Facility	1,500,000
Goddard Space Flight Center	700,000
Jet Propulsion Laboratory	1,020,000
Johnson Space Center	1,400,000
Kennedy Space Center	2,000,000
Langley Research Center	1,500,000
Lewis Research Center	3,000,000
Marshall Space Flight Center	3,575,000
Michoud Assembly Facility	2,000,000
Wallops Flight Facility	300,000
White Sands Test Facility	3,500,000
Various Locations	1,200,000
Miscellaneous Projects Less Than $150,000 Each	795,000
Studies, Assessments, and Design	2,110,000
Total	26,000,000

RESEARCH AND PROGRAM MANAGEMENT

FY 1989 NASA REQUEST, $1,915,000,000

FY 1989 AUTHORIZATION, $1,915,000,000

FY 1990 AUTHORIZATION, $2,115,100,000

FY 1991 AUTHORIZATION, $2,234,000,000

SUMMARY

	Estimated fiscal year 1988	Authorization fiscal year 1989
Personnel and related costs	$1,036,958,000	$1,131,008,000
Travel	42,800,000	51,000,000
Operation of installation	663,242,000	732,992,000
Total	1,743,000,000	1,915,000,000

The Research and Program Management appropriation funds the performance and management of research, technology and test activities at NASA installations, and the planning, management and support of contractor research and development tasks necessary to meet the Nation's ongoing objectives in aeronautical and space research. The objectives of the activities funded by the Research and Program Management appropriation are to (1) provide the civil service staff with the technical and management skills to conduct the full range of programs for which NASA is responsible, (2) provide base maintenance of facilities and manage its use in support of research and development programs, and (3) provide effective and efficient technical and administrative support for the research and development programs. For FY 1989, an authorization of $1,915,000,000 is recommended.

The FY 1989 Research and Program Management appropriation request provides funding for the 22,950 permanent and temporary civil service workyears (FTE) at eight major installations and Headquarters. This civil service workforce is NASA's most important resource and is vital to future space and aeronautics research activities. At the direction of the Committee on Appropriations, NASA, beginning in 1988, has realigned the R&D/SFCDC and R&PM appropriation structures. In the realigned R&PM appropriation, about fifty nine percent provides for the salaries and related costs of the civil service workforce. Three percent is for travel, critical to manage successfully the agency's in-house and contracted

programs. The remaining amount of the Research and Program Management appropriation provides for the research, test and operational facility support, and for related goods and services necessary to operate efficiently and effectively the NASA installations and to accomplish NASA's approved missions.

NASA field centers report to the Program Associate Administrator responsible for the major portion of their technical programs. The principal roles assigned to each installation, based on demonstrated capabilities and capacities to meet NASA's overall program goals, are as follows:

Office of Space Flight:

Johnson Space Centers—Management of the Space Shuttle program, including orbiter production and operation; selection and training of astronauts and mission specialists; Space Transportation System Operations including mission planning, operational procedures and flight control; and management of the Space Station Truss system, airlocks and nodes, subsystems development, including propulsion and EVA, and operations planning and definition.

Kennedy Space Center—Launch of Space Shuttle flights; management of the ground operational phase of the Space Transportation System; the preparation and launch of payloads on the Space Shuttle and expendable launch vehicles, and Space Station operational readiness planning.

Marshall Space Flight Center—Management of the Space Shuttle main engine, solid rocket booster and external tank projects; management of NASA's activities on the Spacelab project; management of large automated spacecraft projects such as the Hubble Space Telescope; conduct and development of experiments in materials processing in space; and management of the Space Station habitation, logistics and laboratory modules.

National Space Technology Laboratory—Space Shuttle engine testing; Earth resources research and technology transfer; and provision of support service functions for other Government agencies located on site.

Office of Space Science and Applications:

Goddard Space Flight Center—Development and operation of Earth orbital flight experiments and automated spacecraft to conduct scientific investigations and demonstrate practical applications; management of tracking and data acquisition activities; management of the Delta launch vehicle program; management and launch of sounding rockets and balloons; operation of an instrumented flight range for aeronautical and space research; and development of the Space Station platforms and payload accommodations. The Wallops Flight Facility is an operational element and component installation of the Goddard Space Flight Center.

Office of Aeronautics and Space Technology:

Ames Research Center—Conduct of activities involving experimental and theoretical aerodynamics research, computational fluid dynamics, aeronautical flight research and testing, rotorcraft technology, short and vertical takeoff and landing technology, technolo-

gy for transatmospheric vehicles, planetary probe research, life sciences, human factors, autonomous systems, guidance and control, and operation of an alternate landing site for the Space Shuttle operational missions. The Dryden Flight Research Facility, an operational element and component installation of Ames located in the Mojave Desert, is the site of advanced flight testing and shuttle landings.

Langley Research Center—Conduct of subsonic aircraft research and technology, emphasizing fuel conservation, safety and environmental effects; hypersonic propulsion; experimental and theoretical aerodynamics; environmental quality monitoring by remote sensing; advance space systems technology; and research in the areas of structures and materials, guidance and controls, and airframe/propulsion integration of the transatmospheric research and technology program.

Lewis Research Center—Conduct of aeronautical and space propulsion research and technology, including propulsion for the transatmospheric research and technology program; space communications research and technology; space energy systems research and technology; development of the space station power system; and management of expendable launch vehicle programs.

Within the Research and Program Management total, the following amounts are earmarked for support of aeronautics and transatmospheric activities: $368,300,000 for FY 89; $445,400,000 for FY 90; $526,300,000 for FY 91. The amount for FY 89 reflects the NASA request to cover the civil service staff needed to perform in-house aeronautical research amd management activities, and other elements of operational costs such as travel, operation of facilities, janitorial and administrative support. This amount provides for 3,124 permanent civil service employees. This request contains $84,400,000 to cover 313 permanent civil service employees. The amounts for FY 90 and FY 91 reflect the provision in Section 107(c) of the bill calling for NASA to increase the number of aeronautical researchers by 50 percent by 1992.

1. Personnel and Related Costs

NASA REQUEST, $1,131,008,000

Authorization, $1,131,008,000 compensation

1. *Permanent Positions*—This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest piece of this functional category.

2. *Other Than Full-Time Permanent Positions*—This category includes the salaries of NASA's non-permanent workforce. Programs such as students participating in cooperative training, summer employment, youth opportunity, and temporary clerical support are covered in this category.

3. *Reimbursable Detailees*—In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

4. *Overtime and Other Compensation*—Overtime, holiday, post and night differential, and hazardous duty pay are included in this category. Also included are incentive awards for outstanding achievement and superior performance.

BENEFITS

In addition to compensation, NASA, as authorized and required by law, makes the employer's contribution to personnel benefits. These benefits include contributions to the Civil Service Retirement Fund, the Federal Employees Retirement System, employees' life and health insurance, payments to the Medicare fund for permanent employees, and social security contributions for non-permanent personnel. Payments to the civil service retirement fund for re-employed annuitants and for severance pay to former employees involuntarily separated through no fault of their own are also included.

SUPPORTING COSTS

1. Transfer of Personnel

Provided under this category are relocation costs required by law, such as the expenses of selling and buying a home, and the movement and storage of household goods.

2. Office of Personnel Management Services

The Office of Personnel Management is reimbursed for activities such as security investigations on new hires, recruitment advertising, and career-maturity surveys.

3. Personnel Training

Training is provided within the framework of the Government Employees Training Act of 1958. Part of the training costs consists of courses offered by other Government agencies, and the remainder provides for training through nongovernment sources.

2. Travel

NASA REQUEST, $51,000,000

AUTHORIZATION, $51,000,000

PROGRAM TRAVEL

The largest part of travel is for direction, coordination and management of program activities including international programs and activities. The complexity of the programs and the geographical distribution of NASA installations and contractors necessitate the need for this category of travel. As projects reach the flight stage, support is required for prelaunch activities, including overseas travel to launch and tracking sites. The amount of travel required for flight projects is significant as it is directly related to the number of systems and subsystems, the number of design reviews, and the number and complexity of the launches and associated ground operations.

SCIENTIFIC AND TECHNICAL DEVELOPMENT TRAVEL

Travel to scientific and technical meetings and seminars permits employees engaged in research and development to participate in both Government sponsored and nongovernment sponsored activities. This participation allows personnel to benefit from exposure to technological advances which arise outside NASA, as well as allowing personnel to present both accomplishments and problems to their associates and provides for the dissemination of technical results to the United States community. Many of the Government sponsored meetings are working panels convened to solve certain problems for the benefit of the Government.

MANAGEMENT AND OPERATIONS TRAVEL

Management and operations travel provides for the direction and coordination of general management matters and travel by officials to review the status of programs. It includes travel by functional managers in such areas as personnel, financial management and procurement. This category also includes the cost of travel in and around the Installations; travel of unpaid members of research advisory committees; and initial duty station, permanent change of assignment, and other family travel expenses. Payments to interagency motor pools are included in the Operation of Installation function (Management and Operations subfunction).

3. Operation of Installation

NASA REQUEST, $732,992,000

AUTHORIZATION, $732,992,000

Operation of Installation provides a broad range of services, supplies, and equipment in support of the centers' institutional activities. These are divided into three major subfunctional areas: Facilities Services (the cost of renting real property, maintaining and repairing institutional facilities and equipment, and the cost of custodial services and utilities); Technical Services (the cost of automatic processing for management activities, and the cost of educational and information programs and technical shops supporting institutional activities); and Management and Operations (the cost of administrative communications, printing, transportation, medical, supply, and related services). The content of the following subfunctions has been adjusted to reflect the realignment of the R&PM appropriation. A description of each major subfunction follows:

FACILITIES SERVICES

1. Rental of Real Property

Rental of real property includes the rental of building space directly by NASA or through the General Services Administration to meet offsite office, warehousing, and other requirements which cannot otherwise be provided in existing buildings at the NASA installations. Most of the funding is required for rental of the NASA Headquarters complex of buildings in the District of Columbia, and nearby Maryland and Virginia that are either Government-owned or leased. NASA must provide rental payments to the General Services Administration in accordance with P.L. 92-313 for these facilities.

2. Maintenance and Related Activities

Maintainence and related activities include the recurring day-to-day maintenance of facilities (grounds, buildings, structures, etc.) and equipment accomplished by non-Civil Service personnel. This involves the mowing and care of grassy areas, care of trees and shrubs, elevators, cranes, pressure vessel inspections, painting and protective coatings, general buildings maintenance, and the maintenance of installed mechanical, electrical, and other systems. In addition, this item includes feasibility studies, project design, construction supervision, inspection, and other institutional facility engineering functions. Included also are any applicable costs associated with recurring facility work as well as materials, hardware, and equipment used in facility maintenance activities, whether accomplished by civil service personnel or contractors. In the cost of equipment, related maintenance and other services are reflected for office, shop, laboratory and other facilities equipment as well as administrative internal communications and television monitoring equipment.

3. Custodial Services

Custodial services include janitorial and building cleaning services, pest control, fire protection services, security services including badging and identification, lock and safe repair, trash and refuse handling, window blinds and light fixture cleaning, and laundry and dry cleaning of facility related items.

4. Utilities Services

Utilities services include the purchase of utilities such as electricity, natural gas, fuel oil, coal, steam, propane, and other fuel commodities as well as water and sewage treatment services. Also included are the related maintenance and operating costs of the utility plants and systems.

TECHNICAL SERVICES

1. Automatic Data Processing

a. Equipment—This category provides for the lease, purchase and maintenance of general purpose data processing equipment which supports institutional operations at each installation. Excluded is equipment dedicated to specific research or operational systems which is funded from the Research and Development or the Space Flight, Control and Data Communications appropriations.

b. Operations—Operations services include programming, computer operations and related services for institutional applications including payroll, financial management, security, maintenance, personnel, logistics, and procurement records and reports.

2. Scientific and Technical Information and Educational Program:

a. Libraries—The technical libraries are established to provide installation staff with books, periodicals, technical reports and other scientific documentation.

b. Education and Information Programs—The educational and informational programs provide for the documentation and dissemination of information about the Agency's programs to the general public, the educational community at the elementary and secondary levels, and the mass communications media. Assistance to the mass communications media includes the assembly and exposition of newsworthy material in support of requests in the form of press kits, news releases, television and radio information tapes and clips, and feature material.

c. Support Services—Support services include safety, and the production of general photographic services, graphics, and audi-visual materials.

MANAGEMENT AND OPERATIONS

1. Administrative Communications

Included in this category are costs not dedicated to a specific program or project and cover leased lines, long distance tolls (including FTS charges), teletype services, and local telephone service.

2. Printing and Reproduction

Included in this category are the costs for duplicating, blueprinting, microfilming, and other photographic reproductions. Also included in this category are Government Printing Office printing costs, contractual printing and the related composition and binding operations.

3. Transportation

Transportation services include the operation and maintenance of all general purpose motor vehicles used by both civil service and support contractor personnel and the operation of the NASA administrative aircraft fleet. The cost of movement of supplies and equipment by commercial carriers and payments to interagency motor pools are also in this category.

4. Installation Common Services

Installation common services include support activities at each installation such as: occupational medicine and environmental health; mail service; supply management; patent services; administrative equipment; office supplies and materials; and postage.

DETAILED EXPLANATION OF DOT PROGRAMS AND FISCAL YEAR 1989 AUTHORIZATION

OFFICE OF COMMERCIAL SPACE TRANSPORTATION

FY 1989 DOT REQUEST, $3,827,000

FY 1989 AUTHORIZATION, $3,500,000

FY 1990 AUTHORIZATION, $3,850,000

FY 1991 AUTHORIZATION, $4,235,000

SUMMARY

	Estimated fiscal year 1988	Authorization fiscal year 1989
Safety planning and development	$488,000	$860,000
Licensing procedures, operation, and enforcement	75,000	650,000
Space hazards analysis and management	50,000	525,000
Industry policy and planning	100,000	0
Program support	0	23,000
Administrative costs	712,000	690,000
Salaries and expenses	384,000	752,000
Total	1,809,000	3,500,000

The Department of Transportation is designated as the federal agency responsible for overseeing and coordinating the conduct of commercial launch operations from national and non-government launch facilities. This includes responsibility for issuing and transferring licenses authorizing all commercial launch activities and ensuring that those activities are conducted in a manner that does not jeopardize public health and safety, the safety of property, or the national security interests and foreign policy interests of the United States. The Office of Commercial Space Transportation (OCST) plans and conducts research, development, and program management activities.

The proposed FY 1989 budget for OCST funds seven principal areas: safety planning and development; licensing procedures; operations and enforcement; space hazards analysis and management; industry analysis and planning; program support; and administrative costs. Specific programs within each of these areas are detailed below. Some of the activities are new starts, while others are continuations and extensions of activities initiated in 1985 through

1988. The objective of these activities is to develop regulations, standards, and policies that will guide all facets of the commercial launch industry and its support industries. The Office intends to develop performance standards which prescribe the broad safety objectives that commercial activities must achieve. It will avoid developing design standards in order to permit industry maximum flexibility for innovation within the limits of safety.

1. SAFETY PLANNING AND DEVELOPMENT

Estimated fiscal year 1988	$488,000
DOT request for fiscal year 1989	860,000
Authorization fiscal year 1989	860,000

The Secretary is responsible for protecting public health and safety and the safety of property. This area provides the basis for appropriate safety regulation at launch sites and on launch ranges. Progress since 1985 includes the identification of technologies and procedures used on government ranges and in other industries that are applicable to commercial space activity. For FY 1989, the analysis and testing necessary to further the safe development of the commercial launch system will be undertaken.

TSC Program Support

The Transportation Systems Center (TSC) has been tasked to provide R&D support to the OCST program. Continuing and additional task efforts have been identified resulting in an increased level of support. TSC's primary role is supporting the OCST administratively and technically by developing plans, pursuing safety research and development, identifying and documenting ground and space operational and accidental hazards, establishing license procedures and promoting and maintaining a technical contractor support base.

Safety Data Acquisition and Assessment

The goal of this activity has been to identify and catalog the space flight safety requirements presently in use at government ranges. Progress in this area has been sufficient to validate the need to examine how those requirements were implemented by the ranges and how they should be applied to commercial ranges. The search for applicable safety requirements for commercial applications has led to a search of the safety data bases of other industries and has resulted in a broader safety perspective. As a complete network or framework of safety requirements for commercial space applications is defined and implementation options identified, the selected options will be integrated, and then validated and tested against other industries before being developed into regulations.

Identification of Critical Safety Issues

The goal of this activity is to identify safety issues critical to the commercial space launch industry. The most visible issues from past years have been the qualifications of operating personnel, flight safety equipment, environmental impact and range siting. These topics are the subject of current research. Other safety issues which are being defined are:

Flight Safety Analysis Methodology
Safety Planning & Procedures
Tracking & Data Acquisition Systems
Flight Termination Systems
Payload design and configurations

These and other safety issues yet to be identified will require analysis before standards are established to protect the public health and safety and protection of property.

Safety Research and Analysis

The long term goal of this activity is to perform the safety research and analysis that is necessary for the protection of public health, safety, and property during commercial space launch operations. The short term goal is to reaggregate and reorganize the existing base of government data in a manner that will permit its use to address commercially oriented safety issues. Work has been initiated on the short term goal and has resulted in identification of areas where supporting data or analysis are deficient and where additional research activity is needed. The areas that have been selected for current work are as follows:

Development of an Interim License Application
Analysis Methodology
Launch Equipment Safety Analysis
Tracking and Safety Data Acquisition and Processing
Launch Safety Procedures and Criteria
Training and Certification of Commercial Launch Personnel

Safety Standards Options

The goal of this activity is to gather the recommendations from the research and analysis and safety issue identification efforts and develop safety options for resolving or mitigating those issues. This effort will include assessing each of the critical safety issues in the context of system safety options for minimizing the threat to public health and safety. The results will determine alternatives or options that may be employed to address each of the identified critical safety issues.

Safety Standards Development

The selected options will then be evaluated to ensure that they are most cost effective, technically feasible and that the costs and risks associated with the selected options are considered and balanced.

2. LICENSING PROCEDURES, OPERATION AND ENFORCEMENT

	Amount
Estimated fiscal year 1988	$75,000
DOT request for fiscal year 1989	650,000
Authorization fiscal year 1989	650,000

This activity involves review of applications to conduct launches, new launch site operations, and to launch payloads falling within DOT's review authority. The licensing activities of the office have grown substantially. They are comprised of pre-application consultation, application processing, and continuing monitoring of data submittals. The complexity of the operation as well as its demand for resources have grown rapidly. Certification of certain types of

safety equipment and possible certification of safety personnel are representative of future activity.

Technical Review and Analysis

This activity includes the review and disposition of private proposals to conduct launches, operate private launch sites, or evaluate payloads not subject to licensing by other Federal agencies. The review process used in previous years, which relied on informal coordination with other Federal agencies, must be strengthened. As launch applications and proposals requiring DOT approval or guidance become more sophisticated and complex, the resource requirements for this activity increase significantly. Resources requested here will be used to refine and improve the licensing process and to conduct licensing reviews.

Siting Analysis

Earlier efforts of the office focused on developing criteria for assessing the general feasibility of proposed launch site locations from the perspective of hazards posed by launches. Considerable work remains to be done in defining safety issues with respect to launch site configurations and ground design layout. Additionally, environmental issues, particularly those relating to noise, will pose significant problems for commercial launch firms considering development of their own facilities. In light of continued private sector interest in commercial launch facilities, these efforts assume increased importance.

Inspection Procedures and Operations

Enforcement authority includes inspection of any launch site, production facility, launch vehicle assembly site, or any site where a payload is integrated with a launch vehicle. This item represents a two fold task: the continued development of inspection guidelines and procedures and actual related to licensing actions from previous years. Development of refined inspection procedures and guidelines assumes added emphasis as the nature of commercial launch industry activities becomes more defined. The Department will rely extensively on reimbursable support from other Federal agencies and contractor support to assist inspection efforts throughout this period.

Incident Investigation Procedures

The series of launch accidents in 1986 demonstrated the importance of having procedures in place to investigate accidents, serious incidents, or any violations of license terms, conditions, or approved safety guidelines. This activity involves both the development and establishment of investigation procedures and the conduct of investigations, as appropriate.

3. SPACE HAZARDS ANALYSIS AND MANAGEMENT

Estimated fiscal year 1988	$50,000
DOT request for fiscal year 1989	525,000
Authorization fiscal year 1989	525,000

The conduct of space operations presents hazards at each step in the process. The control of those hazards during prelaunch, launch, orbital flight, and payload and debris re-entry involves hazard identification, risk assessment, and environmental impact analysis. A study of insurance requirements and options conducted during FY 1987 produced clearer perceptions of many of these risks and the values placed on them. Some progress has been made in establishing risk criteria applicable to the review of commercial launch license applications. It is proposed that this section of the OCST budget be devoted to collecting existing hazard information, assessing new analytical methods, examining current range hazard analysis methods, and integrating information that is useful and applicable to commercial space applications.

Payloads and Orbital Hazards

This activity entails reviewing new payload concepts that do not fall under the licensing jurisdiction of the FCC or DOC. DOT's activity level in this area has increased tenfold in the past year. This effort will address the hazards associated with payload operations such as propulsion, orbital flight and drift, structural integrity, and concentric orbital debris.

Launch Equipment Hazards

The need for safety standards is based on the requirements to mitigate the most serious risks of a launch. Although it might appear that the entire activity is hazardous, the greatest hazards are confined to a few critical phases. In order to provide a basis for focusing the areas of the safety requirements, critieria and standards, it is necessary to understand the nature of equipment risks (e.g., launch vehicle, flight command and control, tracking) and how these are distributed. This effort addresses the unconstrained risks associated with typical launch and supporting equipment designs and configurations during different phases of launch. Analyses of the equipment will be used to determine the probabilities of failure of different types of launch equipment during differing launch conditions. Hazard analyses will profile the loss potential of each equipment combination and its relative importance to the nature of specific activities being proposed.

Range Systems Hazards

The goal of this effort is to establish the risk analysis criteria that will be applied to individual license proposals. To attain the task goal, the hazards associated with each class of range equipment will be assessed. Risk levels will be established by class. These risk levels will be hierarchically summed into a range system risk assessment. The total range system risk level scenario will be used to establish an acceptable risk level budget figure that can be used to postulate and evaluate the effect of subsystem information submitted by applicants. Applicant data can then be checked to insure that the equipment hazards within their arena of associated risks are at or better than the acceptable level.

The components proposed by each applicant, together with their risk profiles, will be analyzed as part of a total system, and the total system risk profile will be determined. This information will contribute to the final determination on a license application.

Contingency and Emergency Preparedness Planning

Emergency preparedness is composed of two components, prevention and reaction. The preventive element addresses prevention of the occurrence of an incident or accident and is achieved through an effective system of safety guidelines, standards, licensing reviews and inspections. The reactive phase is concerned with the response once an incident or accident has occurred, and with minimizing its effect. This effort will develop emergency preparedness guidelines to address the reactive phase and assist the commercial license applicant as well as the Secretary in preparing for and responding to emergencies in a timely and effective manner. The guidelines will address four primary elements of commercial space prepardeness: emergency plan development, training, facilities and equipment. They will be developed from input obtained from the assessment of current range practices, reviews with emergency response organization personnel, and comparisons with design guidelines, codes and standards from other industries. They will reflect the best practices of space and relevant other industries.

Risk Analysis of Safety Critical Equipment

The long term goal of this effort is to determine the optimum equipment requirements necessary to implement a highly reliable space Flight Termination System (FTS). The near term goal is to determine the failure probabilities of existing FTS's. The initial effort will consist of collecting information on current FTS equipment including its performance record in a failure mode and an effects analysis on the command destruct transmitter, flight receiver, explosive devices and triggering mechanism for the environment in which the FTS is expected to work.

4. INDUSTRY POLICY AND PLANNING

Estimated fiscal year 1988	$100,000
DOT request for fiscal year 1989	300,000
Authorization fiscal year 1989	0

The Commercial Space Launch Act directs the Department to encourage, facilitate, and promote privately conducted U.S. commercial space launch activities. In carrying out this responsibility, the Department must obtain detailed, up-to-date information on the capabilities, competitiveness, and economics of the commercial launch services industry and its major customers. The research and development program for the Industry Policy and Planning activity is organized into two major categories: Launch Market Demand and Launch Industry Capabilities.

Launch Market Demand

Research in this area includes various projects to assist the office in obtaining accurate, current information on the current and future demand for commercial space launches by existing or potential customers for such purposes as communications, navigation, surveillance, remote sensing, meteorology, science, and materials processing.

Research on launch market demand will result in comprehensive and systematic profiles of payloads for which U.S. commercial launch services providers can effectively compete. The profiles will be based on analyses of U.S. and foreign launch customers and on assessments of those launch service providers which each customer will seriously consider. They will also reflect the impact of technological changes (e.g., improvements in performance, increases in reliability), reductions in cost, and developments in Government policies and licenses (e.g., FCC or DOC actions on communications or remote sensing, respectively).

Launch Industry Capabilities

Research in this area includes various projects to develop detailed information on the supply of U.S. and foreign launch vehicles and related goods and services. Research will describe and assess the industrial base for producing and launching U.S. commercial ELVs. Supply information is needed to monitor the nature and extent of the availability in the U.S. of alternative means to space and to analyze the competitiveness of U.S. commercial launch services vis-a-vis government-assisted foreign launch services in the context of international trade in space products and services.

Research on launch industry capabilities will result in an up-to-date data base on U.S. and foreign launch vehicles, including performance characteristics, reliability, and cost and on the actual and potential contribution of the U.S. commercial space industry to the Nation's economy, employment, income, and balance of payments.

Research will monitor and analyze investments in new facilities or equipment and changes in production or launch processes to eliminate bottlenecks, to improve efficiency, to improve performance, to increase reliability, and/or to reduce costs. Research will assess short-term technological upgrades in existing vehicles as well as long-term development of new vehicles. Research will collect and analyze information on production and launch of ELVs, development of improved and new vehicles, steady-state and surge capacity of suppliers, and production lead times.

5. PROGRAM SUPPORT

Estimated fiscal year 1988	0
DOT request for fiscal year 1989	$50,000
Authorization fiscal year 1989	23,000

Education and Symposia

In FY 1989, commercial space activities will be at the highest level since the President and Congress started the commercialization initiative. The Department of Transportation, in conjunction with the National Aeronautics and Space Administration and other appropriate agencies, plans to conduct a number of space symposia around the country to promote this new commercial activity. The purpose will be to enhance private investment in commercial space transportation and related endeavors, stimulate interest in space related careers, and create and environment conducive to further commercial space growth.

6. ADMINISTRATIVE COSTS

	Amount
Estimated fiscal year 1988	$712,000
DOT request for fiscal year 1989	690,000
Authorization fiscal year 1989	690,000

OCST's regulatory activities will become more operational in nature due to the launch industry's movement from planning to operations. For example, U.S. launch companies now have over twenty reservations to launch payloads, and many of these reservations are approaching firm launch contracts.

Staffing

Personnel will be required to identify, evaluate, refine and implement various parts of the overall licensing process. Achieving this goal requires a high degree of technical expertise since technical breakthroughs to be expected in the development of this new industry (e.g., launch sites, vehicles and payloads) will require DOT approval. Staff will work with NASA, Air Force and other space related agencies to develop requirements and apply the scientific and technical data from government operations to the private sector. Other important tasks include conduct of safety studies and technical guidance to prospective applicants.

Travel

FY 1989 will see a significant growth in the operational status of the Office's licensing and safety program. Projections of launch license applications to be reviewed in FY 1989 indicate that an increase in travel funds will be needed to support OCST inspection, monitoring, and data collection initiatives.

7. SALARIES AND EXPENSES

	Amount
Estimated fiscal year 1988	$384,000
DOT request for fiscal year 1989	752,000
Authorization fiscal year 1989	752,000

Included under this heading is the staff of the Office of Commercial Space Transportation (OCST). Their primary duty is to encourage, facilitate, and promote commercial space launches by the United States private sector and to license and regulate commercial launches, launch site operations and certain payloads under the Commercial Space Launch Act.

The requested staffing reflects the proposed realignment of positions between the Salaries and Expenses and Transportation Planning, Research, and Development appropriations. These positions are needed in order to license and facilitate launches of the U.S.'s rapidly maturing commercial space launch industry. This will be a challenging task since the first series of satellite launches by the U.S. commercial launch industry will occur in 1989. The Office is currently processing or consulting on the development of six applications.

SECTIONAL ANALYSIS

A bill to authorize appropriations to the National Aeronautics and Space Administration for Research and Development; Space Flight, Control, and Data Communications; Construction of Facilities; and Research and Program Management and for other purposes.

TITLE I—NATIONAL AERONAUTICS AND SPACE CAPITAL DEVELOPMENT PROGRAM

Section 101—Findings

Section 101 includes the requirement for the Administrator to construct the United States International Space Station and sets forth 12 Congressional findings for the Nation's future activities in aeronautics and space.

Section 102—Policy

Section 102 would establish long-term policies for NASA's activities in aeronautics and space. These activities would have to contribute materially to: establishing a permanent manned presence in space; contributing to U.S. world prestige and leadership; providing assured access to space; providing enhanced and more economical space transportation; providing advanced communications technologies; and maintaining technologies for preeminent, safe, and efficient aeronautical systems.

Section 103—Science and Applications 5-Year Capital Development Program

Section 103 would establish a 5-year Capital Development Program for NASA's Science and Applications activities. No less than 20 percent of NASA's requested budget would have to be for these activities. Priorities are established within this section for activities for major missions, for development activities for missions, and the program referred to as "Mission to Planet Earth."

Section 104—Space Research and Technology 5-Year Capital Development Program

Section 104 would establish a 5-year Capital Development Program for NASA's Space Research and Technology activities. The Administrator would be required to increase the request for funding of these activities to 10 percent of the total NASA budget by October 1, 1992. The Administrator would also be required to undertake specific research activities.

Section 105—Space Exploration 5-Year Capital Development Program

Section 105 would establish a 5-year Capital Development Program for NASA's Space Exploration activities. NASA would have to exercise leadership in the 1992 International Space Year and an International Manned Mission to Mars would be established as a major goal of the U.S. space program. Every two years, the Administrator would have to submit a report to the President and the Congress which describes the progress being made to establish space settlements.

Section 106—Space Transportation 5-Year Capital Development Program

Section 106 would establish a 5-year Capital Development Program for NASA's Space Transportation activities. NASA would have to undertake programs to: enhance the safety and efficiency of the space shuttle while reducing its cost of operation; complete system definition studies for a Shuttle derived heavy-lift launch vehicle; initiate the development of a heavy-lift launch vehicle by the end of 1993; launch all payloads on expendable launch vehicles that do not require the presence of man; and develop new technologies for expendable launch vehicles and advanced space transfer and support vehicles.

Section 107—Commercial Use of Space 5-Year Capital Development Program

Section 107 would establish a 5-year Capital Development Program for NASA's activities related to the commercial use of space. The Administrator would have to undertake activities to maximize the commercial use of space including the promotion of new Joint Endeavor Agreements and charging space shuttle launch prices pursuant to Title II of Public Law 99-170. The Administrator would also have to establish clear and consistent ground rules, perform and share with the private sector the results of high risk research, avoid duplicating private sector research, provide support to the private sector on a reimbursable basis, and seek to reduce permanent reliance on government assistance.

Section 108—Aeronautical Research and Technology Development and Validation 5-Year Capital Program

Section 108 would establish a 5-year Capital Development Program for NASA's Aeronautical Research and Technology Development and Validation activities. By the start of FY 1992, NASA would have to increase its request for funding of these activities to 15 percent of the total NASA budget and increase by 50 percent the number of full-time civil service personnel engaged in these activities. Guidance is given to the Administration to conduct several areas of research.

Section 109—Technology Utilization 5-Year Capital Development Program

Section 109 would establish a 5-year Capital Development Program for NASA's Technology Utilization activities. The Administrator would have to encourage and facilitate the practical application of new technologies and seek to expand the Industrial Application Center network. The Administrator would also have to contract for implementation of the Industrial Applications Center located in Oklahoma.

Section 110—Federal Facilities 5-Year Capital Development Program

Section 110 would establish a 5-year Capital Development Program for the construction of federal facilities and submit it with each annual budgetary request.

Section 111—Report on Capital Development

Section 111 would direct the Administrator to submit a 5-year Capital Development Plan to the Congress by January 15, 1989, including economic and budgetary requirements, estimates of launch capacity, estimates of expenditures for all operational requirements and projected investments which are needed.

TITLE II—3-YEAR AUTHORIZATION

Section 201—3-Year Authorization

Subsection 201(a) would authorize funds to be appropriated to the National Aeronautics and Space Administration in the total aggregated amount of $11,488,100,000 for fiscal year 1989, $14,388,300,000 for fiscal year 1990, and $15,745,800,000 for fiscal year 1991. The total authorized funding would consist of the following: (a) for "Research and Development," a total of 9 program line items aggregating the sum of $4,446,800,000 for fiscal year 1989, $6,553,100,000 for fiscal year 1990, and $7,849,700,000 for fiscal year 1991; (b) for "Space Flight, Control, and Data Communications," a total of 3 line items aggregating the sum of $4,841,200,000 for fiscal year 1989, $5,379,000,000 for fiscal year 1990, and $5,261,000,000 for fiscal year 1991; (c) for "Construction of Facilities," a total of 25 line items aggregating the sum of $285,100,000 for fiscal year 1989, $341,100,000 for fiscal year 1990, and $401,100,000 for fiscal year 1991; and (d) for "Research and Program Management," $1,915,000,000 for fiscal year 1989, $2,115,100,000 for fiscal year 1990, and $2,234,000,000 for fiscal year 1991.

Subsection 201(b) would authorize to be transferred, within the funds authorized to be appropriated under this title, for funding the Advanced Communications Technology Satellite program $89,000,000 for fiscal year 1989, $75,000,000 for fiscal year 1990, and $32,000,000 for fiscal year 1991. Not more than 20 percent of the funds transferred for fiscal year 1989 may be from amounts authorized for the programs of the Office of Space Science and Applications.

Subsection 201(c) would authorize amounts appropriated for "Research and Development" and "Space Flight, Control, and Data Communications" to be used (1) for any items of a capital nature (other than acquisitions of land) which may be required for the performance of research and development contracts at non-NASA installations, and (2) for grants to nonprofit organizations (whose primary purpose is the conduct of scientific research) for the purchase

or construction of additional research facilities. Congressional notification is required for the construction of any major facility with a cost in excess of $500,000.

Subsection 201(d) would authorize any amounts appropriated for "Research and Development," "Space Flight, Control, and Data Communications," or "Construction of Facilities," to remain available without fiscal year limitation. Contracts for the maintenance and operation of facilities or for support services under the "Research and Program Management" appropriation could be entered into at any time during the fiscal year for periods no longer than 12 months.

Subsection 201(e) would authorize the use of not more than $35,000 of the "Research and Program Management" appropriation for scientific consultations or extraordinary expenses, upon approval or authority of the Administrator, whose determination would be final and conclusive.

Subsection 201(f) would authorize funds appropriated for "Research and Development," "Space Flight, Control, and Data Communications," or "Research and Program Management" to be used for the construction of new facilities and additions, repair, rehabilitation, or modification of existing facilities, providing the cost of each project does not exceed $100,000. It would also authorize funds appropriated for "Research and Development," or "Space Flight, Control, and Data Communications" to be used for unforseen programmatic facility project needs, provided the cost of each such project does not exceed $500,000. Additionally, it would authorize funds appropriated for "Construction of Facilities" to be used for work on facilities controlled by the General Services Administration, provided the cost of each such project does not exceed $500,000.

Section 202—Construction of Facilities Reprogramming

Section 202 would authorize funds appropriated for individual line items within the "Construction of Facilities" authorization to be increased by 10 percent at the discretion of the Administrator or, following Congressional notification, be increased by 25 percent. The combined total for all such work could not exceed the total authorized for the "Construction of Facilities" in Subsection 201(a).

Section 203—Special Reprogramming Authority for Construction of Facilities

Section 203 would authorize the Administrator to transfer up to ½ of 1 percent of the funds appropriated for "Research and Development" or "Space Flight, Control, and Data Communications," or up to $10,000,000 appropriated for "Research and Program Management" to the "Construction of Facilities" appropriation if he determines that new developments or scientific or engineering changes have occurred in the national program of aeronautical and space activities which require such a transfer. Notification would be required to the Committee 30 days prior to the obligation of funds.

Section 204—Limitations on Authority

Section 204 would provide that no funds appropriated by this Act may be used for any program not presented to the appropriate authorizing committees; deleted by the Congress; or in excess of the funds actually authorized for that program—unless 30 days have passed following the proper notification to the Congress by the Administrator.

Section 205—Geographical Distribution of Research Funds

Section 205 would express the sense of the Congress that it is in the national interest for the Administrator to explore ways and means of giving research and development funds the widest geographical distribution feasible.

Section 206—Arrest Authority

Section 206 would amend the National Aeronautics and Space Act of 1958 by adding a new subsection that grants arrest authority to those employees of the Administration and of its contractors and subcontractors that are authorized to carry firearms under regulations prescribed by the Administrator and approved by the Attorney General.

Section 207—National Mars Commission

Section 207 would establish a 12-member "National Mars Commission" to prepare a strategy and proposal for a cooperative manned Mars mission with the Soviet Union and other interested nations. Within six months, the Commission would have to submit a preliminary report to the President and the Congress. A final report would be submitted later, and the Commission would then go out of existence.

Section 208—Microgravity Research Space Facility

Section 208 would authorize the Administrator to issue a request for proposals to acquire by means of a competitive procurement a commercially developed microgravity research space facility. No contract for the acquisition of this facility could be signed by the Administrator without the express authorization of the Congress. To be "competitive," at least three good-faith proposals would have to be received.

Section 209—Studies on Microgravity Research Capability

The Administrator would have to contract with the National Academy of Sciences to conduct a review of the value and desirable characteristics of a "Commercially Developed Space Facility" and contract with the National Academy of Public Administration to estimate the cost of this facility and to consider the practicability of various financial options.

Section 210—External Tanks

Section 210 would require the Administrator to make available for five years expended Space Shuttle external tanks to any feasible U.S. commercial and nonprofit endeavor. During the first three years, no less than five external tanks would have to be made

available for suborbital intertank experiments to nonprofit institutions of higher education or to nonprofit organizations whose primary purpose is the conduct of scientific research. Any such use of the external tanks would have to be consistent with Space Shuttle safety requirements and the user would have to reimburse NASA for any direct costs that are incurred by NASA in making the tanks available.

Section 211—Manufacturing Technology

Section 211 would amend the National Aeronautics and Space Act of 1958 by establishing as a policy objective the preservation of a preeminent U.S. position in aeronautics and space through research and technology development related to associated manufacturing processes.

Section 212—Buy American

Section 212 would require the Administrator to award contracts to domestic firms according to "Buy American" provisions that are consistent with the public interest and applicable international trade agreements such as the General Agreement on Tariffs and Trade.

Section 213—Space Station Standardization

Section 213 would require the Administrator to report to the Congress within one year on the advisability of designing and constructing a metric docking mechanism that is compatible with the space stations and space vehicles of other nations.

TITLE III—TEN YEAR STRATEGIC PLAN

Section 301—Aeronautics and Space Strategic Plan

Section 301 would require the Administrator to undertake an aggressive and balanced program of science and applications including: the robotic exploration of the solar system; the study and observation of other celestial bodies and phenomena; the enhanced study of Earth; the study of the behavior of biological systems in the space environment; and the behavior of materials under microgravity.

Section 302—Space Research and Technology Strategic Plan

Section 302 would require the Administrator to undertake an aggressive and balanced program of space research and technology development for enabling technologies, focused technologies, extending laboratory activities from the Earth, and cooperating with other space program sectors.

Section 303—Space Exploration Strategic Plan

Section 303 would require the Administrator to pursue the establishment of a U.S. permanently manned International Space Station and the development of those technologies and systems required for a manned mission to Mars and the continued exploration of the Moon.

Section 304—Space Transportation Strategic Plan

Section 304 would require the Administrator to develop improved manned and unmanned space transportation systems.

Section 305—Aeronautical Research and Technology Development and Validation Long-Range Plan

Section 305 would require the Administrator to conduct a vigorous program in aeronautical research to enhance U.S. preeminence in civil and military aviation and to conduct a flight demonstration program (with a first flight in 1995) of an air-breathing hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere.

TITLE IV—COMMERCIAL SPACE LAUNCH ACT AUTHORIZATIONS

Section 401—3-Year Authorization

Section 401 would authorize funds to be appropriated for carrying out the purposes of the Commercial Space Launch Act in the Department of Transportation in the amount of $3,500,000 for fiscal year 1989, $3,850,000 for fiscal year 1990; and $4,235,000 for fiscal year 1991.

TITLE V—CIVIL SPACE PROGRAMS IN THE DEPARTMENT OF COMMERCE

Section 501—Authorizing Legislation

Section 501 would require the Secretary of Commerce to submit, by July 15, 1988, proposed authorizing legislation and budgetary requirements for activities within the Department of Commerce in support of civil space commercial activities.

TITLE VI—DRUG-FREE WORKPLACE

Section 601—Drug-Free Workplace

Section 601 would require that no funds authorized to be expended under this Act shall be expended in any workplace which is not free from illegal use of controlled substances.

EFFECTS OF LEGISLATION ON INFLATION

In accordance with Rule XI, clause 2(1)(4) of the Rules of the House of Representatives, this legislation is assessed to have no adverse long-term inflationary effects on prices and cost in the operation of the national economy. NASA expenditures are labor intensive, with approximately 80 percent of spending directly for jobs and the remainder for materials. In fiscal year 1989, NASA will employ about 22,950 civil servants and support about 193,000 contractor and support services employees. Assuming a multiplier effect of 2.5, the total short-term employment effect on the United States economy is about 540,000 jobs. This represents less than one-half of one percent of the total civilian labor force in the United States—too small to have a significant national effect. There could however be some specific cases of industrial and regional employment and price changes influenced by NASA expenditures.

The most significant economic effects of NASA spending is the long-term productivity advance from new technologies developed for the space and aeronautics program. Many NASA-sponsored advances in air and space transportation, communications satellites, remote sensing satellites, and other innovations have improved the productive capacity of industry and stimulated the development and growth of many new businesses.

NASA is actively pursuing its role to expand the opportunities for private industry to gain access into space effectively and economically use space for commercial ventures. These expanded business opportunities have stimulated and are expected to continue to stimulate more productive, non-inflationary private sector economic growth, job creation, and improve the United States competitive economic position in the world, e.g., improve the United States trade balance.

CHANGES IN EXISTING LAW MADE BY THE BILL, AS REPORTED

In compliance with clause 3 of rule XIII of the Rules of the House of Representatives, changes in existing law made by the bill, H.R. 4561, as reported, are shown as follows (existing law proposed to be omitted is enclosed in black brackets, new matter is printed in italic, existing law is which no change is proposed is shown in roman):

NATIONAL AERONAUTICS AND SPACE ACT OF 1985

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DECLARATION OF POLICY AND PURPOSE

SEC. 102. (a) * * *

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(d) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; [and]

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment[.]; *and*

(9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.

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SECURITY

SEC. 304. (a) * * *

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(f) Under regulations to be prescribed by the Administrator and approved by the Attorney General of the United States, those employees of the Administration and of its contractors and subcontractors authorized to carry firearms under subsection (a) may arrest without warrant for any offense against the United States committed in their presence, or for any felony cognizable under the laws of the United States if they have reasonable grounds to believe that the person to be arrested has committed or is committing such felony. Persons granted authority to make arrests by this subsection may exercise that authority only while guarding and protecting property owned or leased by, or under the control of, the United States under the administration and control of the Administration or one of its contractors or subcontractors, at facilities owned by or contracted to the Adminsitration.

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SECTION 24 OF THE COMMERCIAL SPACE LAUNCH ACT

AUTHORIZED APPROPRIATIONS

SEC. 24. There are authorized to be appropriated to the Secretary $4,000,000 for fiscal year 1985. There is authorized to be appropriated to the Secretary to carry out this Act $586,000 for fiscal year 1986. There is authorized to be appropriated to the Secretary to carry out this Act $4,548,000 for fiscal year 1988. *There are authorized to be appropriated to the Secretary to carry out this Act $3,500,000 for fiscal year 1989, $3,850,000 for fiscal year 1990, and $4,235,000 for fiscal year 1991.*

OVERSIGHT FINDINGS AND RECOMMENDATIONS

Pursuant to rule XI, clause 2(1)(3) of the Rules of the House of Representatives, and under the authority of rule X, clause 2(b)(1)

and clause 3(f), the following statement is made concerning the Committee's oversight findings and recommendations.

The results and findings from those oversight activities are incorporated in the recommendations found in the present bill and report.

CONGRESSIONAL BUDGET OFFICE COST ESTIMATE

U.S. CONGRESS,
CONGRESSIONAL BUDGET OFFICE,
Washington, DC, May 19, 1988.

Hon. ROBERT A. ROE,
Chairman, Committee on Science, Space, and Technology, U.S. House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: The Congressional Budget Office has prepared the attached cost estimate for H.R. 4561, the Multiyear National Aeronautics and Space Administration Authorization Act.

If you wish further details on this estimate, we will be pleased to provide them.

Sincerely,

JAMES L. BLUM, *Acting Director.*

1. Bill number: H.R. 4561.
2. Bill title: The Multiyear National Aeronautics and Space Administration Authorization Act.
3. Bill status: As ordered reported by the House Committee on science, Space, and Technology, May 12, 1988.
4. Bill purpose: H.R. 4561 would authorize appropriations to the National Aeronautics and Space Administration (NASA) and the Office of Commercial Space Transportation (OCST) in the Department of Transportation for fiscal years 1989, 1990, and 1991.
5. Estimated cost to the Federal Government:

(By fiscal year, in millions of dollars)

	1989	1990	1991	1992	1993
NASA:					
Authorization level	11,488	14,388	15,746	——	——
Estimated outlays	6,878	12,183	14,533	6,369	1,299
OCST:					
Authorization level	4	4	4	——	——
Estimated outlays	4	4	4	——	——
Total:					
Authorization level	11,492	14,392	15,750	——	——
Estimated outlays	6,882	12,187	14,537	6,369	1,299

The costs of this bill are in budget functions 250 and 400. Including outlays from prior year appropriations, the total outlays for NASA would be $10.6 billion in 1989, assuming appropriation of the authorized amount.

Basis of Estimate: This estimate assumes that the full amounts authorized would be appropriated for each fiscal year. Detailed information is shown in the table below. The estimated outlays are based on historical spending patterns.

ESTIMATED COST OF H.R. 4561

(By fiscal year, in millions of dollars)

	1989	1990	1991	1992	1993
Research and development:					
Authorization level	4,447	6,553	7,850	.....	.....
Estimated outlays	2,166	4,868	6,747	3,774	1,017
Space flight, control, and data communications:					
Authorization level	4,841	5,379	5,261	.....	.....
Estimated outlays	3,074	5,047	5,289	1,924	147
Construction of facilities:					
Authorization level	285	341	401	.....	.....
Estimated outlays	19	184	281	327	135
Research and program management:					
Authorization level	1,915	2,115	2,234	.....	.....
Estimated outlays	1,620	2,084	2,216	344	.....
Subtotal, NASA:					
Authorization level	11,488	14,388	15,746	.....	.....
Estimated outlays	6,878	12,183	14,533	6,369	1,299
Office of Commercial Space Transportation:					
Authorization level	4	4	4	.....	.....
Estimated outlays	4	4	4	.....	.....
Total, H.R. 4561:					
Authorization level	11,492	14,392	15,750	.....	.....
Estimated outlays	6,882	12,187	14,537	6,369	1,299

6. Estimated cost to State and local governments: None.
7. Estimate comparison: None.
8. Previous CBO estimate: None.
9. Estimate prepared by: Michael Siverts.
10. Estimate approved by: (C. G. Nucklos) (for James L. Blum, Assistant Director for Budget Analysis).

OVERSIGHT FINDINGS AND RECOMMENDATIONS, COMMITTEE ON GOVERNMENT OPERATIONS

No findings or recommendations on oversight activity pursuant to rule X, clause 2(b)(2), and rule XI, clause 2(l)(3), of Rules of the House of Representatives have been submitted by the Committee on Government Operations for inclusion in this report.

COMMITTEE RECOMMENDATION

A quorum being present, the Committee favorably reported the bill H.R. 4561 by voice vote and recommends its enactment.

REPORTING REQUIREMENTS

REFERENCE AND REQUIREMENT

Section 105—Review of space exploration 5-year capital development plan.

Section 106—System definition studies for a Shuttle-derived heavy lift launch vehicle and associated report.

Section 110—Federal facilities 5-year capital development plan.
Section 111—5-year capital development plan.
Section 207—Report and associated proposal for joint mission to Mars.
Section 208—Terms, conditions, and recommendations regarding Commercially Developed Space Facility (CDSF).
Section 209—Microgravity research capability study to be conducted by the National Academy of Sciences.
Section 501—Proposed authorizing legislation and budgetary requirements for the Department of Commerce in support of civil space activities.
Committee View:
Established of NASA long-range plan.
Space station design-to-life-cycle progress report.
Report on the management and integration of the space station.
Programmatic and budgetary plans for the operation and expansion of the tracking and data networks.
Proposal for acquisition of the Advanced Solid Rocket Motor (ASRM).
Progress report on the use of Shuttle external tanks by nonprofit organizations and the private sector.
Plan for preliminary design for the implementation of solar dynamic power technology.

NASA REQUEST

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, March 2, 1988.

Hon. Bill Nelson,
Chairman, Subcommittee on Space Science and Applications, Committee on Science, Space, and Technology, House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: Submitted herewith is a draft bill, "To authorize appropriations to the National Aeronautics and Space Administration for research and development; space flight, control and data communications; construction of facilities; and research and program management; and for other purposes," together with the sectional analysis thereof.

Section 4 of the Act of June 15, 1959, 73 Stat. 75 (42 U.S.C. 2460), provides that no appropriation may be made to the National Aeronautics and Space Administration unless previously authorized by legislation. It is a purpose of the enclosing bill to provide such requisite authorization in the amounts and for the purposes recommended by the President in the Budget of the United States Government for fiscal year 1989. For that fiscal year the bill would authorize appropriations totaling $11,488,000,000, to be made to the National aeronautics and Space Administration as follows:

(1) for "Research and development," amounts totaling $4,446,700,000,

(2) for "Space flight, control and data communications," $4,841,200,000,

(3) for "Construction of facilities," amounts totaling $285,100,000 and,

(4) for "Research and program management," $1,915,000,000, In addition, the bill would authorize appropriations of $2,130,200,000 for fiscal year 1990 and $2,912,500,000 for fiscal year 1991 for the Space Station.

The bill includes a number of other provisions including the following:

First, there is a new section 5 which would give the Administrator a two-year hiring authority to employ up to 15 individuals who would receive their Federal salary without automatic reductions to civil service or military retirement benefits.

Second, there is a new section 7 which would amend the Space Act to allow NASA to withhold from public disclosure information that is subject to export control.

Finally, the last section of the draft bill, section 8, provides that the bill, upon enactment, may be cited as the "National Aeronautics and Space Administration Authorization Act, 1989," rather than "1988."

Where required by section 102(2)(c) of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4332(2)(C)), and the implementing regulations of the Council on Environmental Quality, environmental impact statements covering NASA installations and the programs to be funded pursuant to this bill have been or will be furnished to the House Committee on Science, Space and Technology as appropriate.

The National Aeronautics and Space Administration recommends that the enclosed draft bill be enacted. The Office of Management and Budget has advised that such enactment would be in accord with the program of the President.

Sincerely,

JAMES C. FLETCHER,
Administrator.

Two enclosures.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, April 7, 1988.

Hon. BILL NELSON,
Chairman, Subcommittee on Space Science and Applications, Committee on Science, Space and Technology, House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: Submitted herewith is a new section 7 to be added to the draft FY 1989 NASA Authorization bill, together with the sectional analysis thereof.

Section 7 is a new section which would amend section 304 of the National Aeronautics and Space Act of 1958, as amended, to authorize the Administrator to prescribe regulations allowing civil service and contractor employees who carry firearms to arrest suspects without warrant for certain categories of offenses.

The National Aeronautics and Space Administration recommends that section 7 be enacted as part of the FY 1989 NASA Au-

thorization. The Office of Management and Budget has advised there is no objection to the submission of the new section.

Sincerely,

JAMES C. FLETCHER,
Administrator.

Two enclosures.

SEC. 7. Section 304 of the National Aeronautics and Space Act of 1958, as amended, is amended to add the following subsection:

(f) Under regulations to be prescribed by the Administrator and approved by the Attorney General of the United States, those employees of the Administration and of its contractors and subcontractors authorized to carry firearms, pursuant to subsection (e), above, may arrest without warrant for any offense against the United States committed in their presence, or for any felony cognizable under the laws of the United States if they have reasonable grounds to believe that the person to be arrested has committed or is committing such felony. Persons granted authority to make arrests by this subsection may exercise that authority only while guarding and protecting property of the United States under the administration and control of the Administration or one of its contractors or subcontractors.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, April 11, 1988.

Hon. ROBERT A. ROE,
Chairman, Committee on Science, Space and Technology, House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: Submitted herewith is a proposed new section to be added to the FY 1989 NASA Authorization bill which authorizes NASA to lease a Commercially Developed Space Facility. Also attached is the sectional analysis.

The Office of Mangement and Budget advises that there is no objection to the presentation of this legislative language to the Congress.

Sincerely,

JAMES C. FLETCHER, *Administrator.*

Two enclosures.

New section to be added to the FY 1989 NASA Authorization bill.

SEC. . The Administrator is authorized to enter into and maintain an agreement for future lease of a Commercially Developed Space Facility (CDSF); Provided that such agreement stipulate that no lease payments shall be made before a flight-ready, safety-certified CDSF has been delivered to the launch site pursuant to a mutually agreed launch schedule; Provided further that such agreement may provide for the payment for contingent liability of the Government which may accrue should the Government decide to terminate the agreeement for its convenience prior to the end of the period established in the agreement, provided that the agreement include a provision to limit the amount of such payments that the Government is allowed to make as a result of such termination to amounts provided in advance in Appropriations Acts. At least 15 calendar days prior to entering into any agreement to lease of a CDSF, the Administrator shall submit to the cognizant Authorization and Appropriations Committees a proposed schedule of lease payments and a projection of contingent liability for the term of the agreement. In January of each year, the Administrator shall report to the cognizant Committees the projected aggregate contingent liability of the Government under the agreement authorized herein, with an explanation of any significant deviations from the original schedule. As soon as feasible after entering the agreement, the Admninistrator shall seek advance appropriations to cover payments during the lease period.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, April 19, 1988.

Hon. ROBERT A. ROE.,
Chairman, Committee on Science, Space and Technology, House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: During and since the recess we have worked with your staff to address and resolve the Committee's questions on the matter of the Commercially Developed Space Facility (CDSF) progam. Some of htese issues are far larger than the single CDSF program question, and may therefore remain open, but we have tried to bound each problem and consider it in context.

For example, we now have a firm price for CDSF Shuttle launches—$110 million in FY 1988 dollars. This price conforms with P.L. 99-17, and would apply for the term of the proposed five-year CDSF lease. The same price would also apply to other potential Shuttle commercial customers who reach agreements with NASA in the coming months. We are working on the overall question of Shuttle pricing and expect an Administration policy by the end of the year.

We have submitted proposed legislation to allow NASA to enter into a lease agreement on behalf of the Government, to allow coverage of termination liability, and to establish a mechanism for seeking advanced appropriations soon after reaching an agreement. We recognize that there are differing views as to the most effective funding mechanism for such a lease, as well as the best way to provide assurances to the private sector that funding will be available. We believe that the proposed legislation will let the Congress act on the CDSF lease in terms of an actual negotiated price. We feel that this approach is much to be preferred over the suggestion of a numerical "cap" imposed before we have any substantive data from industry. Furthermore, a cap has some negative aspects: for example, if it is substantial, it becomes an almost automatic bid price; if it is low, it discourages or even prohibits meaningful proposals. There also have been suggestions that the funding responsibility for a lease could be split between NASA and other user agencies; we would argue strongly that this approach dilutes accountability and seriously impairs the procurement process.

We are in the process of developing a descriptive strategy for our microgravity research that identifies the experimental work to be done, the equipment required for that work, and the space carriers

suitable for those tasks. It will be about 60 days, we believe, before that document can be completed and forwarded to you. On the basis of our work to date, however, we have identified two, or perhaps three, categories of mature experiments that may benefit by more microgravity time and/or better microgravity levels than can be provided by the Shuttle-Spacelab combination and that will be ready for execution before the Space Station is in operation.

There have also been questions raised as to the relationship of the CDSF to the Administration's overall commercial space policy. The CDSF represents a considered initiative to encourage private innovation and investment in our space infrastructure.

We are now prepared to release the RFP to industry. The authorization language we have proposed would permit us to proceed to a point of readiness to enter into a lease agreement and then to present the terms of the agreement to the Committees prior to final signature, with the further direction that we will seek advance apppropriations as soon as possible after an agreement is reached. The responses to the RFP are necessary to establish the extent of financial interest in the project, something for which there are no firm data today.

We believe that the sooner this legislation is approved, the better the chances that responses to the RFP will include solid financial commitments. The responses will also define the range of terms and conditions for a lease that industry believes necessary for a good business risk. The responses will tell us what the real fixed-price cost to Government of such a lease would be. We believe this last point to be crucial: we cannot seek advance appropriations without knowing the costs to be covered.

While NASA will protect the confidential nature of the procurement process, the Agency believes the Committee can be provided certain information. To keep the Committee informed on progress, we have identified the following proposed schedule:

—we will provide the source list to whom the RFP was mailed the day after release;
—we will provide the number of proposers on the day following the close of the proposal period;
—within a week following receipt of proposals, we will provide the number of proposals considered to be "acceptable" for evaluation;
—within 30 days following the close of the proposal period, we will identify how many proposals are "within the competitive range," i.e., those which have a reasonable chance of being selected for a final award;
—after evaluation, we will be able to identify the proposer or proposers selected for negotiation (if more than one proposer is involved, we would be compelled to keep the bid price confidential); and,
—after final selection and before award, we will submit the proposed agreement and projected schedule of termination liability to the Committee.

We believe that each of these steps will provide the Committee with the desired insight into the CSDF progress. The Committee can, of course, take action at any point in the process. Recognizing that the Congress retains final control over this program, we request your formal agreement to proceed with the release of the RFP, with responses due 60 days later.

Sincerely,

JAMES C. FLETCHER, *Administrator.*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, May 19, 1988.

Hon. BILL NELSON,
Chairman, Subcommittee on Space Science and Applications, Committee on Science, Space and Technology, House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: Submitted herewith is a new section 8, together with sectional analysis, to be added to the FY 1989 NASA Authorization Bill.

Section 8 is a new section and would add a section 209 to the National Aeronautics and Space Act of 1958, as amended, to authorize the NASA Administrator to enter into agreement with the Secretary of Energy for obtaining nuclear fuel for use as an energy source in outer solar system exploration missions, on terms and at a cost as mutually agreed upon.

The National Aeronautics and Space Administration recommends that section 8 be enacted as part of the FY 1989 NASA Authorization. The Office of Management and Budget has advised there is no objection to the submission of this new section.

Sincerely,

JAMES C. FLETCHER, *Administrator.*

Two enclosures.

SEC. 8. The National Aeronautics and Space Act is further amended by adding the following new section:

NUCLEAR FUEL ACQUISITION

SEC. 209. The Administrator, in coordination with the Secretary of Energy, for the purpose of outer solar system exploration, may request and receive such quantities of nuclear fuel, as necessary only for the specific mission, on terms and at costs as may be agreed upon. Nothing in this section authorizes the providing of such nuclear fuel on those terms for any other purpose or its diversion for any other use.

SEC. 8.—SECTIONAL ANALYSIS.

This amendment to the National Aeronautics and Space Act would add a new section 209, to be codified as 42 U.S.C. 2476c, providing authority to NASA to obtain nuclear fuel from the Department of Energy (DoE), on terms and at costs, as may be agreed upon between the NASA Administrator and the Secretary of DoE, for outer solar system exploration (i.e., beyond two astronomical units).

DOT REQUEST

THE SECRETARY OF TRANSPORTATION,
Washington, DC, April 4, 1988.

Hon. JIM WRIGHT,
Speaker of the House of Representatives,
Washington, DC.

DEAR MR. SPEAKER: The Department of Transportation is submitting for your consideration and appropriate reference a bill to authorize appropriations for the fiscal years 1989 and 1990 for the Office of Commercial Space Transportation of the Department of Transportation, and for other purposes.

Since Congress enacted the Commercial Space Launch Act in 1984, the Department's Commercial Space Transportation Office has put in place the necessary licensing mechanisms to facilitate the launch of commercial payloads by private industry. In 1987, the first DOT launch license was issued to Conatec for a launch from White Sands Missile Range. We are currently processing an application by McDonnell Douglas to launch a foreign communications satellite. The Science, Space, and Technology Committee in the House, and the Commerce, Science, and Transportation Committee in the Senate, were instrumental in authorizing adequate levels of appropriations for these activities.

The Department seeks an authorization of $3,827,000 for continuation of all current activities and expansion of licensing activities in Fiscal Year 1989. We anticipate as many as 10 new license applications for a variety of missions and would process a significant number of them in FY 1989. Our primary licensing objective is, of course, to assure that these activities are conducted in a manner that does not jeopardize public health and safety, the safety of property, or the national security and foreign policy interests of the United States.

The OCST Office was actively involved in the process leading to the President's recently announced decision to place increased reliance on private space launch services to meet this nation's launch needs. The new policy represents a coherent, comprehensive statement of the importance of a vigorous private launch industry in meeting national objectives in space. Our requested authorization for FY 1989 will permit the continuation and expansion of these efforts, which remain critical to the growth of this important industry.

Central to encouragement of this industry is resolving the liability issues for which the Department has responsibility under sections 15(c) and 16 of the Commercial Space Launch Act. A major portion of our FY 1988 and 1989 funding is committed to the necessary hazard analysis and risk assessment work that relates directly to the Department's responsibilities in this area.

The President's recent policy initiative also entails legislative action to address the issue of potentially unlimited liability for third-party damages. The Administration seeks resolution of this problem in a manner consistent with its efforts to reform the tort litigation system generally. To this end, therefore, we propose enactment of the provision appearing as section 2 of the enclosed bill, to accomplish this objective.

The Department appreciates this opportunity to advocate a course of action that will advance the prospects of a private commercial space launch industry in the United States capable of competing successfully with that of other nations.

The Office of Management and Budget advises that the enactment of this proposal would be in accord with the program of the President.

Sincerely,

JIM BURNLEY.

Enclosure.

A BILL To authorize appropriations for the fiscal years 1989 and 1990 for the Office of Commercial Space Transportation of the Department of Transportation, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Section 24 of the Commercial Space Launch Act (Public Law 98-575) (49 U.S.C. 2623) is amended to read as follows:

"SEC. 24. There are authorized to be appropriated for the purpose of carrying out this Act $3,827,000 for fiscal year 1989 and such sums as are necessary for fiscal year 1990. Sums appropriated for research and development shall remain available until expended."

SEC. 2. Section 16 of the Commercial Space Launch Act (49 U.S.C. App. 2615) is amended to read as follows:

"SEC. 16. (a) Each license issued or transferred under this Act shall require the licensee to obtain liability insurance, or demonstrate financial responsibility, at least in such amounts as are considered by the Secretary to be necessary—

"(1) to satisfy potential claims for personal injury, death, or loss of or damage to property resulting from activities carried out under the license; and

"(2) consistent with the international obligations of the United States.

"The Secretary shall prescribe such amounts after consultation with the Attorney General and other appropriate agencies.

"(b) Non-economic damages may not be awarded in excess of $200,000 in any action against a covered party by any person for personal injury or death attributable to the launch of a launch vehicle, the operation of a launch site, or the provision of launch services. As used in this section—

"(1) 'action' means any action or claim filed in Federal or State court (including multiple actions or claims) seeking damages from a covered party for personal injury or death, and includes all plaintiffs and all defendants in such actions, which arise out of or were caused by the same personal injury or death.

"(2) 'covered party' means the United States, employees, contractors, and subcontractors of the United States, persons licensed under this Act, contractors, subcontractors or customers of such licensees, and contractors or subcontractors of such customers.

"(3) 'non-economic damages' means all damages other than damages for economic loss, and includes punitive or exemplary damages.

"(4) 'economic loss' means past or future (A) expenses of health or other care, (B) expenses of rehabilitation, (C) loss of earnings, (D) loss of homemaker services, (E) burial expenses, (F) losses relating to property damage, and (G) any commercial loss, including lost profits or revenues."

SUPPLEMENTAL VIEWS TO H.R. 4561

DRUG-FREE WORKPLACE

The Committee is deeply concerned that the rampant use of controlled substances is undermining the very fabric of American society. The efforts taken by the government to further science and technology are an essential part of our economic progress and further our ability to compete in the world marketplace. Those efforts are threatened by the current plague of illegal drug use in the United States.

The vast majority of the American people overwhelmingly support governmental efforts to provide a drug free workplace. The government has taken major steps to ensure that the Federal workplace is drug free, and has adopted policies that apply to civilian and military employees of the Federal government.

Much of the business of the government is carried out through grants and contracts. The Congress now believes that the power of the purse should be used to encourage those who do business with the government to adopt tough policies prohibiting unlawful use or possession of controlled substances in the workplace by employees.

The Committee has repeatedly discussed this issue and had developed the following statutory language which had been offered, and accepted, by the Committee on Science, Space, and Technology. The language was dropped, by unanimous consent, because the rules of the House of Representatives would have allowed sequential referral of the legislation to a series of other committees because the specificity of the language could be interpreted to fall within the jurisdiction of those other committees.

It was the clear intent of the Committee that before the government shall enter into any contractual or grant relationship with any party it shall be necessary for the party to certify that the party will make best efforts to provide a drug free workplace. It is the intent of the Committee that the certification is both a condition for the awarding of any contract or grant, and its shall also be a continuing condition of the contract or grant.

The Committee adopted this language with the intent to use the heavy threat of withholding Federal funds to ensure that employers take active steps to ensure that their employees who are acting within the scope of their employment maintain a drug free workplace. We have adopted a test of preponderance of the evidence that the employer is making good faith efforts to ensure that random acts of rogue employees do not cause and interruption of payments.

Because of the jurisdictional rules the following language is not in the bill, but we believe that it represents the appropriate implementation of the drug free workplace requirement in the Act.

DRUG FREE WORKPLACE

SEC. (1) GRANTS.—No person or organization shall receive a grant authorized under this Act unless such person or organization has certified to the granting agency that it will provide a drug free workplace by—

(a) publishing a statement of policy prohibiting the unlawful manufacture, distribution, dispensation, or possession of a controlled substance while in the workplace; and

(b) requiring that each employee, as a condition of employment, certify that he or she has received a copy of such statement of policy and understands its contents, and that he will abide by such policy. Such employee shall further agree as a condition of employment to notify the employer of any conviction no later than the employee's next working day after such conviction. The employer shall notify the granting or contracting agency within 72 hours of notification to it by the employee.

(2) CONTRACTS.—No person or organization shall be considered a responsible source, under the meaning of such term as defined in section 4(8) of the Office of Federal Procurement Policy Act (41 U.S.C. 403(8)), for the purposes of being awarded a contract for the procurement of any property or services authorized under this Act unless such person or organization has certified to the contracting agency that it will provide a drug free workplace by—

(a) publishing a statement of policy prohibiting the unlawful manufacture, distribution, dispensation, or possession of a controlled substance while in the workplace; and

(b) requiring that each employee, as a condition of employment, certify that he or she has received a copy of such statement of policy and understands its contents, and that he will abide by such a policy. Such employee shall further agree as a condition of employment to notify the employer of any conviction no later than the employee's next working day after such conviction. The employer shall notify the granting or contracting agency within 72 hours of notification to it by the employee.

(3) DEFINITIONS.—For purposes of this section—

(a) the term "drug free workplace" is defined as a workplace for the performance of work done in connection with a specific grant or contract described in subsections (1) and (2) of an entity at which no employee of such entity unlawfully manufactures, distributes, dispenses, or possesses a controlled substance;

(b) the term "employee" is defined as the employee of a contractor or grantee engaged in the performance of work pursuant to the provisions of the contract or grant described in subsections (1) and (2);

(c) the term "controlled substance" is defined as a controlled substance in schedule I through V of section 202 of the Controlled Substances Act (21 U.S.C. 812); and,

(d) the term "conviction" is defined as a finding of guilt and/or imposition of sentence by any judicial body charged with the responsibility to determine violations of the Federal, state (or governmental subdivisions thereof) criminal statutes described in subsection (4).

(4) WITHHOLDING OF PAYMENTS.—(a) Each contract and grant authorized pursuant to this Act shall contain a provision through which the granting or contracting agency shall withhold subsequent payments due under the terms and conditions of the grant or contract under applicable law upon the occurrence of conviction of an employee for violation of a Federal, state (or governmental subdivision thereof) criminal statute involving manufacture, distribution, dispensation, or possession of any controlled substance, for a violation occurring in the workplace.

(b) Notice of the granting or contracting agency's intent to withhold payments shall be given to the grantee or contractor by certified U.S. mail, return receipt requested, at the grantee's or contractor's address as shown in the contract or grant, or as amended thereafter.

(c) Upon receipt of said proof of notification by the granting or contracting agency from the grantee or contractor, evidenced by the return receipt referenced in paragraph (b), the granting or contracting agency upon the passage of 14 days from the date of return receipt to the agency shall withhold such payment unless, within such 14 day period, the granting or contracting agency receives notice from the contractor or grantee of a request for an agency hearing to determine whether such contractor or grantee was at the time of said conviction or is at the time of hearing in compliance with the requirement of this section. Upon such request for hearing, the granting or contracting agency shall conduct the requested hearing within 14 days from the date of receipt by the granting or contracting agency of the request for hearing but in no event less than 72 hours after the contractor's or grantee's receipt of notice of the hearing. Failure of the granting or contracting agency to timely notify the contractor or grantee shall suspend withholding payment until such time as the granting or contracting agency has afforded the grantee or contractor actual notice of no less than 72 hours prior to such hearing.

(d) Within five (5) days from the date of the hearing described in paragraph (c), the determination as to whether withholding of payment should occur, continue, or terminate shall be made by the granting or contracting agency. Failure of the granting or contracting agency to make such determination within the above stated five (5) day period, shall be deemed a decision to resume or continue all payments thereafter due.

(e) The determination required of the granting or contracting agency as provided in paragraph (d) shall be made favorable to the contractor or grantee, upon a showing by the contracting or grantee, by a preponderance of the evidence, that it is in compliance with subsections (1) and (2) and it is making good faith efforts to maintain a drug free workplace. If a conviction reflects good faith efforts made by a contracting or grantee to enforce a drug free workplace by compliance with this section or through other workplace policy, such conviction for unlawful manufacture, distribution, dispensation, or possession of a controlled substance in the workplace, shall be considered substantial evidence that the employer is taking sufficient action to maintain a drug free workplace

and shall require a favorable detemination for the contractor or grantee.

(f) In the event of a determination by the granting or contracting agency that the contractor or grantee has failed to comply with the requirements of paragraphs (c) and (d) the contractor or grantee may request a reconsideration of such determination based upon the contractor's or grantee's previous or subsequent efforts to comply. Such reconsideration and determination shall be accomplished within the 14 day and 5 day time periods contained within paragraphs (c) and (d), respectively.

(5) EXCEPTION.—This section shall not apply to an entity if the head of the granting or contracting agencies involved determines, in his or her discretion, that withholding payments due under a grant or contract, or not issuing such a grant or not awarding such a contract authorized under this Act, as the case may be, would severely disrupt the operation of such entity to the detriment of the Federal Government of the general public.

BOB WALKER.
JACK BUECHNER.
ERNIE KONNYU.
RALPH M. HALL.
PAUL B. HENRY.
TOM MCMILLEN.
CONNIE MORELLA.
F. JAMES SENSENBRENNER, Jr.
JOEL HEFLEY.
MARILYN LLOYD.
MANUEL LUJAN, Jr.
JIMMY HAYES.
TOM LEWIS.
RON PACKARD.
DON RITTER.
SID MORRISON.
ROBERT C. SMITH.
HAROLD L. VOLKMER.
LAMAR SMITH.
D. FRENCH SLAUGHTER.
DAVE MCCURDY.

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Calendar No. 837

100TH CONGRESS, 2d Session | SENATE | REPORT 100-429

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, 1989

Mr. HOLLINGS, from the Committee on Commerce, Science, and Transportation, submitted the following

REPORT

OF THE

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ON

S. 2209

JULY 26, 1988.—Ordered to be printed

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REPORT

[To accompany S. 2209]

The Committee on Commerce, Science, and Transportation, to which was referred the bill (S. 2209) to authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes, having considered the same, reports favorably thereon with an amendment in the nature of a substitute and recommends that the bill do pass.

PURPOSE OF THE BILL

The purpose of the bill is to authorize appropriations to the National Aeronautics and Space Administration (NASA) totaling $11,104,500,000 for fiscal year (FY) 1987, as follows:

	Budget request	Committee authorization
FY 1989:		
Research and development	$4,446,700,000	$4,278,200,000
Space flight, control, and data communications	4,841,200,000	4,686,200,000
Construction of facilities	285,100,000	260,100,000
Research and program management	1,915,000,000	1,880,000,000

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LEGISLATIVE HISTORY

On March 2, 1988, the administration submitted its FY 1989 budget request for NASA. The Committee considered budget and related policy matters in hearings on February 16, March 7, 10, 22, and May 17. The Committee received testimony from the NASA Administrator and NASA officials associated with the major agency programs, the Director of the Office of Commercial Space Transportation in the Department of Transportation (DOT), and from the space science, space transportation, aeronautics, and educational communities.

On March 23, 1988, Senators Riegle, Hollings, Danforth and Pressler introduced by request, S. 2209, a bill to authorize appropriations for NASA for FY 1989.

On April 4, 1988, the Administration submitted its FY 1989 and 1990 budget request for DOT's Office of Commercial Space Transportation.

On May 24, 1988, the Committee met in executive session and considered the budgets for NASA and the Office of Commercial Space Transportation. S. 2209, the FY 1989 NASA Authorization bill, was ordered reported without objection by the Committee in open executive session with an amendment in the nature of a substitute. The amendment included language authorizing appropriations for FY 1989 for DOT's Office of Commercial Space Transportation.

NASA AUTHORIZATION SUMMARY

[In millions of dollars]

	FY 1989 request	Proposed FY 1989 Senate authorization
I. Research and Development	4,446.7	4,278.2
1. Space Station	967.4	867.4
2. Space Transportation Capability Development	631.1	606.6
Spacelab	88.4	.....
Upper Stages	146.2	153.2
Engineering & Tech. Base	158.9	.....
Payload Ops & Sup. Equip	67.3	.....
Advanced Programs	45.0	.....
Advanced Launch Systems	13.0	6.5
Tethered Satellite System	23.8	.....
Orbital Maneuvering Vehicle	96.5	.....
3. Space Science	1,297.3	1,252.3
A. Physics & Astronomy	791.6	761.6
Hubble Space Telescope Dev	102.2	.....
Gamma Ray Observatory Dev	41.9	.....
Global Geospace Science	101.4	76.4
Advanced X-Ray Astrophysics Fac	27.0	.....
Payload & Instrument Dev	77.1	.....
Shuttle-Spacelab Payload Mgt	61.5	.....
Sp. Station Integrated Planning and Attached Payloads	8.0	.....
Explorer Development	82.1	.....
Mission Operation & Data Analysis	156.2	.....
Research and Analysis	89.1	.....
Suborbital Program	45.1	.....
B. Life Sciences	101.7	91.7
C. Planetary Exploration	404.0	399.0
Galileo Development	61.3	.....
Magellan	33.9	.....

NASA AUTHORIZATION SUMMARY—Continued

[In millions of dollars]

	FY 1989 request	Proposed FY 1989 Senate authorization
Ulysses	10.3	
Mars Observer	102.2	
Mission Ops & Data Analysis	112 y	
Research and Analysis	83.6	
4. Space Applications	562.3	628.3
A. Solid Earth Observations	82.1	
Shuttle/Spacelab Payloads	25.3	
Geodynamics	33.9	
Research and Analysis	22.9	
B. Environmental Observations	368.3	
Applied Research, Data Analysis and Related Activities	108.1	
Payload & Instrument Dev.	19.7	
Scatterometer	15.8	
Upper Atmos. Res. Satellite (UARS)	103.9	
Ocean Topography Experiment (TOPEX)	97.8	
Airborne Science & Applications	23.0	
C. Materials Processing in Space	73.4	
D. Communications	16.2	92.2
E. Information Systems	22.3	
5. Commercial Programs	57.9	57.9
Technology Utilization	19.1	
Commercial Use of Space	38.8	
6. Aeronautical Research and Technology	414.2	404.2
Research & Technology Base	314.2	
Systems Technology Programs	100.0	
7. Transatmospheric Research and Technology	84.4	69.4
8. Space Research and Technology	390.9	350.9
9. Safety Reliability are Quality Assurance	22.4	22.4
10. Tracking and Data Advanced Systems	18.8	18.8
II. Space Flight Control and Data Communications	4,841.2	4,686.2
1. Space Shuttle Productions/Operations Capability	1,400.5	1,335.5
Orbiter Operational Capability	320.0	280.0
Launch & Mission Support	343.7	
Propulsion Systems	711.8	
Charges & Systems Upgrading	25.0	0
2. Space Transportation Operations	2,405.4	2,365.4
Flight Operations	660.1	
Flight Hardware	1,035.2	
Launch & Landing Operations	514.6	
Expendable Launch Vehicles	195.5	155.5
3. Space Tracking & Data Acquisiton	1,035.3	985.3
Space Network	538.9	
Ground Network	248.1	
Communications & Data Systems	248.3	
III. Construction of Facilities	285.1	260.1
IV Research and Programs Management	1,915.0	1,880.0
Total NASA	11,488.0	11,104.5

Summary of Major Provisions

For FY 1989, the Committee would authorize $11,104,500,000 for NASA and $3,827,000 for the office of Commercial Space Transportation. Of the amount authorized for NASA, $4,278,200,000 is authorized for research and development, including $8,000,000 to implement the National Space Grant College and Fellowship Program, and $4,686,200,000 for Space Flight Control and Data Communications. In addition, $260,100,000 is authorized for Construction of Facilities, and $1,880,000,000 for Research and Program Management.

The Committee provides $867,400,000 for the space station program. This is $100,000,000 below the President's FY 1989 budget request, but will be sufficient to begin actual construction of the hardware elements of the space station in earnest. The Committee continues to support strongly the space station program and reduced the FY 1989 request as a means to distribute necessary budget reductions in an equitable fashion.

The Space Transportation Capability Development budget of $606,600,000 is $24,500,000 below the President's FY 1989 budget request. Nevertheless, this level of funding will fully support the Orbiting Maneuvering Vehicle, preliminary activities for the Extended Duration Orbiter (EDO) definition activities for the Crew Emergency Escape Vehicle (CERV), and Spacelab activities. The proposed $7 million augmentation for upper stages will permit NASA to continue procurement of an upper stage for the Advanced Communications Technology Satellite (ACTS) which is scheduled for launch in 1922.

The Committee authorizes $1,252,300,000 for Space Science activities—Physics and Astronomy, Life Sciences and Planetary Exploration—which is a $242,800,000 increase over the FY 1988 NASA operating plan. The $761,600,000 provided by the committee for Physics and Astronomy will allow continued development of the Hubble Space Telescope, scheduled for deployment in November 1989, as well as continued funding for the Gamma Ray Observatory, scheduled for launch in March, 1990. Although the committee continues to support the Global Geospace Science effort, it recommends a rephasing of the program to obtain $25,000,000 savings in FY 1989.

Of major interest to the Committee in the Physics and Astronomy account are the initiation of a new start for the development of the next great observatory, the Advanced X-Ray Astrophysics Facility (AXAF), the continued expansion of the explorer Development program, and a continuing emphasis on the Suborbital flight program, all of which are provide for in this authorization.

The Committee has provided $399,000,000 for the Planetary Exploration program. This level of funding will support the launch of the Magellan satellite to Venus in April, 1989, the launch of the Galileo mission to Jupiter in November, 1989, and activities leading to the launch of the Ulysses mission in October, 1990. It will also support the continued development of the Mars Observer, which is scheduled for launch in 1992.

The Committee authorizes $91,700,000 for the Life Sciences programs, which is $10,000,000 below the President's FY 1989 budget request, but a significant increase over the FY 1988 operating plan.

The Committee authorizes $628,300,000 for Space Applications programs, which is $66,000,000 above the President's request. This increase consists of a general reduction in programs of $10,000,000, and a $76,000,000 increase for the Advanced Communications Technology Satellite (ACTS) which is scheduled for launch in 1992. The Committee authorizes $73,400,000 in FY 1989 for Materials Processing in Space activities including the continued development of

flight hardware. Other programs and activities, such as Solid Earth Observations, the Upper Atmosphere Research Satellite (UARS), Scatterometer, and the Ocean Topography Experiment (TOPEX) satellite are supported strongly by the Committee.

The Committee authorizes $57,900,000 for NASA commercial programs, which is consistent with the President's request.

In Aeronautical Research and Technology, the Committee has authorized $404,200,000 which is $10,000,000 below the administration's FY 1989 request. This is, however, $69,400,000 above the FY 1988 operating plan, and reflects the Committee's view of the importance of these activities to the nation's economic health. Transatmospheric Research and Technology is authorized at $69,400,000 which is $15,000,000 below the President's FY 1989 budget request. Despite this reduction, the Committee continues to support this focused technology development program with NASA participation.

The Committee has made a $40,000,000 reduction in the proposed Pathfinder program, which is a new start candidate within the Space Research and Technology programs. Thus the Committee provides $350,900,000 for these activities, as opposed to the request of $390,900,000. This will, however, provide full funding for the Civilian Space Technology Initiative (CSTI), and $8,000,000 for implementation of the Space Grant Colleges and Fellowship program pursuant to an agreement with Dr. Fletcher. Another program of importance in this area, strongly endorsed by the Committee, is the Engineering Research Center program. This program is fully funded at $16,300,000, and will continue support to the nine universities selected in FY 1988, as well as establishing additional centers in FY 1989. The aim of this program is to expand the Nation's space technology base by using the vast resource base of the Nation's universities.

In recognition of the importance of safety and reliability to the entire civil space program, the Committee authorizes $22,400,000 for the Safety, Reliability and Quality Assurance program. This level of funding is the same as the administration's FY 1989 budget request and is $6,300,000 higher than the FY 1988 operating plan. The Committee also authorizes $18,800,000 for Tracking and Data Advanced Systems programs, which is identical to the President's request.

The total Research and Development budget for FY 1988 is $4,278,200,000, compared with a budget request of $4,446,700,000 and an FY operating plan of $3,294,500,000.

For Space Flight, Control and Data Communications for FY 1989, the Committee authorizes $4,686,200,000, compared to the President's budget request of $4,841,200,000 and an FY 1988 operating plan of $3,810,700,000. Of this amount, $1,335,500,000 is for Space Shuttle Productions and Operations Capability, $2,365,400,000 is for Space Transportation Operations, and $985,300,000 is for Space Tracking and Data Acquisition.

In formulating the Space Flight budget, the Committee felt strongly that no reductions could be made in any accounts which would affect the operations of the space shuttle, the proposed test program, or any anomaly resolution activities. Return of a safe, reliable space shuttle to flight status continues to be one of the highest priorities within the space program.

The President requested $1,400,500,000 for Space Shuttle Productions and Operations Capability in FY 1989. The Committee has reduced this request by $65,000,000—$40,000,000 in the structural spares program, and $25,000,000 in systems changes and upgrading—for a total authorization of $1,335,500,000. Despite these reductions, this account is still $247,200,000 above the FY 1988 operating plan.

The Committee authorizes $2,365,400,000 for Space Transportation Operations, which is $40,000,000 below the President's FY 1989 budget request. The entire $40,000,000 reduction will be applied to the expendable launch vehicle account. It represents a reduction of $15,000,000 for purchase of a second Titan III vehicle and a general reduction of $25,000,000. Despite these actions, the Committee continues to hold the position that it is essential for NASA to maintain a mixed fleet of launch vehicles. The Committee, therefore, provides $155,500,000 for the acquisition of expendable launch vehicles, an increase of $130,000,000 over the current operating plan, despite the severe budgetary constraints.

The Committee authorizes $985,300,000 for Space Tracking and Data Acquisition, which is $50,000,000 below the President's request. The Committee directs NASA to apply these general reductions in the most efficient manner without jeopardizing the integrity of the overall program. NASA must determine the relative costs and benefits of programs such as the Second Tracking Data Relay Satellite (TDRS) ground station and a replacement TDRS satellite.

In FY 1989, the Committee authorizes $260,100,000 for the Construction of Facilities programs. This is a $25,000,000 reduction from the FY 1989 budget request of the President. These reductions would occur at the Kennedy Space Center Space Station Processing Facility and in other general areas. The Committee continues to follow closely the wind tunnel modernization and rehabilitation program that was begun last year, and fully authorizes the requested amounts in FY 1989.

Funding in the Research and Program Management account is authorized at $1,880,000,000 in FY 1989, which is a general reduction of $35,000,000 from the budget request. The Committee expects, however, that NASA will still increase its civil service employee base by 525 positions in FY 1989.

The total authorization for NASA in FY 1989 is $11,104,500,000, compared with $11,488,000,000 requested by the President, and $9,026,500,000 in the FY 1988 operating plan.

The Committee has also included $3,870,000 in the reported bill for the operations of DOT's Office of Commerical Space Transportation.

I. RESEARCH AND DEVELOPMENT—$4,278,200,000

The Committee authorizes $4,278,200,000 for research and development activities in FY 1989. This is $168,500,000 less than the President's FY 1989 request.

The objectives of the NASA program of research and development are to extend our knowledge of the Earth, its space environment, and the universe; to expand the technology for practical applications of space technology; to develop and improve manned and

unmanned space vehicles; and to assure continued development of the long-term aeronautics and space research and technology necessary to accomplish national goals. These objectives are achieved through the following elements:

Space Station.—A program to develop a U.S. space station to continue the Nation's leadership in space and to provide for enhancement of science and applications programs and to further the commercial utilization of space while stimulating advanced technologies.

Space Transportation Capability Development.—A program to provide for the development and use of capabilities related to the Space Shuttle. The principal areas of activity in Space Transportation Capability Development are efforts related to the development and flight certification of the jointly developed United States Italian Tethered Satellite System, development of the Orbital Maneuvering Vehicle, development and operations of the Spacelab systems, the development and procurement of upper stages that place satellites in high altitude orbits, the engineering and technical base support at NASA centers, payload operations and support equipment, and advanced programs study and evaluation efforts.

Space Science and Applications.—A program using space systems, supported by ground-based and airborne observations, (1) to conduct a broad spectrum of scientific investigations to advance our knowledge of the Earth and its space environment, the Sun, the planets, interplanetary and interstellar space, the stars of our galaxy and the universe; and (2) to identify and develop the technology for the useful applications of space techniques in the areas of advanced communications satellite systems technology; materials processing research and experimentation; and remote sensing to acquire information which will assist in the solution of Earth resources and environmental problems.

Technology Utilization.—The program includes activities to accelerate the dissemination to both the public and the private sectors of advances in NASA's research, technology, and development program.

Commercial Use of Space.—A program to increase private sector awareness of space opportunities and encourage increased industry investment and participation in high technology, space-based research and development.

Aeronautics and Space Technology.—A program to conduct the fundamental long-term research and to develop the discipline and systems technology required to maintain U.S. leadership in aeronautics and space.

Tracking and Data Advanced System.—This program includes activities to perform studies and provide for the development of systems and techniques leading to improved tracking and data program capabilities.

RESEARCH AND DEVELOPMENT BUDGET SUMMARY

[In millions of dollars]

	Proposed FY 1989 Senate authorization
I. Research and Development	(4,278.2)
1. Space Station	867.4
2. Space Transportation Capability Development	606.6
3. Space Science	1,252.3
A. Physics and Astronomy	(761.6)
B. Life Sciences	(91.7)
C. Planetary Exploration	(399.0)
4. Space Applications	628.3
A. Solid Earth Observations	(82.1)
B. Environmental Observations	(368.3)
C. Materials Processing in Space	(73.4)
D. Communications	(92.2)
E. Information Systems	(22.3)
5. Commercial Programs	57.9
6. Aeronautical Research and Technology	404.2
7. Transatmospheric Research and Technology	69.4
8. Space Research and Technology	350.9
9. Safety, Reliability and Quality Assurance	22.4
10. Tracking and Data Advanced Systems	18.8

1. Space Station—$867,400,000

The Committee authorizes $867,400,000 for FY 1989 for the Space Station program. This is $100 million less than the President's request.

Summary of FY 1989 funding levels

Development	$935,400,000
Pressurized Modules	(188,000,000)
Assembly Hardware/Subsystems	(288,000,000)
Platforms and Servicing	(56,000,000)
Power System	(154,000,000)
Operations Capability/Utilization	(80,000,000)
Management and Integration	(169,400,000)
Flight Telerobotic System	20,000,000
Transition Definition	12,000,000
Total Space Station	[1] $867,400,000

[1] Reflects general reduction of $100 million.

Development of the U.S. permanently manned Space Station, as directed by President Reagan, will add new momentum to the civil space program and is essential to realizing the national goal of U.S. leadership in space. The Space Station program gives us our first opportunity to gain direct experience in long-term human operations in space and knowledge essential to future space exploration. The Station will uniquely enhance the U.S. Space Science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an evenue of cooperation with our allies, demonstrating the peaceful uses of space for the benefit of all.

The Space Station will be unique because it will provide the United States with a permanently manned presence in space. It

will be versatile because it capabilities will be remarkably diverse. This diversity is reflected in the Station's design, which features pressurized laboratories, accommodations for attached payloads, and free-flyiung unmanned platforms. This new national laboratory, a research center in space, will stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to our storehouse of scientific knowledge. Perhaps the most significant feature of the Space Station, essential to its utility for science, commerce, and technology, is the continuing presence of its crews. Men and women will be aboard the Station base full time. The potential of humans—with their creativity, their dexterity, their ability to perceive, to interact with instruments, and to respond to the unexpected—is unique and essential. The Space Station will be designed to exploit these human capabilities. The Space Station's microgravity environment, high levels of power, and extended time in orbit, will enable scientists to make new discoveries in materials research and life sciences. The Space Station's substantive research capabilities include far more than its pressurized volume. Its free-flying platforms will enable truly synergistic studies of the Earth's atmosphere, land masses, and oceans—referred to as Each system science. Moreover, the Station's external structure is designed to be a stable platform that will be available for mounting a number of specialized instruments and telescopes. Scientific instruments, whether in a laboratory or on a boom, required maintenance, upgrading, repair and replacement. The Station will accommodate these servicing functions. The Space Station will be designed to evolve, to be capable of growth in its capabilities, so that future needs and challenges can be met.

The U.S. Space Station will be a multi-purpose, international facility. In 1984, President Reagan invited the full participation of other nations. During the ensuing definition phase, Canada, member states of the European Space Agency (ESA), and Japan worked closely with the United States to define their participation. These parallel definition and preliminary design studies have resulted in the identification of the Space Station elements they are considering for development. Negotiations with these international partners for the development phase of the program are in their final stages. Negotiators from NASA and the Canadian Ministry of State for Science and Technology reached agreement in December 1987 on the text of a memorandum of understanding for the Canadian cooperation, whereby Canada will provide a mobile servicing system for use on the Station. On April 21, 1988, the federal government of Canada approved this agreement and Canada's contribution of $1.185 billion to the Space station program.

In March 1988, NASA and ESA reached agreement on another proposed memorandum of understanding. ESA will provide a pressurized laboratory module, an unmanned polar platform, and a co-orbiting man-tended free flyer. A preliminary agreement also has been reached with Japan on their participation in the Space Station program.

The basic configuration of the Space Station and the supporting elements has been arrived at as a result of a lengthy and iterative three-year process involving NASA centers, U.S. industry, our international partners, and the national and international science communities. A detailed assessment of the Space Station program was also conducted by the National Research Council (NRC) Committee on Space Station. During this definition period, the design evolved in response to user requirements, developments of advanced technology, trade studies and cost assessments. The evaluation of the various Space Station options led to the selection of a baseline configuration, commonly known as the "dual keel" configuration. The launch of the first element of this configuration was planned for January 1994. Since this estimate represented a considerable cost increase over the target cost estimate made in 1983-84, the reasons for the increase were closely examined.

Following intensive review during early 1987, a phased approach for development of the Space Station was adopted. A "Revised Baseline Configuration" which includes major elements of the dual keel configuration was selected, with a commensurate reduction in design and development costs. As a result of necessary fiscal restraint during the FY 1988-90 period, the planned launch date for the first element launch was adjusted to March 1994. However, this schedule was recently revised as the result of a review conducted by NASA after a significant reduction of Space Station funding in the FY 1988 Continuing Resolution. Currently, the first elements of the Space Station program are scheduled for launch in 1995. However, the 1995 launch date is dependent upon Congressional approval of a three-year budget request for the Space Station program of $6 billion.

The revised baseline for the Space Station is comprised of a single horizontal boom structure with 75 KW of photovoltaic power, the U.S. laboratory and habitability modules and two international laboratory modules (one European and one Japanese), and a Canadian mobile servicing capability. These elements comprise the manned base and provide both internal and external accommodations for attached science and applications payloads. There are also two science and applications platforms, one U.S. and one European, to be launched into polar orbits. A Man-Tended Free Flyer is also under consideration by the European Space Agency as a co-orbiting platform with the manned base.

In addition to the development of the manned base and U.S. polar platform, the Space Station program will include development of a Flight Telerobotics System (FTS). The FTS will be a highly automated telerobotic device capable of precise manipulations in space. The FTS onboard the Space Station will increase crew safety and productivity by reducing extravehicular activity (EVA) time, allowing the use of robotics for hazardous tasks, and free crew members for scientific tasks. The FTS will play a key role in the development of automation and robotics (A&R) technologies.

As noted above, a key design objective of the Space Station is to enable hardware and software to evolve in response to inceased user demands and the need for augmented operational capabilities. The Transition Definition activities will provide for systems studies to define options for evolution of the Space Station consistent with future agency missions and for technology developments, primarily in automation and robotics, that will enhance Space Station pro-

ductivity. These activities are essential for the long-term cost-effective utilization of the Space Station.

The Office of Space Station initiated a definition study during FY 1987 to reevaluate the requirements for an assured crew return capability. This activity, the crew emergency return vehicle definition study, will be continued in FY 1988 and FY 1989 under Space Transportation Capability Development and managed by the Office of Space Flight.

Space Station operations encompass all activities required to maintain the Space Station and platforms for its planned lifetime. This includes logistics support, crew training, mission operations, engineering support, launch processing, and user training and operations. The FY 1988 budget requested funds to support preliminary operations planning. These funds have been deferred based on an assessment that it was premature to initiate operations planning tasks at this time.

Since submission of the FY 1988 budget last year, the Space Station program has completed a series of intensive reviews regarding program content and rationale, flight system configuration, and overall reasonableness of the total cost estimates.

The most comprehensive review was conducted at the request of the President by the NRC Committee on Space Station. The NRC's task was to access NASA's cost estimates for the Space Station program and to examine Space Station mission requirements and alternative configurations. This Committee issued its final report on September 10, 1987. The Committee found that the reviewed baseline configuration was "a satisfactory starting point for the Space Station . . . and reflects thoughtful compromises among the priorities and sometimes conflicting requirements of its early scientific and engineering users." The Committee also stressed the importance of having a robust space transportation system, development of an adequate ground test program and backup hardware policy, strengthened Space Station program management, and emphasis on the operational aspects of the program. Preparation of a new Space Station program cost estimate in early 1988 was also advocated. These recommendations will receive special attention during the upcoming Program Requirements Review. After the Program Requirements Review is completed, NASA will provide the Committee with a revised estimate of the Space Station program's cost and schedule.

The NASA studies include an extensive series of analyses relating to the Space Station operations, led by the Space Station Operations Task Force (SSOTF). The results of the SSOTF's work were sent to Congress in the fall of 1987. Concurrent and subsequent study efforts were also conducted in the areas of operations costs management and Space Station science operations management concepts. These reports were sent to Congress in August and October 1987, respectively. NASA also conducted a transportation study that reviewed the capability of the Shuttle as well as other unmanned launch vehicle systems to provide space transportation in support of on-orbit assembly and Space Station operations. Results of this study were furnished to the NRC and subsequently documented in a report transmitted to Congress in January 1988.

Also, as directed in Congressional legislation, NASA prepared and forwarded to Congress an additional development report: the Space Station program plan for selective design parameters, submitted in April 1987. This report is consistent with and supportive of the revised baseline program's flight hardware configuration and overall transportation, assembly, and operations planning.

Due to the bipartisan budget agreement, the Congress directed a significant reduction in the funding appropriated for the Space Station program in FY 1988. The amount requested by NASA for FY 1988, $767.0 million, was reduced to $425,000,000, including $100 million transferred from 1987 replacement orbiter production funds. After adjustments for a directed realignment between the research and development appropriation and the research and program management appropriation, the revised plan for FY 1988 is $392,300,000.

NASA has developed, and submitted to the Congress in April of 1988, a "Space Station Capital Development Plan" and a "Space Station Program Response to the FY 1988 and 1989 Revised Budgets." These reports include revised program cost estimates, both annual and total, that are consistent with the current budget allocation. These revised estimates include the necessary initial adjustments to program milestones.

In addition, NASA will complete a management plan responsive to the recommendations of the NRC which will also address necessary civil service staffing levels to support the program. The *final* capital development plan and a revised Space Station development plan will be submitted to the Congress following the Program Requirements Review.

This budget requests the funding levels for the Space Station of $967,400,000 for the present budget year, $2,130,200,000 for FY 1990 and $2,912,500,000 for FY 1991. The administration is requesting legislation for a Congressional commitment to a three-year advance authorization and appropriation of Space Station funds for FY 1989 through FY 1991. Later this year, the administration plans to request legislation to establish a total program cost ceiling. These measures on the part of Congress and the administration will provide increased program stability while maintaining cost control discipline for both development and operations. The long-term commitment will help assure potential international participants that the United States will recognize the importance of cooperation on the Space Station program.

In support of the President's policy on the commercial use of space, NASA will, in consultation with the Office of Management and Budget, revise its guidelines on the commercialization of the Space Station to reaffirm, clarify and strengthen its commitment to private sector investment and involvement in the Space Station program. Proposals for commercial involvement in the development of the revised baseline program will be considered in the Program Requirements Review. NASA will give positive consideration to proposals to accelerate private sector investment in Space Station development and operations in the form of either goods or services which have not yet been contracted. Further, NASA will seek to reply on private sector design, financing, construction and

operation of future Space Station requirements, including those currently under study.

Space Station—Committee Comments

The Committee strongly supports the development of a permanently manned space station in cooperation with our allies. However, the Committee also realizes that the space station program cannot be fully funded within a constrained NASA budget. To try and develop a space station at the expense of the NASA core programs would be a tragic mistake. The Committee, therefore, authorizes $867,400,000 for FY 1989—$100 million less than the President's budget request—in order to spread the Committee's proposed reductions to the FY 1989 NASA budget request in a fair and equitable manner. The Committee feels strongly that this level of funding is adequate to permit NASA to aggressively initiate Phase C/D of the program—the hardware/development phase.

Since the severe reduction to the space station program in the FY 1988 Continuing Resolution (P.L. 100-203), the Committee has been deeply concerned about the fate of the space station program. The lack of financial commitment to the program has already extended the prposed schedule and has dramatically increased the proposed costs. Today we find ourselves equipped with a standing army ready to start construction of the space station, but this army has considerably less money for hardware development than was originally planned. The reasons for these problems are myriad, but the principal problem is trying to provide sufficient budget resources for a major initiative at a time of severe fiscal constraint.

The irony of this situation is that at the very moment when the budget debate is coming to a head in the Congress, NASA and the State Department have just successfully completed two-and-a-half years of negotiations with ESA Canada, and Japan to enlist their financial support for and participation in the space station program. At this very moment, the final Memoranda of Understanding and Intergovernmental Agreements between the United States and its allies/partners are being reviewed by the administration and prepared for final submission to the Committee for its approval.

The Committee is fully cognizant of the severe budget pressures that confront the Congress and the severe constraints that have been self-imposed on the Congress as a result of last year's Budget Summit. However, the Committee also is well-aware of the importance of the space station program to our national and economic security, technological leadership, and foreign policy standing. The Committee feels strongly that the space station program is a national priority and should be a budget priority. Unfortunately, there does not yet appear to be a consensus in the Congress on that position.

The Committee also believes strongly that FY 1989 is critical to the success of the space station program and to the overall standing of the Nation's civil space program. If the next President finds a well-defined space station program with strong international support, the program's future will be enhanced considerably. If, however, the next President finds a program lacking support or resources, the program's fate would be less certain. Therefore, the Committee has provided a level of funding sufficient to initiate the full-scale development of hardware in FY 1989.

Needless to say, the Committee intends to work diligently in FY 1989 to secure a reasonable level of funding for the space station program and to build a favorable consensus on Capitol Hill for this program. To that end, the Committee strongly urges the President and the White House to lend their full support to help achieve the maximum funding possible for FY 1989. In FY 1988, Congress appropriated only $425 million of a budget request of $767 million. The space station program cannot afford to have a similar action repeated in FY 1989.

As the Committee noted in its FY 1988 NASA Authorization Bill Report (S. Rpt. 100-87), "it is time for the U.S. to realize that our leadership in space has significantly eroded, and, if certain measures are not taken, our space program could experience a significant reduction in vitality and effectiveness." Unquestionably, the top priority of our civil space program is NASA's core program of activities, of which the space station is a singularly important feature. Adequate funding is essential if our civil space program and, in particular, the space station are to achieve the level of success our civil space program enjoyed in years past.

Now is the time for Congress and the administration to realize that NASA's core program, in particular the President's space station initiative, is at great risk and that all of its energy must be devoted to minimizing the FY 1989 NASA budget reductions to a level adequate to support a balanced civil space program.

As stated in section 10 of the bill, the Committee maintains its belief that the space station is a facility that should be used for peaceful purposes in accordance with international law. Accordingly, the Committee has incorporated language in the FY 1989 bill which affirms this position. The same language was included in the FY 1985, 1986, 1987 and 1988 Senate bills and restates Article IV of the 1967 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Celestial Bodies.* Pursuant to this standard, the Department of Defense (DOD) is perceived to be a user of the space station, and it is recognized that it may conduct research and development activities on the space station facilities.

Finally, the Committee is concerned that definite decisions have not been made concerning whether or not the space station should be metric and whether or not the space station polar platform should be launched on an expendable launch vehicle. The Committee urges NASA to resolve these issues by no later than October 1, 1988, and to report its final decisions and rationales to the Committee.

2. SPACE TRANSPORTATION CAPABILITY DEVELOPMENT—$606,600,000

The Committee authorizes $606.6 million for FY 1989 for space transportation capability development. This is $24,500,000 less than the President's request.

Summary of FY 1989 funding levels

Spacelab	$80,400,000

Upper Stages	153,200,000
Engineering and technical base	158,900,000
Payload operations and support equipment	67,300,000
Advanced programs	45,000,000
Advanced launch systems	6,500,000
Tethered satellite system	23,800,000
Orbital maneuvering vehicle	96,500,000
Total Space Transportation Capability Development	$606,600,00

The principal areas of activity in Space Transportation Capability Development include the Spacelab; the Upper Stages required to place satellites in high altitude orbits; the Engineering and Technical Base support at the manned space flight centers; Payload Operations and Support Equipment for accommodating NASA payloads; Advanced Programs study and evaluation efforts; the development and first flight of the United States/Italian Tethered Satellite System; and the development and first flight of the Orbital Maneuvering Vehicle.

Spacelab was developed jointly by NASA and ESA. It is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit cargo bay. The development program continues with a recertification program to insure flight safety, the procurement of flight hardware to support the flight program and necessary modifications including replacing the onboard computer system.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle or expendable launch vehicles alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket motor integrity program to establish an engineering data base for improving the success rate of U.S. built solid stage components.

The Engineering and Technical Base provides the core capability for the engineering, scientific, and technical support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL) for research and devleopment activities. Additional requirements above the core level of capability are funded by the benefiting programs.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the STS payloads during pre-launch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS support services for NASA payloads, satellite servicing tools and techniques development, flight demonstrations, and multi-mission payload support equipment.

Advanced Programs conducts concept feasibility studies and selected system definitions and preliminary design (Phase B) studies and undertakes related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation and system requirements and to evaluate new space transportation initiatives. Complementary objectives are to assimilate generic technology and advanced planning activities, and to provide an advanced planning programmatic link between the Office of Space Flight and other NAS program offices. Activity is focused on four major areas—advanced transportation, advanced operations support, satellite servicing and advanced missions. Concept definition and key advanced development are under way and planned in these areas to assess performance, reliability and operational efficiency improvements and to reduce future program risks and development costs through the effective use of new technolgy. Included as part of the Advanced Programs Development Program are definition studies of a Crew Emergency Return Vehicle (CERV) to provide approaches for additional crew return capability from the Space Station manned base.

The Advanced Launch System (ALS), as outlined in the joint DOD/NASA report to Congress, is a joint DOD/NASA program to develop and field this nation's next generation of unmanned launch systems. The ALS program will permit this nation to achieve the goal of reduced cost to space. Both NASA and DOD are moving aggressively forward with ALS and are jointly managing the effort. As directed by Congress in the FY 1988 DOD Appropriations Bill, a total of $70 million has been transferred from DOD to NASA to fund the NASA directed ALS-Propulsion Focused Technology program activities. Within this total, $65,100,000 will be utilized in STS Capability Development, and $4,900,000 will be used in the Research and Program Management Appropriations to fund the necessary support to these propulsion activities. Advanced Program Development will direct and fund study efforts for unique civil mission requirements not satisfied in the joint DOD/NASA ALS baseline design.

The Tethered Satellite System (TSS), a joint Italian-U.S. development effort, will provide a new reusable capability for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (10 to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of a current drawn throught the tether.

The development of the Orbital Maneuvering Vehicle (OMV), initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond the reach of the Space Shuttle or the Space Station.

Four dedicated Spacelab flights have been flown on the STS including the first Spacelab reimbursable flight, Deutschland-1 (D–1). In addition, several smaller Spacelab elements have flown on other STS flights as partial payloads. These flights have demonstrated the unique capabilities and benefits offered by many of the Spacelab elements. The Spacelab Astro-1 mission, scheduled for the first quarter of 1989, will be the first Igloo Pallet Configuration of the Spacelab Pallet System. Preparations are now in process for resumption of operational flights for DOD for two dedicated U.S. Materials Science Laboratory flights in FY 1990 and a dedicated U.S. Microgravity Laboratory mission in FY 1992.

In addition to NASA missions, the Spacelab program will also support three reimbursable missions: the U.S. DOD Starlab, the German D–2, and the Japanese SL–J.

In Upper Stages, funding is included for production, launch, flight support, and integration of Inertial Upper Stages (IUS) vehicles to accommodate the TDRS D, E, and F missions, and the Galileo, Ulysses (including a PAM-S vehicle), and Magellan planetary missions. Funding also is included for production of a Transfer Orbit Stage (TOS) vehicle for the Mars Observer mission in the FY 1989 budget. The FY 1989 budget request also supports the Solid Propulsion Integrity Program that was created in 1984 to establish an urgently needed data base for use of composite materials in upper stage motor nozzles and to restore user confidence in U.S. launch systems. The results and finding of this program are being used in the Shuttle Solid Rocket Motor redesign effort. The program scope is being expanded to examine motor bondlines as well as continuing the nozzle efforts.

In Payload Operations and Support Equipment, funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA payloads receiving support during this year include Hubble Space Telescope, TDRS, Galileo, Ulysses, Magellan, Astro, Long Duration Exposure Facility Retrieval, Upper Atmospheric Research Satellite, and Gamma Ray Observatory. Efforts will continue to provide the means to maintain and repair satellites on-orbit by developing a series of tools, aids, and techniques, and to demonstrate capabilities and methods of improving the efficiency of on-orbit operations. The FY 1989 engineering and technical base request provides for a continuation of the FY 1988 level of support for basic research and development facilities and services at the centers, with an expansion of computational capability by acquiring a class VI computer for use at JSC and increased Safety, Reliability and Quality Assurance (SR&QA) and engineering support at JSC, KSC, and MSFC.

The Advanced Programs effort is focused on four major areas—advanced transportation, advanced operations support, satellite servicing, and advanced missions. Concept definition and key advanced development are under way and planned in these areas to assess performance, reliability, and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Advanced transportation study efforts focus on cargo vehicles, manned vehicles, and space transfer vehicles. Studies are under way to define the evolution of manned vehicles, including Space Shuttle enhancement concepts (Shuttle Block II), and next generation concepts (Shuttle II). In addition, definition studies are under way to analyze mission requirements for the design and development of a CERV to provide approaches for additional crew return capability from the Space Station. Advanced operations support systems efforts focus on the study and assessment of innovative ground, flight and on-orbit operations techniques to achieve improved safety as well as reduced life-cycle costs for space transportation and orbital systems. The complementary Advanced Operation Effectiveness activity will focus on demonstration of autonomous and expert systems technology to improve the safety and reduce the costs of Shuttle operations. The satellite servicing study effort, encompassing satellite servicing systems and tether applications, focuses primarily on the development of systems and procedures designed to utilize Shuttle capabilities that are compatible with the Space Station and the OMV. Advanced missions activity will continue to focus, with expanded scope and increased depth, on potential manned and unmanned missions beyond the Space Station. Focused orbital debris studies, augmented by the development of a debris measurement radar, will be continued.

Studies, with a directed focus building upon the joint DOD/NASA ALS baseline design, are planned to examine vehicle and propulsion systems to satisfy national requirements. The ALS-Propulsion Focused Technology program, a NASA-directed element of the core DOD/NASA ALS program, is focused on demonstrating the performance and operating capabilities of critical propulsion system components.

The TSS hardware development was initiated in FY 1984, and systems definition studies were completed in FY 1985. Comprehensive design and requirements validation, procurement of long lead time flight hardware elements and tooling, systems development and integration, and deployer manufacturing and integration will continue through FY 1989. The Italians started satellite and core equipment development in FY 1984. U.S. science instruments for the satellite are being funded in the Physics and Astronomy budget. A cooperative first flight on the Space Shuttle is presently planned for 1991.

The OMV will be a reusable, remotely operated propulsion vehicle with the capability to deliver, retrieve and service payloads and spacecraft deployed at a wide range of altitudes and inclinations. The development contract was initiated in late 1986 with a planned initial capability in 1991. Based on budgetary reductions and current shuttle manifest planning, the initial capability requirement has been rescheduled to 1993. The initial operational use of the OMV is in support of the Hubble Space Telescope servicing requirements. The FY 1989 budget request includes funds for continuation of the design and development, initial testing, and production of flight hardware.

Space Transportation Capability Development—Committee Comments

The Committee authorizes $606,600,000 for Space Transportation Capability Development in FY 1989. This is $24,500,000 less than the President's budget request. The Committee's reduction reflects a general reduction of $25 million to be distributed in a cost-effective manner, a reduction of $6,500,000 to the new ALS line item, and an increase of $7 million to procure a TOS upper stage for the Advanced Communications Technology Satellite, which is scheduled for launch in 1992.

The Committee was pleased to see a significant increase in the number of planned Spacelab missions in the most recent NASA manifest. Spacelab missions offer a unique laboratory environment for research and development and are important precursor missions to the space station.

The Committee also is pleased to see that NASA and the Air Force have reached agreement on ALS development and management plan that is satisfactory to both agencies and the involved

Congressional Committees. This focused technology program will significantly enhance existing launch systems and operations and could lead to significantly improved future launch systems. Despite the fact the majority of the NASA funding for the ALS Propulsion Funding is provided by the Air Force, the Committee intends to oversee closely these activities.

The Committee would like to recognize NASA and the Air Force for their inputs into the Office of Technology Assessment's "Launch Options for the Future: A Buyer's Guide" Special Report, requested by the Committee. The report examines the economic and non-economic criteria for a wide range of space transportation system options and is a most useful document in determining the relationship between U.S. space goals and launch system requirements.

Finally, the Committee is concerned about the substantial cost escalation in the TOS program and its effect on the total estimated costs of the Mars Observer and Advanced Communications Technology Satellite programs. The Committee, therefore, directs NASA to submit by October 1, 1988, a detailed estimate of the current TOS program costs, compared to the original estimate, with a complete explanation of these increases.

3. Space Science—$1,252,300,000

The Committee authorizes $1,252,300,000 for Space Science—Physics and Astronomy, Life Sciences and Planetary Exploration—for FY 1989. This is $45 million less than the President's request.

A. PHYSICS AND ASTRONOMY—$761,600,000

Summary of FY 1989 funding levels

Hubble Space Telescope Development	$102,200,000
Gamma Ray Observatory Development	41,900,000
Global Geospace Science	76,400,000
Advanced X-ray Astrophysics Facility Development (AXAF)	27,000,000
Payload and Instrument Development	77,100,000
Shuttle/Spacelab Payload Mission Management and Integration	61,500,000
Space Station Integrated Planning and Attached Payloads	8,000,000
Explorer Development	82,100,000
Mission Operations and Data Analysis	156,200,000
Research and Analysis	89,100,000
Suborbital Program	45,100,000
Total Physics and Astronomy	[1] $761,600,000

[1] Reflects general reduction of $5 million.

The objectives of the Physics and Astronomy program are to increase our understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. Objects studied by the Astrophysics program include distant galaxies and galactic clusters, as well as stars and other structures in nearby galaxies and the interstellar medium in our galaxy. Unusual and exotic phenomena—such as quasars, neutron stars, pulsars and black holes—are of particular interest to the Astrophysics program and are the target of many ground-based and space-based research programs.

Intensive study of our own Sun, with its multitude of time-varying phenomena, provides key answers to a vast range of questions requiring comprehensive research into solar-terrestrial processes and the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

The objectives of the Physics and Astronomy program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights and suborbital opportunities. In the future, the Space Station will act as a platform for attached payloads and as a servicing point for major free-flying observatories which require assembly, maintenance and refurbishment in orbit. Space-based research allows observations in wavelength regions such as the infrared or the ultraviolet which cannot be carried out on the ground due to the obscuring effects of the atmosphere. Also, observations in the visible light region are vastly improved when conducted above the atmosphere. The entire program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the scientific communities and the general public for application to the advancement of scientific knowledge, education and technology.

Hubble Space Telescope Development

The Hubble Space Telescope, to be launched by the Space Shuttle in June 1989, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbent atmosphere. This telescope will be able to resolve spatial features by a factor of 10 better than the typical ground-based optical telescope and will observe the universe at approximately seven times the distances now possible. This means some 350 times the volume of the present universe will be available for study. This increased capability will allow us to address basic questions concerning the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe—its beginning and end.

The Hubble Space Telescope will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The Hubble Space Telescope will operate in space above the atomospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the Hubble Space Telescope will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The Hubble Space Telescope will be an automated observatory.

Gamma Ray Observatory Development

The Gamma Ray Observatory (GRO), scheduled to be launched by the space shuttle in March 1990, will study the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving synthesis of elements, cosmic rays interacting with the interstellar medium, and transformations involving the fundamental particles of physics. GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma ray bursts to the diffuse gamma ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rest on a foundation of exploratory investigations and developments from a previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Participation in the GRO mission includes the university science community as well as government and industry. International involvement, with a complete Principal Investigator team based in Europe, is extensive.

Global Geospace Science

Global Geospace Science (GGS) will be part of the U.S. contribution to the International Solar Terrestrial Physics (ISTP) program. This program is an international, multi-spacecraft, collaborative science mission designed to provide the measurements necessary for a few and comprehensive understanding of the interaction between the Sun and the Earth.

GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program to provide instruments and launch support and to gain science return in a cooperative effort with ESA and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort will be greatly enhanced by the addition of the two spacecraft proposed in the GGS program. The combined program will include five spacecraft missions: two U.S. spacecraft, *Wind* and *Polar;* two ESA spacecraft, *Soho* and *Cluster;* and one ISAS spacecraft, *Geotail,* most of which are to be launched by NASA.

The GGS mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial environment. GGS consists of two fully instrumented U.S. spacecraft, *Wind* and *Polar,* making simultaneous measurements in key geospace regions. Instruments and theory investigations were selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multispectral global auroral imaging, and multi-point study of magnetospheric response to solar wind.

Essentially all commitments by the foreign governments are in place, and their development activities have commenced. GGS will allow the United States to become a full partner in the ISTP program, reinforcing our commitments to international cooperation, and is essential to maintaining continued leadership in solar terrestrial physics.

Advanced X-Ray Astrophysics Facility Development

The FY 1989 budget request includes a request for a "new start" for the advnced X-ray astrophysics facility (AXAF). AXAF is the third of four "great observatories" to be proposed by NASA and is a telescope facility designed to observe the universe in the X-ray region of the electromagnetic spectrum.

AXAF is 100 times more sensitive and has 1,000 times more capability for spectroscopy than any previous or planned X-ray mission. AXAF needs to be undertaken immediately in order to fly in concert with the Hubble Space Telescope, which will observe the universe in visible and ultraviolet radiation, and the Gamma Ray Observatory, which will observe in gamma rays. The scientific return of these "Great Observatories" will be enhanced enormously if flown together to observe the whole range of phenomena in the cosmos, from the most tranquil to the most violent, and to provide a complete physical picture of the universe's most enigmatic objects. Moreover, immediate initiation of AXAF will provide a scientific opportunity that is unlikely to be repeated for many generations. The closest supernova to occur near Earth since the invention of the telescope, 400 years ago, was seen last year, and can be studied by AXAF provided that it is launched by 1995, before the X-rays fade. Supernovae are responsible for the origin of all the heavier elements in the unviverse including those essential for life.

The AXAF, with its 1.2-meter class grazing incidence telescope, will double the energy coverage which was provided by the Einstein Observatory (HEAO-2). If approved, AXAF will be launched in 1995 using the Space Transportation System (STS). It will be a long-lived observatory designed for on-orbit instrument replacement and servicing. With the Shuttle, and eventually the Space Station, the United States has the unique capability to maintain this telescope in orbit.

An extensive preparatory program has been completed for AXAF, including completion of 32 months of observatory definition in January 1987, which included the fabrication of the finest X-ray mirror ever built. NASA and industrial teams are in place and ready to proceed with AXAF.

In this era in which U.S. leadership in space is being challenged, a new start for AXAF will provide a bold statement that in the premier scientific discipline of astrophysics, we will be second to none.

Payload and Instrument Development

The recent reorganization of the Office of Space Science and Applications (OSSA) established a new Space Physics Division and placed budget responsibility for all payload development in the appropriate discipline divisions of OSSA. Consequently, funds for development of Physics and Astronomy payloads have been transferred to the newly created Payload and Instrument Development budget line. In addition, funding for reflight of the Imaging Spectrometric Observatory (a Spacelab-3 atmospheric physics experiment) on ATLAS-1 has been transferred to the Environmental Observations Payload and Instrument Development. Spartan funding has also been transferred to the Physics and Astronomy Research and Analysis line to provide additional funding for the Supernova campaign.

FY 1989 instrument development activities support a wide range of instrumentation—from early test, checkout and design of instruments for long duration free-flying missions to international flights of opportunity.

The COSTR program will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity.

The Tethered Satellite System (TSS) will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The objective of the initial TSS mission in January 1991 is to verify the controlled deployment, retrieval and on-station stabilization of a satellite tethered from the orbiter and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter. TSS is an international cooperative project with the Italian government.

The Shuttle experiment to test the theory of relativity will develop a multigyroscope experimentation package to fly as an attached payload on the Shuttle in 1993 as an integral part of the study of relativity.

Astrophysics and Space Physics Payloads include a number of instruments designed for flight on the Space Transportation System. Emphasis will be on technology definition for the High Resolution Solar Observatory (HRSO) as well as instrument development for study of the complex relationships of solar irradiance and the near-Earth plasma environment (Atmospheric Laboratory for Applications and Science—ATLAS) and the diffuse X-ray background and spectra of point and extended sources (Shuttle High Energy Astrophysics Lab—SHEAL).

Shuttle/Spacelab Payload Mission Management and Integration

The primary objective of the Spacelab Payload Mission Management program is to manage the mission planning, integration, and execution of all NASA Spacelab and attached Shuttle payloads.

Mission management activities are continuing for Physics and Astronomy missions including the ASTRO-1 mission and SHEAL. ASTRO-1 is scheduled for flight in 1989; SHEAL is currently planned for flight in 1992. The primary instrument on SHEAL, a broad-band X-ray telescope, is also under consideration for an early flight on the ASTRO mission in order to make timely observations of the Supernova 1987a.

Mission management activities are continuing on several other space science and applications missions such as the ATLAS. The first of this series is planned for flight in 1991. Other examples include flight of an imaging radar in the early 1990's; a series of Spacelab Life Sciences Missions (SLS), the first scheduled for launch in December 1989; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); and flight of the on-going series of Materials Science Laboratories (MSL's).

Space State Integration Planning and Attached Payloads

The primary objective of the Space Station Integration Planning and Attached Payloads program is to initiate the necessary planning, definition and development of payloads and missions as OSSA begins its preparations as a future major user of the Space Station complex. This includes the definition of attached payloads suitable for deployment on the early Space Station, as well as the definition of integration and operational requirements, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Studies continue to define the end-to-end science operations requirements for the Space Station era (i.e., the cycle from identification of science requirements through mission planning and operations to dissemination, analysis and archiving of data). Studies also continue to determine the best use of Space Station resources (e.g., power, crew time, volume, data handling capabilities, pointing capabilities) vis-a-vis science requirements. Potential attached payloads have been identified for further feasibility and definition and appropriate studies are under way.

The two-year study phase for Space Station Integration Planning activities will be completed in FY 1988. In FY 1989, definition and development will continue on those attached payloads selected for early flight on the Space Station. Additionally, Space Station payload development activities are augmented in FY 1989 in the cognizant science disciplines where the payloads, hardware and support equipment will be defined and developed through a judicious program of Spacelab test flights. They include facilities and instrumentation for microgravity experiments, as well as Life Sciences hardware, support equipment and studies, and Advanced Technology Development for the polar platform payload (Earth Observing System). The total augmentation for Space Station related payload activities included in the OSSA FY 1989 budget is approximately $50 million.

Explorer Development

Investigations selected for Explorers are usually of an exploratory or survey nature, or have specific objectives not requiring the capabilities of a major observatory.

Explorers under development will study the properties of the cosmic microwave background, which is important for understanding the early universe and cosmology, survey the sky in the extreme ultraviolet for the first time, and measure time variable phenomena in x-ray sources. The Explorer program also provides a means of developing instruments for "payload-of-opportunity" missions, such as those involving other federal agencies or international collaboration.

The San Marco-D mission, a cooperative project with Italy, was launched on March 25, 1988, on a Scout expendable launch vehicle. The Cosmic-Ray Isotope Experiment (CRIE) will be included in the Combined Release and Radiation Effects Satellite (CRRES), an Air Force Mission now scheduled for launch in 1990.

In FY 1986, a new cooperative mission called Solar-A was initiated with the Japanese. Solar-A will be launched in 1991 to study the Sun during the upcoming solar maximum.

In FY 1988, development continues on the Cosmic Background Explorer (COBE) scheduled for launch on a Delta in February 1989, on the Extreme Ultraviolet Explorer (EUVE) scheduled for launch on a Delta in August 1991, and on the X-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT) scheduled for launch on a Delta in February 1990

Definition and design will continue in FY 1988 on the X-ray Timing Explorer (XTE). This mission, the last currently planned major effort in the Explorer line, can be ready for launch as early as 1983. During FY 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over 43 were received and are currently being evaluated for further definition.

In addition to the traditional "Delta-Class" Explorer missions NASA issued on May 9, 1988, an Announcement of Opportunity for Scout-class Explorer missions. While subject to more stringent constraints than Delta-class missions (weight, telemetry, power, etc.), it is anticipated that a significant number of scientifically exciting missions can utilize this capability and be developed on a short time-scale. Following a peer review of proposals, it is anticipated that several Scout missions will be selected for development, with the initial one being launched as early as 1991.

Mission Operations and Data Analysis

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program also supports the operation of a number of spacecraft after their originally planned objectives have been achieved for purposes of conducting specific investigations that have continuing high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and space physics operational satellite projects. Actual satellite operations, including control center and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

In addition to the normal support required for mission operations, the Hubble Space Telescope program encompasses several unique aspects which must be provided for in advance of the launch. The Hubble Space Telescope is designed to operate for more than a decade, using the Space Shuttle/Orbital Maneuvering Vehicle combination and/or Space Station for on-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments.

The Hubble Space Telescope will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Since operations will be carried out through an independent Hubble Space Telescope Science Institute. The Institute will operate under a long-term contract with NASA. While NASA will retain operational responsibility for the observatory, the Institute will implement NASA policies in the area of planning, management, and scheduling of the scientific operations of the Hubble Space Telescope.

Initiation of the definition and implementation of a unified data system will be undertaken. This unified data system will ensure the fullest access and exploitation of the various mission data sets, with emphasis on the wealth of data to be returned by the Great Observatories. An initial definition process involving extensive inputs from the astrophysical community has now been completed, and FY 1989 funding in the Mission Operations and Data Analysis (MO&DA) area will enable the principal elements of this essential system to be put in place.

Research and Analysis

The research and analysis program provides for the preliminary studies required to define missions and/or payload requirements, as well as providing a research and technology base necessary to define, plan and support flight projects.

The objectives of the research and analysis program's supporting research and technology activities include optimizing the return expected from future missions, enhancing the value of current space missions, developing theories to explain observed phenomena and predict new ones; and continuing the acquisition, analysis and evaluation of data from laboratories, balloons, rockets and spacecraft activities.

The space research and technology program carries out its objectives through universities, non-profit and industrial research institutions, NASA centers and other government agencies.

The advanced technological development (ATD) activities, on the other hand, support detailed planning and definition of potential new physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field and that those missions use the appropriate technology and techniques.

Candidate missions for the 1980's and early 1990's that require ATD activities include the AXAF and the Space Infrared Telescope Facility (SIRTF).

Suborbital Program

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stel-

lar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and on an international cooperative basis.

Forty-four suborbital rockers are currently scheduled for launch in FY 1988. Included in this number are eight NASA launches in Greenland as a follow-up to the FY 1985 effort. In addition, 72 C-141 aircraft missions are planned, including support of the SN 1987a Supernova campaign with additional flights in the southern hemisphere. FY 1988 activities continue the study of a Stratospheric Observatory For Infrared Astronomy (SOFIA) as a potential follow-on for the C-141 in the 1990's. SOFIA would incorporate a three-meter class infrared telescope mounted in a suitable aircraft.

The Balloon Program provides a cost-effective means to test flight instrumentation in the space radiation environment and for making observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared astronomy.

The Balloon Program funding is required for purcahse of balloons, helium, launch services, tracking and recovery, as well as for maintenance and opertions of the National Scientific Balloon Facility (NSBF) at Palestine, TX. This facility supports the launch of about 80 percent of NASA's balloon payloads, and it is the nation's primary means for carrying out large scientific balloon operations. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

Funds for 1989 will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NNSBF in Palestine, Texas. This funding is also required to continue definition activitives for balloon improvement and long-duration balloon flights. In FY 1989, the Airborne Science and Applications funding will be used to continue flights of the Kuiper Airborne Observatory.

Physics and Astronomy—Committee Comments

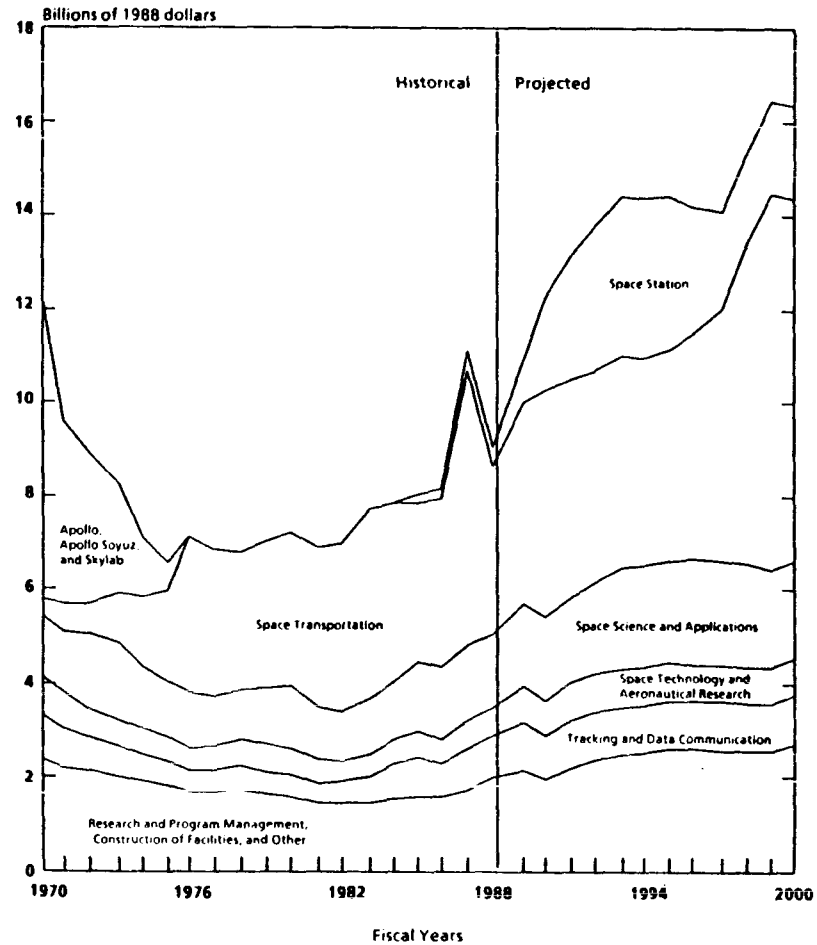
The Committee authorizes $761,600,000 for Physics and Astronomy in FY 189. This is $30 million les than the President's budget request. The Committee's proposed reduction constsists of a $5 milion general reduction and a rephasing of the GGS program, a FY 1988 new start, that results in a $25 million reduction.

Notwithstanding the recommended reduction of $25 million from the GGS budget request, the Committee would like to indicate that this in no way reflects diminished support of the program. The Committee still strongly endorses the GGS program and the participation of the United States in the ISTP program. Unfortunately, the current status of the GGS program provides an opportunity for a FY 1989 budget reduction.

As part of its discussion of the FY 1989 Physics and Astronomy budget, the Committee applauds the management and staff of NASA's OSSA for their efforts to formulate a strategic plan, with specific goals and evaluation criteria, for space science and applications. The "Office of Space Science and Applications Strategic Plan 1988" is a most useful document and a honest effort to instill more order and predictability in the space science and applications program.

As can be seen in the illustration below, taken from the recent CBO Report "The NASA Program in the 1990s and Beyond," the space science and applications program has experienced severe fluctuations since 1970 and needs to experience real growth in the future years if the United States is to retain its leadership in space science. The Committee strongly supports NASA's space science and applications programs, yet believes that our civil space program needs a broader base of support if the visions of OSSA are to become realities. That is one of the principal reasons why the Science, Technology, and Space Subcommittee conducted a field hearing on March 7, 1988, in Boston, Massachusetts, on Space Science and Applications.

Summary Figure 1.
NASA Budget: Historical and Projected (the "Core Program")



SOURCES: Historical data, NASA budget plans as presented in *NASA Budget Estimates* for various years, and Congressional Budget Office projections.

In light of certain problems of the past and, in particular, the hardships suffered by the space science community as a result of the shuttle grounding, the Committee believes that FY 1989 funding for the space science and applications programs is particularly critical. The Committee continues to support the conclusions of the NASA Advisory Council report, "The Crisis in Space and Earth Science," and the recommendations of the Rogers Commission concerning the importance of a mixed fleet. The Committee believes that it has provided sufficient resources to support a balanced and robust space science and applications program in FY 1989, and the Committee hopes 1989 will be the "Year of Space Science" with the successful launch of the Hubble Space Telescope and the Magellan and Galileo missions.

In the area of Physics and Astronomy, the Committee is pleased to endorse AXAF as a new start in FY 1989. The third of the great observatories, AXAF will be a space-based observatory equipped with special mirrors capable of forming images of astronomical objects in x-ray light. AXAF will produce pictures 10 times sharper, will be able to detect sources 100 times fainter, and will be 1,000 times more sensitive than its predecessor—the Enstein High Energy Astronomy Observatory. In addition, AXAF will help the United States reacquire its world leadership position in astrophysics.

The Committee should indicate that despite its strong support of AXAF, the recent experience with cost overruns and management problems in the Hubble Space Telescope Program are cause for concern. Accordingly, the Committee intends to oversee the AXAF program very closely.

The Committee is pleased to support NASA's request for an augmentation for the Explorer Program in FY 1989 and applauds NASA's decision to initiate the procurement of Scout-class expendable launch vehicles for these missions characterized by their low costs and quick return of scientific data. This initiative by NASA provides greater balance to the NASA manifest between the flight of small missions and large missions. Needless to say, the Committee looks forward to the 1989 launch of the COBE mission on a Delta expendable launch vehicle.

The Committee reiterates its strong support of the mission operations and data analysis, as well as research analysis line items, the lifeline of the university space science community, and is pleased to support a slight increase in the suborbital program, another program of significant value to the members of the space science academic community.

Finally, the Committee reiterates its strong support of the Gravity Probe B mission and the innovative management approach being used to implement this program. The Committee strongly supports the Gravity Probe B project and recommends $22 million for this activity in FY 1989.

B. LIFE SCIENCES—$91,700,000

The Committee authorizes $91,700,000 for Life Sciences in FY 1989. This is $10 million less than the President's request.

Summary of FY 1989 funding levels

Life Sciences Flight Experiments	$54,500,000
Research and Analysis	42,800,000
Total Life Sciences	[1] $91,700,000

[1] Reflects general reduction of $5.6 million.

The goals of the Life Sciences program are to advance knowledge in all areas of space life sciences and to develop medical and biological systems which enable human habitation in space. Results from the research program are applied to: the immediate needs of maintaining astronaut health and productivity; understanding the response of biological mechanisms to weightlessness; the design of controlled ecological life support systems; understanding the origin, evaluation and distribution of life in the universe; and understanding the biosphere of the planet Earth.

Continuing support of the Life Sciences program is essential to: understand the basic biological mechanisms of gravitational responsivity; evolve the critical technologies necessary to enable long-term piloted space flight; and develop the capability to sustain a permanent manned presence in space. The research program includes ground-based and space research efforts which are mutually supportive and integrated. This research program also studies fundamental biological processes and space-related medical problems through a variety of disciplines and techniques.

The Life Sciences research and analysis program includes five major elements: (1) space medicine, which addresses the health and well-being of space crews by seeking to understand and prevent adverse physiological changes which occur in space flight and upon return to Earth; (2) space biology, and integrated basic science research program that studies the fundamental mechanism of gravitational interaction with all orders of plants and animals in flight and ground experiments; (3) controlled ecological life support systems, a program of research and critical technology development for life support systems necessary to maintain life in space autonomously for long periods of time; (4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and (5) biospheric research, which explores the interaction between life on Earth and its physical and chemical environment.

The Life Sciences Flight Experiment program supports the research and analysis program with the selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations in space involving humans, animals and plants. Experiments are currently conducted on the Shuttle and Spacelab and are being readied for conduct on the Space Station. An international cooperative program, the U.S./U.S.S.R. Working Group in Space Biology and Medicine, pursue investigations of joint interest.

Life Sciences Flight Experiments

The objective of the Life Sciences Flight Exeriment program is to assimilate information and scientific questions from various life sciences disciplines and develop payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation of weightlessness. The program includes selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations involving humans, animals and plants.

Funding for FY 1989 is required for the final preparation and flight of approved experiments on the first dedicated Life Sciences mission (Spacelab Life Sciences-1 (SLS-1)) which is scheduled to be launched in FY 1991 and will concentrate on studies of human and animal biomedical responses, with emphasis on cardiovascular, bone metabolism and vestibular functions. SLS-1 will be unique in several respects: it will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and it will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space.

Final preparations are also under way to support the flight of the first International Microgravity Laboratory (IML-1) mission in 1990. Approximately 50 percent of the payload relates to space life sciences, with the United States focus on plants, neurovestibular studies, human performance, radiation and cellular differentiation.

Efforts will continue on definition and development of new experiments (selected through the Announcement of Opportunity (AO) process) and hardware that will be flown on future Spacelab/Shuttle missions—i.e., Shuttle mid-decks, the Japanese SL-J mission, the second dedicated life sciences mission (SLS-2), the German D-2 mission, IML-2, SLS-3, and the DOD Starlab mission. Collaboration with the Soviet Union on its COSMOS biosatellite program will continue with joint research on the next COSMOS flight in 1989.

To ensure that the Space Station will serve life sciences research objectives, studies will be conducted in FY 1989 to determine how space biology research will be accommodated on the Space Station, as well as to define instrument and facility requirements.

In FY 1989, research efforts will be increased on the feasibility of extending operational tours of duty of flight crews on the Space Station in order to achieve greater cost-effectiveness. The program will decrease transportation costs by helping to reduce yearly Shuttle flights needed to support crew rotations on the Space Station from eight to an estimated four to five. It will allow more effective use of human resources by maintaining crew health and productivity with countermeasures that minimize impact on in-flight crew time.

In FY 1989, development will begin on an integrated centrifuge facility that will support a broad spectrum of life sciences research using small animals and plants. For the first time, it will provide continuous on-board 1-G control that can separate influences of weightlessness from other effects of space flight. It will allow scientists to test the response of living organisms to operational forces at various stages of adaptation to weightlessness.

Research and Analysis

The research and analysis activity supports Life Sciences program goals of advancing knowledge in all areas of space life sciences and developing medical and biological systems which enable human habitation in space. The program is composed of five ele-

ments: (1) space medicine; (2) space biology; (3) controlled ecological life support systems research; (4) exobiology; and (5) biospheric research.

In FY 1989, the Space Medicine program will resume collecting information on occupational exposure in microgravity on each Shuttle flight and conduct in-flight clinical testing of countermeasures, especially in the area of vestibular dysfunction, cardiovascular deconditioning and muscular atrophy. Resolving problems associated with the initial adaptation to weightlessness, such as space motion sickness and fluid shifts, will continue to be of high priority.

In conjunction with NASA's development of the Space Station, the Space Medicine program will support extended duration crew operations in space with estensive research in the physiological changes associated with longer exposure to weightlessness. Bone demineralization, muscle atrophy and cardiovascular deconditioning will be studied in ground-based simulation so appropriate countermeasures can be designed. This accelerated program of directed research, bed rest studies and protocol development and evaluation will allow more effective use of human resources in space by developing physiological countermeasures that minimize impact on in-flight crew time. Critical technology requirements will be addressed, and research on implementation will be initiated.

In FY 1989, OSSA will collaborate with the Office of Aeronautics and Space Technology on NASA's proposed new initiative: Project Pathfinder. The Project will research critical path elements for long-term manned missions in order to inform policymakers of the requirements (as well as uncertainties, risks and technological issues) involved in such efforts as a lunar base or manned Mars mission. Life science research will be directed to the Humans in Space element of Project Pathfinder and focus on the areas of human performance, extravehicular activity and life support.

In FY 1989, the Space Biology program will concentrate ground research on: developing working models of functioning gravity-sensing neural (information) networks to understand neurosensory processing in microgravity; understanding the physiological side effects of centrifugation in preparation of use of the Shuttle/Space Station centrifuge as a research tool; and identifying the cellular events of the gravity-perception mechanism in plants.

The Controlled Ecological Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environment of manned spacecraft, and the Exobiology program will emphasize the development of new flight experiment concepts to investigate models of early Solar System evolution and mechanisms for the synthesis of biologically significant molecules in space.

In FY 1989, definition and design phases will be completed in the program's microwave observing project which will analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy. Funds will be used to begin the development phase of signal processing systems which will be used with existing radio astronomy facilities and NASA's Deep Space Network antennas.

Life Sciences—Committee Comments

The Committee authorizes $91,700,000 for Life Sciences in FY 1989. This is $10 million less than the President's budget request. This $10 million reduction is achieved by a general reduction of $5,600,000 and a deferral to FY 1990, without prejudice, of the Search for Extraterrestial Observing Project. This deferral will result in a reduction of $4,400,000.

The Committee is pleased to augment the Life Sciences budget by $22 million over the FY 1988 appropriation. This increase reflects the Committee's strongly held view that the Life Sciences program and budget must be expanded if the Nation is to maintain a permanently manned presence in space or to undertake long duration missions to other planetary bodies.

C. PLANETARY EXPLORATION—$399,000,000

The Committee authorizes $399 million for Planetary Exploration in FY 1989. This is $5 million less than the President's request.

Summary of FY 1989 funding levels

Galileo Development	$61,300,000
Magellan	33,900,000
Ulysses	10,300,000
Mars Observer	102,200,000
Mission Operations and Data Analysis	112,700,000
Research and Analysis	83,600,000
Total Planetary Exploration	[1] $399,000,000

[1] Reflects general reduction of $5 million.

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to understand the Earth better through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and, (4) to provide a scientific basis for the future use of resources available in near-Earth space. The strategy that has been adopted calls for a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the small bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies, and then proceed to levels of more detailed study.

Galileo will be launched on a Shuttle/Inertial Upper Stage (IUS) combination in October 1989 on a trajectory using gravity assists at Venus and Earth. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the preceding Voyager and Pioneer missions. During twenty-two months of operation in the Jovain system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analysis, while the orbiter will have the capability

to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA and ESA activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studies from the Earth's orbit. Ulysses will be launched in October 1990 using the Shuttle and IUS/PAM-S launch stages.

Magellan will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to pentrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale features and to address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to accurately detemine the planet's gravity field as well as internal stresses and density variations. With these data, the evolutionary history of Venus can be compared with that of the Earth. Magellan is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer, schedued for launch in 1992, will follow up on the earlier discoveries of Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. The mission will utilize a modified Earth-orbiting spacecraft, thereby benefiting from the previously developed technology.

The Planetary Explorations program is also founded on a coordinated ground-based research and analysis effort. Research and analysis activities will continue to maximize the scientific return from both ongoing and future missions and from such Earth-based activities as lunar sample and meteorite analysis, telescopic observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups and for the wide dissemination of scientific results. A close coupling is also maintained between the research programs and planning activities that are undertaken to define the scientific rationale and technology needed for future missions. The program also supports the growing involvement of U.S. scientists as participants on foreign-sponsored missions.

Galileo Development

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter and its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in situ* measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by NAS to provide continuity, balance, and orderly progression of the exploration of the solar system.

The orbiter and probe will be launched together in October 1989 as a single combined payload using a shuttle/IUS combination on an initial trajectory toward Venus, followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter not otherwise obtainable with this launch vehicle. When the orbiter arrives at Jupiter in November 1995, it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which both Jupiter's major satellites and the dynamic magnetosphere will be extensively mapped. During this time ten close flybys of Jupiter's four major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTGs) developed by the Department of Energy. The orbiter will carry approximately 100 kg of scientific instruments and the probe will carry approximately 25 kg of scientific instruments.

Funds for FY 1989 will provide for completion of spacecraft system testing and for preparing the spacecraft to be shipped to KSC for initiation of integration with the IUS and Shuttle. Mission operations software development and testing will also continue in preparation for a launch in October 1989.

Magellan

The objective of the Magellan mission is to address fundamental questions regarding the origin and evolution of Venus through global radar imagery of the planet. Magellan will also obtain altimetry and gravity data to determine accurately the planet's gravity field as well as internal stresses and density variations. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The Magellan spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution (120 to 200 meter) images of the planetary surface as well as altimetric data. Gravity data will be obtained by processing radio signals from the spacecraft. Spacecraft development is making extensive use of existing designs, technology, and residual hardware. For example, the spacecraft will use an existing spacecraft structure, large antenna, and propulsion components from the Voyager program.

In April 1989, the Magellan spacecraft will be launched by the Shuttle/IUS on a direct trajectory to Venus. Arriving at Venus in July 1990, the spacecraft will perform a retropropulsive maneuver and enter a near-polar elliptical orbit. After an initial check-out period, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution of about 150 meters.

During FY 1988, spacecraft structural testing will be initiated, the flight model of the radar instrument will be delivered for integration with the spacecraft, the spacecraft assembly will be completed and environmental testing will be initiated for the entire spacecraft flight system. Integration of the mission operations system will be completed, to be followed by initiation of operations testing and training preparatory for launch.

In FY 1989, the spacecraft will be shipped to KSC following final testing. Upon arrival, the spacecraft wil be integrated with the IUS and Shuttle and undergo final preparation prior to launch in April 1989.

Ulysses

Ulysses is a joint mission of NASA and ESA. ESA is providing the spacecraft and some scientific instrumentation. The United States is providing the remaining scientific instrumentation, the

launch tracking support, and the RTG. The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. To provide a better understanding of solar activity on the Earth's weather and climate, the mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude.

Ulysses was restructured in FY 1981 from a two spacecraft mission—one provided by the United States and one provided by ESA to a single ESA spacecraft mission. However, the U.S. participation in the program remains substantial. NASA is responsible for five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators.

The Ulysses launch is planned for October 1990, using the Shuttle and IUS/PAM-S launch stages, and its mission will end in July, 1995. During 1988, documentation of the spacecraft/launch vehicle interface will be completed, while support to ESA will continue in order to make the spacecraft compatible with the new upper stage configuration. Launch approval activities involving the RTG and support for retesting the spacecraft and the science instruments will also be continued.

Funding for 1989 will support launch approval activities for the Radioisotope Thermoelectric Generators (RTGs). Periodic testing of the spacecraft and science instruments will also continue.

Mars Observer

The Mars Observer mission is the first in a series of planetary observer missions utilizing a lower cost approach, to inner solar system exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well defined and focused set of science objectives and uses modified production-line Earth-orbital spacecraft and instruments with previous space flight heritage. The objectives of the Mars Observer mission are to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and observe their interaction with the Martian environment over all four seasons of a full Martian year.

The limitation on the number of launch opportunities through 1990 and the further restrictions placed on scheduling by timing requirements for planetary launches have necessitated delaying the planned launch of Mars Observer from 1990 until the following planetary opportunity, 25 months later. The current plan is to launch the mission in 1992 with a Transfer Orbit Stage. The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of a full Martian year, which is about two Earth-years.

In FY 1988, it is planned to continue detailed design of the instrument hardware and system design of the overall mission and to complete design of the Payload Data Subsystem. Detail design of the spacecraft and parts and subassembly procurements will be continued.

Funding for 1989 will support the completion of spacecraft and instrument designs. Initial hardward fabrication for both the spacecraft and instruments will also begin. Funding is also included for the procurement of additional spacecraft and instrument spares.

Mission Operations and Data Analysis

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions. Currently, two major classes of planetary spacecraft are operating—the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operation systems and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now exploring the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. In January 1986, Voyager 2 made a close flyby of the planet Uranus, the first time this planet has ever been visited by a spacecraft. During this flyby, it made detailed observations of the planet, its rings, and moons. Upon completion of the Uranus encounter, the spacecraft began its path to the planet Neptune, where, in 1989, it will provide us with our first close look at this distant planet.

Pioneers 10 and 11 continue to explore the outermost solar system. Pioneer 10 will soon enter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6-9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun.

The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the Solar Wind. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. The Pioneer Venus was the only spacecraft able to observe the Comet at its closest approach to the Sun, thus providing critical enhancements to the data gathered by foreign spacecraft.

The planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory (JPL). In addition, the activity supports the development of the Space Flight Operations Center (SFOC) at JPL. This facility will be a versatile, cost-effective means for carrying out multimission data acquisition, telemetry, image processing, and for commanding of planetary and orbital spacecraft.

Funding for FY 1989 is required for the continued operation and data analysis activities in support of the Pioneer missions as well as the August 1989 Voyager/Neptune encounter. Operations activities will also begin for the Magellan mission, which will be launched in April 1989. Development activities will also continue on the SFOC at the Jet Propulsion Laboratory.

Research and Analysis

The research and analysis program consists of four elements required to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch and provide co-investigator support to ESA's Giotto mission, which encountered Halley's Comet in 1986.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, and U.S. scientist participation on foreign missions.

At present, the instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation, which are optimized for such missions. At the same time, the support for U.S. science investigators on foreign missions currently is being provided for U.S. participation on the U.S.S.R. Phobos missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies, the technological and fiscal feasibility is evaluated, and the scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee, an advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system.

The Mars Data Analysis program continues to support analysis of data obtained by Viking and earlier missions so that we are scientifically prepared for the next phase of Mars exploration. It also supports the establishment of a Planetary Data System which will permit the archiving of these and all other data products in a manner which will promote and facilitate their use.

During FY 1989, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the development of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager. Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1989 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition activities will continue to support development of new state-of-the-art instruments with emphasis on those supporting a future mission to Saturn and its moon Titan and for a Cosmic Dust Collection Facility planned as an attached payload for the Space Station. The Mars Data Analysis Program will support continued analysis of Mars data in preparation for new Mars missions and for continued development of the Planetary Data System to archive all planetary data for enhanced accessibility for all users. Within Advanced Programs, advanced technology development for potential future missions will also be continued with emphasis on the Mariner Mark II spacecraft.

The FY 1989 Halley's Comet Co-Investigations and Watch funding is required to continue support of U.S. co-investigators, who will be analyzing and archiving the data acquired during ESA's Giotto mission encounter with Halley's Comet. International Halley Watch funding will support the archiving and distribution of ground-based observations.

The FY 1989 funding will also provide for continued operations of both the Infrared Telescope Facility in Hawaii and the Lunar Curatorial Facility in Houston, Texas.

Planetary Exploration—Committee Comments

The Committee authorizes $399 million for Planetary Exploration in FY 1989. This reflects a general reduction of $5 million to the President's budget request.

The Committee is deeply committed to a robust space science program and believes that the launch of our Nation's planetary spacecraft will greatly rejuvenate our space science program. The fact that two of the Planetary Exploration Program's spacecraft, Galileo and Ulysses, were both prepared for launch in May 1986 and are now scheduled for launch in November of 1989 and 1990, respectively, is indicative of the setbacks suffered by space science.

In light of these facts, the Committee has strongly endorsed NASA's FY 1989 budget request and program mix. Except for a general reduction of $5 million, the Committee has met the FY 1989 budget request despite severe budget pressures.

The Committee looks forward to the launches of the Magellan mission to Venus on the space shuttle in April 1989, and the Galileo mission to Jupiter on the space shuttle in November 1989. The Committee also anxiously awaits the Voyager/Neptune encounter in August, 1989.

However, the Committee is concerned with reports that NASA may be required to descope the instruments for the Mars Observer Mission because of technical problems in the development phase. The fact that similar problems have surfaced in other programs recently—ACTS and the GOES meteorological satellite—is cause for serious concern. The Committee expects to be advised formally of any problems in this program as soon as they occur in order to prevent unnecessary cost escalations or schedule delays.

At this point, the Committee also should indicate that pursuant to the availability of funds, it has authorized the procurement of a Titan III for the Mars Observer Mission and has authorized initi-

ation of the procurement of a Titan IV planetary backup. As is noted in the Committee Comments for Expendable Launch Vehicles, the Committee has partially funded the Titan IV.

The Committee believes that the Mars Observer mission is an important space science mission that has important foreign policy implications. The current degree of interaction and data sharing between the United States and Soviet Union, both of whom have aggressive Mars Missions planned, points to the potential benefits of international cooperation in space. Despite these recent advances, the Committee does not yet believe the conditions exist—political, budgetary or foreign policy—to support initiation of a joint U.S./U.S.S.R. Mars program leading to support a cooperative manned mission to Mars. The Committee does look most favorably at on-going activities between the Unites States and the Soviet Union in the global change arena and towards furtherance of the April, 1987 Agreement Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes. And the Committee hopes these areas of mutual cooperation are broadened and expanded over the course of time. However, the Committee believes that many small steps are required over an extended period of time before the United States commits to a major space initiative with the Soviet Union.

Finally, committee members are hopeful that the FY 1990 NASA budget request will contain a new start request for the Comet Rendezvous Asteroid Flyby/Cassini Mission and that the final approved budget will be able to accommodate these two missions critical to the leadership position of the U.S. planetary science program.

4. Space Applications—$628,300,000

The Committee authorizes $628,300,000 for Space Applications—Solid Earth Observations, Environmental Observations, Materials Processing in Space, Communications and Information Systems—in FY 1989. This is $66 million more than the President's request.

Of this amount, $82,100,000 is for Solid Earth Observations; $358,300,000 is for Environmental Observations; $73,400,000 is for Materials Processing in Space, $92,200,000 is for Communications, and $22,300,000 is for Informations Systems. However, a general reduction of $10 million must be absorbed by these accounts at NASA's discretion.

A. SOLID EARTH OBSERVATIONS—$82,100,000

The Committee authorizes $82,100,000 for Solid Earth Observations in FY 1989. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to the Space Applications account.

Summary of FY 1989 funding levels

Payload and Instrument Development	$25,300,000
Geodynamics	33,900,000
Research and Analysis	22,900,000
Total Solid Earth Observations	[1] 82,100,000

[1] Could be required to absorb part of $10 million general reduction to the Space Applications account.

The objectives of the Solid Earth Observations program are to understand the processes controlling the state of the land-surface and the interior of the Earth, as well as the interaction of the solid Earth with the atmosphere and the oceans. The Solid Earth Observations Program is an integral part of the overall NASA Earth Science and Applications effort to increase understanding of the planet Earth through the study of its dynamics, the physical processes which affect habitability, and solar-terrestrial environment.

The major objectives of the Solid Earth Research and Analysis program are to characterize the current state of the terrestrial landscape, including the biosphere and hydrosphere, and the changes and change mechanisms that are occurring within that landscape. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climate system, the composition and evolutioin of the Earth's crust and the processes that shape the Earth's crust are essential to these objectives.

The geodynmics research objectives include determination of the movements and deformation of the Earth's crust, the processess which drive tectonic plates, the rotational dynamics of the Earth and its interactions with the atmosphere and oceans, the Earth's gravity and magnetic fields, and the interior structure and composition of the Earth. These objectives require precise measurements of crustal movements and Earth orientation over an extended period along with accurate knowledge of the Earth's geopotential fields and their variability.

The objective of the Shuttle/Spacelab payload development program is to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data for solid earth observations research. The Shuttle Imaging Radar-B (SIR-B), which was flown on the Shuttle in October 1984, has demonstrated the utility of spaceborne imaging radar for geopolitical exploration. The Large Format Camera (LFC), required for high resolution mapping applications, was flown successfully on the Shuttle in 1984 and is presently under consideration for commercialization. The next generation Shuttle Imaging Radar (SIR-C), which involves the use of SIR-B components, is a multi-polarized, dual frequency instrument under development for flight in 1991. The imaging spectrometer and solid-state sensor research efforts will continue to focus on the development of such features as electronic scan, inherent geometric and spectral registration and programmable high spatial and spectral resolution.

Payload and Instrument Development

The objective of this program is to develop, test, and evaluate Earth-viewing remote sensing instruments and systems to obtain data for and to develop the techniques for land remote sensing research.

Components of the SIR-B will be used in building the next generation Imaging Radar instrument, SIR-C. The SIR-C will use

multi-polarized, dual frequency sensor technology. SIR-C is in the development phase; System Requirements Review, Antenna Preliminary Design Review and System Preliminary Design Review are complete. In October 1987, NASA signed a Memorandum of Understanding with the Federal Republic of West Germany agreeing to joint missions of SIR-C with an X-band imaging radar to be provided by a joint German/Italian project (X-SAR). Preparations continue for commercialization of the LFC.

Advanced spectrometer technology development activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and liner array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the Shuttle Imaging Spectormeter Experiment (SISEX) and the linear array focal plan will continue.

Funding for FY 1989 is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the SISEX.

Geodynamics

The objective of the Geodynamics program is to understand the origin, evolution, and current state of the solid Earth by measuring the movement and deformation of the tectonic plates and by measuring its rotational dynamics and potential fields. Laser ranging to satellites and the moon, microwave interferometry using astronomical radio sources and transmissions from the Global Positioning Satellite System (GPS) are used to determine precise position locations. The global gravity and magnetic fields are determined from satellite observations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about six cm per year. In addition, measurements indicate that about four cm of this movement is occurring in Southern California.

In FY 1989, measurements of plate motion between North America and Europe will be continued in cooperation with countries in Europe, Middle East, Far East, South, and Central America. Measurements of the motions of the Pacific Plate will be continued in cooperation with Japan and China. Regional crustal deformation measurements in western North America will continue in cooperation with The National Oceanic and Atmospheric Administration (NOAA), Canada and Mexico. The Caribbean studies will be continued and include more sites along the plate boundary and on the plate itself.

LAGEOS-1 (Laser Geodynamics Satellite) and other satellites will continue to be used for studies of plate motion. NASA systems in the United States, Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The LAGEOS-2, a joint mission with Italy, is presently under development by Italy and will be launched by the United States on the Space Shuttle in 1991.

Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1989. In addition, system studies of a second magnetic field satellite for long-term measurements of the Earth's field (Magnolia/MFE), studies of geopotential research, and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

Research and Analysis

The research and analysis program has four main elements and four main goals. The broad goal of the Biogeochemical Processes program is to achieve an improved understanding of the role of terrestrial biota in processes of global significance through the use of airborne and spaceborne sensors. The goals of the Hydrology program are to use remote sensing to achieve a better understanding of the regional and global storages and fluxes of the land component of the Earth's hydrologic cycle, to investigate the role of the hydrologic cycle in regional and global biogeochemistry, and to examine the interactions between land surface processes and regional and global climate.

The goal of the Geology program element is to derive a better understanding of the Earth's geology, geological history, and the processes that have shaped the surface of the Earth over geological time using spaceborne sensors. The Remote Sensing Science program's goal is a crosscutting activity which supports the three other disciplinary program elements through theoretical modeling and field measurements of land surface properties.

In FY 1989 emphasis will be on investigations using multiple sensors operating in the visible, near-infrared, shortwave infrared, thermal infrared, and the microwave. Advanced airborne instruments which are prototypes for the future Earth Observing System (EOS) will be used in a variety of geologic, ecological and hydrological experiments. The theoretical basis for the use of combined sensors will be developed within the Remote Sensing Science program element. Current theoretical models will be used in the design of these experiments which will be designed to meet specific scientific goals in the other program elements.

As a part of NASA's program for the study of Global Change, there will be a series of multitemporal ecosystems studies using the airborne prototypes of EOS instruments. Vegetation is dynamic over a growing season, and remote sensing coverage at an instant in time only captures one stage of the annual cycle. Repetitive coverage of selected sites offers the opportunity to study dynamic, and not just static, properties of ecosystems. NASA plans to select a small number of sites to be scheduled for multiple data acquisition spanning the growing season and to encourage several investigators to conduct investigations at any one site.

The two board goals of the Geology program expressed above will be addressed through focused efforts which will be idendified in workshops to be held during 1988. These are expected in the fields of volcanism (volcanic processes, monitoring, and hazard identifica-

tion/prevention), quaternary land climatologic history, and neotectonics of actively faulting areas.

Operational satellite systems will be used in conjunction with the advanced airborne sensors. Multiyear data sets from the Landsat Multispectral Scanner, the Advanced Very High Resolution Radiometer (AVHRR) and the Scanning Multifrequency Microwave Radiometer (SMMR) will be used to study global change on the decadal scale. Global data sets will be maintained using the AVHRR and the Special Sensor Microwave Imager (SSMI), which replaces the SMMR.

The initial phase of the International Satellite Land Surface Climatology Project's (ISLSCP) First ISLSCP Field Experiment (FIFE) will be completed. Guest investigators will be supported to broaden the base of users of this comprehensive data set, and mechanisms will be established to make the data available to other investigators.

Solid Earth Observations—Committee Comments

The Committee authorizes $82,100,000 for Solid Earth Observations in FY 1989. This is the same as the President's budget request. However, NASA may apply to this account a portion of the $10 million general reduction to Space Applications.

The Committee continues to believe that there is compelling scientific need to increase U.S. access to and utilization of multiple sources of remotely sensed data. This is especially true in light of the increased interest in Global Change issues. The Committee, therefore, is pleased that NASA, NOAA, the National Science Foundation (NSF), and the U.S. Geological Survey have agreed to participate in an Interagency Working Group on Data Management for Global Change. This Working Group should play a significant role in building a national data and information system for global change research which is consistent across agencies and involves and supports the university and other user communities. The Committee believes that this initiation should provide a vital link to other sources of remotely sensed data, and the Committee expects to be informed of significant developments related to this initiative.

Meanwhile, NASA should continue its activities to develop, test and evaluate Earth-viewing remote sensing activities, in particular the SIR-B.

As noted above, there is a growing interest in global change issues. The Committee, therefore, intends to work closely with NASA and other involved Federal agencies in the formulation of a National Global Change Research Plan that results in a well-defined, orderly global change research program.

B. ENVIRONMENTAL OBSERVATIONS—$368,300,000

The Committee authorizes $368,000,000 for Environmental Observations in FY 1989. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to the Space Applications account.

Summary of FY 1989 funding levels

Upper Atmosphere Research and Analysis	$34,000,000
Atmospheric Dynamics and Radiation Research and Analysis	32,800,000
Oceanic Processes Research and Analysis	21,600,000
Payload and Instrument Development	19,700,000
Mission Operations and Data Analysis	18,500,000
Interdisciplinary Research and Analysis	1,200,000
Scatterometer	15,800,000
Upper Atmosphere Research Satellite Program	102,900,000
Ocean Topography Experiment	97,800,000
Airborne Science and Applications	23,000,000
Total Environmental Observations	[1] $368,300,000

[1] Could be required to absorb part of $10 million general reduction to the Space Applications account.

The objectives of the Environmental Observations program are to improve our understanding of the processes in the atmosphere and the oceans; to provide space observations of parameters involved in these processes; and to extend the national capabilities to predict environmental phenomena, both short- and long-term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively, and sometimes only, observed from space. NASA's programs include scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites provide a unique view of the radiative, chemical, and dynamic processes occurring in the atmosphere and oceans.

To achieve these goals, a number of significant objectives have been established for the next decade. These include advancing the understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; optimizing the use of space-derived measurements in understanding large-scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; and improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation; flight of the instruments on the Space Shuttle, dedicated spacecraft and flights of opportunity; collection of *in situ* ancillary or validation data; and scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then to collect appropriate data, through remote and *in situ* means, which will address specific program objectives.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Eargh orbit which will make comprehensive measurements of the state of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable.

Detailed definition studies of the instruments have been completed, and the design and development activities are well under way.

Development of the UARS observatory will continue in FY 1989, consistent with a planned launch in 1991.

The Earth Radiation Budget Satellite (ERBS) was successfully launched in 1984, and data continues to be collected from the satellite. NOAA-F was launched December 12, 1984, and NOAA-G was launched September 17, 1986, both equipped with Earth Radiation Budget Experiment instrumentation. NASA is also continuing to support NOAA by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis.

Design and development activities are being continued in FY 1989 on the NASA Scatterometer (NSCAT), the objective of which is to acquire global ocean data for operational and research use by both military and civil sectors. While the U.S. Navy reviews the possible continuation of the Navy Remote Ocean Sensing System (N-ROSS) program, Scatterometer instrument development continues along with planning for alternative spacecraft flight opportunities.

Development of the Ocean Topography Experiment (TOPEX) began in FY 1987 and will continue in FY 1989. Its objective is to acquire precise observations of the surface topography of the oceans. These data, in conjunction with those from NSCAT, will enable the first determination of the wind forcing and ocean current resposne of the global oceans. Spacecraft development efforts have begun at Fairchild, while the Johns Hopkins Applied Physics Laboratory continues work on TOPEX Altimeter development.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long-term trends of the Earth's atmosphere, oceans and polar ice, and provides near real time data. Collection and analysis of Solar Mesosphere Explorer (SME) data, the only mesosphere data currently available, continues.

Shuttle payload and instrument development activities provide the airborne and spaceborne data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument activities include Shuttle payloads such as Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS), Active Cavity Radiometer (ACR), and Light Detection and Ranging (LIDAR).

Along with the Solid Earth Observations program, the Environmental Observations activities compose an integral part of NASA's total Earth sciences and applications efforts, with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and solar-terrestrial environment.

Elements of the Mission Operations and Data Analysis Program and the Payload and Instrument Development Program as well as the entire Tether Satellite Payloads, Space Physics Research and Analysis, and Global Geospace Science programs have been transferred to Physics and Astonomy in the recent OSSA reorganization and creation of the Space Physics Divison.

Upper Atmosphere Research and Analysis

The upper atmosphere research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric processes research, and tropospheric chemistry research.

In particular, the goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the stratosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities.

A variety of *in situ* and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from a limited number of satellites are now generally available to the scientific community, including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents. This data is being exploited to determine if trends in the ozone amount can be detected and to understand those processes which are directly involved with these trends.

Recent developments in our understanding of the ozone layer have revealed a possible non-linear dependence of ozone depletion on the amount of fluorocarbon released to the atmosphere. These findings place increased urgency on the need to verify the completeness and accuracy of the theoretical stratospheric models. In FY 1989, tests of the models will be continued by means of field measurements, model calculations, and interpretation of satellite data. The development of more realistic two- and three-dimensional models will be continued. The global data sets from past and present satellites will be further analyzed in FY 1989 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1989 to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena of the atmosphere; they also help to validate satellite observations. Studies of potential new instruments for use on future satellites and suborbital measurement platforms will also be conducted in FY 1989 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric compositon and upper atmosphere measurements.

The recent observations of a depletion in the amount of ozone over Antarctica in the austral spring have attracted a great deal of attention. In order to understand the chemical and dynamic processes that are causing this phenomena, a major aircraft mission conducted in late FY 1987-early FY 1988 using NASA ER-2 and DC-8. Analysis and interpretation of the results of this mission will be a critical effort in FY 1988. An Arctic and/or return Antarctic mission is planned for FY 1989 based on the results of the 1987 campaign.

Atmosphere Dynamics and Radiation Research and Analysis

The research and analysis activities within the Atmospheric Dynamics and Radiation program combine a core effort which is essential in order to use space technology to address problems in atmospheric sciencies. The three main thrusts in the program are in the areas of Global-Scale Processes, Mesoscale Processes and Climate Research.

The objectives of the global-scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capabilities to observe the atmosphere from space.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and local to regional scales (severe weather, such as tornadoes and hurricanes). Since all of the characteristic parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured.

Finally, the Climate Research Program seeks to develop a space capability for global observations of climate parameters to increase our understanding of the process that influence climate and its predictability. In accordance with the National Climate Program priority, research in solar and Earth radiation is led by NASA.

A significant research effort to develop the capability for observing rainfall from space continues. Studies of instruments, sampling requirements, algorithm development, and modeling indicate the feasibility of sensing rainfall from space for climatic purposes. Under a bilateral agreement with the Science and Technology Agency of Japan, NASA is cooperating in a joint study of a special mission to measure tropical rainfall. Studies to accommodate a rainfall measurement experiment on the Space Station have been initiated and will be continued.

Funding for FY 1959 is required for support of the Global Backscatter Experiment (GLOBE). Two field campaigns are scheduled in GLOBE using the NASA DC-8. These airborne observations and the auxiliary observations to be made from ground-based and satellite observatories will be used to determine the seasonal and geographic variations in the backscatter of laser radiation due to atmospheric aerosols. In addition to increasing our understanding of the optical properties of the atmosphere, these data are needed in the system design of the Laser Atmospheric Wind Sounder (LAWS), a facility instrument for the future EOS.

An initiative in Radiative Gas Effects is being planned as a potential new focus for the Climate Research program during FY 1989. In particular, plans for the detection of greenhouse effect on climate from space observations will be pursued.

Funding for FY 1989 also is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and weather fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in four-dimensions. Continued analysis of the data collected in interagency field experiments during FY 1986 and 1987 will be performed. In addition, experimental, theoretical, and computational work will be done to better define the capabilities and requirements for the remote measurement of rainfall; and preliminary planning, experiment design, and technology development will begin for the large, multiagency STORM program to evaluate the research and operations potential of new meteorological remote sensors such as the sounder on GOES-NEXT, NEXRAD, AWIPS-90, ASOS, SSM-I, AVHRR-3 and high-altitude active and passive sensors to estimate precipitation.

Oceanic Processes Research and Analysis

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems.

The Oceanic Processes R&A program is organized into three discipline areas: (1) physical, (2) biological, and (3) polar oceanography. In physical oceanography, satellite scatterometers and altimeters are used to observe surface roughness and topography, from which surface winds and ocean current response can be estimated. In biological oceanography, color scanners are used to observe chlorophyll concentration, from which primary productivity can be estimated. In polar oceanography, microwave radiometers and synthetic aperture radars are used to estimate the characteristics of sea-ice cover and the details of its motion.

The Oceanic Process R&A program operates in concert with other federal agencies (Navy, NOAA, and NSF) and foreign countries (Canada, Europe, and Japan) for the World Climate Research Program (WCRP). Component WCRP efforts include the Tropical Ocean/Global Atmosphere (TOGA) and World Ocean Circulation Experiments (WOCE), a Global Ocean Flux Study (GOFS) and a Program for International Polar Oceans Research (PIPOR).

In FY 1989, the physical oceanography research activities will include implementation planning for WOCE and TOGA, as well as the development of assimilation techniques to incorporate altimeter and Scatterometer data into numercial models for use in determining the general circulation of the oceans. In biological oceanography, global ocean productivity will be assessed based on analyses of Nimbus-7 Coastal Zone Color Scanner (CZCS) data, in order to help with the conceptual design of the Global Ocean Flux Study. In addition, implementation studies will be performed with EOSAT for potential flight of an ocean-oriented color scanner (Sea WIFS) aboard the Landsat-6 spacecraft. In polar oceanography, emphasis will be placed on the experimental design for PIPOR, which is planned to involve direct reception at the Alaska Synthetic Aperture Radar (SAR) Facility in Fairbanks of SAR data from the ESA ERS-1 (Earth Resources Satellite) and from the Japanese Earth Resources Satellite (JERS)-1 spacecraft, due for launch in 1990 and 1992, respectively.

Significant work on the NASA Ocean Data System will be performed in order to optimize its use as a scientific support facility for the ocean research community. NASA's activities are being co-

ordinated with the Office of Naval Research, NSF, and NOAA in order to assure that appropriate computing facilities, data archives, and communication networks will be available for the utilization of spaceborne observations from missions, planned within the next decade.

Payload and Instrument Development

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Environmental Observations program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical. Instrument development activities support a wide range of instrumentation—from airborne to international flights of opportunity.

Funds for 1989 will be used to support the Measurement of Air Pollution from Satellites (MAPS) science team activities including data reduction, refurbishment for reflight and upgrading of the ground services equipment. The FY 1989 funding for ATMOS is required to support the ground observation program as well as continued science team activities, data processing and analysis, and limited refurishments. FY 1989 funding is also required to continue the ACR data processing, science team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Preliminary definition on the advanced instrumentation and data facilities associated with the future EOS will be continued in FY 1989. The EOS is the intended payload on the Space Station's polar platform. Instrument definition and feasbility studies will be continued along will related system engineering and payload accommodation studies. Release of an Announcement of Opportunity to the Scientific Community is presently planned for FY 1988. Further detailed review of those proposals will be conducted in FY 1989.

Development activities will continue on the international (United States and France) (LIDAR) airborne instrumentation following completion of critical design reviews in preparation for the integration, ground test and first flight in FY 1989 of this multi-phase user program. In this program, both NASA and the French are supplying scientific knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting.

Mission Operations and Data Analysis

The objective of the extended mission operations program is to provide for the operations, data processing, validation and data analysis of missions which have completed basic operations funded by approved project support.

Operation of the Nimbus and SME satellites and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meterological satellite. The SME and Nimbus satellites continue to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in FY 1989; these *in situ* observations are needed to verify the quality of remote observations and improve the ability to interpret them.

In addition, FY 1989 funding is required for operating the ERBS spacecraft and for data processing and analysis from the total three-instrument system, and from the SAGE-II instrument of ERBS.

Interdisciplinary Research and Analysis

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological processes on the land, along with the interactions between the land, the oceans, and atmosphere, which are of particular importance in assessing the impact of these phenomena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

In FY 1989, interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radiation, Upper Atmosphere/Troposphere Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the ocenas in the global carbon cycle.

Scatterometer

The NSCAT will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves). Flight of the instrument in 1992 for three years will provide an overlap of data gathering with the World Ocean Circulation Experiment, Tropical Ocean-Global Atmospheres Experiment planned by the international oceanographic community; and additionally, concurrent flight with TOPEX would result in unique measurements of the ocean's driving force (winds) and the resulting ocean response (topography).

The Scatterometer was designed to fly on the N-ROSS satellite in 1992. The N-ROSS program was cancelled in December 1986 due to financial constraints, but a lower cost version of N-ROSS was proposed by the Navy for reinstatement in April 1987. Unfortunately, after review by DOD, no funds were included in the FY

1989 DOD budget request for N-ROSS. In the meantime, NASA has been exploring a number of alternatives to N-ROSS, the most cost-effective of which will be selected for implementation.

During FY 1988, the antenna contract will be completed, and all six flight antennas will be finished. The Traveling Wave Tube (TWT) contract is scheduled to be completed, and the development of the other flight hardward items will be continued. The instrument Critical Design Review, which was delayed due to the N-ROSS cancellation, will be held, and delivery of the second computer system for the ground data system will occur.

Planned activities in FY 1989 include the continuation of flight hardward development leading to the beginning of flight unit integration and testing at the end of the fiscal year; the completion of software requirements definition; the initiation of detailed software design, both for the ground data and flight systems; conducting the PDR for the mission operation system; and confirmation of the science team which was delayed due to the uncertainty of N-ROSS.

Upper Atmosphere Research Satellite Program

The UARS program is the next logical step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for a STS launch in 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first intergrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere.

The FY 1989 funds are required for continuation of the development activities on the ten UARS instruments including flight hardware fabrication, instrument assembly and environment testing, leading to instrument delivery to the spacecraft in 1989. The spacecraft development and hardware fabrication activities will continue, including completion of the spacecraft mechanical test model program and the start of spacecraft integration and test in late FY 1988.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the flight hardware so that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time. In order to achieve this, FY 1989 funding is required to continue design and development of the ground data handling facility including hardware delivery and checkout, software preliminary and critical design reviews, science team support and science algorithm development.

Ocean Topography Experiment

The goal of this program, TOPEX, is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability.

NASA and the French Space Agency (CNES) are collaborating on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in late 1991 using Ariane. TOPEX is also being planned in concert with WOCE, a major international oceanographic field program being planned under the auspices of WCRP.

In FY 1989, the design of the satellite, sensor, and ground data system will be completed, leading to the initiation of full-scale spacecraft system development. Final arrangements are expected to be made by CNES for the French-provided Ariane launch vehicle; the mission design will be refined based on input from and interaction with the Science Team; and the Science Team will be confirmed so that they can begin to refine their post-launch research and verification plans.

Airborne Science and Applications

This effort covers operation of an ER-2, two U-2C's, a C-130, and a DC-8 in order to support Earth-sensing and atmospheric research. The DC-8 was acquired to replace the CV-990 research facility, "Galileo II," which was destroyed in 1985. The replacement DC-8 has undergone required upgrades and modifications and carried out initial operations in Antarctica in 1987 as part of the Ozone Hole campaign. Acquisition of a second ER-2, to replace the aging U-2C's is under way. These aircraft support other major segments of the Space Science and Applications program dealing with the Earth, the oceans, and the atmosphere.

Requested FY 1989 funding will allow operation of the DC-8, two ER-2's, and the C-130. Operation of the aircraft will allow continuation of such projects as the collection and analysis of stratospheric air samples, testing of newly developed instrumentation, the demonstration of new sensor concepts, the investigation of the Ozone Hole phenomena, and participation in numerous other field experiments, such as First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE). The FY 1989 budget will also provide for NASA's final payment to the U.S. Air Force, thereby completing the purchase of the second ER-2 aircraft.

Environmental Observations—Committee Comments

The Committee authorizes $368,300,000 for Environmental Observations in FY 1989. This is the same as the President's budget request. However, NASA may apply to this account a portion of the $10 million general reduction to Space Applications.

The Committee notes that the interest in Global Change, highlighted in the Committee Comments for the Solid Earth Observations, is further solidified in this account that supports the development of ocean/atmospheric spacecraft, advanced instruments, and aircraft observations. At the outset, the Committee applauds the members of the NASA research teams who participated in the Antarctica Ozone Hole Campaign last year and who supported the U.S.

delegation to the Montreal Protocol Talks concerning chlorofloro-carbons.

The Committee reiterates its support of the Upper Atmospheric Research Satellite program—this mission will provide the first integrated global measurements of ozone concentration and chemical species that affect ozone—and the Ocean Topography Experiment. Both of these missions appear to be on schedule for launch in 1991 and should significantly improve our understanding of atmospheric and oceanic processes.

The Committee strongly supports the proposed enhancement in FY 1989 of the preliminary definition activities of the advanced instrumentation and data facilities of the EOS—the intended payload on the space station's polar platform.

The Committee is concerned that the Navy has once again terminated the N-ROSS and that currently there is no assigned spacecraft on which to fly the NSCAT. The Committee understands that discussions are under way with the government of Japan to fly the scatterometer on a Japanese spacecraft, and the Committee expects to be kept well-apprised of the situation. Meanwhile, the Committee recommends that NASA proceed with the development of the scatterometer and complete the hardware development as soon as possible.

Finally, committee members recommends that NAA earmark $10 million of the approved FY 1989 budget for Environmental Observations for Earth Probes—small-scale expendable satellites with focused science objectives that will result in the evolutionary development of earth science satellites.

C. MATERIALS PROCESSING—$73,400,000

The Committee authorizes $73,400,000 for Materials Processing in FY 1989. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to the Space Applications account.

Summary of FY 1989 funding levels

Research and Analysis	$13,600,000
Microgravity Shuttle/Space Station Payloads	59,800,000
Total Materials Processing	[1] $73,400,000

[1] Could be required to absorb part of $10 million general reduction to the Space Applications account.

The mission of the Microgravity Science and Applications Program is to foster the development of near-earth space as a natural resource by exploiting microgravity and other unique attributes that may be attained in an orbiting spacecraft. In this environment we can advance knowledge about the fundamental nature of matter, increase understanding of the role of gravity in various industrial processes, and produce limited quantities of certain exotic high value materials for specialized applications. In FY 1989, ground-based research and payload development will be concentrated in six major areas: metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena.

During FY 1989, ground-based research will support definition studies for Shuttle and Space Station experiment candidates in areas such as containerless experiments, solidfication and crystal growth, and processing of biological materials. Researchers will conduct experiments in drop tubes, towers and aircraft. The ground-based research program also includes support for studies conducted under Technical Exchange Agreements.

The Microgravity Shuttle/Spacelab Payloads program provides a range of experimental capabilities for all participants in the Materials Processing in Space program. The payloads program currently supports a wide variety of hardware development, from unique flight experiments necessary to conduct basic research into the fundamental nature of matter to the modular, multi-user research facilities that will be the cornerstone of microgravity science and applications research on the Space Station. Experiments will be flown on Shuttle and Spacelab, as well as any promising commercial space facility.

Research an Analysis (Materials Processing)

The research and analysis activity provides the scientific foundation for all current and future projects in the Microgravity Science and Applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities and applications activities leading toward privately funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which have been extensively reviewed by peer groups prior to selection.

Ground-based research and analysis will be continued in FY 1989 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the centers for bioprocessing research located at the University of Arizona and the University City Science Center in Philadelphia, PA. as well as the Microgravity Materials Science Lab at the Lewis Research Center.

Microgravity Shuttle/Space Station Payloads

The Mocrogravity Shuttle/Space Station payloads program provides a wide range of opportunities for experiments in microgravity science and applications. NASA currently supports the development of STS mid-deck, Spacelab and cargo-bay experiments. This policy maximizes the effective use of the STS by matching an experiment with the hardware location best suited to meet its scientific and technical requirements. In some cases, the payload program supports an evolutionary program of testing flight experiment concepts in the mid-deck before committing to more complex and ambitious Spacelab or cargo-bay mounted hardware.

- The Materials Processing in Space program is preparing to use Space Station as a major platform for conducting microgravity research. During FY 1987, NASA received funds from Congress to begin technical definition of six major multi-user research facilities

designed to take advantage of Space Station's unique capabilities. NASA's Microgravity Science and Applications Division (MSAD) is developing a strategy for orderly evolution of microgravity experiments from ground-based research to the Shuttle, and finally to Space Station. During FY 1988 and FY 1989, MSAD will continue Space Station hardware definition and will initiate equipment development for both the first U.S. Microgravity Laboratory Spacelab mission and any promising commercial microgravity facility.

In addition to the planned Space Station Initiative, the Materials Processing in Space program is placing increased emphasis on NASA's Physics and Chemistry Experiments (PACE) program, which uses microgravity research to challenge and improve existing scientific theory about the fundamental nature of matter. As other nations increase their ability to exploit the characteristics of near-Earth space, the "cutting edge" experiments generated by the PACE program will play an increasingly important role in assuring continued U.S. leadership in microgravity research.

Funding for FY 1989 is required to continue basic and applied research activities using STS mid-deck Spacelab and cargo-bay experiments leading to several flights over the next few years. Investigations are planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will continue on a number of PACE initiatives as well as several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metallic casting, and levitation. An augmentation has been included, building on the FY 1988 congressional increase, to develop the advanced second and third generation microgravity payloads which will be flown on the STS, Space Station, and any promising commercial space facility.

Materials Processing—Committee Comments

The Committee authorizes $73,400,000 for Materials Processing in FY 1989. This is the same as the President's budget request.

The Committee is most supportive of NASA's materials processing activities and believes that the long-term return from this program will be substantial. However, the Committee is concerned that if early unrealistic expectations for success are not met support for the program in later years could be affected.

As a result of the Committee's assessment of the proposed Commercially Developed Space Facility, the Committee has instructed NASA to contract with NAS to undertake a thorough and independent review of the Nation's microgravity research program and implementation plan. The Committee expects NASA to cooperate fully with this study and to provide all pertinent data.

The Committee is optimistic that as a result of this Academy study, which builds upon the findings and recommendations of NAS's recent report, "Industrial Applications of the Microgravity Environment," the Committee will be able to determine better the interim requirements for materials processing in space.

Meanwhile, the Committee continues to support the Materials Processing in Space program and will continue to work with NASA to maintain U.S. technological leadership in this critical area.

D. COMMUNICATIONS—$92,200,000

The Committee authorizes $92,200,000 for Communications in FY 1989. This is $76 million more than the President's budget request and reflects the Committee's strong support of the Advanced Communications Technology Satellite and the Nation's continued leadership in communications. However, this account could be required to absorb part of the $10 million general reduction to the Space Applications account.

Summary of FY 1989 funding level

Advanced Communications Technology Satellite (ACTS)	$76,000,000
Advanced Communications Research	10,486,000
Search and Rescue	1,350,000
Radio Science and Support Studies	2,900,000
Communications Data Analysis	1,464,000
Total Communications	[1] $92,200,000

[1] Could be required to absorb part of $10 million general reduction to the Space Applications account.

Advanced communications research continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to pursuing technologies with high potential for improving spectrum and orbit utilization, satellite antennas, on-board processing intersatellite links and around terminal designs, since these technologies are the key to future growth of the communication satellite and terminal markets. In addition, the mobile communications technology program will continue to address the development of critical enabling technologies needed to insure growth of a commercial mobile satellite service in the United States. This effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system in the early 1990's.

The search and rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system in which Norway, the United Kingdom, Bulgaria, Finland, and Denmark also participate.

Radio science and support studies, formerly technical consultation services, will provide for studies of radio interference, propagation and special systems required for the growth of existing satellite services and the extension of new satellite applications. Support to the Department of State, the Federal Communications Commission (FCC), the National Telecommunications and Information Administration, and other agencies in the development of frequency and orbit sharing techniques and strategies for upcoming World Administrative Radio Conferences (WARCS) is continuing.

Advanced Communications Research

The advanced communications research program emphasizes the development of high-risk technology required to maintain U.S. preeminence in the international satellite communications market, to

enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies.

In FY 1988, work is continuing on advanced communications technologies. Laser inter-satellite link communications technologies are being developed that will permit communications between satellites and ground terminals, satellites and low Earth orbiting vehicles, such as the Space Shuttle or Space Station, and between satellite and other geosynchronous orbiting satellites, such as the Tracking and Data Relay Satellite (TDRS). Technology development is also under way in the area of monolithic microwave integrated circuits (MMIC), which have significant potential for applications in multiport spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. A number of industry studies are being sponsored to assess new areas of communications technologies required for the 1990's.

The mobile communications technologies activity is aimed at accelerating the introduction of a commercial mobile satellite service in the United States and developing and testing power, bandwidth and orbital-slot efficient ground segment technology and networking techniques needed to insure its growth. An innovative NASA offer to industry was signed in FY 1985 by a consortium of U.S. companies which would provide a launch for the first generation commercial satellite in exchange for satellite transponder capacity that would be used by NAS and other government agencies for experimentation and technology validation. The endeavor to commercialize this new service got a recent boost with the allocation of frequencies and the formation of a single consortium that is applying to the FCC for license approval. NASA is planning a major government/industry conference in May to exchange information and facilitate the transfer of technology to industry.

The Research and Analysis program will continue to support development of the technologies necessary for future space communications satellite systems. During FY 1989, NASA will continue to work with U.S. industry and other government agencies to complete field testing of advanced communications hardware and help accelerate the introduction of mobile satellite communications service in the United States. Work in laser communications technologies will be continued.

Search and Rescue

The United States (NASA, NOAA, the Coast Guard, the Air Force, and the Federal Aviation Administration), Canada, France, and the Soviet Union developed the search and rescue system in which Norway, the United Kingdom, Bulgaria, Finland and Denmark also participate. The Search and Rescue (SAR) satellite system was declared operational in July 1985. NOAA maintains operational responsibility for search and rescue, while NASA's role is tightly focused on the research and development aspects.

The SAR program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve significantly the ability to detect and locate general aviation aircraft and marine vessels during emergencies. The system has received world-wide acclaim and has been credited with saving over 1,000 lives to date.

Funding in FY 1989 will continue the NASA unique research and development role in low-cost emergency beacon development, the next generation satellite-borne SAR equipment and advanced techniques to improve system precision.

Radio Science and Support Studies

Radio science and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intra-satellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1988, the radio science and support studies program will continue further development of a geostationary arc allotment concept as part of the U.S. preparations for the FY 1988 Space WARC. Also, propagation studies will continue to help minimize radio signals atmospheric interference problems in space communications.

During FY 1989, major emphasis of the radio science and support studies program will be studied to identify and quantify the adverse effects of propagation phenomena on satellite communications as well as remote sensing. Work will coninue to identify systems and technologies that make effective use of the frequency spectrum and geostationary orbit.

Communications Data Analysis

The objectives of communications data analysis are to support and to document a wide range of user experiments and demonstrations of the application of satellite communications. Past experiments on experimental satellites, such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to make informed decisions regarding the satellite communications functions. NASA's role to stimulate use of unique space facilities has led to wider applications of commercial satellites that better meet the needs of potential users.

The remaining ATS satellite, ATS-3, continues to support NSF, NOAA, the Department of Commerce, the Department of Interior, the Drug Enforcement Administration, several universities, state and local governments, and a number of domestic and international disaster relief organizations. Support is provided through satellite voice and data links for Scientific and communications experiments to North and South America, most of the Atlantic Ocean, and a large part of the eastern Pacific, including Hawaii and Antarctica.

Communications data analysis support of ATS-3 will continue, as will experiment definition and data analysis for laser communications analysis.

Communications data analysis, formerly the experiment coordination and operations support, assists other federal agencies and

public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. Operation of the ATS-3, launched in 1967, will continue.

Communications—Committee Comments

The Committee authorizes $92,200,000 for Communications in FY 1989. This is $76 million above the President's request and would accommodate the continued development of the ACTS.

The Committee strongly supports the ACTS program because it is critical to the future of the United States in the world communications market. Furthermore, the Committee continues to believe that the development of the ACTS technologies is an appropriate research and development function of NASA.

The Committee funds that the OMB justification for the exclusion of any funding request for ACTS in FY 1989 is without merit and in direct conflict with the President's Directive on National Space Policy. The Committee expects funding for the ACTS program to be included in the FY 1990 budget submission.

At a time when the United States suffers from an adverse balance of trade and the Europeans and Japanese are mounting substantial threats to our share of the world communications market, the Committee believes it is essential that the government and private sector cooperate to share the high costs and risks associated with the development of new technologies. The ACTS program is patterned on such a cooperative venture and represents a conscious effort on the part of the Congress to sustain the Nation's leadership in communications.

The Committee instructs NASA to proceed vigorously with the ACTS program in order to have the satellite ready for launch in 1992.

The Committee wants both NASA and the prime contractor for the ACTS program to realize that the Committee was most displeased with the revelations and events that led to the restructuring and capping of the ACTS program contract in January of this year. The Committee expects the program to live within this cap and would look unfavorably upon attempts to exceed this cap. The fact that the management and instrument development problems have delayed the launch of the ACTS for nearly two years, from 1990 to 1992, is already cause for concern. As a result of this delay, the previous advantage the United States enjoyed over its foreign competition in the development of this advanced communications technology has now been diminished.

E. INFORMATION SYSTEMS—$22,300,000

The Committee authorizes $22,300,000 for Information Systems in FY 1989. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to the Space Applications account.

Summary of FY 1989 funding levels

Data Systems	$11,400,000
Information Systems	10,900,000
Total Information Systems	[1] $22,300,000

[1] Could be required to absorb part of the $10 million general reduction to the Space Applications account.

The objectives of the Information Systems program are to: apply advanced data systems technology to support the data management, scientific computing and information systems needs of NASA scientific research programs; conduct research programs and projects in the area of information systems and related technologies to enhance scientific productivity in the handling and analysis of data acquired from space flight experiments and observations; and implement information system standards, coordinate data systems requirements, and promote multi-mission sharing to lower information systems costs.

The information systems program provides the focus for integrated information systems planning across OSSA scientific disciplines. This includes definition of an end-to-end architecture or planning model to exploit commonality of requirements as appropriate, and to define interfaces for integrating mission- and discipline-specific portions with common core capabilities. The information systems program also provides leadership in assessing and evaluating advanced techniques, capabilities, and technologies especially as they support the information systems requirements associated with the highly complex sensors, complicated operational scenarios, extended-duration missions and multi-disciplinary requirements anticipated during the Space Station era.

The FY 1989 information systems program will continue emphasis on science information systems in support of Space Science and Applications programs, includes the ocean, climate, land processes, and planetary and astrophysics systems. Emphasis will be placed on the coordinated development of these systems to promote interdisciplinary studies. In addition, emphasis will continue on the applications of computer science technologies to support the work of the NASA science disciplines. Funding is included for continued operation of scientific computing resources such as the NASA Space and Earth Sciences Computing Center, the Massively Parallel Processor, and the National Space Science Data Center. The information systems program will continue to develop common software to support ongoing research in the space and Earth sciences and continue development of data management and data archiving to support flight projects, science, applications, and research disciplines.

Information Systems—Committee Comments

The Committee authorizes $22,300,000 for Information Systems in FY 1989. This is the same as the President's budget request.

The Committee strongly supports the development and demonstration of advanced information systems and believes they are critical to the success of the Nation's space program.

5. COMMERCIAL PROGRAMS $57,900,000

The Committee authorizes $57,900,000 for Commercial Programs in FY 1989. This includes $19,100,000 for Technology Utilization

and $38,800,000 for Commercial Use of Space. This is the same as the President's request.

Summary of FY 1989 funding levels

Technology Utilization	$19,100,000
Commercial Use of Space	38,800,000
Total Commercial Programs	$57,900,000

Technology Utilization

The NASA Technology Utilization Program is designed to strengthen the national economy and industrial productivity through the transfer and applications of aerospace technology resulting from NASA's research and development programs. To accomplish this objective, NASA has established and operates a number of technology transfer mechanisms to provide timely access of useful technologies to the private and public sectors of the economy. Almost every part of U.S. industry is affected by the technology transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation and safety are areas in which aerospace technologies have been especially beneficial. The specific objectives of the program are:

—To accelerate and facilitate the application of new technology into the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

—To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist;

—To develop applications of NASA's aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

NASA has continued its broad and comprehensive efforts to promote and encourage the effective applications and use of new and innovative aerospace technologies throughout the public and private sectors of the U.S. economy. Of particular note is the upward growth of industrial and business subscribers to *NASA Tech Briefs* which now exceeds 160,000 readers. This 100 percent increase since January 1985 represents a growth rate averaging over 5,000 new subscribers per month—an effective measure of the importance and value which U.S. industry places on new and emerging technologies.

Moreover, the NASA-sponsored Industrial Applications Center (IAC) network has made significant strides in developing effective linkages with state-sponsored institutions engaged in industrial and economic growth. This broadening and strengthening of the nationwide technology transfer network is continuing to gather momentum with nearly 30 of the 50 States now being linked to transfer products and services available through the IAC efforts. NASA expects to continue this effort during the balance of FY 1988 and into FY 1989. An additional milestone was reached in late 1986 when the Federal Laboratory Consortium (FLC) for Technology Transfer (established under P.L. 99-502) and NASA elected to enter into an agreement in early 1987 which establishes formal linkages between the IAC network and the various Federal laboratories. Based on the successful completion of an experimental program between the IAC at the University of Southern California and the FLC Farwest Region, IAC industrial clients will now be able to gain controlled access to Federal laboratories nationwide that are engaged in research and development activities of parallel commercial interest. This effort is spurring the acceleration of technology transfer and application of Federally-sponsored technologies into the mainstream of the U.S. economy. NASA is also seeking to familiarize and involve the private sector to a greater extent. The hiatus in Shuttle flights caused by the Challenger accident has shifted the focus of NASA's commercial programs from in-space experimentation to ground-based opportunities and exploitation of available technology. The IACs are a natural focal point for increasing awareness of available technology and opportunities.

Several important events occurred during the past 18 months in which several NASA-sponsored technology applications projects came to fruition. Among these was the first human implant of the Programmable Implantable Medication System (PIMS) at the Johns Hopkins University (JHU) Hospital in November 1986. This successful human application of PIMS culminates several years of an intensive collaborative effort between NASA, the JHU Applied Physics Laboratory, and various private sector firms, and initiates a two-year clinical test period in which over 20 implantations will occur. All of these applications during the test period will be for patients with chronic diabetes.

Finally, NASA authorizes experimental technology transfer programs involving process and product at the Jet Propulsion Laboratory (JPL) as a means to enhance access to that laboratory's technology by small and large industrial firms. In May 1986, NASA entered into a cooperative agreement with the non-profit California based Research Institute for the Management of Technology (RIMTECH) to introduce JPL technology to industrial users in the Southern California area. For an entry fee, RIMTECH clients are offered NASA's technical assistance, information retrieval services, licensing rights and the possibility of cofunding of projects in the development stage. NASA, in turn, fulfills its charter and accrues the benefits of a broadened high-tech base industry, incentives for JPL employee creativity, potential royalties from patent licensing, and reverse technology transfers to NASA and the JPL from industry. At present, 15 industrial firms are participating in these programs, and another 25 firms are expected to join within the next 12 months.

In FY 1989, NASA plans continued strengthening of the Technology Counselor network at its field installations to provide for expanded identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA Industrial Applications Centers.

In FY 1989, a broadening of application team responsibilities also is anticipated to assist NASA Industrial Applications Centers in bringing together industrial client problems with existing aerospace technologies leading to project definition and industry driven cooperative projects. This effort will result in increased tangible

and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

Finally, in FY 1989, NASA will utilize its existing dissemination center network to contact and acquaint U.S. industrial firms with opportunities to actively intereact and participate with NASA in technology transfer and space commercialization. Such contacts are envisioned on a face-to-face basis, with appropriate follow-up including seminars, conferences and workshops to explore more detailed characteristics of the "opportunities" for interaction.

Commercial Use of Space

The goal of the Commercial Use of Space program is to establish a national focus in support of opportunities for the expansion of U.S. private sector investment and involvement in civil space activities. The specific objectives of the program are to:

—Establish close working relations with the private sector and academia to encourage investment in space technology and the use of the *in situ* attributes of space—vacuum, microgravity, temperature and radiation for commercial purposes.

—Facilitate private sector space activities through improved access to available NASA capabilities and the development of the new high technology space ventures and markets.

—Encourage an increase in private sector investment in the commercial use of space, independent of NASA funding.

—Develop and implement commercial space policy NASA-wide.

Sixteen Centers for the Commercial Development of Space (CCDS) have been established since the start of the program. The average cost of a CCDS is just under $1,000,000 per year. Several CCD's have developed strong linkages with the private sector and are developing flight hardware for applied research in space.

In order to maintain momentum in commerical use of space activities, NASA will develop methods to facilitate private sector agreements and commitments to develop commercial opportunities in space. Institutions with strong research capabilities in sciences and engineering, in collaboration with industry and/or industrial associations, will be encouraged to participate in NASA-sponsored workshops and endeavors to accelerate U.S. commercial leadership in the use of space. Resources support and technical assistance will be partially furnished by NASA with the remainder furnished by the Center for the Commercial Development of Space.

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities will be partially achieved by increasing the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for potential commercial research.

Through coordination with various industrial sectors and NASA program offices, the commerical research and development enhancement efforts will provide generic, multi-use research experimentation equipment. This equipment, as well as ground-based hardware, software and analytical tools, will be developed in order to expand the technical research data base on the commercial uses of space required by the private sector to help make economic decisions to commit to research and, potentially, manufacture.

The NASA support for Joint Endeavor Agreements (JEAs) is directly proportional to the number of commercial research and development flight experiments scheduled, and it is intended to encourage private sector use of space facilities. The use of ground-based research facilities, aircraft and sounding rockets for commercial experimentation will be given emphasis in order to provide limited access to the microgravity environment for certain commercial experiments.

Commercial Programs—Committee Comments

The Committee authorizes $57,900,000 for Commercial Programs in FY 1989. This inlcudes $19,100,000 for Technology Utilization and $38,800,000 for Commercial Use of Space. This is the same as the president's budget request.

The Committee was pleased with the findings of the January NASA Report on how the NASA Technology Utilization Program places emphasis on projects and activities in applying technology to meet the needs of individuals with disabilities in the areas of employment, education, housing and recreation. The Committee believes this is and should continue to be an area of emphasis within NASA and that NASA should make every effort to disseminate information on technology transfer to these critical areas.

The Committee continues to support (CCDS) and the development of multi-user, multi-use government hardware. The Committee believes these two initiatives are a realistic approach to promoting commercial space activities. The combined involvement of government, industry and the university sectors in these activities is seen as a critical element of their potential success. However, based upon the Committee's review of the President's "Space Policy and Commercial Space Initiative to Begin the Next Century," the proposed request for proposal for a Commercially Developed Space Facility, and other related issues, the Committee realizes that there are still substantial differences of opinion as to the feasibility of "truly" commercial space activities and the type of Federal incentives and inducements that are required. While support for the CCDS program is broad-based, most other initiatives contained in the President's commercial space policy surface a variety of questions and issues.

The Committee is concerned that unrealistic expectations of space commercialization may fall short of the near-term realities and that over the long-run, this could affect adversely support for and the potential benefits of these activities.

The Committee also is concerned that non-operational space agencies, on occasions, have detracted from the administration's space commercialization process, and, consequently some space activities have suffered. The Committee is also concerned that certain fundamental budgetary and policy concerns have not been addressed adequately in all cases in the space policymaking process. The negotiations between the Committee, NASA and OMB concerning the Commercially Developed Space Facility clearly high-

lighted some of these deficiencies on the part of the executive and legislative branches.

The dilemma for the Committee is how to establish a commercial space policy with reasonable expectations and guidelines when it is not permitted access to the administration's space policymaking apparatus until after the fact.

Clearly, in the eyes of the Committee, NASA has a dominant role in the promotion of commercial space activities—and, on occasion, NASA has been uncertain of its appropriate role. However, the Committee is hopeful that this situation has been ameliorated and will continue to improve. Yet, because other federal agencies are involved with commercial space policy formulation, NASA is often unable to represent fully the Administration's position, and this has caused confusion at times. However, the Committee continues to believe that NASA is the key to the implementation of space commercialization.

The Committee recognizes the need for a consensus on space commercialization. It is unfair for U.S. companies and space entrepreneurs to be caught between the executive and legislative branches and to be faced with unclear and confusing guidelines and policies. To correct this deficiency, the Committee urges NASA and the administration to establish a Working Group with the Congress on space commercialization. Initially, this Working Group could consist of appropriate staff members who would seek to identify some near-term goals and guidelines that could give additional momentum to space commercialization. It would be the hope of the Committee that this Working Group could help support space commercialization and, where indicated, recommend changes to the administration's commercial space policy.

The Committee expects to work closely with the Office of Commercial Programs in formulating a reasonable commercial space policy, and the Committee has enlisted the assistance of the Congressional Budget Office (CBO) in this matter. (CBO has been asked to prepare a report on space commercialization.) It is still quite clear to the Committee that there are more questions than answers regarding commercial space initiatives and that much work needs to be done to ensure the success of space commercialization. However, the Committee is committed to asking the hard questions, finding the solutions, and proposing the best remedies and policies.

Finally, the Committee would like to indicate that it endorses NASA's proposal for use of external tanks in compliance with the President's Commercial Space Policy. The terms and conditions outlined in NASA's solicitation for expressions of interest in use of external tanks, as printed in the *Commerce Business Daily* on May 27, 1988, are agreeable to the Committee and represent a prudent strategy.

6. Aeronautical Research and Technology—$404,200,000

The Committee authorizes $404,200,000 for Aeronautical Research and Technology in FY 1989. This is $10 million less than the President's request and reflects a general reduction.

Summary of FY 1989 funding levels

Research and Technology Base	$314,200,000
Systems Technology Programs	100,000,000
Total Aeronautical Research and Technology	[1] $404,200,000

[1] Reflects general reduction of $10 million.

The goal of the NASA aeronautical research and technology program is to conduct research which contributes to a technology base that enables preeminence of U.S. civil and military aviation. This goal is supported by five comprehensive program objectives: (1) emphasize emerging technologies with potential for order of magnitude advances in capacity or performance which will enhance the U.S. defense and economic competitiveness; (2) maintain NASA's laboratory strength by repairing and modernizing critical aging national facilities, ensuring that necessary advanced scientific and engineering computational capabilities are available, and enhancing staff technical excellence by selecting highly qualified personnel and providing them with challenging career opportunities; (3) ensure the timely transfer of research results to the U.S. aeronautics community through reports, conferences, workshops, and active participation of industry in cooperative research programs; (4) ensure the strong involvement of universities in NASA's program to broaden the nation's base of technical expertise and innovation; and (5) provide technical expertise and facility support to DOD, other government agencies, and U.S. industry for major aeronautical programs. These objectives require a broad program of fundamental research that focuses on critical technologies and accelerates technology readiness for future vehicles. The program is based on a strong commitment to revitalize American competitiveness in the world aviation marketplace, enhance the safety and capacity of the national airspace system, and assure U.S. superiority for national security.

The NASA aeronautical research and technology program is intended to develop and validate emerging technologies for use by the aviation industry well in advance of specific applications through long-term independent research and technology development which is not driven by the development and operational pressures often encountered by DOD and industry. Fundamental research in the traditional aeronautical disciplines is pursued concurrently with systems research and technology validation.

With the U.S. superiority in aeronautics challenged as never before, the FY 1989 budget request reflects the need to accelerate technologies which are vital to long-term U.S. competitiveness, to continue a strong program in fundamental disciplines and in key areas of systems research, and to revitalize critical NASA wind tunnels. NASA's FY 1989 aeronautics program is focused on achieving the bold objectives established in the report, "National Aeronautical R&D Goals: Technology for America's Future," by the Office of Science and Technology Policy, and by its sequel report, "Agenda for Achievement," which enunciates an eight-point action plan for achieving the goals.

The FY research and technology program is committed to developing the technology basis for improving the nation's competitiveness and clear-cut product superiority in the international marketplace, enhancing the safety of aviation, and increasing the margin of the country's preeminence in aviation for national security.

Technologies are being pursued that offer an order of magnitude increase in vehicle capabilities and a substantially positive impact on U.S. competitiveness. Research efforts have been expanded in composite materials, advanced propulsion, and aviation safety. The demands for NASA's unique wind tunnels are growing with the emergence of the national aero-space plane (NASP) program, research on high speed civil transports, and a new generation of military aircraft. In order to ensure wind tunnel availability to meet these demands, a major revitalization program is required over the next five years to modernize NASA's major wind tunnels for productive use for the next decade and into the 21st century. This program is included in the FY 1989 construction of facilities budget.

A. RESEARCH AND TECHNOLOGY BASE—$314,200,000

The Committee has authorized $314,200,000 for FY 1989 for Research and Technology Base. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to Aeronautical Research and Technology.

Summary of FY 1989 funding levels

Fluid and Thermal Physics Research and Technology	$26,500,000
Applied Aerodynamics Research and Technology	64,300,000
Propulsion and Power Research and Technology	70,100,000
Materials and Structure Research and Technology	40,100,000
Information Sciences Research and Technology	23,000,000
Controls and Guidance Research and Technology	35,700,000
Human Factors Research and Technology	19,700,000
Flight Systems Research and Technology	28,800,000
Systems Analysis	6,000,000
Total Research and Technology Base	[1] 314,200,000

[1] Could be required to absorb part of $10 million reduction to Aeronautical Research and Technology.

Fluid and Thermal Physics Research and Technology

In fluid and thermal physics, increased research emphasis will be placed on analytical, computational, and experimental studies of turbulence through the focused efforts of a newly formed center for turbulence research. In fundamental fluid physics, investigations using the numerical simulation of the flow instabilities which produce transition from laminar to turbulent flow will be accelerated, leading to an improved understanding of both the mechanisms of transition and the control of transition. This knowledge can enable reductions in aircraft drag and simplification of aircraft thermal management systems. Hybrid laminar flow control for aircraft drag reduction will be validated experimentally through a flight test research program initiated in FY 1989.

Applied Aerodynamics Research and Technology

The objective of applied aerodynamics research and technology is to provide new, validated technology applicable to future U.S. military and civil aircraft from subsonic to hypersonic speeds. The approach is to conduct comprehensive ground and flight experiments involving realistic vehicle configurations and key configuration components. Such work is focused on technology areas expected to render major gains in advanced vehicle performance.

In applied aerodynamics, efforts will focus on high-angle-of-attack and separated flow aerodynamics in both ground and flight test. Control of separated flow will be studied to determine cellular formation, control, and wing stall departure and spin resistance. Boundary-layer transition will be investigated for all speed regimes. By utilizing advanced optical and electronic technologies, innovative wind tunnel instrumentation will be developed for infrared boundary-layer transition visualization, micro-encapsulated liquid crystal methods for advanced flow visualization, laser fluorescence for hypersonic flow sensing, and laser velocimetry for supersonic and hypersonic shock propagation measurements. Experimental hardware, which has been under development for the past two years, will be used in an experimental flight investigation program to validate hybrid rotocraft computational fluid dynamic codes for the prediction of rotor airloads and their resultant effects on aircraft vibration and acoustics.

Propulsion and Power Research and Technology

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is being conducted in a wide variety of subsystems with applications ranging from the general aviation class through the hypersonic aerospace plane.

Propulsion research will continue to emphasize improvement of the fundamental understanding of stationary and rotating component flow fields with the development of unsteady, viscous, computational analysis methods and enhanced experimental verification through three-dimensional nonintrusive measurement capabilities. The focus will be on several specific propulsion technology developments: high-rate fuel injection and adiabatic components for rotary engines, offering a potential for improvement of 40 percent in fuel consumption and 30 percent in power density; axicentrifugal compressor staging arrangements and uncooled radial flow turbines, offering the potential for a 40 percent improvement in efficiency for small gas turbines; powered-lift components (inlets, ducts, augmenting fans, ejectors) and control integration, providing significant improvements for advanced short takeoff and vertical landing vehicles; and the critical component data base needed for hypersonic propulsion. Increased emphasis on advanced propulsion concepts will enhance the technology development of four innovative configurations, offering the potential for high payoff improvements in future propulsion systems; high throughflow turbomachinery, offering a 20 percent range increase for a Mach 3 cruise mission; air turboramjet cycle for extending variabie cycle flexibility for the Mach 0 to 6 regime; variable geometry components, providing performance tailoring for multiple operating conditions with a 15 to 25 percent reduction in specific fuel consumption and 10 to 15 percent increase in thrust-to-weight ratio; and an off-axis, high-pressure

core, offering the potential for a 20 to 30 percent increase in efficiency.

Materials and Structures Research and Technology

The objectives of the materials and structures research and technology program are to: (1) develop and characterize advanced metallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, durability, weight reduction of up to 40 percent, and reductions in aircraft life cycle cost. Areas of emphasis include high-temperature engine and airframe materials and structural concepts, composite materials applications, life prediction, thermal and dynamic response including aeroelasticity, helicopter structural dynamics and airloads, and more accurate and efficient integrated design optimization methods for airframes and engines.

In FY 1989, the materials and structures program will continue to develop advanced materials and innovative structural concepts aimed at reducing aircraft weight and cost. These include high-temperature aluminum alloys for subsonic and moderate supersonic speed aircraft, regenerative cooling of hypersonic aircraft, and deformable wing structures for high-performance aircraft. In addition, increased emphasis will be placed on developing high-temperature composites technology for use at up to 600 degrees Fahrenheit. The composites program will focus on the development of advanced materials, advanced fabrication methods that are especially tailored to take advantage of composite material characteristics, advanced structural concepts, and design and qualification test methods. Advanced structural concepts and fabrication methods will include filament winding and protrusion techniques to reduce parts count for structures and subsystems, while new design and qualification methods will reduce structural design and testing costs. These areas will be supported by continued development of advanced computational methods of reduce structural design time and minimize costly testing. Also during FY 1989, greater emphasis will be placed on analysis of large-scale airframe structures using advanced multiprocessor computers.

Information Sciences Research and Technology

The objectives of the information sciences research and technology program are to provide the fundamental capabilities: (1) to exploit advanced computer architectures to meet NASA's unique computing requirements, (2) to increase the agency's ability to develop high-quality aerospace systems software, and (3) to provide the advanced theory, concepts and capability to effectively use and manage aerospace information.

Research in information sciences and will continue on concurrent processing for highly reliable and high-performance computer architectures which will be more immune to hardware and software failures. A family of parallel processing computers will be used to research novel concepts in parallel processors controlled by new software algorithms. Also, studies will continue to assess the reliability gain from formal specifications, software prototyping, computer-aided software engineering systems, software, reuse, and formal verification. Support will be provided to NASA's computer networking system in order to increase the effectiveness and productivity of NASA's distributed computing resources.

Controls and Guidance Research and Technology

The specific objectives of the controls and guidance program are: (1) exploitation of emerging controls, guidance, and artificial intelligence technologies for the development of advanced automation concepts; (2) development of highly reliable system architectures and validation methods leading to flight-crucial systems; (3) development of sensors for airborne wind shear detection and flight management avoidance techniques; (4) development of advanced control, guidance and display theories, concepts, and analysis methods; and (5) development of new methodologies for achieving multidisciplinary integration.

In controls and guidance, the advanced transport systems research vehicle (B-737) has returned to flight research status after overhaul and upgrade of its avionics systems, and emphasis will be placed on flight evaluation of takeoff and landing performance monitoring, high-speed rollout and turnoff capacity improvements, and navigation systems for reduced airport congestion and delays. Increased emphasis will be placed on development of automation concepts leading to enhanced safety and productivity in the national airspace system. Adopting state-of-the-art space automation techniques and methods, evaluations will be conducted jointly with the Federal Aviation Administration (FAA) at the Stapleton Airport in Denver, of an air traffic controller advisor and expert schedule advisor. These evaluations offer the promise of allowing reductions in controller workload and more efficient handling of air traffic. In FY 1989, research will continue on the detection, avoidance, and recovery from wind-shear encounters.

Human Factors Research and Technology

The objective of the aeronautical human factors research and technology program is to provide the capability to design effective crew-cockpit systems using advanced cockpit automation technologies which will properly integrate the diverse systems, operators, and procedures within the mission requirements and environment. This is necessary for safety, productivity, efficiency, and increased effectiveness in advanced commercial and military aircraft, rotorcraft, and the NASP program. Human capabilities and limitations of crew personnel and their interactions with systems, components, procedures, and flight requirements are determined and refined in order to delineate guidelines. These guidelines provide the road map to understand how to integrate the crew with automation technologies in the cockpit. There are four areas of emphasis: (1) flight management, (2) human engineering methods, (3) rotorcraft, and (4) subsonic transports.

Human factors research will emphasize the development of methods for designing pilot decision aids and information transfer improvements in order to increase safety and reduce peak work-

load. To address the fact that over the last 30 years approximately 70 percent of the world-wide jet fleet accidents were caused by human error, the human factors research will be accelerated in areas directly related to aviation safety and automation. This research will emphasize the development and validation of methodologies for intelligent, error tolerant systems; improved human/automation interfaces for increased situational awareness; and aircraft/active control technology integration. The goal of this activity is to reduce substantially the risk of human error.

Flight Systems Research and Technology

The objective of the flight systems research and technology program is to provide the necessary research and technology development for an improved an validated base of advanced technology for application by industry to future generations of the entire spectrum of aircraft. In many cases, joint funding is provided by NASA, (DOD, and the FAA. The program is organized into the following categories: (1) aviation safety; (2) flight instrumentation and test techniques; (3) fighter/attack aircraft; and (4) flight support. The activities within this program encompass advanced engineering techniques and the establishment of the feasibility of concepts to ensure rapid application of promising new technology essential to meeting one or more of the following goals: (1) reducing aircraft accidents resulting from weather effects (heavy rain and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of needed information; and (3) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high-angle-of-attack (up to 90 degrees) flight conditions and vertical landing capability.

In FY 1989, flight systems research will be directed toward the technology needs of aviation safety, flight test methodologies, and supporting research for high-performance aircraft. Research is being conducted to improve the understanding of the effects of weather and icing conditions on the safe operation of aircraft and rotorcraft and to develop the technologies which will improve the safety of future vehicles. Research will be conducted using the F-18 high-angle-of-attack research aircraft to validate emerging experimental and computational methods for the prediction of high-angle-of-attack aerodynamics, flight dynamics, and handling qualities.

Systems Analysis

Systems analysis research studies will focus on defining the research and technology requirements for advanced high-speed transport aircraft. Emphasis will be placed on assessing the impact of advanced technologies for reducing engine emissions, sonic boom, and airport noise. The goal of this research is to ensure that future high-speed civil transports will be environmentally compatible with respect to concerns about atmospheric ozone depletion and noise. Advanced supermaneuverability fighter configurations will be analyzed to determine the benefits of advanced technologies in aerodynamics, propulsion, materials, structures, and controls.

B. SYSTEMS TECHNOLOGY PROGRAMS—$100,000,000

The Committee authorizes $100 million for Systems Technology Programs in FY 1989. This is the same as the President's request. However, this account could be required to absorb part of the $10 million general reduction to Aeronautical Research and Technology.

Summary of FY 1989 funding levels

Materials and Structures Systems Technology	$29,200,000
Rotorcraft Systems Technology	4,800,000
High-performance Aircraft Systems Technology	11,900,000
Advanced Propulsion Systems Technology	14,000,000
Numerical Aerodynamic Simulation	41,000,000
Total Systems Technology Programs	[1] $100,000,000

[1] Could be required to absorb part of the $10 million general reduction.

Materials and Structures Systems Technology

The objective of the materials and structures systems technology program is to develop advanced materials and structural concepts for future advanced aircraft propulsion systems and primary structures.

In FY 1988, the turbine engine hot section technology element and the ceramics for turbine engines element were combined and augmented to form the advanced high-temperature engine materials technology program. The programs were combined to focus their efforts on developing fundamental technology for revolutionary advances in high-temperature materials for advanced propulsion systems.

The objective of the advanced composite materials systems technology program is to develop advanced materials and innovative structural concepts to fully exploit the benefits of advanced composite materials for cost-effective primary structures for future aircraft applications. The program objectives will be accomplished through materials development, design and fabrication of innovative structural concepts, structural analysis and improved life prediction methods, and demonstration of improved structural performance through subscale and full-scale tests of critical components representative of advanced composite airframe structures.

For FY 1989, advanced high-temperature engine materials research will emphasize fiber development, composite mechanics, and interfaces. Strong, stiff, lightweight reinforcement fibers, which are capable of maintaining chemical stability and mechanical properties at elevated temperatures, are a central issue to this entire program.

During 1989, advanced composite materials and structures research in the Research and Technology Base will focus on developing fundamental technology for application of composites to primary airframe structures. This research will be directed toward exploiting new organic-composite materials for use at up to 600 degree Fahrenheit and advanced processing and fabrication concepts for low-cost composite structures.

Rotorcraft Systems Technology

The rotocraft systems technology program consists of interrelated research on three fronts: (1) completion of noise prediction and reduction in cooperation with industry, (2) increased focus on technology for high-speed rotocraft, and (3) completion of the flight research on the X-wing concept under a joint program with the Defense Advanced Research Projects Agency.

In FY 1989, the program will increase the effort on high-speed rotocraft. In noise technology, with the completion of the NASA/American Helicopter Society noise program and the release of their ROTONET code, the emphasis will shift to in-house acoustics research for military application and specific issues for high-speed rotocraft designs. In addition, prediction of tilt rotor noise will be validated in all flight modes in order to understand the source phenomena and potential areas for reduction.

Cooperative efforts will also take place with the FAA for civil certification issues and with the Navy for V-22 tilt rotor technology assistance. The immense payoff of this technology for the nation through civil application is recognized in the government and by the industry and regional transportation authorities.

In FY 1989, the Rotor Systems Research Aircraft X-wing research program will be concluded. The completion of the flight tests of a full-scale X-wing rotor will provide the data base for determining the next step in the development of this technology which offers significant potential for high-speed rotocraft applications.

High-Performance Aircraft Systems Technology

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research tests of advanced aircraft concepts and systems.

The flight research activity in FY 1989 will involve several high-performance aircraft tests designed to investigate advanced concepts. Several projects will continue their flight phases during this period including the X-29 aircraft (No. 1 and 2) and the F-18 high-angle-of-attack research aircraft.

Advanced Propulsion Systems Technology

The objective of the advanced propulsion systems technology program is to explore and exploit advanced technology concepts for future aircraft propulsion systems in high-payoff areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology analytical and experimental data base necessary for achieving the concept's full potential.

In FY 1989, advanced turboprop systems research will continue to emphasize source noise, cabin environment, turboprop and airframe installation aerodynamics, and the development of advanced aerodynamic and structural analysis techniques for both single- and counter-rotation propellers.

· In addition, in FY 1989, the general aviation/commuter engine technology effort will continue to demonstrate component improvements through the practical application of validated analysis codes that will enable high-performance small engine systems.

Numerical Aerodynamic Simulation

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the nation's capabilities in computational fluid dynamics and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. Ongoing research and technology base efforts in computational aerodynamics are benefiting significantly from the advanced computational capabilities to be provided by the NAS program. This program provides the computational capabilities required to obtain solutions to problems which are currently intractable.

FY 1989 will be an important year in the development of the NAS system. The second high-speed processor will be integrated into the NAS system. This event had slipped due to unavailability of a supercomputer meeting the HSP-2 requirements. With HSP-2 integrated into the system, secure processing will be available while users have access to the other high-speed processor.

With the second processor, the number of users and projects supported by NAS will increase accordingly. Support processing will be upgraded to satisfy the additional requirements of the system. Mass storage continues to be a primary concern for computer systems. The NAS program will double the mass storage capacity in late FY 1989, and efforts with industry on developing more capable systems are being pursued.

Aeronautical Research and Technology—Committee Comments

The Committee authorizes $404,200,000 for Aeronautical Research and Technology in FY 1989. This is $10 million less than the President's budget request. However, the Committee would like to indicate that in the absence of extreme budget constraints, no general reduction would be imposed.

The Committee was most pleased with the FY 1989 budget request. For the first time in many years, the first "A" of NASA, the "A" for Aeronautics, received a well-balanced budgetary and programmatic commitment—a commitment in line with a program that represents more than a $15 billion surplus to the U.S. balance of trade.

The Committee also was pleased with the details of the "Civil Aeronautics Technology Development and Validation Plan" and the "Major NASA Wind Tunnel Revitalization Program" reports. These documents have been well-received by the Committee and have significantly influenced the formulation of the FY 1989 NASA Authorization Bill (discussion of the "Wind Tunnel Revitalization Program" is under "Construction of Facilities—Committee Comments").

The Civil Aeronautics Technology Development and Validation Plan, prepared at the request of this Committee of NASA in conjunction with private industry, describes the technological efforts required in the next decade to assure continued U.S. leadership in future civil aircraft markets. The plan is consistent with the recommendations of the 1987 report entitled "National Aeronautical R&D Goals, Agenda for Achievement," issued by the Aeronautical Policy Review Committee, and describes a technology program that could be implemented in each of three areas to enhance U.S. competitiveness in future civil aircraft markets—subsonic transport, high-speed civil transport, and civil tiltrotor and commuter aircraft. This plan clearly substantiates the need for both technology development and validation, including flight testing, if the United States is to continue to be a leader in aeronautics.

In the first three decades of the next century, the commercial transport aircraft market is projected to total about $1.5 trillion in 1988 dollars, with an annual world market of $50 billion per year—2½ times the projected annual market for the rest of this century. Clearly, this is a market in which the United States must maintain its competitiveness in the future. Continuing advances in efficiency and performance of subsonic transport aircraft are key to maintaining our positive trade balance in this important market sector and to preventing a further decline in the U.S. share of the world aviation markets.

Implementing the plan for development and validation of technology for subsonic transpaort aircraft should provide substantial benefits to both derivative and new transport aircraft, provided the aircraft industry is prepared to incorporate the technology into its products. Consequently, emphasizing areas consistent with the industry's priorities for various technologies is a key means to early applications—the joint development of the plan by NASA, and the aircraft industry reflects that approach. A further assurance of early application of the technology is the willingness of industry to invest in the technology development and validation costs with the government. A successful recent example of joint NASA and industry investment in systems technology development is the Advanced Turboprop Program (ATP), wherein the industry has shared a significant portion of the program costs, and the the technology results are being applied in new propulsion systems now in development by the industry. The Committee recommends that NASA and the industry identify those technology development and validation efforts for subsonic transport aircraft which the industry is willing to share costs, to an extent similar to the ATP program. To that end, the Committee recommends that NASA request funding for those efforts starting in FY 1990.

A large component of the projected worldwide transport aircraft market and the only major new opportunity in this market sector is in high speed transports for the long-range trans-Pacific routes. By 2025, this market segment alone is projected to be larger than today's subsonic transport market—with potential sales of 1,500 high speed commercial aircraft. The need to carry 300,000 passengers daily to the Pacific rim nations will profoundly impact the aircraft and airline industries in the next century and will drive the requirement for long haul, high speed transport aircraft.

Although the primary requirement for a high speed commercial transport aircraft will certainly be economic soundness, environmental acceptability will also be a major factor in the success of such an aircraft. As a consequence, the initial emphasis in the technology development and validation program should be focused on the technologies that could lead to an environmentally acceptable aircraft through reductions in aircraft engine noise and emissions and sonic boom overpressure level. Therefore, the Committee requests that NASA initiate those elements of the proposed program in FY 1989 that could produce early information on the environmental issues and increase that emphasis on those technnologies in its FY 1990 program.

Tiltrotor aircraft technology has been under development by the DOD and NASA for several years and will be demonstrated and further developed in the V-22 Osprey program. Results obtained from the V-22 program and further studies of intercity air transportation needs should provide information at some future time to determine whether additional efforts to develop a civil version of the tiltrotor design are justified.

Commuter aircraft technology has also been a focus of the NASA aeronautics program for many years, and there are many advances in technology available that have not been incorporated in this class of aircraft. The competitiveness of this segment of the U.S. aircraft industry is overwhelmingly affected by factors unrelated to technology. Therefore, the Committee recommends that the current level of effort in this area is appropriate.

Finally, the Committee would like to indicate that it is so intrigued with recent reports—government and non-government reports—concerning the potential markets for a new high speed commercial transport that it held an all-day workshop at the Library of Congress on May 24, 1988, to explore this issue. The Committee hopes that the results of this workshop, combined with the results of these additional reports, will result in a fiscal year 1990 initiative for a more efficient, environmentally sound, high speed commercial transport.

7. Transatmospheric Research and Technology—$69,400,000

The Committee authorizes $69,400,000 for Transatmospheric Research and Techology in FY 1989.

Summary of FY 1989 funding levels

Transatmospheric Research and Technology	$69,400,000

The National Aero-Space Plane (NASP) program is a joint effort between NASA and DOD to accelerate the development of critical enabling technologies for a revolutionary class of hypersonic-transatmospheric vehicles. Such vehicles could be capable of taking off from the landing on conventional runways, using airbreathing propulsion up to, or near, orbital speed, and providing rapid and lower cost access to space. The program will accelerate the development and validation of key technolgies through application of analytical prediction methods coupled with testing in ground-based facilities. The critical technolgies being pursued in the current phase of the program include efficient airbreathing propulsion systems, with

emphasis on scramjet performance that provides the necessary thrust from takeoff to near orbital speeds; reusable thermal structures that can withstand repeated combinations of extreme peak heating and signficiant long-duration heat loads; and complete integreation of the propulsion system with the airframe for a minimum weight system with good performance throughout a broad range of accelerating cruising, and maneuvering flight conditions. A necessary precursor to the development and flight validation of an experimental vehicle (X-30), these technolgies will form the critical data base required for design and integration of complex propulsion and structural systems into a vehicle configuration capable of transatmospheric flight.

The FY 1989 NASP activities will emphasize extensive detailed design, component fabrication, and tests by the engine and airframe contractors, as well as continued refinement of the supporting technology maturation effort in preparation for the decision on whether to proceed with development of the X-30 research vehicle.

The engine contractors will continue to refine their concepts to achieve the performance required to accomplish the X-30 mission goals. Emphasis will be on integration with the vehicle configurations being developed by the airframe contractors, since the desired performance depends critically on the integrated propulsion-airframe system.

The technology maturation effort will continue to focus on critical disciplines as an underpinning of the engine and airfame efforts. The technology maturation activities concentrate on four key objectives: (a) an airbreathing propulsion system with high specific impulse; (b) vehicle structural weight improvement with reusability and durability over a wide temperature range; (c) integrated systems and subsystems in aeropropulsion, thermal management controls, etc; and (d) sound design and analysis tools based on advanced computational methods fully verified by test.

Finally, the major effort to scale up and characterize advanced lightweight, high-temperature materials in a cooperative effort with contractors begun in FY 1988 will be significantly expanded in FY 1989.

Transatmospheric Research and Technology—Committee Comments

The Committee authorizes $69,400,000 for Transatmospheric Research and Technology in FY 1989. This is $15 million less than the President's budget request.

The NASP program continues to represent an important opportunity for revolutionary advances in U.S. aeronautical and space capabilities. The most significant technological barriers to the successful completion of the NASP progam—air-breathing propulsion, structures and materials, and aerodynamic computational methods—will require many years of sustained effort and support if they are to lead to the development of a prototype and eventually an operational vehicle. While the Committee is fully aware of the fact that national security missions are the most likely early applications of this joint NASA/SOD program, in the long term the NASP offers the promise of enhancing our competitive position in several major areas of aeronautical research and development. With the technology base that emerges from this program, the United States should be able to meet the competition that we face in this area from the Soviet Union, Japan, ESA and others.

Unfortunately, due to budget constraints and competing priorities, the Committee has approved only half of the proposed FY 1989 increase.

8. Space Research and Technology—$350,900,000

The Committee authorizes $350,900,000 for Space Research and Technology in FY 1989. This is $40 million less than the President's request.

Summary of FY 1989 funding levels

Research and Technology Base	$134,100,000
Civil Space Technology Initiative (CSTI) Program	156,800,000
Pathfinder	60,000,000
Total Space Research and Technology	[1] $350,900,000

[1] This includes a general reduction of $8 million for equipment and an augementation of $8 million for the Space Grant College and Fellowship Program.

The overall goal of the space research and technology progam is to provide advanced technologies that ensure continued U.S. leadership in space to meet national needs. Achieving this goal requires a commitment to provide a broad base of advanced technology for vehicle and subsystem concepts, components, devices, and software; to develop technical strengths in the engineering disciplines within the agency, industry, and academia; and to perform critical technology demonstrations that facilitate the transfer of new technology to future space missions with a high level of confidence.

The research and technology base program provides the well spring of innovative and fundamental research for future NASA and other civil space missions. Within this program, high-leverage technological advances and concepts are, if successful, brought to the level of demonstrating proof of principle. This program is in effect a seedbed for generating the more highly mission-focused program that consists of major technology thrusts to enhance Earth-to-orbit transportation, improve operational capabilities at low Earth orbit for enhancing the effectiveness of Shuttle/Space Station, and provide increased capabilities to conduct Earth-orbital science programs. The Pathfinder program provides those emerging and innovative technologies required to enable a broad set of future space exploration missions. Depending on future decisions, such missions could include a return to the Moon to build an outpost, and both autonomous and piloted missions to Mars and other destinations in the solar system. Proof-of-concept testing for mission-critical engineering designs will be an important product of the CSTI and Pathfinder programs and will directly support the continuing evolution and maturation of mission plans. In support of the objective of encouraging the development of engineering and research capabilities in the academic sector, the univeristy activities have been combined into a separate focused budget line item which includes the space engineering research center program, the university system design program, and univeristy innovative research.

In FY 1989, the space research and technology program will be significantly augmented to provide a greater emphasis on focused technology (CSTI and Pathfinder) and university space research programs. The research and technology base program will shift emphasis to explore newly emerging areas that offer longer range, high-leverage program benefits. The university space research program includes augmentation and expansion of the university engineering research centers and the university advanced design effort. Development of the concepts and plans for an expended in-space research and demonstration program will be pursued. The following described in greater depth the planned FY 1989 activities.

A. RESEARCH AND TECHNOLOGY BASE—$134,100,000

The Committee authorizes $134,100,000 for the Research and Technology Base in FY 1989. However, this account could be adjusted to reflect the $8 million general reduction for equipment and the $8 million increase for the Space Grant College and Fellowship Program.

Summary of FY 1989 funding levels

Aerothermodynamics Research and Technology	$11,500,000
Space Energy Conversion Research and Technology	13,800,000
Propulsion Research and Technology	19,700,000
Materials and Structures Research and Technology	17,500,000
Space Data and Communications Research and Technology	9,300,000
Information Sciences Research and Technology	9,000,000
Controls and Guidance Research and Technology	6,700,000
Human Factors research and Technology	5,300,000
Space Flight Research and Technology	18,100,000
Systems Analysis	6,900,000
University Space Research	16,300,000
Total Research and Technology Base	[1] $134,100,000

[1] Could be further adjusted to reflect the $8 million general augmentation

Aerothermodynamics Research and Technology

The aerothermodynamics program provides the basis for fundamental understanding and prediction of the combined effects of heat transfer and aerodynamics on vehicles during ascent and entry. This activity is enabling to the successful development and design of advanced aerospace vehicles. Current program emphasis is on development and validation of computational fluid dynamics codes that incorporate real-gas and nonequilibrium effects to more accurately predict performance of aeroassisted orbital transfer vehicles.

Space Energy Conversion Research and Technology

The space energy conversion program provides the fundamental understanding and technology basis for the development of future space power systems ranging from relatively low power levels required for spacecraft to high-capacity, nonnuclear power for large space systems. Photovoltaic power technology will focus on improving the efficiency and reducing the degradation rate of photovoltaic cells through improved designs and materials. Technologies for lightweight deployment systems, reduced weight substrates, and ultrathin cover glass are being developed. Higher energy chemistry and improved battery designs are being developed to provide improvements in the energy density and life of storage systems. The goal is to improve the total system (photovoltaic and storage) performance to permit a 50 percent increase in payload weight. Research continues on fuel cells for application at higher power levels (greater than 25 kilowatts) where they offer significant potential weight advantages. New conversion catalyst materials and designs are being developed to achieve reduced system weight and to increase life. Technologies for high-efficiency thermal-to-electric conversion, high-temperature thermal storage, and lightweight high-concentration-ratio solar collectors are being developed for solar dynamic systems. The goal of these technologies is to provide a 25 percent reduction in collector area and a substantial reduction in weight over current high-capacity systems.

Propulsion Research and Technology

The propulsion technology program focuses on key lifetime and performance issues associated with space propulsion systems. Variable-flow turbomachinery, enhanced heat transfer combustors, and high-expansion-ratio nozzle technology for space-baseable orbit transfer vehicles will be investigated. The ultimate benefit will be to reduce substantially the cost of space operations by reducing the amount of mass required to be transported to Earth orbit. In addition, the potential of very high-energy-density propellant combinations, such as liquid oxygen with metalized fuels, will be assessed for Earth-to-orbit propulsion systems. For ascent vehicle operations, candidate propulsion systems that can operate efficiently with propellants produced *in situ* on Mars or on the Moon will be indentified and their performance and operational capabilities explored to greatly reduce Earth launch requirements. Research on auxiliary propulsion will develop concepts for control of an evolutionary space station and space vehicles which operate with mixtures of gaseous oxygen and hydrogen derived from electrolytic systems. Electric propulsion technology will address fundamental issues governing thruster life, performance, and weight through improved inert gas ionization processes and cathode materials and designs.

Materials and Structures Research and Technology

The materials and structures program will focus on extended space durability, structures for lighweight vehicles, and concepts to enable the development of large space structures. The dimensional stability and durability of metal-matrix, carbon-carbon and graphite-epoxy composites will be evaluated for long-term service life in both low-Earth-orbit and geosynchronous-Earth-orbit environments. The approach will include both the development or computational chemistry methods to describe atomic oxygen interactions and accelerated testing methods. Structural concepts will be developed incorporating mechanisms to adjust stiffness, damping, and shape in order to enable construction of large high-precision space structures. Hot structures for integral cryogenic tankage will be pursued, and toughened ceramic thermal protection systems will be developed.

Space Data and Communications Research and Technology

Space data and communications research will be directed toward increasing traveling wave tube efficiencies, developing and packaging monolithic microwave integrated circuit components, refining 20/30 gigahertz antenna technology, and advancing electro-optic research aimed at laser communications.

Information Sciences Research and Technology

Areas addressed by the information sciences program include computer sciences, sensors, and photonics. In the computer science area, emphasis will continue to be placed on concurrent processing for improved physical simulations and visualization of scientific data. Sensor research will concentrate on the use of artifical intelligence techniques in autonomous onboard data analysis. Investigation of new materials, devices, and analytical models leading to the development of improved sensor systems will continue. In the area of photonics, research will focus on improved photonic materials and devices for use in real-time computer vision systems and very low-cost, wide-bandwidth signal analysis.

Controls and Guidance Research and Technology

Controls and guidance research will support the implementation of future advanced Earth-to-orbit transportation systems, aeromaneuvering vehicles, and interplanetary space travel. Particular emphasis is being placed on real-time, fault-tolerant distributed control architectures and system autonomy in the real-time environment of a maneuvering vehicle. The development of analytical tools and techniques for the precision pointing and control of large flexible spacecraft and the control of extremely large flexible transportation vehicles is a principal research focus.

Human Factors Research and Technology

Space human factors research includes development of advanced concepts and hardware for extravehicular activity, such as hard space suits and development of highly intergrated displays and controls to support telepresence and astronaut and crew performance.

Space Flight Research and Technology

Space flight research includes the continued development of orbiter experiments to use the shuttle as a research testbed vehicle. The in-space technology experiments program was expanded to define and develop seven flight experiments selected from 58 NASA in-house generated proposals. The program was also expanded further by the selection of 41 externally sponsored flight technology experiments from 231 university and industry proposals.

System Analysis

The objectives of the systems analysis program are to identify technology requirements for prescribed mission concepts and opportunities for enabling new and improved concepts; to integrate these into a comprehensive technology set of planning options; and to generate candidate plans to develop these technologies in a timely manner. Close coordination with the Offices of Space Flight, Space Science and Applications, Space Operations, Space Station, and Exploration and other users is maintained to ensure proper understanding of missions and to gain assistance in prioritization of enabling and high-leverage technologies. This analysis program is directed at the systems-focused areas of space transporation, spacecraft, and large space systems and at emerging, new mission concepts and mission-enabling technologies.

University Space Research

The objective of the university space research program is to enhance and broaden the capabilities of the nation's engineers community to participate more effectively in the U.S. civil space program. It is an integral part of the strategy to rebuild the space research and technology base. The program responds to remedy the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program elements include the university space engineering research program, which supports interdisciplinary research centers; the university innovative research program, which provides grants to individuals with outstanding credentials; and the university advanced space design program, which funds advanced systems study courses at the senior and graduate levels.

B. CIVILIAN SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM—$156,800,000

The Committee authorizes $156,800,000 for the Civilian Space Technology Initiative Program in FY 1989. This is the same as the President's request. However, this account could be adjusted to reflect the $8 million reduction for equipment and the $8 million increase for the Space Grant College and Fellowship Program.

Summary of FY 1989 funding levels

Automation and Robotics	$25,900,000
Propulsion	46,700,000
Vehicle	28,000,000
Information Technology	17,100,000
Large Structures and Control	25,100,000
High-capacity Power	14,000,000
Total Civilian Space Technology Initiative Program	[1] $156,800,000

[1] Could be further adjusted to reflect the $8 million general reduction or the $8 million augmentation.

The CSTI is developing the technologies to enable reliable and lower cost access to space and to support enhanced space operations and science missions. Support for future space transportations systems includes: autonomous systems research and prelaunch and postlaunch operations; reusable, high-performance engines for next-generation launch vehicles; and a flight demonstration of aerobraking for orbit transfer vehicles. Future Earth-orbiting operations and science missions will be enhanced through an expanded effort in automation and robotics; technology to significantly increase data processing and storage capabilities; ground and in-space experiments to expand the design data base for very large, flexible structures; and technology for high-capacity nuclear

power conversion systems. New sensor technologies and capabilities to deploy large, extremely precise surfaces will further enhance Earth and deep space observation.

The objective of the CSTI program, begun in FY 1988, is focused on research in technologies to enable reliable and lower cost access to space and to support space operations and science missions. The CSTI program is a positive first step to restore the agency's technical strength and provide options for high-priority civil space goals of the future. The research is targeted at opportunities with clearly defined end objectives to validate technology advances. Three broad categories—transportation, operations, and science technology—are supported.

Automation and Robotics

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. The goal of the robotics element is to evolve the capability for remote space operations from the current level of teleoperations (direct human control) of a single crane-like arm, through the telerobotic operation (human supervisory control) of dexterous multiarmed manipulators, to the robotic operation (human task-level control) of multiple intelligent manipulators. The goal of the autonomous systems element is the use of artificial intelligence technology to effect the reduction of manpower involved in ground control; automation of control of subsystems aboard the Space Station, spacecraft, and space transportation vehicles; and elimination of astronaut time spent performing housekeeping functions.

In FY 1989, the telerobot demonstration facility at the Ames Research Center will perform its first test in which all of its subsystems (artificial intelligence, run-time control, sensing and perception, operator control, and manipulation and control mechanization) are implemented. The task will be to remove and replace a module in the spacecraft mockup. This will be the first implementation of the concept of traded control in which the automatic control system and the human operator can pass control smoothly to each other during the task.

Research and development in each of the five robotics core technology areas also will continue. This includes task planning, operator interface, sensing and perception, control execution, and systems integration and architecture.

In addition, in FY 1989 the expert system for monitoring of shuttle communications will be tested during the next Shuttle flight, where it will operate in parallel with the human controllers who will have actual control. The expert system for control of the environmental control system during launch processing actually will be used during the next Shuttle launch. This will be the world's first operational use of artificial intelligence in a space mission.

Propulsion

The objective of the CSTI propulsion program is to provide a validated design and analysis capability that can be applied to the design and development of advanced propulsion systems for future low-cost reusable Earth-to-orbit (ETO) vehicles and recoverable boosters.

In FY 1989, the CSTI ETO propulsion program will continue to conduct LOX-hydrocarbon specific technology tasks to verify high-pressure ignition, combustion performance and stability, heat transfer and cooling, and will begin the design and fabrication of appropriate large-scale technology turbopumps. Models and design concepts developed in the subscale research and technology base program will be used for the design of the large-scale hardware.

The Space Shuttle main engine testbed effort will include the final assembly of the testbed engine and the initial hot-fire operations utilizing the newly activated S1C test stand at the Marshall Space Flight Center. Research quality diagnostic instrumentation, including selected advanced technology sensors, will be installed and calibrated. Advanced technology components (turbine blades, diagnostic sensors) will be prepared for installation for the second hot-fire test sequence.

For the hybrid boosters system, FY 1989 efforts include evaluating candidate fuels, establishing burning characteristics, evaluating propellant configurations, selecting an oxidizer pump concept, evaluating spray concepts, and establishing the mechanisms for a safe abort option. For pressure-fed liquid booster systems, tasks include propellant selection, combustion stability characterization, pressurization systems, design, nozzle size and number optimization, and structural design and material evaluation. Both systems will enter the mid-size hardware fabrication and test phase in FY 1989.

The aeroassist flight experiment (AFE) will investigate the critical vehicle design and environmental technologies applicable to the design of the aeroassist orbital transfer vehicle. Aerodynamic braking maneuvers, which occur in the upper regions of the Earth's atmosphere at or near geosynchronous return velocities, produce aerothermodynamic environments that cannot be simulated in ground facilities or modeled using existing analytical techniques. It is necessary, therefore, to obtain critical aerodynamic and aerothermodynamic data from flight experiments.

The technology data base developed by the AFE will enable the use of aerosassist in conjunction with an orbital transfer vehicle to achieve minumum fuel expenditure in a return to low Earth orbit from a high energy orbit, such as geosynchronous.

In FY 1989, the preliminary design of the AFE spacecraft and associated ground and airborne support hardware will be completed, and final design initiated. Component structural testing on the aerobrake will begin. Software simulations will be conducted to evaluate guidance and navigation control schemes. Wind tunnel and arcjet testing will be continued to support the design data base for the AFE. Additionally, mission requirements will be defined, and a preliminary mission operation timeline prepared.

Information Technology

The objective of the information technology program is to discover, invent, and develop new materials, devices, components, and systems that will enable active and passive detection and imaging of electromagnetic radiation and subsequent data storage systems for space missions in the next century. Of special importance are

tunable laser sources and millimeter wave sensors for both active and passive remote sensing of the Earth's atomsphere and surface.

In FY 1989, research efforts will proceed in three technically deficient areas: direct detectors and heterodyne frequency sources (local oscillators), frequency mixers, and quasi-optical components for the submillimeter portion of the electromagnetic spectrum.

In addition, in the active remote sensing area, the research effort will be focused on the necessary technology to implement solid-state laser systems for future missions.

Large Structures and Control

The objective of the large structures and control element of CSTI is to develop integrated structures and control technology to enable the development of large flexible structures and high-precision structures to meet long-range requirements for complex multibody platforms, spacecraft, and large scientific instruments.

During FY 1989, the revised Construction of Flexible Structures I structural flight hardware will be developed in preparation for a 1991 space experiment (requiring a 1990 delivery to Kennedy Space Center). Control sensors and actuators will be integrated into the structure, and ground tests will be conducted to establish control/structure response characteristics and for comparison with analytical predictions.

In addition, in FY 1989, the CSTI technology activity will continue to develop integrated control/structure analysis and design methodology and test methodology focused on selected structures, including the COFS I flight article. This will be a multicenter activity involving Langley Research Center, Marshall Space Flight Center, Goddard Space Flight Center, and the Jet Propulsion Laboratory and will be directed toward developing a NASA-wide approach to accelerate the design, development, and qualification of future large space structures.

High-capacity Power

The objective of this program is to develop the technology base for a nuclear power system capable of supplying high-capacity, long-life power for potential future sustained lunar and planetary base operations and any future evolutionary developments to the space station, and to supply power to electric propulsion systems for interplanetary cargo transfer vehicles. This is a joint activity with the Department of Energy (DOE) and DOD. The NASA program emphasis is on thermal-to-electric conversion, heat rejection, and power management and distribution subsystems. Higher conversion efficiencies in conjunction with improved thermal and power management and distribution systems materials and design innovations can enable a fivefold increase in the electrical power that can be delivered from the available thermal output of the SP-100 reactor, while more than doubling the system power-to-weight ratio.

During FY 1989, preliminary design of the Stirling space engine will be completed. After design review an approval, the detailed design efforts for the test engine(s) will be initiated, as well as test planning.

Technology development efforts for the power management and distribution system components will be increased, and a definition and assessment effort directed at fault-survivable power system concepts will be initiated in FY 1989. Research and technology tasks addressing the space environmental effects and interactions will also be conducted.

C. PATHFINDER—$60,000,000

The Committee authorizes $60 million for the Pathfinder program in FY 1989. This is $40 million less than the President's request. However, this account could be adjusted to reflect the $8 million general reduction for equipment and the $8 million increase for the Space Grant College and Fellowship Program. An amount of $20 million of the $60 million provided is earmarked for SP-100.

Summary of FY 1989 funding levels

Exploration Technology	$17,000,000
Operations Technology	41,000,000
Humans-In-Space Technology	13,000,000
Transfer Vehicle Technology	14,000,000
Mission Studies	15,000,000
Total Pathfinder	[1] $60,000,000

[1] Reflects a general reduction of $40 million. Also, this account could be further adjusted to reflect the $8 million general reduction or the $8 million augmentation.

Project Pathfinder is an important new program through which NASA will develop a broad set of technologies that will enable decisions on future space missions. Project Pathfinder is the critical next step, augmenting CSTI, in strengthening the technology foundation of the civil space program and the nation's technology leadership. Moreover, Pathfinder is an essential prerequisite to any future decision by the Nation's leadership to go forward with ambitious civil space missions. Pathfinder is organized into four technology areas: exploration, operations, humans-in-space, and transfer vehicles. In addition, mission studies will be conducted to support the detailed formulation of mission requirements and technology options. The technologies included in the exploration element are related to the gathering of scientific knowledge and technical understanding at mission sites on the Moon and Mars. The space operations element will address critical technologies for *in-situ* materials processing, fabrication, and assembly and repair of massive and complex systems in Earth orbit and at lunar and Martian orbits and surfaces. The humans-in-space program will address the technology for improving astronaut productivity, maintenance or health, with minimal or no dependence on resupply of expendables. The transfer vehicle element will support transportation to and from geostationary Earth orbit, the Moon, Mars, and other planets.

Exploration Technology

The essential technologies for the future robotics and piloted exploration of the Moon, Mars, and other planets in the solar system are grouped into four separate elements: planetary rover; sample acquisition, analysis, and preservation; surface power; and optical communications. The planetary rover element will focus on the development and integrated testing of technologies for mobility, navi-

gation, site identification, and portable power. The sample acquisition, analysis, and preservation element will focus on the methodology for sample identification and selection, chemical and physical analysis, the development of special tools for sample acquisition, and sample preservation techniques. The surface power element will perform research leading to high power-to-weight, photovoltaic arrays, and regenerative fuel cells that are resistant to the dust, chemical reactants, and temperature environments ambient to the Moon and Mars. Optical communications hardware will be developed to support a subsequent flight demonstration at interplanetary distances.

In FY 1989, activities will be initiated in these technology areas.

Operations Technology

The space operations thrust will provide the critical technologies required for logistical support of human activities. For Earth orbit operations, this program will greatly extend our capabilities to maintain the infrastructure and to support major new science missions. For lunar and Mars missions, the critical technologies for preparing to depart Earth orbit, for performing tasks on lunar or Martian surface sites, and for safe return to Earth from those sites will be addressed. The specific program objectives include devloping the capability for *in-situ* lunar materials utilization, development of technology for advanced on-orbit operations, and the development of nuclear power for transportation and sustained lunar and planetary operations. Critical issues, such as the extent to which manned activities can be self-sustaining through processing of extraterrestrial materials, will determine the course of space exploration. The elements of the program include autonomous rendezvous and docking technology, resource processing pilot plant research, in-space assembly and construction, cryogenic fluid depot technology, and space nuclear power technology.

In FY 1989, activities will be initiated or continued in operations technology, including rendevous and docking, resource processing pilot plant research, in-space assembly and construction, cryogenic fluid depot, and space nuclear power (SP-100).

Humans-In-Space Technology

The objectives of the Human-In-Space Technology portion of the Pathfinder program are to enable: (1) on-demand, extended surface extravehicular activity (EVA) with mobility, dexterity, simple servicing and maintenance, and long-life systems; (2) productive cognitive and physical performance over long self-sufficient missions in different gravity environments and with protection from space radiation; and (3) self-sufficiency and significant reduction in life-support expendable weight and transport requirements for long missions (greater than one year). Existing technologies for these functions cannot be scaled to meet human performance and life-support requirements over long, self-sufficient missions. Furthermore, technology identification and advancement cannot effectively proceed without the determination of human performance and support requirements. This program will be conducted jointly with the Office of Space Science and Applications (OSSA). OSSA will determine the biomedical requirements and implement the life sciences portion of the program.

The objective of the EVA/suit program is to provide technology for a highly mobile, lightweight, rugged pressure suit and portable life support system that will allow safe and efficient EVA work during planetary missions. The objectives of the human performance program are to determine human capabilities, limitations, and adaptability for individual and group work during long-duration missions and to develop supporting human-machine interface technologies.

Finally, the objective of the closed-loop life support program is to provide a high degree of closure in the crew life support system for long/duration space missions to provide air revitalization, water reclamation, and waste treatment. Based on physical and chemical processes, highly efficient subsystems will be developed and integrated into a total life support system which will minimize the requirements for stored consumables and spares and eliminate the need for resupply.

In FY 1989, ENA suit system concepts will be assessed, life support processes will be modeled, and human performance mission-equivalent tasks will be developed and identified.

Transfer Vehicle Technology

Transfer vehicle technology addresses reusable transportation to and from geostationary Earth orbit, the Moon, Mars, and other destinations in the solar system. This thrust provides the technologies for a significant reduction in mission costs by reducing the mass required to be launched into low Earth orbit and in transit, as well as reductions in the transit time. The broad objectives toward these goals include research into higher performance, reusable, reliable, space-based transfer vehicles that have low operational cost. The efforts which support the objectives include chemical transfer propulsion, chemical vehicle propulsion, high-energy aerobraking, autonomous lander, and fault-tolerant systems technology.

In FY 1989, activities will be initiated in all of these key technology areas.

Mission Studies

Using the exploration scenarios identifed in Dr. Sally Ride's report, *Leadership and America's Future in Space,* as a starting point, the mission studies will: (1) identify other viable scenarios to be considered; (2) develop a more detailed definition of each of the candidate scenarios; (3) conduct trades and analyses of the scenarios to begin the process of narrowing down viable and desirable candidates; and (4) identify the prerequisites (technology, infrastructure, and precursor missions) for conducting such missions. Of critical importance are the long-lead technologies and infrastructure elements. Special emphasis studies will be conducted to investigate the high-leverage elements to identify the high-payoff options and critical technologies associated with these elements. These mission studies will serve to continually refine the Pathfinder technology program, ensuring that the critical and enabling technologies are receiving proper attention.

In FY 1989 two-year parallel contracts of the more viable scenarios will be conducted focusing on conceptual design and definition studies. These parallel studies will define end-to-end mission scenarios and perform first-order systems trades, including mission unique functions, infrastructure (transportation, Space Station, and operating systems), and prerequisites (technology, science research, and precursors).

Finally, special emphasis studies will be developed through academia, industry, and other government agencies for definition of critical issues.

Space Research and Technology—Committee Comments

The Committee authorizes $350,900,000 for Space Research and Technology in FY 1989. This is $40 million less than the President's budget request and represents a $40 million reduction, without prejudice, to the Pathfinder Program—a proposed FY 1989 new start. The Committee also has earmarked $8 million of the Space Research and Technology Program for implementation of the Space Grant College and Fellowship Program initiated pursuant to Title II of P.L. 100-147 and has reduced the proposed equipment augmentation by $8 million.

The Committee continues to support a more vibrant research and technology capability within NASA and feels that such a program is critical to maintenance of U.S. leadership in space. The Committee also is well aware of the findings and recommendations of the National Research Council report on *Space Technology to Meet Future Needs,* and it agrees with the general thrust of this report—the United States does need to make a greater commitment to space research and technology.

It is because of these positions that the Committee's proposed reduction in the Pathfinder Program, a FY 1989 new start, is being made reluctantly. However, the Committee recognizes that the Pathfinder Program can be more easily redefined, rescheduled and slowed down at the outset of the program than at any other point of the program.

Despite the Committee's continued support of space research and technology, it was dismayed to discover that a significant percentage of the FY 1989 NASA budget request for the Pathfinder program was for activities already ongoing in FY 1988. The Committee thought NASA understood that when this situation occurred last year with the initiation of SCTI it was not to be repeated. The Committee hopes NASA thoroughly understands this issue now.

Concerning the Pathfinder Program, for FY 1989, NASA is instructed to allocate $20 million of the $60 million total recommended by the Committee for the Pathfinder Program for the SP-100 program, a critical element of the Pathfinder Program. This augmentation above the FY 1988 level and the terms and conditions of the existing NASA/DOE/DOD memorandum of understanding is intended to manifest the Committee's support of this initiative and commitment to sustained NASA participation.

The Committee also requests the Administrator of NASA to submit to the Committee by September 15, 1988, a report on NASA's need for advanced nuclear power sources, including a list of potential NASA missions and programs that require such sources, the type and level of power and capability required, and the proposed timing for development and deployment of such sources. The report shall address the role, projected budget, and program milestones of the SP-100 program, including an analysis of the relative roles and contributions of DOD and DOE to the SP-100 program.

The Committee, pursuant to its agreement with NASA, has earmarked $8 milion of the FY 1989 Space Research and Technology Program budget request for initiation of the Space Grant College and Fellowship Program. Based on inputs received during this year's Subcommittee field hearings, it is clear to the Committee that the availability of bright young scientists, engineers and technicians is critical to the ultimate success of the Nation's space program. Implementation of the Space Grant College and Fellowship Program, as well as a sustained commitment to ongoing activities, should help ameliorate the current situation.

Along this same line, the Committee applauds NASA's initiation and implementation of the University Space Research Engineering Research Centers Program. The fact that over 115 proposals were submitted in response to the agency's program announcement is indicative of the level of interest in the university community. The Committee strongly supports this initiative and NASA's efforts to use university-based centers as an integral part of the strategy to rebuild the nation's space technology base. The Committee assumes full funding in FY 1989, $16,300,000, for this program.

9. Safety, Reliability and Quality Assurance—$22,400,000

The Committee authorizes $22,400,000 for Safety, Reliability and Quality Assurance in FY 1989.

Summary of FY 1989 funding level

Safety, Reliability, Maintainability and Quality Assurance	$22,400,000

The Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) program supports NASA's overall goals through activities in safety, reliability, quality assurance, maintainability, systems engineering, and program practices through independent assessment activities which reduce program risk. Specific objectives of the program are:

—To identify and provide independent assessment of issues that have potential impact on mission success.

—To support in-depth reviews, studies and analyses of issues and problems for readiness to launch.

—To conduct major tests and provide a viable problem reporting, corrective action, and trend analysis program throughout NASA.

—To perform radiation characterization on emerging technologies and complement the Air Force program for testing on-orbit radiation effects.

—To upgrade existing software standards, guidebooks, and training; and identify software management product assurance and automated work stations.

—To develop product assurance methodology for procuring reliable, custom large-scale integrated and very large-scale integrated circuit components.
—To upgrade technology and emphasize the safety, reliability and performance of NASA's aerospace battery power systems.
—To plan, document, and establish policy for a NASA-wide SRM&QA Information System.
—To increase the safety of high hazard operations and develop safety risk management policy and guidance for all NASA programs.
—To support industrial, aviation, fire protection, and ground operations safety activities.
—To provide policies, procedures and surveillance for all agency safety, quality, maintainability, and reliability activities.

In FY 1989, the SRM&QA program will continue to conduct activities in support of the objectives of NASA. This funding level will provide for enhanced capabilities which will implement the reporting and documentation of significant problems, assess problem resolutions and analyze trends, and other safety systems as required. NASA will develop a data base of failures, anomalies, and unsatisfactory conditions for analysis and assessment of remedial and preventive actions. Trend analysis of flight and critical ground hardware problems will be conducted, as well as for certain generic program hardware.

Problem reporting requirements, hazards analysis, and failure modes and effects analyses, accessible through an agency-wide tracking and reporting system, will continue to be supported in the Space Transportation Systems program through the Program Compliance Assessment Status Systems effort, and integrated engineering standards and practices will be implemented and a data base brought on-line.

The NASA safety program will increase the safety of hazardous operations, develop a better understanding of the failure modes of highly stressed wind tunnel components and pressure systems, and quantify the hazard potential of new, exotic propellants, existing cryogenic proplellants, and new composite materials. In addition, the Independent Systems Assurance Assessments program will develop between use of numerical techniques for reliability analysis and risk assessment.

Finally, the Non-Destructive Evaluation measurement assurance program will continue to provide state-of-the-art quantitative advanced inspection techniques for solid rocket motors, composites and ceramics and will explore inspection techniques such as microfocus X-ray, fiber optics, acoustic emission, computer tomography, and laser thermography.

Safety, Reliability and Quality Assurance—Committee Comments

The Committee provides $22,400,000 for FY 1989 for Safety, Reliability and Quality Assurance (SR&QA). This is the same as the President's budget request.

The Committee continues to support NASA's Safety, Reliability and Quality Assurance program and is committed to the reestablishment of this program as the hallmark of NASA. Between now and the next flight of the space shuttle, the Committee expects to be kept well informed by the SR&QA Office if any safety issues surface. The return to flight of a safe, reliable space shuttle is the highest priority of the Nation's civil space program, and the SR&QA Office, along with every individual associated with the shuttle program, must work to ensure a safe return to flight.

10. Tracking and Data Systems—$18,800,000

The Committee authorizes $18,800,000 for Tracking and Data Systems in FY 1989.

Summary of FY 1989 funding levels

Advanced Systems	$18,800,000

The objective of the Advanced Systems Program is to perform studies and provide for the development of tracking and data systems and techniques required to obtain new, higher performance tracking and data handling capabilities that will address planned future mission requirements and also improve the cost effectiveness and reliability needed for overall support of the total mix of spaceflight missions.

Activities planned for FY 1989 include efforts to obtain location accuracies at the decimeter level for Earth-orbiting spacecraft which would make possible a new class of high precision Earth observatory missions on the Shuttle, Space Station and on free-flying spacecraft. The techniques being analyzed for particular application include the Department of Defense's Global Positioning System and the use of Very Long Baseline Interferometry. Work will continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nano-radians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible. Studies will continue on ground-based navigation strategies, analyses, and demonstrations for Galileo, Ulysses, and Mars Observer.

Tracking and Data Advanced Systems—Committee Comments

The Committee authorizes $18,800,000 for Tracking and Data Advanced Systems in FY 1989. This is the same as the President's budget request.

The Committee continues to support these activities that will improve the cost effectiveness and reliability of space missions.

II. SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS—$4,686,200,000

The Committee authorizes $4,686,200,000 for Space Flight, Control and Data Communications in FY 1989. This is $155 million less than the President's request.

The objective of the NASA program of space flight, control and data communications is to provide for the operational activities of the Space Transportation System (STS) and tracking and communication system support to all NASA flight projects. This objective is achieved through the following elements.

Shuttle Production and Operational Capability

This program is to provide a fully capable fleet of Space Shuttle orbiters, main engines, launch site and mission operations control requirements, initial spares, production tooling, and related supporting activities.

Space Transportation Operations

This program is to provide the standard operational support services for the Space Shuttle and the expendable launch vehicles. Within Shuttle operations, external tank and solid rocket booster flight hardware is produced; operational spare hardware is provisioned, overhauled and repaired, and manpower, propellants, and other materials are furnished to conduct both flight and ground (launch and landing) operations.

Space and Ground Network, Communications and Data Systems

This program is to provide vital tracking, telemetry, command, and data acquisition support to meet the requirements of all NASA flight projects. This support is currently provided by a worldwide network of NASA electronic ground stations interconnected by a communications system using ground, undersea, and satellite circuits. The Tracking and Data Relay Satellite System (TDRSS) will become the primary system for supporting upcoming Earth orbiting missions.

Summary of FY 1989 funding levels

Shuttle Production and Operational Capability	$1,335,500,000
Space Transportation Operations	2,365,400,000
Space and Ground Networks, Communication and Data Systems	985,300,000
Total Space Flight, Control and Data Communications	$4,686,200,000

The primary program objective of the current activity in the STS is to complete the safe return to Space Shuttle flight activities. The Space Shuttle is the key element of a versatile STS that is available to a wide variety of national users and certain international users. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, spacecraft scientific experiments, and national security payloads. In addition to transporting materials, equipment and spacecraft to orbit, the Shuttle offers unique capabilities that cannot be achieved with Expendable Launch Vehicles (ELV): retrieving payloads from orbit for reuse; servicing and repairing satellites in space; transporting to orbit, operating, and returning space laboratories; and performing rescue missions.

Shuttle Production and Operational Capability provides for the national fleet of Shuttle orbiters including the replacement orbiter which was fully funded in FY 1987. This budget element also provides for the launch site facilities, initial spares, production tooling, and related support activities. In addition, there is also included the design, test, analysis and certification associated with the recovery actions necessary, as a result of the Challenger accident, to verify the flight hardware and mission support processes necessary for returning to flight.

This line contains five subdivisions: Orbiter Operational Capability, Orbiter Replacement, Propulsion, Launch and Mission Support, and Changes and System Upgrades. Orbiter Operational Capability includes orbiter design modifications and system improvements, mission kits, procurement of a spares inventory for the operational orbiter fleet, necessary safety modifications identified by the NASA investigation and the Rogers Commission during the post-Challenger accident review process, initiation of a new set of structural spares to maintain the capability to produce orbiter vehicles, and continuation of work started in FY 1988 on an Extended Duration Orbiter (EDO) capability. Orbiter replacement will provide a replacement Orbiter for Challenger which is necessary to restore a significant element in the Nation's space launch capability. Propulsion Systems provides for Space Shuttle Main Engines (SSMEs), External Tank (ET), and Solid Rocket Booster (SRB) design improvements, safety modifications, capability investments, rate tooling and development of an Advanced Solid Rocket Motor (ASRM). Launch and Mission Support provides the Johnson Space Center (JSC) mission operations capability development, equipment provisioning of the facilities for launch and landing at the Kennedy Space Center (KSC) and the initial lay-in of spares and ground support equipment. Changes and Systems Upgrade provides funding for potential changes and systems modifications as well as for unanticipated new requirements not covered elsewhere.

Space Transportation Operations provides the standard operational support services for the Space Shuttle and ELVs for NASA payload requirements. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower, propellants, and other materials are furnished to conduct and support both flight and ground operations. The Shuttle Operations program provides for the launch of NASA missions, DOD, other U.S. Government and certain commercial and international missions on a reimbursable basis. The launch schedule calls for one flight in FY 1988 (the first launch is scheduled for late summer 1988), seven flights in FY 1989, and ten flights in FY 1990.

The Shuttle provides launch services to non-NASA users on a reimbusable basis to satisfy DOD and civil government requirements. A limited number of foreign and commercial launches are planned following the resumption of flights based on administration policy decisions.

The ELV/Mixed Fleet plan provides launch services for unmanned civil U.S. government space missions not requiring the Space Shuttle's unique capabilities. Initially, ELV services will be procured, for selected high priority missions previously manifested on the Space Shuttle. Consistent with the Competition in Contracting Act, expendable launch vehicle services will be acquired from the U.S. private sector, where possible.

1. Shuttle Production and Operational Capability—$1,335,500,000

The Committee authorizes $1,335,500,000 for shuttle production and operational capability in FY 1989. This is $65 million less than the President's request.

Summary of FY 1989 funding levels

Orbiter Operational Capability	$280,000,000
Launch and Mission Support	343,700,000
Propulsion Systems	711,800,000
Change and System Upgrading	0
Total Shuttle Production and Operational Capability	$1,335,500,000

The objectives of this program are to provide for the completion of the modifications required to return the STS to a safe flight status, the completion of the national fleet of Shuttle orbiters, including building a replacement orbiter for the Challenger; the development and production of the propulsion systems; the development of launch site capabilities; and the potential changes and upgrading of the STS. Also included is the development of the EDO and the ASRM.

Orbiter Operational Capability

The primary objective of this program is to continue the return of the three orbiter fleets to safe flight status in FY 1988. This will provide safe and reliable access to space for NASA, DOD and certain domestic and international users of space. In support of this objective, orbiter production activities include the necessary safety modifications identified by the Rogers Commission and the post-Challenger accident review process, as well as the development and installation of necessary hardware, software and procedural modifications. Also included will be the work necessary to continue work on an EDO capability.

In FY 1989, a new set of structural spares will be initiated in order to sustain the capability to produce another vehicle in addition to providing additional spares for inventory.

The procurement and fabrication of the orbiter spares inventory is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A logistics depot has been established at KSC for repair and maintenance of orbiter parts.

In FY 1989, Orbiter funds provide for the procurement of a logistics capability including an inventory of spares to support operations requirements, the continuation of previously approved systems improvement programs, necessary safety modifications identified as a result of the Challenger accident review process, initiating of the manufacture of a replacement set of structural spares, and the engineering analysis and integration support for the flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, the on-board flight software, and implementation of a crew escape system during orbiter controlled gliding flight. Starting in FY 1989, work on the EDO will be continued under the orbiter program. In FY 1988, Congress appropriated funds in Research and Development to initiate the EDO.

In addition, the development, qualification and production of flight units for an improve auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will continue. The orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, as well as procuring orbiter support items and capability changes to the on-board flight software.

Replacement Orbiter

In order to provide assured access to space and to maintain U.S. preeiminence in space, NASA has been directed to procure a replacement orbiter (OV-105), with full funding provided in FY 1987. This replacement orbiter will provide a significant increase in existing National launch capability to fly off the backlog of national security, international, U.S. space industry, and NASA missions resulting from the Challenger accident.

Currently, a set of structural spares is being completed and used as the foundation for the production of OV-105. A contract has been signed with Rockwell International for the production of this orbiter; work began on August 1, 1987, and OV-105 is planned to be delivered in 1991.

Launch and Mission Support

This activity supports the development of launch and mission support capabilities, principally at JSC and KSC. A "second line" of facilities is provided in the launch site equipment budget to support processing and checkout of up to three orbiters in flow and to sustain the operational launches at KSC. In FY 1989, the third mobile launch platform will be completed.

Funding has been included for upgrading landing aids for end of mission and contingency/abort landing sites. Capability improvements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. Funding for a pre-flight adaptor trainer has also been added to help prepare the crews for a weightless environment. Consistent with the recommendations of the Rogers Commission, improvements in simulation training including new host computers and interface hardware are being made. Other activities include implementing required modification and upgrades on the T-38 proficiency aircraft and procuring a fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft. Procurement of extravehicular mobility unit (EMUS) and associated improvements are also included.

In FY 1989, Launch Site Equipment includes activities to improve the capability to support the flight rate requirements at KSC. The mission support capability requirements continue to establish an inventory of crew equipment, principally EMUs, to support the flight rate, and the mission operations capability funding in FY 1989 provides for completion of replacement of the host computers, selected critical items for the shuttle training simulators and replacement Advanced Data Processing (ADP) and other hardware in the Mission Control Center.

Propulsion Systems

Propulsion Systems provides for the production of SSMEs, the implementation of the capability to support operational requirements, and anomaly resolution for the SSME, SRB, and ET. The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spare engines,

ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes the reclamation and refurbishment of hardware produced prior to the Challenger accident, continued replacement of reusable hardware lost during the 51-L failure and subsequent ground testing of the SRB redesign, continuation of test data analyses and evaluation, completion of solid rocket motor (SRM) tooling modifications, procurement of transportation equipment to support the projected flight rate, and development of the ASRM. Engineering analysis and modification of booster hardware for certification of a 20 flight reuse capability will continue in FY 1989. Systems support primarily provides for support to the testing of the SSME in the main propulsion test article configuration.

The redesign of the SRB to resolve deficiencies in the previous design will be completed through certification and reflight in FY 1988. Assessment of flight data, including analysis and evaluation, will be continuing in FY 1989. There will be a continuing activity to improve tooling and procedures to enhance process control and product quality. Reclamation of reusable SRM hardware produced prior to the Challenger accident will be accomplished through static firing and refurbishment. Refurbishment of the case hardware will include modification to the redesigned configuration.

Funding for the FY 1989 budget is based upon resumption of the flight program in the late summer of 1988 (August/September time frame) and the design, test, and certification of the program and recertification of all flight hardware to assure compliance with flight requirements. The SSME program will continue production of flight hardware and the development programs including improvements to the current configuration and the alternate turbopump programs. The SRB FY 1989 funding will primarily focus upon continued evalution and analysis of flight data to assess thoroughly the redesign. Modification of booster hardware necessary to obtain a 20-flight reuse capability will continue as well. The ET program supports the production of tanks with required off-the-shelf equipment.

The ASRM project is intended to enhance the flight safety, reliability and performance of the Space Shuttle fleet. The ASRM will not be subject to the constraint of maximum utilization of existing hardware that limited changes on the recent SRM design activities. The ASRM may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins. Production processes will be examined to utilize the latest applicable technology and process automation to enhance reproducibility and reliability.

During the ASRM definition studies, now being conducted, the contractors will perform preliminary designs on a segmented motor and monolithic motor. Also, they will provide design data on a modern, automated production facility to maximize material and process controls for enhanced reliability. An additional objective of the ASRM is to achieve increased payload capability. The definition studies will examine achieving this objective with the requirement that there be no compromise to flight safety and reliability, and that the impact to other Shuttle elements be held to an absolute minimum.

The Request for Proposal (RFP) for the development phase will be issued at or near the end of the definition studies in the June/July period of 1988. One contractor is to be selected for developing, and the contract start is anticipated in January 1989. The development program is anticipated to extend for about 5 years with the first flight in early 1994. The development period is based on the original SRM development. The scope of the development will include modification or acquisition of facilities, the development and the test of the new design and production of verfication units. The ASRM development is comparable in scope and complexity to that of the SRM, and the technological base is greater than that at the start of the SRM project.

The asbestos-free installation development program previously included as a separate development will be incorporated into the scope of the ASRM development. This requirement is driven by environmental and production safety concerns rather than by technical or performance issues. Costly duplication of qualification tests can be avoided by incorporating this effort into the overall ASM. However, if the ASRM is not approved or the existing asbestos-based insulation production is stopped before the ASRM is available, the separate development will have to be reinstated.

Changes and systems upgrading

Management, technical flight experience, and cost review of the Shuttle program have stressed the need for providing an allowance for changes and modifications which inevitably are required in a large, complex, and technically demanding space system.

The Changes and Systems Upgrading budget provides for potential changes to improve system reliability, safety and performance.

The funding for fiscal year 1989 will provide for those changes which are considered to have the highest priority. The objectives are to improve reliability, increase operating safety margins, and reduce costs.

Space Shuttle Production and Operational Capability—Committee Comments

As was the case in FY 1988, restoring the space shuttle to flight status is the highest priority for NASA in FY 1989. Therefore, the Committee has provided $1,335,500,000 for Space Shuttle production and Operational Capability in FY 1989, including the Presidents full request of $88 million for development of an ASRM. The Committee's authorization is $65 million below the President's request. This represents a $40 million reduction to the space shuttle structural space program and a $25 million reduction to the Administrator's discretionary account for changes and system upgrading. The Committee is reluctant to recommend any reductions to this account because of the high priority given to return to flight of the space shuttle. Reductions, therefore, are recommended in the two accounts that do not affect those efforts.

Concerning the structural spaces program, the Committee recommends a funding level of $17,300,000 in FY 1989. This is an in-

crease of $6,300,000 to the current program and should permit the prime contractor to retain critical subcontractor skills and to proceed with the critical spares—wins, orbital maneuvering subsystem (OMS) pods, feedlines, remote power controller among others.

The Committee is well aware of the arguments in support of the structural spares program and an option for a fifth orbiter. However, to bring the FY 1989 budget request in line with the realities of the congressional budget process, the Committee has recommended reductions in those activities not directly associated with the return-to-flight of the shuttle.

The Committee was pleased to see that the FY 1989 budget request included a new start for the ASRM facility. The Committee sees this initiative as a critical element of the space shuttle program and necessary for its enhanced safety, reliability and performance—a position that has been endorsed in two different reports of the National Research Council. The Committee, therefore, fully funds this program in FY 1989.

The Committee is concerned that NASA and OMB are still uncertain as to whether or not certain options in the ASRM request for proposals require legislation. To leave its options open, the Committee has included language in section 7 of the bill that permits continued discussions of this issue since it is the Committee's impression that enabling legislation would be required if option two or three were to be pursued. However, the Committee expects a formal notification on this matter from the administration as soon as possible.

The Committee also wants it to be perfectly clear that the Committee strongly endorses the ASRM program and feels that the request for proposals should be issued in a most timely manner so as to get this critical program under way. The Committee feels even more strongly that the selection criteria for the ASRM should be formulated by NASA alone and that the key criteria should be safety, reliability and performance.

The Committee also would like to indicate that it has been most pleased with NASA's efforts to keep the Committee informed of developments in the SRM test program, anomaly resolution activities, and return-to-flight issues. The Committee is pleased with NASA's methodology in selecting a crew escape system, with the involvement of the astronaut crops, and with the decision to incorporate the pole ejector into STS-26. The Committee also is pleased with the results of the Qualification Motor 6 full-scale test firing and anxiously awaits the results of the Qualification Motor 7 firing in June, the Production Verification Motor firing and the Flight Readiness Firing in July. The Committee still strongly adheres to the position that the successful implementation of these test firings is a necessary prerequisite to the return to flight of the space shuttle.

The Committee would like to reiterate its support of NASA's acquisition of a second space shuttle aircraft carrier, a fourth training aircraft and fourth orbiter.

In conjunction with the Spacelab program, the Committee is pleased to see NASA aggressively assessing the development of an EDO. The Committee strongly believes that an EDO could significantly enhance our Nation's space transportation infra-structure and that extended space shuttle flight duration could result in greater opportunities for space-based research and development. The Committee supports the $10 million allocation within the FY 1989 budget request for an EDO and recommends that NASA consider seriously including in the FY 1990 budget request a new start request and separate line item for an EDO.

Despite the fact that NASA's November 1987, *Report to the Congress on an Extended Duration Orbiter* substantiates the feasibility of an EDO, its relative value and cost, it provides a qualified, but not well documented, assessment of the feasibility of a commercial EDO venture and alludes to the fact that a commercial EDO might be less economically attractive than a government-developed EDO.

To better understand the relative merits of a commercial EDO vis-a-vis a government EDO, the Committee directs NASA to submit to the Committee by October 1, 1988, a report detailing the number and type of EDO options that are being assessed, the current status of these proposals, and the trade-off considerations between a government EDO program or commercial EDO venture. In light of the significant interest of this Committee and the administration in space commercialization, the Committee wants to be fully aware of these competing considerations before it renders a final opinion as to whether an EDO should be a government program or a commercial venture.

Finally, the Committee would like to recommend that NASA include a separate line item in the FY 1990 budget request for space shuttle spares. A separate line item for space shuttle spares would enable Congress to assess more accurately and thoroughly the role of these spares in the shuttle program and would highlight their importance to maintaining a robust space transportation system.

2. Space Transportation Operations—$2,365,400,000

The Committee authorizes $2,365,400,000 for Space Transportation Operations in FY 1989. This is $40 million less than the President's requests.

Summary of FY 1989 funding levels

Shuttle Flight Operations	$660,100,000
Shuttle Flight Hardware	1,035,200,000
Shuttle Launch and Landing Operations	514,600,000
Shuttle Operations Subtotal	$2,209,900,000
Expendable Launch Vehicles and Services	155,500,000
Total Space Transportation Operations	$2,365,400,000

Space Transportation Operations provides launch services to NASA payloads utilizing a mixed fleet approach of the Shuttle and ELVs. Launch services are also provided, on a reimbursable basis to DOD, other civil agencies, and certain commercial and international users. The Shuttle program launch schedule is based on a resumption of flight activity in late summer 1988 with one flight in FY 1988, seven in FY 1989, and ten in FY 1990. The ELV planning reflects use of a mix of launch systems based on individual payload requirements.

The major program elements of Shuttle Operations are Flight Operations, Flight Hardware and Launch and Landing Operations.

These elements provide for the standard service operation of the Shuttle including pre-flight preparation activities, procurement and refurbishment of flight hardware and maintenance and operation of equipment and facilities necessary to support all phases of the Shuttle flight process.

The ELVs/Mixed Fleet plan was initiated in FY 1987 as a result of an assessment of NASA's space transportation requirements after the Challenger accident. This assessment showed that U.S. Civil Government spacecraft should be launched on a mixed fleet in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The missions currently planned for launch on ELVs are selected high priority missions previously manifested on the Space Shuttle for West Coast launches and selected East Coast launches which do not require the Shuttle's unique capabilities and can transition to ELVs without significant impact to the spacecraft.

Shuttle Flight Operations

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of pre-flight planning, crew training, and operations control activities. The planning activities range from the development of operational concepts and techniques to detailed systems operational procedures and checklists. Whereas the integration activity includes orbiter sustaining engineering, payload integration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. Finally, the support activity includes base operations support to Shuttle operations and systems level support at the manned space flight centers.

Currently, the resources for Flight Operations are focused upon preparing for resumption of flight, correcting a backlog of system discrepancies and incorporating a large number of changes to ground systems, hardware, software, and procedures including those resulting from the ongoing process of analysis and decision-making in the wake of the Challenger accident. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are critical to the safe operation of the Shuttle and significant emphasis is being placed on insuring that the flight products and crew training satisfying revised and more stringent operational requirements.

In FY 1989, the Flight Operations portion of the Shuttle Operations budget continues to support that activity predominately associated with the effort at JSC to plan for and conduct STS missions from launch to landing. The functions are essentially the same as in the past: to maintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; to maintain and operate aircraft for proficiency, training and orbiter ferry requirements and to perform analyses of and conduct of the mission planning necessary for each mission.

Shuttle Flight Hardware

The Flight Hardware program element provides for the procurement of ETs, the manufacturing and refurbishment of SRB hardware and motors; and operational support to the Orbiter including orbiter spares, ET disconnects, spare components and flight support for the SSMEs and maintenance and refurbishment of flight crew equipment.

In FY 1989, requirements for Orbiter flight spares, crew equipment spares, and logistics are based on projected flight rates, maintenance schedules, operational usage, repair times, and lead times to procure or repair flight hardware.

The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the Orbiter, the EMU and other crew equipment. The flight equipment processing contract (FEPC) which was initiated during FY 1986 is continuing its buildup to full capability to support the projected flight rates. SSME hardware provides for manufacturing and delivery of overhauled engines, engine component spares and flight support. Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and fabrication of units which will be flown during FY 1989, as well as the support of the production of units which will be flown thereafter. Additionally, two static firing tests of the redesigned SRM will be conducted to monitor the consistency of production characteristics.

Shuttle Launch and Landing Operations

Launch and Landing Operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the processing facilities at KSC.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off.

Support to Shuttle processing is provided by the Base Operations Contractor (BOC). The BOC is responsible for operations support functions such as propellants and life support, railroad maintenance, pressure vessels, Shuttle landing facility and facility and equipment modifications.

The Payload and Ground Operations Contract (PGOC) is the major contract for the payload processing activities. In Shuttle Operations, the PGOC contractor provides the standard service processing of all STS payloads into an integrated cargo prior to loading into the Shuttle. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

Launch operations funding in FY 1989 provides for manpower and support services necessary for processing launches from KSC. Funding also supports the manpower required for sustaining engineering, spares provisioning, logistics, launch processing system op-

eration and maintenance, and maintenance/modification of all other shuttle-related ground support equipment and facilities. Flight safety will continue to be emphasized through testing, engineering and quality control.

Payload and launch support funding provides propellants for launch operations, base support and contractor support for the assembly of individual payloads into a total cargo.

Expendable Launch Vehicles/Mixed Fleet

The ELVs/Mixed Fleet plan, initiated in 1987, provides launch services for selected NASA payloads not requiring the Space Shuttle's unique capability. Four performance classes of expendable vehicles are planned in the mixed fleet. A small class capable of launching payloads up to 1,000 pounds into low Earth orbit; a medium class capable of launching payloads up to 10,000 pounds into orbit; an intermediate class capable of launching payloads up to 30,000 pounds; and a large class capable of launching payloads of 40,000 pounds or more. NASA plans to utilize competition where possible in the acquisition of ELV services in these performance classes to accommodate a range of spacecraft requirements in FY 1992 and beyond. In the interim, NASA will acquire expendable launch vehicle services for selected high priority missions previously manifested on the Space Shuttle consistent with the Competition in Contracting Act (CICA). In this interim period, two Delta II launches, one for the Roentgen Satellite (ROSAT) and one for the Extreme Ultraviolet Explorer (EUVE) are being acquired through DOD. DOD has also been requested to provide a Titan IV vehicle to be available in 1991 to provide a back-up for either the Magellan, Galileo or Ulysses planetary missions presently manifested on the Shuttle. Titan III vehicles are being evaluated for launch of the TDRS-F and Mars Observer spacecraft in the 1991/92 time period. In addition, discussions are in progress to obtain Atlas/Centaur Launch services for the Combined Release and Radiation Effects Satellite (CRRES) as part of a barter in exchange for residual hardware from previous programs. Assuming that CRRES is launched on this vehicle, several of the planned experiments which could not be accommodated on Atlas/Centaur would be launched on Scout vehicles.

In FY 1989, funds are required for continuation of launch vehicle procurements through the DOD for the ROSAT and the EUVE missions. In addition, funding is required to initiate work on the Titan III, Titan IV, Atlas/Centaur and Scout launches described above. Funding is required for medium class vehicles for the Geotail and Wind spacecraft of the Global Geospace Science project. Procurement of launch services for small class vehicles in support of Science and Application missions, planned to be launched at a rate of two per year, will be initiated with these funds.

Space Transportation Operations—Committee Comments

The Committee authorizes $2,365,400,000 for Space Transportation Operations in FY 1989. This is $40 million less than the President's budget request. This reduction, as described below, is applied to the ELVS line item. As was the case with the Space Shuttle Production and Operational Capability account, the Committee recommends no reductions to any space shuttle return to flight activities.

The Committee anxiously awaits the launch of STS-26 and the resumption of a regular flight schedule by NASA. It is with great concern, therefore, that the Committee acknowledges the explosion of the Pacific Engineering and Production Company plant in Henderson, Nevada on May 4. The Committee has received the preliminary briefings on the possible ramifications of the loss of this source of a critical component of the SRB propellant and its impact on the proposed space shuttle flight rate. The Committee anxiously awaits the findings of the National Security Council (NSC) Task Force that is assessing this issue and has added language to the authorization for space transportation operations to give NASA maximum flexibility in dealing with this matter. The Committee appreciates NASA's cooperation in this matter and expects to work closely with NASA and the NSC to formulate a reasonable response.

As regards the Committee's reduction of the ELV budget request, it should be noted that the Committee still strongly supports the mixed fleet concept. However, due to the severe budget constraints in FY 1989, the Committee cannot increase the program from its current level of funding, $28 million, to the requested level of funding, $195,500,000. The Committee has authorized $155,500,000 million in FY 1989. This should permit the aggressive acquisition of Scout- and Delta-class vehicles, a commercial Titan III for the Mars Observer, and initiation of the acquisition of a Titan IV, planetary backup. The Committee has deferred a decision on a second Titan III until FY 1990 and assumes a general reduction of $25 million.

3. Space and Ground Networks, Communication and Data Systems—$985,300,000

The Committee authorizes $985,300,000 for Space and Ground Networks, Communications and Data Systems in FY 1989. This is $50 million less than the President's request and reflects a general reduction of $50 million.

Summary of FY 1989 funding levels

Space Network	$538,900,000
Ground Networks	248,100,000
Communications and Data Systems	248,300,000
Total Space and Ground Networks, Communication and Data Systems	[1] $985,300,000

[1] Reflects a general reduction of $50 million.

The purpose of this program is to provide vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of DOD, other government agencies, commercial firms, and other countries and international organizations engaged in space research.

Support is provided for Earth orbital, planetary and solar system exploration missions, research aircraft, sounding rockets and balloons. Tracking and acquisition of data for the space projects is

presently accomplished through the use of a worldwide network of NASA ground stations, and by the first of three tracking and data relay satellites (TDRSS) in geosynchronous orbit working with a highly specialized ground station. Ground facilities are interconnected by terrestrial and communications satellite circuits linking the spacecraft and their control centers for execution of the missions.

To meet the support requirements levied by the wide variety and large number of flight projects, NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network, including the Tracking and Data Relay Satellite System (TDRSS), which will provide all low Earth orbital mission support when it becomes fully operational.

Space Network

The Space Network consists of the TDRSS and a number of NASA ground elements to provide the necessary tracking, telemetry, command, and communications services to low Earth orbital spacecraft. The TDRSS, when fully operational, will consist of a three satellite constellation, including an on-orbit spare, in geostationary orbit and ground facilities located at White Sands, NM. From the White Sands location, satellite and ground comunications links interconnect the NASA elements of the network and any remotely located user facilities.

The FY 1989 request includes funding for: repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands complex and other NASA elements of the network; support activities such as systems engineering, documentation and mission planning; equipment modification and replacement; analytical studies to define the spacecraft required for the next generation TDRSS; the development and integration of an additional spacecraft to replace the TDRS lost in the Challenger accident; and the implementation of a second TDRSS ground terminal at White Sands.

In FY 1989, the space network budget request would provide for continuation of the construction phase of an optional TDRS spacecraft to replace the satellite lost in the Challenger accident. It also would permit selection of a single contractor for implementation of a second TDRSS ground terminal and initiation of definition activities for an advanced tracking and data relay satellite to meet future mission requirements.

Ground Networks

The Ground Networks provide support to three broad categories of missions: Earth orbital spaceflight; planetary and solar system exploration; and aeronautics, balloons and sounding rockets. Earch orbital support is provided primarily by the STDN, a network of eight geographically dispersed ground stations. The Deep Space Network, with ground stations located at three sites approximately 120 degrees apart in longitude, provides support to the planetary and solar system exploration missions as well as Earth orbital missions not compatible with TDRSS. Aeronautics, balloons and sounding rocket research are supported by specially instrumented ranges, as well as mobile systems.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities as required to support new missions. The workload in FY 1989 will include support to the Space Shuttle, the Voyager-2 encounter with the planet Neptune, and the Magellan spacecraft launch. Magellan will perform radar imaging of Venus during FY 1990. Preparations will be under way for the future Galileo, Ulysses, and Mars Observer planetary encounter missions, and the Global Geospace Science (GGS) mission. Ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM) will continue to receive Ground Networks and/or Space Network support. Aircraft test programs will also be supported.

Communications and Data Systems

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support.

Communication circuits and services provide for the transmission of data among the remote tracking and data acquisition facilities, launch areas, and the mission control centers. Real-time information is crucial to determine the condition of the spacecraft and payloads for the generation of spacecraft and payload control commands. Data received from the various spacecraft must be processed into a usable form for spacecraft monitoring in the control centers and before the transfer of data to the experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects, and international cooperative efforts.

Major activities under way include: implementing necesary changes to the Hubble Space Telescope mission control and data capture system, and misson control and data processing capabilities required to support upcoming missions such as Gamma Ray Observatory (GRO), Sapcelabs, Upper Atmosphere Research Satellite (UARS), GGS and Advanced X-ray Astronomy Facility (AXAF). In addition, studies are continuing to evaluate Space Station support requirements.

Space Tracking and Data Acquisition—Committee Comments

The Committee authorizes $985,300,000 for Space Tracking and Data Acquisition in FY 1989. This is $50 million less than the President's request.

The Committee is most supportive of the Space Tracking and Data Acquisition program and is well aware of its importance to the operation of the Nation's space program. However, to distribute equitably the proposed reduction to the FY 1989 NASA budget request, the Committee recommends a general reduction of $50 million from this account. The Committee anticipates that NASA can spread this reduction efficiently and economically and with mini-

mum impact to the acquisition of a replacement TDRS and to the initiation of development activities for a second TDRS system ground station.

The high priority status of the Space Tracking and Data Acquisition program is reflected by the fact that two of the first three payloads scheduled for launch on the space shuttle are tracking, data and relay satellites. The Committee, therefore, intends to work closely with NASA to insure the timely deployment of these satellites and the timely development of the necessary space tracking and data relay infrastructure.

III. CONSTRUCTION OF FACILITIES—$260,100,000

The Committee authorizes $260,100,000 for Construction of Facilities in FY 1989.

The Construction of Facilities (COF) appropriation provides contractual services for the report, rehabilitation and modification of existing facilities, the construction of new facilities; the acquisition of related facility equipment; the design of facilities projects; and advanced planning related to future facilities needs.

The funds requested for FY 1989 provide for the continuation of prior year endeavors in meeting the facilities requirements for the Space Flight and Space Station programs; initiating of a structured multi-year effort to restore and modernize NASA's aeronautical research and development facilities; repair, rehabilitation and modification of other facilities to maintain, upgrade and improve the usefulness of the NASA physical plant; minor construction of new facilities, facility planning and design activities, and environmental compliance and restoration.

The projects and amounts in the budget estimates reflect Space Station and Space Flight requirements that are time-sensitive to meet specific program objectives. Other programs requirements for 1989 include construction of an auxiliary chiller facility at the Johnson Space Center; modifications to the X-ray Calibration Facility to support the Advanced X-Ray Astrophysics Facility Program at the Marshall Flight Center; modernization of the Space Environment Simulator and modifications for utility reliability at the Goddard Space Flight Center; refurbishment of the 25-Foot Space Simulator at the Jet Propulsion Laboratory; projects to repair, restore and moder e NASA's aeronautical research and development facilities at Ames, Lewis, and Langley Research Centers; and refurbishment of the Electric Power Laboratory at the Lewis Research Center.

The FY 1988 program continues to meet the objectives of preserving and enhancing the capabilities and usefulness of existing facilities and ensuring safe, economical and efficient use of the NASA physical plant. This request continues the necessary rehabilitation and modification program begun in prior years and continues a repair program. The purpose of the repair program is to restore facilities to a condition substantially equivalent to their originally designed capability. The minor construction program continues to provide a means to accomplish smaller facility projects which accommodate changes in technical and institutional requirements. The Environmental Compliance and Restoration Program will ensure that statutory environmental requirements will be met and any necessary remedial action promptly taken.

Funds requested for facility planning and design cover advance planning and design requirements for potential future projects, master planning, facilities studies, engineering reports and studies and the preparation of facility project design drawings and bid specifications.

Summary of FY 1989 funding levels

(1) Modifications to Processing Technology Facility for Space Station, Marshall Space Flight Center	$3,700,000
(2) Construction of Addition for Space Systems Automated Integration and Assembly Facility, Johnson Space Center	9,200,000
(3) Replacement of High Pressure Gas Storage Vessels, National Space Technology Laboratory	3,500,000
(4) Increase Chiller Capacity, LC-39 Utility Annex, Kennedy Space Center	2,300,000
(5) Rehabilitation of Pad A, LC-39, Kennedy Space Center	4,600,000
(6) Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility, Johnson Space Center	4,900,000
(7) Modification for Advanced Engine Development, Test Stand 116, Marshall Space Flight Center	13,500,000
(8) Modifications to Orbiter Modification and Refurnishment Facility for Sa.fing and Deservicing, Kennedy Space Center	2,800,000
(9) Modification to the X-Ray Calibration Facility, Marshall Space Flight Center	11,400,000
(10) Construction of Auxiliary Chiller Facility, Johnson Space Center	7,800,000
(11) Modernization of Space Environment Simulator, Goddard Space Flight Center	2,800,000
(12) Modifications for Utility Reliability, Goddard Space Flight Center	3,100,000
(13) Refurbishment of 25-Foot Space Simulator, Jet Propulsion Laboratory	12,000,000
(14) Repair and Modifications of 12-Foot Pressure Wind Tunnel, Ames Research Center	36,500,000
(15) Rehabilitation and Modifications to 10×10 Supersonic Wind Tunnel, Lewis Research Center	14,500,000
(16) Refurbishment to Hypersonic Facilities Complex, Langley Research Center	12,800,000
(17) Refurbishment of Electric Power Laboratory, Lewis Research Center	6,100,000
(18) Construction of National Resource Protection at various locations	2,600,000
(19) Repair of facilities at various locations, not in excess of $750,000 per project	27,000,000
(20) Rehabilitation and Modification of Facilities at various locations, not in excess of $750,000 per project	34,000,000
(21) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project	9,000,000
(22) Environmental compliance and restoration	26,000,000
(23) Facility planning and design not otherwise provided for	20,000,000
Total Construction of Facilities	[1] $260,100,000

[1] Reflects a general reduction of $10 million.

Construction of Facilities—Committee Comments

The Committee authorizes $260,100,000 for Construction of Facilities in FY 1989. This is $25 million less than the President's request. This reduction consists of the deferral of the Space Station Processing Facility at the Kennedy Space Center, without preju-

dice, until FY 1990 (−$15 million) and a general reduction of $10 million.

The Committee was most pleased with the recommendations of the *Major NASA Wind Tunnel Revitalization Program* report and strongly endorses the proposed FY 1989 construction of facilities. The repair and modification of the 12-foot pressure wind tunnel at Ames, the rehabilitation and modernization to the 10x10 supersonic wind tunnel at Lewis, and the refurbishment of the hypersonic facilities complex at Langley are high priority projects that will help the United States retain its technological leadership in aeronautics.

The Committee realizes that these three wind tunnel initiatives are only the first steps of a much larger program. But the Committee is prepared to support NASA in this effort and to restore, rehabilitate and modernize these valuable assets.

IV. RESEARCH AND PROGRAM MANAGEMENT—$1,880,000,000

The Committee authorizes $1,800 million for Research and Program Management (R&PM) in FY 1989. This is $35 million less than the President's request.

The R&PM appropriation funds the performance and management of research, technology and test activities at NASA installations and the planning, management and support of contractor research and development tasks necessary to meet the Nation's ongoing objectives in aeronautical and space research. The objectives of the activities funded by the R&PM appropriation are to; (1) provide the civil service staff with the technical and management skills to conduct the full range of programs for which NASA is responsible, (2) provide base maintenance of facilities and manage its use in support of research and development programs, and (3) provide effective and efficient technical and administrative support for the research and development programs.

The 1989 R&PM appropriation request provides funding for the 22,950 permanent and temporary civil service work years (FTE) at eight major installations and Headquarters. This civil service work force is NASA's most important resource and is vital to future space and aeronautics research activities. At the direction of the Committees on Appropriations, NASA, beginning in 1988, has realigned the R&D/SFCDC and R&PM appropriation structures. In the realigned R&PM appropriation, about 59 percent provides for the salaries and related costs of the civil service work force. Three percent is for travel, critical to manage successful NASA's in-house and contracted programs. The remaining amount of the R&PM appropriation provides for the research, test and operational facility support, and for related goods and services necessary to operate efficiently and effectively the NASA installations and to accomplish NASA's approved missions.

NASA field centers report to the Program Associate Administrator responsible for the major portion of their technical programs. The principal roles assigned to each installation, based on demonstrated capabilities and capacities to meet NASA's overall program goals, are as follows:

Office of Space Flight

Johnson Space Center.—Management of the Space Shuttle program, including orbiter production and operation: selection and training of astronauts and mission specialists; Space Transportation System Operations, including mission planning, operational procedures and flight control; and management of the Space Station Truss system, airlocks and nodes, subsystems development, including propulsion and extravehicular activity, and operations planning and definition.

Kennedy Space Center.—Launch of Space Shuttle flights: management of the ground operational phase of the Space Transportation System; the preparation and launch of payloads on the Space Shuttle and expendable launch vehicles, and Space Station operational readiness planning.

Marshall Space Flight Center.—Management of the Space Shuttle main engine, solid rocket booster and external tank projects; management of NASA's activities on the Spacelab project: management of large automated spacecraft projects such as the Hubble Space Telescope; conduct and development of experiments in materials processing in space; and management of the Space Station habitation, logistics and laboratory modules.

National Space Technology Laboratories.—Space Shuttle engine testing; Earth resources research and technology transfer; and provision of support service functions for other government agencies located on site.

Office of Space Science and Applications

Goddard Space Flight Center.—Development and operation of Earth orbital flight experiments and automated spacecraft to conduct scientific investigations and demonstrate practical applications; management of tracking and data acquisition activities; management of the Delta launch vehicle program; management and launch of sounding rockets and balloons; operation of an instrumented flight range of aeronautical and space research; and development of the Space Station platforms and payload accommodations. The Wallops Flight Facility is an operational element and component installation of the Goddard Space Flight Center.

Office of Aeronautics and Space Technology

Ames Research Center.—Conduct of activities involving experimental and theoretical aerodynamics research, computational fluid dynamics, aeronautical flight research and testing, rotocraft technology, short and vertical takeoff and landing technology, technology for transatmospheric vehicles, planetary probe research, life sciences, human factors, autonomous systems, guidance and control, and operation of an alternate landing site for the Space Shuttle operational missions. The Dryden Flight Research Facility, an operational element and component installation of Ames located in the Mojave Desert, is the site of advanced flight testing and shuttle landings.

Langley Research Center.—Conduct of subsonic aircraft research and technology, emphasizing fuel conservation, safety and environmental effects; hypersonic propulsion; experimental and theoretical

aerodynamics; environmental quality monitoring by remote sensing; advanced space systems technology; and research in the areas of structures and materials, guidance and controls, and airframe/propulsion integration of the transatmospheric research and technology program.

Lewis Research Center.—Conduct of aeronautical and space propulsion research and technology, including propulsion for the transatmospheric research and technology program; space communications research and technology; space energy systems research and technology; development of the space station power system; and management of expendable launch vehicle programs.

The 1989 budget provides the necessary resources to apply these in-house capabilities to program activities. A summary description of, and the funding required by functional category, include:

1. *Personnel and Related Costs.*—Includes salaries and benefits, the government's contribution to personnel benefits for NASA permanent and temporary civil service employees (including the government's cost of the Federal Employees Retirement System (FERS) and the Civil Service Retirement System (CSRS)), and for personnel of other government agencies detailed to NASA. In 1989, the cost of an additional 525 FTE is included. The additional FTE will complete the staffing requirements for space transportation system recovery and strengthen further the NASA Inspector General staff. This category also includes other personnel related costs, such as moving expenses (excluding the associated travel of people), recruiting and personnel investigation services provided by the Office of Personnel Management, and the training of NASA civil service employees.

2. *Travel.*—Includes the cost of transportation, per diem, and related travel expenses of civil service employees who travel for the direction, coordination and management of NASA program activities, including overseas launch and tracking sites; for contract management; for flight mission support; for meetings and technical seminars and symposia; and for permanent and temporary relocations.

3. *Operation of Installation.*—Provides a broad range of services, supplies, and equipment in support of each center's institutional activities. These are divided into three major subfunctional areas: Facilities Services, covering the cost of rental of real property, maintaining and repairing institutional facilities and equipment, and the cost of custodial services and utilities; Technical Services, covering the cost of automatic data processing for management activities, and the cost of educational and informational programs and technical shops supporting institutional activities; and Management and Operations, covering the cost of administrative communications, printing, transportation, medical, supply and related services. The realignment of appropriation structures in 1988 affected the Operation of Installation portion of R&PM. The amounts by major subcategory are as follows:

A. *Facilities Services.*—Includes rental of real property; the cost of maintenance, repair and related activities for facilities and equipment; custodial services; minor modifications and alterations; and utilities services.

B. *Technical Services.*—Includes the cost of general purpose automatic data processing for management activities (including development of agencywide automated systems); education and informational programs; other essential technical services.

C. *Management and Operations.*—Includes the cost of administrative communications; printing and reproduction; Administrative supplies; general purpose materials and equipment; transportation of equipment and supplies (including payments to interagency motor pools); medical services and other support.

Summary of FY 1989 funding levels

Personnel and Related Costs	$1,131,008,000
Travel	51,000,000
Operation of Installation	732,992,000
Facilities Services	(302,588,000)
Technical Services	(183,958,000)
Management and Operations	(246,446,000)
Total Research and Program Management	[1] $1,880,000,000

[1] Reflects general reduction of $10 million

Research and Program Management—Committee Comments

The Committee authorizes $1,880 million for R&PM in FY 1989. This is $35 million less than the President's budget request. The proposed reduction is a general reduction to be spread efficiently and economically by NASA.

The Committee has long believed that NASA's key asset has been its talented and dedicated managers, scientists, engineers and support staff. However, the Committee is concerned that not enough emphasis has been placed by NASA or the Congress on developing the next generation of qualified scientists and engineers or on retaining the current generation.

So concerned is the Committee that this year it held a field hearing in Wichita, KS to explore this and other issues related to the future competitiveness of the United States. Not all the answers were positive. There are trends in the scientific and engineering community that are alarming. Clearly, corrective measures must be taken now if the situation is to be improved and if these talented young engineers, scientists and technicians are to be attracted to employment in the Federal government.

First, NASA must have an exciting mix of programs and missions. The challenge and rewards of public service must help compensate for any pay disparity that might exist between the public and private sectors.

Second, NASA must expand its educational outreach activities and fellowship programs. The recently implemented NASA University Space Engineering and Research Program is a step in that direction, as will be the implementation of the National Space Grant College and Fellowship Program. These programs are critical to the success of NASA and the civil space program and require greater focus and attention. To help highlight these programs, the Committee strongly urges NASA to create a separate line item and a detailed description of educational programs in the FY 1990 budget submission.

Third, there is a clear and compelling need to reexamine the existing Federal personnel system to see what changes and improvements could be made to retain and attract people with the necessary technical and managerial capabilities to NASA. Along this line, the Committee has been working closely with the Senate Governmental Affairs Committee on legislation to implement a demonstration program in NASA using an alternative compensation system. This legislative proposal has progressed rapidly, and the Committee is hopeful that floor action will occur on such a measure this summer.

However, in addition to the people-resource issue, there are very real near-term issues that could seriously affect NASA. The fact that action on a proposed FY 1988 supplemental appropriations bill apears to have ceased is cause for concern, since it includes transfer authority for NASA to remedy a possible personnel problem brought on by the significant reductions in the FY 1988 Continuing Resolution (P.L. 100-203). The Committee is hopeful that the FY 1989 HUD-Independent Agencies Appropriations Bill can be enacted in time to give NASA this necessary authority.

The Committee also is concerned that NASA might again be trying to do too much with too few resources—in particular, people. The fact that NASA requested an augmentation of nearly 2,100 full-time equivalent slots in FY 1989 from OMB and only got 525 is cause for concern. The Committee also is alarmed about reports that NASA Center Directors' requests for additional people—people critical to the safe and reliable return-to-flight of the space shuttle—cannot always be provided.

The Committee has fully endorsed the Administration's request for 525 new civil service positions in FY 1989. However, the Committee realizes that with the proposed FY 1989 NASA program mix, the augmentation of 525 positions will not be enough. The fact that NASA and OMB are currently reviewing a possible FY 1989 augmentation of personnel for the space station program highlights the Committee's concern.

The Committee, therefore, instructs NASA to submit to the Committee by March 15, 1989, a five-year personnel plan for NASA. This plan should include NASA's best estimate of personnel requirements—civil service and contractor personnel—for the period FY 1990-94 and the estimated budget requirements. This report also should indicate how these personnel requirements will be allocated to the individual programs.

Consistent with its actions in the FY 1988 NASA Authorization Bill, the Committee earmarks $250,000 of the funds authorized for R & PM for activities associated with organizing the national and international aspects of the International Space Year (ISY). These monies are to be divided equally between NASA's Office of External Relations and the Office of Space Science and Applications.

The Committee also would request that NASA submit a project status report for each of the major NASA parograms included in the FY 1990 budget request by March 1, 1989. The Committee has found these documents to be a most useful tool in formulating the authorization bill and would would like to see these reports continued.

Finally, the Committee is concerned that certain activities, which are clearly NASA tasks, are being done occasionally by NASA contractors. This would include assistance with preparation of testimony, reports, and answers to questions posed by Congressional Committees. The Committee supports contracting out when the service rendered can be done more efficiently and economically by a private sector operation than a Federal operation. However, when it is done to augment staffing capability, impaired by caps on hiring, the Committee has concerns. The Committee has yet to explore this matter to a degree where it can make any substantive recommendations. However, the Committee does intend to explore this issue.

Amendment to National Aeronautics and Space Act of 1958 To Authorize Warrantless Arrests Under Certain Circumstances By Designated Personnel—Section 8

Presently, section 304(e) of the National Aeronautics and Space Act of 1958 provides the authority for certain NASA personnel as well as certain employees of contractors and subcontractors to carry firearms in the fulfillment of their official duties.

This amendment to section 304 of the NASA Space Act, specifically a new subsection (f), would provide the authority to arrest without warrant to NASA employees designated by the Administrator as well as those contractor and subcontractor personnel carrying out their official duties while guarding and protecting property of the United States under the administration and control of NASA or its contractors or subcontractors.

Subsection (e) and new subsection (f) when read together would allow certain NASA personnel, as well as certain subcontractor and contractor personnel, to make an arrest for the violation of Federal, and in some instances State laws, occurring on NASA property or involving property owned by or in the custody of NASA if the person has reason to believe that the person to be arrested has committed or is committing a felony. Security personnel shall use the minimum degree of force, including firearms, necessary to effectuate the arrest. NASA will develop regulations to be approved by the Administrator and the Attorney General before this authority will be exercised.

The authority is consistent with that granted to DOE pursuant to 42 U.S.C. 2201(k).

John C. Stennis Space Center—Section 9

Section 9 incorporates the provisions of S. 2216, a bill to designate the National Space Technology Laboratories in Bay St. Louis, MS, as the "John C. Stennis Space Center." S. 2216 was introduced by Senator Cochran on March 25, 1988.

The Committee included this provision as a just and fitting tribute to the retiring Senate Pro Tempore and the distinguished Chairman of the Senate Appropriations Committee.

This section was strongly endorsed by the White House and NASA, and on May 20, 1988, the National Space Technology Laboratories was officially renamed the John C. Stennis Space Center by Executive Order.

Authorization for NASA to Obtain Nuclear Fuel from the Department of Energy for Planetary Missions—Section 11

This section provides authority to NASA to obtain nuclear fuel from DOE, on terms and at costs, as may be agreed upon between the NASA Administrator and the Secretary of DOE, for outer solar system exploration (i.e., beyond two astronomical units).

NASA missions to the outer solar system (i.e., beyond two astronomical units) use radioisotope thermoelectric generators (RTGs) because they provide the necessary power for less mass than batteries, fuel cells, solar arrays, or other alternatives at the solar intensities at those distances. The United States has unquestioned preeminence in outer solar system exploration, and NASA has planned a series of missions which will maintain this Nation's leadership position. These missions include, among other things, the Comet Rendezvous-Asteroid Flyby (CRAF), Cassini, and the Saturn Orbiter/Saturn Probe, all of which will require RTGs.

DOE plans, however, to institute a policy of full cost recovery for future production of RTGs. By interagency agrreement, NASA currently receives fuel at approximately half price. This new policy will represent a cost impact of $70-100 million to the CRAF and Cassini projects alone.

The Committee is currently exploring this issue with the Senate Committee on Energy and Natural Resources and hopes to further amend this section before consideration by the Senate to allow acquisition "at less than full cost."

International Space Rescue Initiative—Section 12

The Committee and the World acknowledged the tragedy of our astronaut loss in the Challenger disaster. And the Committee and the World hope that such a tragedy will never again occur. However, space exploration is a risky business, and the Committee realizes that precautions must be taken to reduce the risks of space. Since the Challenger tragedy, NASA has gone to great length, following the Rogers Commission report, to secure crew egress in the case of an aborted space shuttle launch and landing. However, what if the mishap occurred in space? Are the United States and the other spacefaring nations of the world able to rescue a stranded astronaut?

Current international law, to which the United States is a cosignator, provides for human rescue at sea. SOLAS, the International Convention for the Safety of Life at Sea, spells out in minute detail, the provisions for human rescue regardless of national registry or cargo. Such a regime and capability also should exist for the rescue of humans in space. But at present it does not.

The "Return of Astronauts and the Return of Objects Launched into Outer Space" International Space Agreement of 1968 sets precedent for addressing human space rescue. But it lacks specific detail or an implementation plan. It is clear, therefore, that some additional steps are required if space rescues are to be feasible.

One possible mechanism for pursuing such an opportunity is the April, 1987 Agreement between the United States and the Union of Soviet Socialist Republics concerning cooperation in the "Exploration and Use of Outer Space for Peaceful Purposes." Expansion of this agreement could provide an opportunity for the United States and Soviet Union to enlist the support of other nations to move forward immediately with a working group to explore the possibility of space rescue. The group would be required to consider the compatibility of life support systems, space suits, docking and communication systems and the ability to respond in a timely manner in case of a mishap. An earlier initiative by the White House for a simulated rescue mission using the U.S. space shuttle and the Soviet Union's space station was rejected by the Soviet Union. However, the situation today is dramatically different—both with the Soviet Union and our spacefaring allies—and the timing appears to be right for creating an international space rescue working group.

In addition to the pressing reality of saving human life, this proposal relates to decisions involving billions of dollars. NASA is currently considering development of a new space suit (EMU), a space station crew emergency rescue vehicle, communications upgrading, among others. As NASA considers these issues, it should at least consider the compatibility of these systems with those of other spacefaring nations as was done in the report on international spacecraft and docking systems that was just submitted to the Committee.

The Committee expects NASA to take the initiative immediately to start the interagency process of creating a working group to deal with this issue. The Committee is very eager to work with NASA and the other agencies involved and feels it is time to move forward.

Office of Commercial Space Transportation—Section 13

The Committee has authorized $3,827,000 for the operations of the Office of Commercial Space Transportation (OCST) within the DOT. This conforms to the President's request and will enable OCST to meet projected demand in FY 1989 from entities seeking a DOT license to launch commercial expendable launch vehicles.

OCST was established pursuant to P.L. 98-575, with the specific purpose of establishing and enforcing the licensing and regulatory regime necessary for commercial space transportation operations. These activities include safety research and planning, licensing procedures.

The Committee's authorization represents an increase of more than $2 million over the FY 1988 appropriated amounts. The Committee concurs in the need for these increases due to projected commercial launch operations beginning in FY 1989. The Office currently has under review and in process six commercial launch applications. The Office anticipates that 10 more requests for licensing actions will be received before the end of the calendar year. This is a 250 percent increase over 1987, so clearly additional personnel will be required if the Office is to perform its statutory duties.

The Committee is concerned over the trend in appropriations for OCST, which have averaged only 50 percent of the President's request. The Committee feels that this situation is aggravated by the location of OCST in the Office of the Secretary of Transportation,

where it competes for resources against other activities of that office.

The Committee strongly believes that the current placement of the OCST budget within the Office of the Secretary of Transportation's budget request is detrimental to the efficient operations of that office, and to the Congressional funding process. The Committee, therefore, directs DOT and OMB to consider a separate line item for OCST in the FY 1990 budget submission.

The primary focus of OCST is to ensure that each commercial launch licensed by the Office has undergone thorough and rigorous safety analyses. This process is, by definition, complex and time-consuming and involves much more than simple processing of license applications. For example, in FY 1988, OCST produced a document entitled *Hazard Analysis of Commercial Space Transportation.* This analysis will serve as a basis for assessing risks associated with launches of commercial vehicles, as well as for imposing minimum insurance requirements on vehicle operators. This document required knowledge and analyses in many complex areas such as hazardous materials transportation, and risk assessment and management.

The Committee believes that as long as a commercial expendable launch industry exists, there must be adequate resources to properly oversee and regulate that industry. This is essential to ensure that the United States can fulfill its obligations under international treaties, as well as to protect fully the health and safety of the public.

The Committee has chosen not to incorporate the President's proposal for expendable launch vehicle liability reforms in the authorization bill. This proposal was included in the budget submission for OCST. The Committee has initiated hearings in this area, and has commissioned a study by the Congressional Research Service to examine the world space insurance markets. These actions will provide a basis on which to decide whether further action is necessary in this area.

Estimated Costs

In accordance with paragraph 11(a) of rule XXVI of the Standing Rules of the Senate and section 403 of the Congressional Budget Act of 1974, the Committee provides the following cost estimate, prepared by the Congressional Budget Office:

U.S. Congress,
Congressional Budget Office,
Washington, DC, May 26, 1988.

Hon. Ernest F. Hollings,
Chairman, Committee on Commerce, Science and Transportation, U.S. Senate, Washington, DC.

Dear Mr. Chairman: The Congressional Budget Office has prepared the attached cost estimate for S. 2209, the National Aeronautics and Space Administration Authorization Act, 1989.

If you wish further details on this estimate, we will be pleased to provide them.

Sincerely,

James L. Blum,
Acting Director.

CONGRESSIONAL BUDGET OFFICE COST ESTIMATE

1. Bill number: S. 2209.
2. Bill title: The National Aeronautics and Space Administration Authorization Act, 1989.
3. Bill status: As ordered reported by the Senate Committee on Commerce, Science, and Transportation, May 24, 1988.
4. Bill purpose: S. 2209 would authorize appropriations to the National Aeronautics and Space Administration (NASA) and the Office of Commercial Space Transportation (OCST) in the Department of Transportation for fiscal year 1989.
5. Estimated cost to the Federal Government:

(By fiscal year, in millions of dollars)

	1989	1990	1991	1992	1993
NASA:					
Authorization Level	11,105				
Estimated Outlays	6,667	3,629	624	169	16
OCST:					
Authorization Level	4				
Estimated Outlays	3	1			
Total:					
Authorization Level	11,108				
Estimated Outlays	6,670	3,630	624	169	16

The costs of this bill are in budget functions 250 and 400. Including outlays from prior year appropriations, the total outlays for NASA would be $10.4 billion in 1989, assuming appropriation of the authorized amount.

Basis of estimate: This estimate assumes that the full amounts authorized would be appropriated for each fiscal year. Detailed information is shown in the table below. The estimated outlays are based on historical spending patterns.

ESTIMATED COST OF S. 2209

(By fiscal year, in millions of dollars)

	1989	1990	1991	1992	1993
Research and Development:					
Authorization Level	4,278				
Estimated Outlays	2,083	1,613	436	145	
Space Flight, Control, and Data Communications:					
Authorization Level	4,686				
Estimated Outlays	2,976	1,579	131		
Construction of Facilities:					
Authorization Level	260				
Estimated Outlays	17	148	56	23	16
Research and Program Management:					
Authorization Level	1,880				

ESTIMATED COST OF S. 2209--Continued

[By fiscal year, in millions of dollars]

	1989	1990	1991	1992	1993
Estimated Outlays	1,590	290			
Subtotal, NASA:					
Authorization Level	11,105				
Estimated Outlays	6,667	3,629	624	169	16
Office of Commercial Space Transportation:					
Authorization Level	4				
Estimated Outlays	3	1			
Total, S. 2209:					
Authorization Level	11,108				
Estimated Outlays	6,670	3,630	624	169	16

6. Estimated cost to State and local governments: None.

7. Estimate comparison: None.

8. Previous CBO estimate: On May 19, 1988, CBO prepared an estimate for H.R. 4561, the Multiyear National Aeronautics and Space Administration Authorization Act, as ordered reported by the House Committee on Science, Space, and Technology, May 12, 1988. H.R. 4561 would authorize appropriations to NASA and the OCST for fiscal years 1989 through 1991, including $11,492 million for 1989, $14,392 million for 1990, and $15,750 million for 1991.

9. Estimate prepared by: Michael Sieverts.

10. Estimate approved by: James L. Blum, Assistant Director for Budget Analysis.

Regulatory Impact Statement

In accordance with paragraph 11(b) of rule XXVI of the Standing Rules of the Senate, the Committee provides the following evaluation of the regulatory impact of the legislation.

Primarily, this bill authorizes the appropriation of funds for the conduct of space and aeronautical research and development activities to carry out the policy and purpose of the National Aeronautics and Space Act of 1958. These activities are conducted in NASA laboratories, by NASA personnel and through contracts with industry, universities, and research institutions for research and development and for supporting scientific and technical services. The Committee has concluded that the nature of these activities is such that there is no regulatory effect on individuals and businesses and no effect on individual privacy.

The bill also authorizes the appropriation of funds for OCST at DOT. This office licenses and regulates the commercial expendable launch vehicle industry in order to protect the public health and safety and comply with existing U.S. treaty and international law obligations. This office was created to reduce the regulatory burden and paperwork requirements on the industry, and the Committee's action represents the reauthorization of an existing program.

Thus, OCST and NASA programs have no effect on individual privacy and should not have an unacceptable regulatory effect on the individuals or businesses who choose to participate.

Neither of the above mentioned programs would have an inflationary impact or any additional paperwork requirements.

Section-by-Section Analysis

SECTION 1

The short title of this bill is the "National Aeronautics and Space Administration Authorization Act, 1989.".

SECTION 2

This section authorizes $11,104,500,000 for NASA in FY 1989.

These monies are distributed to four appropriations accounts:

1. *Research and Development.*—$4,278,200,000 for space station, space science and applications, space transporation capability development, commercial programs, aeronautical research and technology, transatmospheric research and technology, and space research and technology.

The major assumptions in this area are funding of $867,400,000 and a strong endorsement for the space station in FY 1988, restoration of funding for the Advanced Communications Technology Satellite program, initiation of a new space technology initiative—Pathfinder—but at a reduced level of funding, approval of a "new start" for the Advanced X-Ray Astrophysics Facility, and funding of the Space Grant College and Fellowship Program.

2. *Space Flight, Control and Data Communications.*—$4,686,200,000 for space shuttle production and operations capability, space transportation operations, space tracking and data acquisition, and expendable launch vehicle (ELV) operations.

The major assumptions in this account are deferral of funding for the structural spares program for a fifth orbiter, endorsement of a new start for the advanced solid rocket motor program, augmentation of the current ELV procurement program at NASA, and full support of the space shuttle operations budget request and anomaly resolution activities to facilitate the return of a safe, reliable shuttle to flight status.

3. *Construction of Facilities.*—$260,100,000 for a variety of repair, rehabilitation, and new construction activities required for a robust civilian space program.

The major assumptions in this account are that some space station facilities can be delayed because of program delays and that the repair of certain wind tunnel facilities at the NASA Ames, Lewis, and Langley Research Centers is of the highest priority. These tunnels are critical to both civil and military aircraft development.

4. *Research and Program Management.*—$1,880 million for all civil service staff, maintenance of facilities and support of research and development programs and contract activities, and technical and administrative support of research and development programs.

The major assumption in this account is that NASA will increase the civil service employee base by 525 new slots, primarily for space transportation activities.

SECTIONS 3, 4, AND 5

These sections establish strict parameters for the Administrator of NASA concerning the amount of flexibility he or she has with construction of facilities activities, the transfer of funds from one account to another, and the use of funds for activities not approved by the Committee. These provisions are included in the NASA Authorization bill each and every year.

SECTION 6

This section instructs NASA to distribute its research and development funds on a geographical basis where possible. The Committee annually legislates this requirement and believe it is in the national interest.

SECTION 7

This section gives NASA the authority to permit the funds provided in section 2(b)(1) of this bill for the construction of a Government-owned, company-operated advanced solid rocket motor facility to be used for a company-owned, company-operated facility if NASA determines that the latter is in the national interest and is in the best interest of a safe, reliable space shuttle program. At present, the proposed request for proposal for the advanced solid rocket motor program requires all contractors to bid for (1) a Government-owned, company-operated facility and (2) a privately financed facility, both of which would be on a tentative Government site. Bidders also would have a third option of proposing a privately financed facility at the site of the offerer's choice.

NASA lacks the legal authority to enter into a contractual agreement for option 2 (privately-financed facility at Government site) or Option 3 (privately-financed facility at site chosen by offerer. This section gives NASA that authority.

SECTION 8

Presently, subsection 304(e) of the National Aeronautics and Space Act of 1958 provides the authority for certain NASA personnel, as well as certain employees of contractors and subcontractors, to carry firearms in the fulfillment of their official duties.

This amendment to section 304 of the NASA Space Act, specifically a new subsection (f), would provide the authority to arrest without warrant to NASA employees designated by the Administrator as well as those contractor and subcontractor personnel carrying out their official duties while guarding and protecting property of the United States under the administration and control of NASA or its contractors or subcontractors.

Subsection (e) and new subsection (f) when read together would allow certain NASA personnel as well as certain subcontractor and contractor personnel to make an arrest for the violation of Federal and, in some instances, State laws occurring on NASA property or involving property owned by or in the custody of NASA if the person has reason to believe that the person to be arrested has committed or is committing a felony. Security personnel shall use the minimum degree of force, including firearms, necessary to effectuate the arrest.

NASA shall develop regulations to be approved by the Administrator and the Attorney General before this authority is exercised.

The authority is consistent with that granted to DOE pursuant to 42 U.S.C. 2201(k).

SECTION 9

This section requires that the National Space Technology Laboratories of NASA, located in Bay St. Louis, MS, is named and designated "John C. Stennis Space Center."

This is a just and fitting tribute to the retiring Senate Pro Tempore and the distinguished Chairman of the Senate Appropriations Committee. This tribute is strongly endorsed by NASA and the White House.

SECTION 10

This section reiterates the Committee position that the space station may be used only for peaceful purposes. This language is consistent with existing U.S. treaty obligations (the Outer Space Treaty) and current law—P.L. 99-170. This language permits DOD research and development activities on the space station.

SECTION 11

This section gives the Administrator of NASA the authority to obtain nuclear fuel from DOE for outer solar system exploration on terms and at costs that may be agreed upon.

SECTION 12

This section expresses the Sense of the Senate that the President should establish a multilateral Space Rescue and Space Assistance Working Group to explore the creation of an international space rescue regime and the development of compatible docking, communications, and life support systems to support the effectiveness of this regime.

Such a regime would permit all spacefaring nations to reiterate their commitments to the 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space and would extend to incidents of distress in space the principles of rescue universally accepted with respect to incidents of distress at sea and in the air.

SECTION 13

This section authorizes $3,827,000 for FY 1989 for OCSP in DOT. This Office oversees the regulation and licensing of commercial ELV activities and was established by this Committee pursuant to P.L. 98-575—the Commercial Space Launch Act. The level authorized is the administration's request.

CHANGES IN EXISTING LAW

In compliance with paragraph 12 of rule XXVI of the Standing Rules of the Senate, changes in existing law made by the bill, as

reported, are shown as follows (existing law proposed to be omitted is enclosed in black brackets, new material is printed in italic, existing law in which no change is proposed is shown in roman):

THE NATIONAL AERONAUTICS AND SPACE ACT OF 1958

Section 304 of that Act

SECURITY

SEC. 304. (a) * * *
(b) through (e) * * *
(f) Under regulations to be prescribed by the Administrator and approved by the Attorney General of the United States, those officers and employees of the Administration and of its contractors and subcontractors authorized pursuant to subsection (e) to carry firearms may arrest a person without warrant for any offense against the United States committed in their presence, or for any felony cognizable under the laws of the United States if they have reasonable grounds to believe that such person has committed or is committing such felony. Individuals granted authority to make arrests by this subsection may exercise that authority only while guarding and protecting property of the United States under the administration and control of the Administration or one of its contractors or subcontractors.

THE COMMERCIAL SPACE LAUNCH ACT

Section 24 of that Act

AUTHORIZED APPROPRIATIONS

SEC. 24. There are authorized to be appropriated to the Secretary $4,000,000 for fiscal year 1985. There is authorized to be appropriated to the Secretary to carry out this Act $586,000 for fiscal year 1986. There is authorized to be appropriated to the Secretary to carry out this Act $4,548,000 for fiscal year 1988. *There is authorized to be appropriated to the Secretary to carry out this Act $3,827,000 for fiscal year 1989.*

O

Public Law 100-685
100th Congress

An Act

To authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes.

Nov. 17, 1988
[S. 2209]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Aeronautics and Space Administration Authorization Act, Fiscal Year 1989".

National Aeronautics and Space Administration Authorization Act, Fiscal Year 1989.

TITLE I—NATIONAL AERONAUTICS AND SPACE CAPITAL DEVELOPMENT PROGRAM

FINDINGS

42 USC 2451 note.

SEC. 101. Congress finds that—

(1) in accordance with section 106 of the National Aeronautics and Space Administration Authorization Act of 1988 (Public Law 100-147), a space station, hereafter referred to as the United States International Space Station, shall be constructed in order to establish a permanent presence for man in space for the following purposes—

(A) the conduct of scientific experiments, applications experiments, and engineering experiments;

(B) the servicing, rehabilitation, and construction of satellites and space vehicles;

(C) the development and demonstration of commercial products and processes; and

(D) the establishment of a space base for other civilian and commercial space activities including an outpost for further exploration of the solar system;

(2) expendable launch vehicles should be used to launch those payloads that do not require the presence of man;

(3) the space shuttle launches should be used to fulfill the Nation's needs for manned access to space;

(4) preeminence in space and aeronautics is key to the national security and economic well being of the United States;

(5) United States space policy needs long-range goals and direction in order to provide understanding for near-term space projects and programs;

(6) over the next five years the National Aeronautics and Space Administration, hereafter referred to as the "Administration", should pursue leadership in science through an aggressive set of major and moderate missions while maintaining a robust series of cost effective missions that can provide frequent flight opportunities to the scientific community

(7) over the next five years the Administration should prepare for the transition to the United States International Space

Station of those science and technology programs that can be most efficiently and effectively conducted on that facility;

(8) the Administration should encourage the United States private sector investment in space and, to the maximum extent practicable provide frequent flight opportunities for the development of technologies, processes and products that benefit from the space environment;

(9) the Administration should enhance the existing space transportation capability through a robust mixed fleet of manned and unmanned vehicles in order to increase the reliability, productivity, and efficiency and reduce the cost of the Nation's access to space;

(10) the United States faces an increasingly successful foreign challenge to its traditional preeminent position in aeronautics which is rapidly reducing its lead in both civil and military aircraft;

(11) NASA's personnel are an integral component and resource for the Nation's space program, and an innovative personnel system should be developed;

(12) the establishment of a permanent presence in space leading ultimately to space settlements is fully consistent with the goals of the National Aeronautics and Space Act of 1958;

(13) the United States civil space activities should contribute significantly to enhancing the Nation's scientific and technological leadership, economy, pride, and sense of well-being, as well as United States world prestige and leadership;

(14) civil sector activities should be comprised of a balanced strategy of research, development, operations, and technology for science, exploration, and appropriate applications;

(15) assured access to space, sufficient to achieve all United States space goals, is an essential element of United States space policy, and the United States space transportation systems must provide a balanced, robust, and flexible capability with sufficient resiliency to allow continued operation despite failures in any single system;

(16) the goals of the United States space transportation system are—

(A) to achieve and maintain safe and reliable access to, transportation in, and return from, space;

(B) to exploit the unique attributes of manned and unmanned launch and recovery systems;

(C) to encourage, to the maximum extent feasible, the development and use of United States private sector space transportation capabilities; and

(D) to reduce the costs of space transportation and related services;

(17) recognizing that communications advancements are critical to all United States space activities, the Administration should continue research and development efforts for future advances in space communications technologies;

(18) the goal of aeronautical research and technology development and validation activities should be to contribute to a national technology base that will enhance United States preeminence in civil and military aviation and improve the safety and efficiency of the United States air transportation system; and

(19) aeronautical research and technology development and validation activities should—

(A) emphasize emerging technologies with potential for breakthrough advances;

(B) consist of—

(i) fundamental research in all aeronautical disciplines, aimed at greater understanding of aeronautical phenomena and development of new aeronautical concepts; and

(ii) technology development and validation activities aimed at laboratory-scale development and proof-of-concept demonstration of selected concepts with high payoff potential;

(C) assure maintenance of robust aeronautical laboratories, including a first-rate technical staff and modern national facilities for the conduct of research and testing activities;

(D) be conducted with the close, active participation of the United States aircraft industry so as to accelerate the transfer of research results to aviation products;

(E) include providing technical assistance and facility support to other government agencies and United States industry;

(F) include conducting joint projects with other government agencies where such projects contribute materially to the goals set forth in this section;

(G) assure strong participation of United States universities both in carrying out aeronautical research and training future aeronautical research personnel; and

(H) be conducted, where practical, so that United States industry receives research results before foreign competitors.

REPORT ON LONG-RANGE SPACE CAPITAL DEVELOPMENT PROGRAM PLAN

SEC. 102. In consideration of Senate Report No. 100-429 and House of Representatives Report No. 100-650, the Administrator shall, by March 15, 1989, submit to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a 5-year Capital Development Plan including, but not limited to, the following:

(1) Economic assumptions and budgetary requirements for fulfilling the objectives of such plan.

(2) Estimates of total expenditures needed to maintain the operation of the national launch systems, related tracking and data services, civil service requirements, and all other current services.

(3) A detailed operating plan for fiscal year 1989 and program plans for fiscal years 1990 through 1993 setting forth specific program priorities, objectives, schedules, and milestones.

(4) Estimates of total projected investments in space hardware, facilities, and other capital improvements needed to fulfill the objectives of such plan.

BUDGET INCREASE

SEC. 103. It is the sense of the House of Representatives that the budget for the National Aeronautics and Space Administration should increase substantially over the five years following the date of enactment of this Act with a goal of at least 15 percent growth per annum in order to—

(1) rededicate the United States space program to the goal of leadership in critical areas of space science, space technology, space exploration, aeronautics, space applications, and space commercialization;

(2) reverse the dramatic decline in real spending for such program since the achievements of the Apollo program;

(3) forge a robust national space program that maintains a healthy balance between manned and unmanned space activities and recognizes the mutually reinforcing benefits of both;

(4) continue with the development and deployment of a permanently manned space station; and

(5) enhance United States preeminence in civil and military aviation and improve the safety and efficiency of the United States air transportation system.

BUDGET REQUEST

31 USC 1105 note.

SEC. 104. Commencing in fiscal year 1990 and every year thereafter, the President shall submit to Congress a budget request for the National Aeronautics and Space Administration for the immediate fiscal year and the following fiscal year, and include budget estimates for the third fiscal year.

TITLE II—FISCAL YEAR 1989 NASA AND MULTIYEAR SPACE STATION AUTHORIZATION

AUTHORIZATION

SEC. 201. (a) There is hereby authorized to be appropriated to the National Aeronautics and Space Administration for fiscal year 1989, except as otherwise stated:

(1) For "Research and development" for the following programs:

(A) United States International Space Station, $900,000,000 for fiscal year 1989, $2,130,200,000 for fiscal year 1990, and $2,912,500,000 for fiscal year 1991.

(B)(i) Space transportation capability development, $606,600,000.

(ii) In addition to the funds authorized pursuant to this section, there are authorized to be appropriated for space transportation capability development any additional funds transferred to the Administration from any other agency pursuant to a fiscal year 1989 appropriations Act.

(C) Physics and astronomy, $761,600,000.

(D) Life sciences, $91,700,000.

(E) Planetary exploration, $410,300,000.

(F) Space applications, $628,300,000.

(G) Technology utilization, $19,100,000; provided, however, that the Administrator shall contract for implementation of the Industrial Applications Center located in

Oklahoma through the National Aeronautics and Space Administration's Rural Technology Applications Team.

(H) Commercial use of space, $38,800,000.

(I) Aeronautical research and technology, $404,200,000.

(J) Transatmospheric research and technology, $69,400,000.

(K) Space research and technology, $350,900,000.

(L) Safety, reliability, and quality assurance, $22,400,000.

(M) Tracking and data advanced systems, $18,800,000.

(2) For "Space flight, control and data communications" for the following programs:

(A) Space shuttle production and operational capability, $1,335,500,000, of which $51,000,000 is provided for the advanced solid rocket motor program.

(B)(i) Space transportation operations, $2,365,400,000, including such funds as may be necessary to ensure the availability of ammonium perchlorate for the production of solid rocket motors.

(ii) In addition to the funds authorized pursuant to this section, there are authorized to be appropriated for space transportation operations any additional funds transferred to the National Aeronautics and Space Administration from any other agency pursuant to a fiscal year 1989 appropriations Act.

(C) Space and ground network communications and data systems, $985,300,000.

(3) For "Construction of facilities", including land acquisition as follows:

(A) Modifications to processing Technology Facility for Space Station, Marshall Space Flight Center, $3,700,000.

(B) Construction of Addition for Space Systems Automated Integration and Assembly Facility, Johnson Space Center, $9,200,000.

(C) Replacement of High Pressure Gas Storage Vessels, National Space Technology Laboratory, $3,500,000.

(D) Increase Chiller Capacity, LC-39 Utility Annex, Kennedy Space Center, $2,300,000.

(E) Rehabilitation of PAD A, L-C 39, Kennedy Space Center, $4,600,000.

(F) Refurbish Atmospheric Reentry Materials and Structures Evaluation Facility, Johnson Space Center, $4,900,000.

(G) Modification for Advanced Engine Development, Test Stand 116, Marshall Space Flight Center, $13,500,000.

(H) Modifications to Orbiter Modification and Refurbishment Facility (OMRF) for Safing and Deservicing, Kennedy Space Center, $2,800,000.

(I) Modification to the X-Ray Calibration Facility (XRCF), Marshall Space Flight Center, $11,400,000.

(J) Construction of Auxiliary Chiller Facility, Johnson Space Center, $7,800,000.

(K) Modernization of Space Environment Simulator, Goddard Space Flight Center, $2,800,000.

(L) Modifications for Utility Reliability, Goddard Space Flight Center, $3,100,000.

(M) Refurbishment of 25-Foot Space Simulator, Jet Propulsion Laboratory, $12,000,000.

(N) Repair and Modifications of 12-Foot Pressure Wind Tunnel, Ames Research Center, $36,500,000.

(O) Rehabilitation and Modifications to 10x10 Supersonic Wind Tunnel, Lewis Research Center, $14,500,000.

(P) Refurbishment to Hypersonic Facilities Complex, Langley Research Center, $12,800,000.

(Q) Refurbishment of Electric Power Laboratory, Lewis Research Center, $6,100,000.

(R) Construction of National Resource Protection at various locations, $2,600,000.

(S) Repair of facilities at various locations, not in excess of $750,000 per project, $27,000,000.

(T) Rehabilitation and modification of facilities at various locations, not in excess of $750,000 per project, $34,000,000.

(U) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project, $9,000,000.

(V) Environmental compliance and restoration, $26,000,000.

(W) Facility planning and design not otherwise provided for, $20,000,000.

(X) Construction of an advanced solid rocket motor facility, $27,000,000.

Of the amounts authorized pursuant to subparagraphs (S) through (W), the Administrator may obligate up to $5,600,000 in order to expand the Launch Complex-39 Operation Support Building at the Kennedy Space Center. Notwithstanding subparagraphs (A) through (X), the total amount authorized by this paragraph shall not exceed $290,100,000.

(4) For "Research and program management", $1,915,000,000.

Contracts.
Grants.

(b) Notwithstanding the provisions of subsection (e), appropriations authorized in this title for "Research and development" and "Space flight, control and data communications" may be used for (1) any items of a capital nature (other than acquisition of land) which may be required at locations other than installations of the Administration for the performance of research and development contracts, and (2) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities; and title to such facilities shall be vested in the United States unless the Administrator of the National Aeronautics and Space Administration (hereafter in this title referred to as the 'Administrator') determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Each such grant shall be made under such conditions as the Administrator shall determine to be required to ensure that the United States will receive therefrom benefit adequate to justify the making of that grant. None of the funds appropriated for "Research and development" and "Space flight, control and data communications" pursuant to this title may be used in accordance with this subsection for the construction of any major facility, the estimated cost of which, including collateral equipment, exceeds $500,000, unless the Administrator or the Administrator's designee has notified the President of the Senate and the Speaker of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technol-

ogy of the House of Representatives of the nature, location, and estimated cost of such facility.

(c) When so specified and to the extent provided in an appropriation Act, (1) any amount appropriated for "Research and development", for "Space flight, control and data communications", or for "Construction of facilities" may remain available without fiscal year limitation, and (2) maintenance and operation of facilities, and support services contracts may be entered into under the "Research and program management" appropriation for periods not in excess of twelve months beginning at any time during the fiscal year. Contracts. 42 USC 2459a.

(d) Appropriations made pursuant to subsection (a)(4) may be used, but not to exceed $35,000, for scientific consultation or extraordinary expenses upon the approval or authority of the Administrator, and the Administrator's determination shall be final and conclusive upon the accounting officers of the Government.

(e)(1) Funds appropriated pursuant to subsection (a)(1), (2), and (4) may be used for the construction of new facilities and additions to, repair, rehabilitation, or modification of existing facilities, provided the cost of each such project, including collateral equipment, does not exceed $100,000.

(2) Funds appropriated pursuant to subsection (a) (1) and (2) may be used for unforeseen programmatic facility project needs, provided the cost of each such project, including collateral equipment, does not exceed $500,000.

(3) Funds appropriated pursuant to subsection (a)(4) may be used for such work on facilities controlled by the General Services Administration, provided the cost of each such project, including collateral equipment, does not exceed $500,000.

(f) Of the amounts authorized pursuant to subsection (a) (1) through (4), up to $8,000,000 may be made available for the National Space Grant College and Fellowship program established under the National Aeronautics and Space Administration Authorization Act of 1988 (Public Law 100-147).

CONSTRUCTION OF FACILITIES REPROGRAMMING

SEC. 202. Authorization is hereby granted whereby any of the amounts prescribed in section 201(a)(3) (A) through (X)—

(1) may be varied upward 10 percent, in the discretion of the Administrator or the Administrator's designee, or

(2) following a report by the Administrator or the Administrator's designee to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate on the circumstances of such, may be varied upward 25 percent to meet unusual cost variations. Reports.

The total cost of all work authorized under paragraphs (1) and (2) shall not exceed the total of the amounts specified in section 201(a)(3) (A) through (X).

SPECIAL REPROGRAMMING AUTHORITY FOR CONSTRUCTION OF FACILITIES

SEC. 203. Where the Administrator determines that new developments or scientific or engineering changes in the national program of aeronautical and space activities have occurred; and that such changes require the use of additional funds for the purposes of

construction, expansion, or modification of facilities at any location; and that deferral of such action until the enactment of the next authorization Act would be inconsistent with the interest of the Nation in aeronautical and space activities; the Administrator may transfer not to exceed ½ of 1 percent of the funds appropriated pursuant to section 201(a) (1) or (2) to the "Construction of facilities" appropriation for such purposes. The Administrator may also use up to $10,000,000 of the amounts authorized under section 201(a)(3) for such purposes. The funds so made available pursuant to this section may be expended to acquire, construct, convert, rehabilitate, or install permanent or temporary public works, including land acquisition, site preparation, appurtenances, utilities, and equipment. No such funds may be obligated until a period of 30 days has passed after the Administrator or the Administrator's designee has transmitted to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a written report describing the nature of the construction, its cost, and the reasons therefor. Reports.

LIMITATIONS ON AUTHORITY

SEC. 204. Notwithstanding any other provision of this Act—

(1) no amount appropriated pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House Committee on Science, Space, and Technology or the Senate Committee on Commerce, Science, and Transportation;

(2) no amount appropriated pursuant to this Act may be used for any program in excess of the amount actually authorized for that particular program by section 201(a) (1), (2), and (4); and

(3) no amount appropriated pursuant to this Act may be used for any program which has not been presented to either such committee,

unless a period of thirty days has passed after the receipt by the Speaker of the House of Representatives and the President of the Senate and each such committee, of notice given by the Administrator or his designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such proposed action.

GEOGRAPHICAL DISTRIBUTION OF RESEARCH FUNDS

SEC. 205. It is the sense of the Congress that it is in the national interest that consideration be given to the widest geographical distribution of Federal research funds whenever feasible, and that the National Aeronautics and Space Administration should explore ways and means of distributing its research and development funds whenever feasible. 42 USC 2459 note.

ARREST AUTHORITY

SEC. 206. Section 304 of the National Aeronautics and Space Act of 1958 is amended by adding at the end the following new subsection: 42 USC 2456a.

"(f) Under regulations to be prescribed by the Administrator and approved by the Attorney General of the United States, those employees of the Administration and of its contractors and subcontractors authorized to carry firearms under subsection (e) may arrest without warrant for any offense against the United States Regulations.

committed in their presence, or for any felony cognizable under the laws of the United States if they have reasonable grounds to believe that the person to be arrested has committed or is committing such felony. Persons granted authority to make arrests by this subsection may exercise that authority only while guarding and protecting property owned or leased by, or under the control of, the United States under the administration and control of the Administration or one of its contractors or subcontractors, at facilities owned by or contracted to the Administration.".

ADVANCED SOLID ROCKET MOTOR AUTHORITY

SEC. 207. If, after evaluation of proposals received in response to the request for proposals for an advanced solid rocket motor required by section 121(b) of the National Aeronautics and Space Administration Authorization Act of 1988 (Public Law 100-147; 101 Stat. 868), the Administrator determines that it is in the best interests of the United States to select a proposal offering a privately financed and non-Government-owned production facility to be constructed on a Government or non-Government site, funds otherwise authorized in section 201(a)(3)(X) of this Act for the construction of a Government-owned production facility on a Government-owned site shall be available, without fiscal year limitation, for that purpose.

STUDIES ON MICROGRAVITY RESEARCH CAPABILITY

Contracts. Reports.

SEC. 208. (a) The Administrator shall contract with the National Academy of Sciences to undertake a review of the Nation's microgravity research capability and issue a report addressing—

(1) the scientific and commercial value to the Nation of achieving a man-tended capability through a Commercially Developed Space Facility (CDSF) prior to man-tended operations of the space station;

(2) the technical characteristics of a CDSF that would enable its optimum use;

(3) the anticipated microgravity research and manufacturing requirements of commercial users and the Government;

(4) the extent to which existing and proposed facilities could support these requirements;

(5) the likelihood that a CDSF would become commercially self-sustaining and an estimate of when that could occur;

(6) the state of space automation technology and its relevance to the capabilities required for a CDSF;

(7) how a decision by the Government to lease facilities on a CDSF might affect the viability of other proposed commercial microgravity research facilities; and

(8) the effect a commitment to the CDSF would have on the current space transportation system launch schedule.

Contracts.

(b) The Administrator shall contract with the National Academy of Public Administration to—

(1) estimate the developmental, operational, and other costs to the Government associated with a CDSF;

(2) consider the practicability of various financial options by which the Government could participate in a CDSF, including leasing, lease-purchase, and purchase;

(3) consider, as regards the lease option, instead of providing for a flat level of lease obligations, the practicability of reducing

on a yearly basis the level of Government lease operations during the years of operation of a CDSF; and

(4) consider, as regards the lease option, the practicability of making the minimum levels of Government lease obligations in the years of operation of a CDSF contingent on the attachment, by the CDSF operator, of certain minimum levels of irrevocable contract commitments with entities other than the United States Government.

Reports.

(c) Based on the above reports, the Administrator shall provide a report to the House Committee on Science, Space, and Technology and the Senate Committee on Commerce, Science, and Transportation with policy options related to a CDSF and microgravity facilities, to be delivered no later than May 15, 1989.

BUY AMERICAN

Contracts.

SEC. 209. (a) The Administrator shall award to a domestic firm a contract that, under the use of competitive procedures, would be awarded to a foreign firm, if—

(1) the final product of the domestic firm will be completely assembled in the United States;

(2) when completely assembled, not less than 50 percent of the final product of the domestic firm will be domestically produced; and

(3) the difference between the bids submitted by the foreign and domestic firms is not more than 6 percent.

(b) This section shall not apply to the extent to which—

(1) such applicability would not be in the public interest;

(2) compelling national security considerations require otherwise; or

(3) the United States Trade Representative determines that such an award would be in violation of the General Agreement on Tariffs and Trade or an international agreement to which the United States is a party.

(c) For purposes of this section—

(1) the term "domestic firm" means a business entity that is organized under the laws of the United States and that conducts business operations in the United States; and

(2) the term "foreign firm" means a business entity not described in paragraph (1).

(d) This section shall apply only to contracts for which—

(1) amounts are made available pursuant to this Act; and

(2) solicitations for bids are issued after the date of the enactment of this Act.

Science and technology.

INTERNATIONAL SPACE DOCKING CAPABILITY

Union of Soviet Socialist Republics.

SEC. 210. (a) It is the sense of Congress that the Administrator should establish a multilateral working group of representatives from the space agencies of appropriate spacefaring nations, including the Union of Soviet Socialist Republics, and from appropriate international entities, to explore the technological and procedural principles that would be necessary to achieve an international space docking capability, and the establishment of international docking interface standards for addressing requirements for compatible interfaces for docking, communications, and life support systems,

and also space rescue missions which could particularly benefit from the use of such a capability.

(b) Within 6 months after the date of the enactment of this Act, the Administrator shall advise the Congress on the status of establishing an International Space Docking Working Group as recommended in subsection (a).

JOHN C. STENNIS SPACE CENTER

Mississippi.

SEC. 211. The National Space Technology Laboratories of the National Aeronautics and Space Administration located in Bay St. Louis, Mississippi, is named and designated as the "John C. Stennis Space Center". Any reference in a law, map, regulation, document, record, or other paper of the United States to such center shall be held to be a reference to the "John C. Stennis Space Center".

OUTER SOLAR SYSTEM EXPLORATION

SEC. 212. The Administrator, in coordination with the Secretary of Energy, for the purpose of outer solar system exploration, may request and receive such quantities of nuclear fuel as are necessary only for the specific mission, on terms and at costs as may be agreed upon. Nothing in this section authorizes the providing of such nuclear fuel on those terms for any other purpose or its diversion for any other use.

COMMERCIAL SPACE LAUNCH ACT AUTHORIZATION

SEC. 213. Section 24 of the Commercial Space Launch Act (49 App. U.S.C. 2623) is amended by adding at the end thereof the following: "There is authorized to be appropriated to the Secretary to carry out this Act $3,827,000 for fiscal year 1989.".

NATIONAL AERONAUTICS AND SPACE ACT OF 1958 AMENDMENT

SEC. 214. Section 102(c) of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451(c)) is amended—

(1) by striking "and" at the end of paragraph (7);

(2) by striking the period at the end of paragraph (8) and inserting in lieu thereof "; and"; and

(3) by adding at the end the following new paragraph:

"(9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.".

Science and technology.

DRUG-FREE WORKPLACE

SEC. 215. (a) No funds authorized to be appropriated under this Act, or under any other Act authorizing appropriations for fiscal year 1989 through 1993 for the Administration, shall be obligated or expended unless the Administration has in place, and will continue to administer in good faith, a written policy designed to ensure that all of its workplaces are free from the illegal use, possession, or distribution of controlled substances (as defined in the Controlled Substances Act) by the officers and employees of the Administration.

42 USC 2459 note.

(b) No funds authorized to be appropriated to the Administration for fiscal years 1989 through 1993 shall be available for payment in connection with any grant, contract, or other agreement, unless the recipient of such grant, contractor, or party to such agreement, as the case may be, has in place and will continue to administer in good faith a written policy, adopted by the board of directors or other government authority of such recipient, contractor, or party, satisfactory to the Administrator of the Administration, designed to ensure that all of the workplaces of such recipient, contractor, or party are free from the illegal use, possession, or distribution of controlled substances (as defined in the Controlled Substances Act) by the officers and employees of such recipient, contractor, or party.

(c) The provisions of this section, and the provisions of the Steel and Aluminum Energy Conservation and Technology Competitiveness Act of 1988, the National Institute of Standards and Technology Authorization Act for Fiscal Year 1989, the National Science Foundation Authorization Act for Fiscal Years 1989 and 1990, and the National Nutrition Monitoring and Related Research Act of 1988, relating to a drug-free workplace, shall not be effective until January 16, 1989.

OHIO CENTER FOR AEROSPACE

SEC. 216. (a) The Administrator may, without regard to section 321 of the Act of June 30, 1932 (40 U.S.C. 303b), and on such terms as the Administrator may deem to be appropriate, lease, for a term not to exceed 99 years, real property located at the Lewis Research Center in Cuyahoga County, to the State of Ohio, or a subdivision or agent thereof, or to a corporation or foundation organized exclusively for educational or scientific purposes which is exempt from taxation under section 501(c)(3) of the Internal Revenue Code of 1986 (26 U.S.C. 501(c)(3)), or to any other not-for-profit entity, for the purpose of the construction and operation thereon of an Institute whose purpose is the conduct of aeronautical and space research, the education and training of aeronautical and space engineers, and the transfer of aeronautical and space technology between the United States public and private sectors. This lease shall be renewable for additional periods in the discretion of the Administrator.

(b) Subject to the availability of appropriations therefor, the Administrator may enter into agreements, on such terms as the Administrator may deem to be appropriate, with the State of Ohio, or a subdivision or agent therefor, or with a corporation or foundation organized exclusively for educational or scientific purposes which is exempt from taxation under section 501(c)(3) of the Internal Revenue Code of 1986 (26 U.S.C. 501(c)(3)), or to any other not-for-profit entity, pursuant to which the Administration may provide administrative, maintenance, instructional, and other appropriate support, with or without reimbursement, to an Institute whose purpose is the conduct of aeronautical and space research, the education and training of aeronautical and space engineers, and the transfer of aeronautical and space technology between the United States public and private sectors.

(c) The Administrator may redelegate the authority conferred in subsections (a) and (b), to such subordinate officers and employees as the Administrator may designate.

SPACE SETTLEMENTS

42 USC 2451 note.

SEC. 217. (a) The Congress declares that the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements, will fulfill the purposes of advancing

science, exploration, and development and will enhance the general welfare.

(b) In pursuit of the establishment of an International Space Year in 1992 pursuant to Public Law 99-170, the United States shall exercise leadership and mobilize the international community in furtherance of increasing mankind's knowledge and exploration of the solar system.

(c) Once every 2 years after the date of the enactment of this Act, the National Aeronautics and Space Administration shall submit a report to the President and to the Congress which— Reports.

(1) provides a review of all activities undertaken under this section including an analysis of the focused research and development activities on the Space Station, Moon, and other outposts that are necessary to accomplish a manned mission to Mars;

(2) analyzes ways in which current science and technology can be applied in the establishment of space settlements;

(3) identifies scientific and technological capacity for establishing space settlements, including a description of what steps must be taken to develop such capacity;

(4) examines alternative space settlement locations and architectures;

(5) examines the status of technologies necessary for extraterrestrial resource development and use and energy production;

(6) reviews the ways in which the existence of space settlements would enhance science, exploration, and development;

(7) reviews mechanisms and institutional options which could foster a broad-based plan for international cooperation in establishing space settlements;

(8) analyzes the economics of financing space settlements, especially with respect to private sector and international participation;

(9) discusses sociological factors involved in space settlement such as psychology, political science, and legal issues; and

(10) addresses such other topics as the National Aeronautics and Space Administration considers appropriate.

PEACEFUL USE OF SPACE STATION

SEC. 218. No civil space station authorized under section 201(a)(1)(A) of this Act may be used to carry or place in orbit any nuclear weapon or any other weapon of mass destruction, to install any such weapon on any celestial body, or to station any such weapon in space in any other manner. This civil space station may be used only for peaceful purposes.

COMMERCIAL SPACE PROGRAMS

SEC. 219. Section 201 of the National Institute of Standards and Technology Authorization Act for Fiscal Year 1989 is amended by adding at the end the following new subsection: 15 USC 3704 note.

"(f) COMMERCIAL SPACE PROGRAMS.—Nothing in this section authorizes the Department to establish an Office of Commercial Space Programs or to place such an office into the Technology Administration without prior authorization of the Congress.".

Science and technology. 42 USC 2451 note.

TITLE III—TEN YEAR STRATEGIC PLAN

AERONAUTICS AND SPACE STRATEGIC PLAN

SEC. 301. The Administrator should develop an aggressive and balanced plan of science and applications including but not limited to—

(1) the robotic exploration of other solar system bodies;

(2) the study and observation of other celestial bodies and phenomena at spectral wave lengths and resolutions that will enhance our understanding of the universe;

(3) the enhanced study and monitoring of Earth as an interacting system;

(4) the development of a full understanding of the behavior of biological systems in the space environment; and

(5) the development of a full understanding of physics and chemistry of the macroscopic behavior of materials in the microgravity environment.

SPACE RESEARCH AND TECHNOLOGY STRATEGIC PLAN

SEC. 302. The Administrator should develop an aggressive and balanced plan of space research and technology including but not limited to—

(1) fundamental and innovative research as the seedbed for enabling technologies for future civil space missions;

(2) focused technology programs keyed to long range, high priority civil space missions;

(3) technology research and demonstrations, extending laboratory activities from Earth to space-based facilities such as the Space Shuttle, Space Station, orbital platforms, and eventually the Moon and other planetary bodies; and

(4) cooperation with, and service to, other space program sectors with advanced technology and use of ground and space-based facilities.

SPACE EXPLORATION STRATEGIC PLAN

SEC. 303. The Administrator should develop a plan in pursuit of the continued manned exploration of the solar system and low-Earth orbit, including but not limited to—

(1) the establishment of an operational United States International Space Station that shall be permanently manned; and

(2) the development of those technologies and systems required for manned exploration of space beyond earth orbit.

SPACE TRANSPORTATION STRATEGIC PLAN

SEC. 304. The Administrator should develop a plan to improve the manned and unmanned space transportation system including—

(1) the continued enhancement of the space shuttle and its ground system in order to increase safety and efficiency and reduce costs;

(2) the completion of the development of a heavy-lift expendable launch vehicle if consistent with mission requirements of the Administration, the Department of Defense, and other Federal agencies; and

(3) the initiation of preliminary design activities for the next generation of a manned space launch system beyond the space shuttle.

AERONAUTICAL RESEARCH AND TECHNOLOGY DEVELOPMENT AND VALIDATION LONG-RANGE PLAN

SEC. 305. The Administrator should develop a plan in pursuit of—

(1) a vigorous program in aeronautics research and technology development and validation, emphasizing emerging technologies with the potential for breakthrough advances to enhance United States preeminence in civil and military aviation; and

(2) in cooperation with the Department of Defense, a technology development program (with an option for a flight demonstration in 1995) to prove the feasibility of an air-breathing hypersonic aerospaceplane capable of single-stage-to-orbit operation and hypersonic cruise in the atmosphere.

100TH CONGRESS
2d Session | HOUSE OF REPRESENTATIVES | REPORT
100-701

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT-INDEPENDENT AGENCIES APPROPRIATIONS BILL, 1989

JUNE 14, 1988.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BOLAND, from the Committee on Appropriations, submitted the following

REPORT

[To accompany H.R. 4800]

The Committee on Appropriations submits the following report in explanation of the accompanying bill making appropriations for the Department of Housing and Urban Development, and for sundry independent agencies, boards, commissions, corporations, and offices for the fiscal year ending September 30, 1989, and for other purposes.

INDEX TO BILL AND REPORT

85-589

SUMMARY OF THE BILL

The Committee recommends $59,709,920,000 in new budget (obligational) authority for the Department of Housing and Urban Development and 16 independent agencies and offices. This is $2,350,029,000 above the 1988 appropriations level.

The following table summarizes the amounts recommended in the bill in comparison with appropriations for fiscal year 1988 and budget estimates for fiscal year 1989.

SUMMARY OF ESTIMATES AND NEW BUDGET (OBLIGATIONAL) AUTHORITY IN BILL

Department or agency	Appropriations, 1988	Budget estimates, 1989	Recommended in bill	Bill compared with— Appropriations, 1988	Bill compared with— Budget estimates, 1989
[1]	[2]	[3]	[4]	[5]	[6]
American Battle Monuments Commission	$12,408,000	$15,085,000	$15,085,000	+$2,677,000	.....
Cemeterial Expenses, Army	8,164,000	13,195,000	13,195,000	+5,031,000	.....
Consumer Information Center	1,279,000	1,354,000	1,354,000	+75,000	.....
Consumer Product Safety Commission	32,696,000	32,917,000	34,500,000	+1,804,000	+$1,583,000
Council on Environmental Quality	826,000	870,000	870,000	+44,000	.....
Department of Housing and Urban Development	13,289,657,000	11,612,185,000	12,930,332,000	−359,325,000	+1,318,147,000
Environmental Protection Agency	5,027,442,000	4,779,008,000	5,163,882,000	+136,440,000	+384,882,000
Federal Emergency Management Agency	632,337,000	698,396,000	733,932,000	+101,595,000	+35,536,000
Federal Home Loan Bank Board [1]	(31,923,000)	(33,609,000)	(33,609,000)	(+1,686,000)	.....
National Aeronautics and Space Administration	8,856,461,000	11,488,000,000	10,706,000,000	+1,849,539,000	−782,000,000
National Credit Union Administration [2]	(600,000,000)	(600,000,000)	(600,000,000)	.....	.....
National Science Foundation	1,717,000,000	2,050,000,000	1,885,000,000	+168,000,000	−165,000,000
Neighborhood Reinvestment Corporation	18,720,000	19,094,000	19,094,000	+374,000	.....
Office of Consumer Affairs	1,670,000	1,708,000	1,708,000	+38,000	.....
Office of Science and Technology Policy	1,888,000	1,787,000	1,587,000	−301,000	−200,000
Selective Service System	25,459,000	26,113,000	26,313,000	+854,000	+200,000
Veterans Administration	27,733,804,000	27,927,068,000	28,177,068,000	+443,184,000	+250,000,000
Total	57,350,891,000	58,666,772,000	59,709,920,000	+2,350,029,000	+1,043,148,000

[1] Limitation on administrative expenses, corporate funds.
[2] Limitation on direct loans.

TITLE I

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

HOUSING PROGRAMS

ANNUAL CONTRIBUTIONS FOR ASSISTED HOUSING

(INCLUDING RESCISSION)

1988 appropriation	$7,887,405,000
Estimate, 1989	6,886,765,000
Recommended in bill	7,673,765,000
Increase above estimate	+787,000,000

The Administration's fiscal year 1989 budget proposes 100,000 incremental housing voucher units, 1,000 Indian housing units, 7,000 section 202 housing for the elderly units, and an additional 16,787 non-incremental units.

The Committee has repeatedly stressed that the Department of Housing and Urban Development's subsidized housing programs

that other Federal agencies make adequate contributions for the Handbook to fully meet the demand for this important publication.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

(INCLUDING TRANSFER OF FUNDS AND RESCISSIONS)

1988 appropriation	$3,274,200,000
Estimate, 1989	4,446,700,000
Recommended in bill	4,166,700,000
Decrease below estimate	−280,000,000

The Committee recommends a total of $4,166,700,000 for this account in fiscal year 1989. This is $280,000,000 below the budget request and includes the following increases, decreases, and changes to the program areas described below:

—$65,000,000 from the $967,400,000 requested for the space station. The balance of $902,400,000 shall include not less than $46,000,000 for the flight telerobotic servicer (FTS). The latter represents an increase of $26,000,000 above the budget request of $20,000,000.

The Committee strongly believes than an allocation of not less than $900,000,000 must be accorded the space station in 1989. The Committee notes that a funding level of $650,000,000 to $700,000,000 is necessary just to keep the current level of effort underway. The fact is that level of effort, for all practical purposes, produces no hardware. The Committee also believes that without a $900,000,000 appropriation in 1989, it would be virtually impossible to achieve the planned 1990 level of approximately $2,100,000,000. Reductions below $900,000,000 in 1989 and approximately $2,000,000,000 in 1990 would, of necessity, mean a further delay in the first element launch of the space station.

Originally, the Committee had hoped that these funds could be provided without encumbrance. However, scorekeeping adjustments agreed to in the 1989 budget resolution require the Appropriations Committee to reduce the section 302(b) allocation to the HUD-Independent Agencies Subcommittee by $439,000,000 in budget authority and $87,000,000 in outlays. That reduction, which occurred after the subcommittee had made its recommendations, has caused the Committee to suggest the delayed obligation of $450,000,000 of space station funds. Those monies will become available only if the next President submits a special message to the Congress indicating that he intends to proceed with the use of the money and the development of the space station program. If that message is not received by April 15, 1989, $300,000,000 is rescinded and $150,000,000 is transferred to the space flight, control and data communications account. This $150,000,000 would be intended to partially restore funding reductions in the space shuttle, tracking, and expendable launch vehicle programs. If the President does not submit a message to proceed with the development of the space station, the $150,000,000 transferred to space flight, control and data communications shall be allocated among the activities identified above with the approval of the Committees on Appropriations. The Committee would expect that the highest priority be attributed to the space shuttle.

In addition, the Committee has made provision for the orderly termination of the program, in the absence of a Presidential message, by including $65,400,000 that would only be available for termination costs. The remaining balance of $387,000,000 is provided for obligations for the space station from October 1, 1988 through April 15, 1989. This will permit an obligation rate of approximately $60,000,000 per month for the first six and one-half months of fiscal year 1989. That compares with the current obligation rate of approximately $45,000,000 per month.

In summary, the Committee considered several options—including cancelling the space station and substantially reducing the funding level for 1989. It rejected those alternatives in favor of an approach which gives the next President the option of proceeding with the space station or terminating it. If the decision is to proceed with the space station, the recommendation of $902,400,000 will maintain the current first element launch date of March 1995. If the decision is to cancel the space station, the recommendation includes the means necessary to address termination costs and other NASA priorities.

NASA has accorded the space station the highest priority (next to the space shuttle) and views this program as the Nation's next logical step in space. The Committee has sought to address that priority by making a number of difficult reductions in other program areas. The Committee believes it is essential, however, to point out that unless sufficient resources are allocated by the next Administration to NASA and sufficient 302(b) allocation is provided to the HUD Subcommittee through the budget process—it will be exceedingly difficult to provide for a 1990 space station level of $2,100,000,000 and a 1991 level of $2,900,000,000.

—$11,000,000 from the Advanced X-ray Astrophysics Facility. The Committee has recommended $16,000,000 of the $27,000,000 requested for this activity. The $16,000,000 is intended for the purpose of beginning work on a high-resolution mirror assembly technology development program for AXAF. This will be a three-year program which, if successful, should lead to a development start for the AXAF spacecraft in fiscal year 1992. The Committee has recommended this approach owing to the high risk nature of the fabrication and testing of AXAF high-resolution mirrors. If this work proceeds to a successful testing of the mirrors (which should occur in the March to June 1991 time period) the Committee will expect to recommend funding for the development of the AXAF spacecraft. One of the critical design goals of AXAF is a one-half arcsecond resolution. The Committee expects that goal, as well as other technical milestones, will be essentially demonstrated during testing.

Although no development funds are provided for AXAF instruments or for the AXAF spacecraft, the Committee has no objection to the use of advanced technology development monies to continue phase B prime work on the spacecraft and research and analysis funds to continue a similar effort on the instruments. The Committee would expect to provide initial instrument development funding in fiscal year 1990.

AXAF represents a highly sophisticated and technically demanding space venture. The successful fabrication and testing of the mirror assembly is essential to a workable and useful facility. By recommending the approach described above, the Committee hopes that the AXAF project can proceed with the assurance that the high risk mirror assembly effort can meet the very demanding design goals. Finally, the Committee will expect NASA to report on the mirror assembly effort every six months beginning on January 1, 1989.

—$60,000,000 from the $100,000,000 requested for the Pathfinder program. The reduction may be taken at the agency's discretion.

—$35,000,000 from the $631,100,000 requested for space transportation capability development. The reduction may be taken at the agency's discretion.

—$15,800,000 from the $84,400,000 requested for the National Aerospace Plane.

—$10,000,000 from the $414,200,000 requested for aeronautical research and technology.

—$35,000,000 from the $156,800,000 requested for the civil space technology initiative. The reduction may be taken at the agency's discretion.

—$10,000,000 from the $404,000,000 requested for planetary exploration to be taken at the agency's discretion.

—$10,000,000 from the $111,300,000 requested for space telescope operations, maintenance and refurbishment.

—$10,000,000 from technology utilization, commercial programs, and information systems to be taken at the agency's discretion.

—$25,000,000 from the $101,700,000 requested for life sciences activities. The reduction may be taken at the agency's discretion.

—$35,000,000 from the $101,400,000 requested for the global geospace science mission.

—$10,000,000 from the $15,800,000 requested for the "scatterometer." It appears that the Navy may not proceed with the Navy Remote Ocean Sensing System (N-ROSS). Therefore, this project may be substantially delayed or transferred to another research satellite.

—$10,000,000 from the $97,800,000 requested for the ocean topography experiment (TOPEX).

+$76,000,000 for the Advanced Communications Technology Satellite (ACTS).

+$10,000,000 to the $146,200,000 requested for upper stages. The additional funds are required to purchase an upper stage for ACTS, which is currently manifested on the shuttle.

—$25,000,000 from the funds appropriated in fiscal year 1988 for the industrial space facility. Although the Committee has supported this facility as an excellent interim capability between the spacelab and space station—particularly if the first element launch of space station continues to be delayed—it appears that the legislative committees will not authorize the program. Therefore, in keeping with an earlier commitment, the Committee is recommending a rescission of the $25,000,000 for the Industrial Space Facility. However, if funding for this activity is ultimately authorized in the 1989 budget process, the Committee will consider making available monies at a subsequent time.

The Committee has also earmarked $5,000,000 from available resources for a new total ozone mapping spectrometer (TOMS). The Committee applauds the efforts of NASA through the international space year and other ventures designed to cooperate with other nations in addressing the observation of environmental problems. It believes that cooperative efforts hold the most promise for a successful resolution of common environmental problems and urges that TOMS be considered for a bilateral mission. The Committee further urges NASA to continue negotiations with space agencies in Japan, the Soviet Union, and Europe in connection with both the TOMS mission and the development of other joint earth observation missions of mutual benefit.

Finally, in the research and development account, the Committee is "capping" the 1989 amounts for a number of programs. In accordance with the agreement as outlined in the letter from NASA to the Committee dated August 9, 1984, these "caps", if included in the conference report, may not be exceeded without the approval of the Committees on Appropriations.

1. Gamma Ray Observer—$41,900,000
2. Galileo—$61,300,000
3. Magellan—$33,900,000
4. Hubble Space Telescope—$102,200,000
5. Ulysses—$10,300,000
6. Mars Observer—$102,200,000
7. Upper Atmospheric Research Satellite—$103,900,000
8. TOPEX—$87,800,000

Also, the Committee is "capping" the total cost for Titan III/TOS integration at $13,000,000—and at $5,200,000 in fiscal year 1989. The Committee is permitting the agency to proceed with a modest effort to integrate a TOS upper stage on a Titan III for launch of a Mars Observer satellite in 1992.

SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS

1988 appropriation	$3,908,309,000
Estimate, 1989	4,841,200,000
Recommended in bill	4,414,200,000
Decrease below estimate	−427,000,000

The space flight, control and data communications account includes the program elements that provide for the national fleet of space shuttle orbiters, including main engines, launch site mission operations, control requirements, spares, production tooling, and related supporting activities. This account also provides the standard operational support services for the space shuttle and expendable launch vehicles, and includes tracking, telemetry, command, and data acquisition support required to meet all NASA flight projects.

The Committee recommends a total of $4,414,200,000 for this account in 1989. This is a decrease of $427,000,000 below the budget request and is $505,891,000 above the 1988 level. The recommendation includes the following increases, decreases, and changes to the program areas described below:

—$90,000,000 from the $1,035,300,000 requested for tracking and data acquisition including $78,800,000 requested for a TDRSS re-

placement spacecraft and $70,000,000 requested for a second TDRSS ground terminal. The reduction may be taken at the agency's discretion from within the total $1,035,300,000 requested under the tracking budget.

—$15,000,000 of the $15,000,000 requested for a TITAN III expendable launch vehicle for the Mars Observer mission. The Committee has made this reduction on a budget priority basis. The Committee notes that Mars Observer is currently "double booked" on both the shuttle and a TITAN III. If the space shuttle does not appear to be meeting the existing flight manifest schedule, funding for a TITAN III will be considered in a subsequent appropriations bill.

—$60,000,000 from the $60,000,000 requested for a TITAN III expendable launch vehicle for a tracking and data relay satellite launch (TDRSS). This reduction is taken on the basis of a lower budget priority. Future TDRSS satellites should be capable of launch on the shuttle without an ELV back-up.

—$23,000,000 from the $43,000,000 requested for a TITAN IV expendable launch vehicle for a "back-up" planetary mission capability. The Committee will consider a reprogramming of additional funds in fiscal year 1989 if such action is necessary. The Committee has accorded this expendable launch vehicle the highest priority on the following basis:

1. It may be purchased under the existing Air Force contract at a substantial savings.
2. The TITAN IV backs up three planetary missions—Magellan, Galileo, and Ulysses—all currently manifested on the shuttle.
3. If no TITAN IV back up is required for the above three missions, it can be used to launch a future planetary mission (such as CRAF-CASSINI) to Saturn.

—$12,000,000 from the $51,000,000 requested for Delta II expendable launch vehicles. This reduction is consistent with the "slowdown" of the global geospace science mission addressed under the research and development account.

—$5,000,000 from the $88,000,000 requested for the advanced solid rocket booster. In addition, $27,000,000 of the funds requested under the space flight account are transferred to the construction of facilities account to provide NASA with the necessary flexibility if a government-owned/contractor-operated facility is chosen for production of a new solid rocket motor.

+$10,000,000 for an extended duration orbiter (EDO). The additional funds are to be targeted for an enhanced EDO of approximately 30 days duration.

—$205,000,000 from the $3,610,400,000 requested for the space transportation system (shuttle). The reduction may be taken at NASA's discretion from the shuttle production or shuttle operations line items. The Committee also urges NASA to review carefully all funding currently requested by the Kennedy, Johnson, and Marshall Space Centers for shuttle activities. The Committee believes that shuttle costs, consistent with safety, must be brought under control.

Finally, NASA may withhold until the fourth quarter of fiscal year 1989 the $227,000,000 payment to the Federal Financing Bank requested for the tracking and data relay satellite system. This payment is made annually in connection with the "off-budget" financing of the TDRSS program. The funds are to be held until the last quarter to provide NASA flexibility in connection with any unforeseen shuttle operations costs during fiscal year 1989.

CONSTRUCTION OF FACILITIES

1988 appropriation	$178,272,000
Estimate, 1989	285,100,000
Recommended in bill	270,100,000
Decrease below estimate	—15,000,000

The Committee recommends $270,100,000 for construction of facilities in 1989. The reduction includes, without prejudice, $27,900,000 requested for space station facilities. The Committee believes that these projects can be delayed for an additional year without impacting the space station program. This should be possible in view of the fact that the first element launch of the space station has been delayed by one full year since the original 1989 budget assumptions were made.

The Committee is also providing $27,000,000 from the space flight account for construction of a government-owned/contractor-operated facility (GO/CO) to provide NASA with the flexibility necessary to construct a new facility for the production of an advanced solid rocket motor.

Finally, a general reduction of $14,100,000 has been made and may be taken at the agency's discretion.

RESEARCH AND PROGRAM MANAGEMENT

1988 appropriation	[1] $1,495,680,000
Estimate, 1989	1,915,000,000
Recommended in bill	1,855,000,000
Decrease below estimate	—60,000,000

[1] Does not include transfer of $242,438,000 agreed to in conference on the 1988 Appropriations Act. The conferees indicated that the formal transfer of some institutional costs would be made in a future Appropriations Act.

The research and program management appropriation funds the performance and management of research, technology and test activities at NASA installations, and the planning, management and support of contractor research and development tasks necessary to meet the Nation's ongoing objectives in aeronautical and space research. The objectives of the activities funded by this appropriation are to (1) provide the civil service staff with the technical and management skills to conduct the full range of programs for which NASA is responsbile, (2) provide base maintenance of facilities and manage its use in support of research and development programs, and (3) provide effective and efficient technical and administrative support for the research and development programs.

The bill includes $1,855,000,000 for research and program management in fiscal year 1989, a decrease of $60,000,000 below the budget request. The Committee recommends that $20,000,000 of the reduction be taken from the $96,800,000 increase requested for personnel and related costs and $40,000,000 be taken from the $80,100,000 increase requested for travel and operation of installations.

The Committee notes that end-of-year employment at headquarters has grown from 1,306 in 1984 to 1,672 requested for 1989—a 28 percent increase. The reduction of $20,000,000 in personnel and related costs should include 100 positions at NASA headquarters. That reduction should include:

—25 in the Office of Management. This will still provide an increase of 8 positions above the 1988 level of 274.
—10 positions in the Administrator's offices. This will still provide for an increase of 15 positions above the 1984 level of 26.
—10 in External Relations. This will still provide an increase of 5 positions above the 1984 level of 74.
—25 from the Inspector General. This represents the increase requested for the IG above the 1988 level of 136.
—2 in the Office of General Counsel. This will maintain the 1984 level of 36.
—2 in Procurement and Small Business. This will provide for an increase of 12 above the 1984 level of 77.
—1 in the Office of Exploration. This will maintain the 1988 level of 10.
—15 in Space Flight programs. This will provide an increase of 5 positions above the 1988 level of 175.
—2 from Safety, Reliability and Quality Assurance. This will provide for an increase of six above the 1988 level of 64.
—3 in Commercial Programs. This will provide for an increase of one above the 1988 level of 37.
—5 from Tracking and Data Programs. This level is an increase of 1 above the 1984 level of 54.

The balance of the reduction in personnel and related costs and the entire reduction in travel and operation of installations is to be taken at the Agency's discretion.

National Credit Union Administration

Central liquidity facility

	Direct loan limitation	Administrative expenses
1988 limitations	($600,000,000)	($813,000)
Estimate, 1989	(600,000,000)	(880,000)
Recommended in bill	(600,000,000)	(880,000)

The National Credit Union Administration Central Liquidity Facility (CLF) was established on October 1, 1979, as authorized by the National Credit Union Central Liquidity Facility Act. The enabling legislation provides that the Facility shall exist within the National Credit Union Administration. The Facility borrows funds to supply temporary loans to member credit unions. Loans may not be made to expand a credit union's portfolio. Borrowings are made from the Federal Financing Bank.

Loans to credit unions are authorized for the following purposes:

—Short-term adjustment credit to meet temporary requirements for funds such as emergency outflows from managerial difficulties or local economic downturns;

The Federal Savings and Loan Insurance Corporation is authorized under title IV of the National Housing Act to insure savings in all Federal savings and loan associations and in state-chartered savings and loan institutions which apply and qualify for insurance. This protection, which insures each saver in a member association against financial loss up to a statutory limit of $100,000, may be provided either through the prevention of defaults or the payment of insurance to savings account holders in the event of liquidation. The Corporation is also authorized to make loans to institutions in financial difficulty. The Corporation functions under the direction of the Federal Home Loan Bank Board which provides administrative services.

TITLE IV

GENERAL PROVISIONS

The Committee recommends that those general provisions applicable to the Department and agencies carried in the current fiscal year be continued in fiscal year 1989 with the exception of section 415, which was applicable to certain public housing projects.

Transfer of Funds

Pursuant to Clause 1(b), Rule X of the Rules of the House of Representatives, the following statements are made describing the transfers of funds provided in the accompanying bill.

The Committee recommends that $200,000,000 be transferred from the rehabilitation loan fund and $150,000,000 be transferred from the flexible subsidy fund to community development grants in the Department of Housing and Urban Development.

The Committee recommends that not to exceed $381,528,000 be transferred from the various funds of the Federal Housing Administration to salaries and expenses of the Department of Housing and Urban Development. This will allow funds for activities of the Federal Housing Administration to be carried in a consolidated account covering all operating expenses of the Department.

The Committee recommends that $10,178,000 be transferred from the National Flood Insurance Fund to salaries and expenses of the Federal Emergency Management Agency (FEMA) to fund all administrative costs from one account. In addition, $43,200,000 is recommended for transfer from the National Flood Insurance Fund to FEMA's emergency management planning and assistance account to continue the present method of funding flood plain management activities.

The Committee has recommended a provision under the research and development account of the National Aeronautics and Space Administration which would result in the transfer of $150,000,000 to space flight, control and data communications if the President does not submit a message to the Congress by April 15, 1989, supporting the development of the space station. This provision is intended to partially restore funding reductions to the space shuttle, tracking, and expendable launch vehicles if the space station program is terminated.

The Committee recommends providing authority during 1989 to allow the Veterans Administration to transfer unobligated balances in the direct loan revolving fund to the loan guaranty revolving fund. This will permit available funds in the direct loan revolving fund to be used for losses sustained in the loan guaranty program.

The Committee recommends providing authority under administrative provisions for the Veterans Administration for any funds appropriated for 1989 for compensation and pensions, readjustment benefits, veterans insurance and indemnities, and the loan guarantee revolving fund to be transferred between those four accounts. This will provide the Veterans Administration flexibility in administering its entitlement programs.

Rescission of Funds

Pursuant to clause 1(b), rule X of the Rules of the House of Representatives the following statements are made describing rescission of funds provided in the accompanying bill.

The Committee recommends the proposed rescission under the Department of Housing and Urban Development, Annual contributions for assisted housing of recaptured budget authority estimated to be $303,500,000.

The Committee recommends the proposed rescission of not more than $50,000,000 of budget authority (and $2,000,000 in annual contract authority) under the rental housing assistance program in the Department of Housing and Urban Development. The Department proposes to convert projects under the rental assistance payments program to the section 8 program in 1988. The number of units eligible for payment is estimated to decline by 1,000 in 1989 due to mortgage insurance terminations. Therefore, authority previously provided under the rental housing assistance program will be recaptured and is no longer required.

The Committee has recommended a provision under the research and development account of the National Aeronautics and Space Administration which would result in the rescission of $300,000,000 if the President does not submit a message to the Congress by April 15, 1989, supporting the development of the space station. This provision is intended to give the next President the option of either proceeding with or terminating the space station development program.

The Committee recommends a rescission of $25,000,000 of budget authority under the Research and development account of the National Aeronautics and Space Administration. The Committee had provided $25,000,000 in fiscal year 1988 for the Industrial Space Facility. The Committee is now recommending a rescission of those funds in view of the fact that it appears that the appropriate legislative committees will not authorize the program.

Compliance With Rule XIII—Clause 3

In compliance with Clause 3 of Rule XIII of the Rules of the House of Representatives, changes in existing law made by the bill, as reported, are shown as follows (existing law proposed to be omitted is enclosed in black brackets, new matter is printed in italic, existing law in which no change is proposed as shown in roman):

Section 105(c)(2)(A) of the Housing and Community Development Act of 1974 is amended as follows to clarify the eligibility of community development grant funds:

Section 105(c)(2)(A). In any case in which an assisted activity described in subsection (a) is designed to serve an area generally and is clearly designed to meet identified needs of persons of low and moderate income in such area, such activity shall be considered to principally benefit persons of low and moderate income if (i) not less than 51 percent of the residents of such area are persons of low and moderate income; [or] (ii) in any metropolitan city or urban county, the area served by such activity is within the highest quartile of all areas within the jurisdiction of such city or county in terms of the degree of concentration of persons of low and moderate income; *or (iii) the assistance for such activity is limited to paying assessments (including any charge made as a condition of obtaining access) levied against properties owned and occupied by persons of low and moderate income to recover the capital cost for a public improvement.*

Inflationary Impact Statement

Clause 2(l)(4) of Rule XI of the House of Representatives requires that each Committee report on a bill or resolution shall contain a statement whether enactment of such bill or resolution may have an inflationary impact on prices and costs in the operation of the national economy.

Critics of Government spending suggest that practically any spending by Government is inflationary. If that were true, then the funds proposed in this bill would be inflationary. However, all Federal spending is not inherently inflationary. It should be analyzed in the context of the economic situation in which it occurs, the financial condition of Government at the time, and the sectors of the economy which the spending may affect.

The amount proposed for appropriation totals $59,709,920,000. This is $1,043,148,000 above the President's request. Included in the total recommended are funds for veterans benefits, assisted housing, community development grants and environmental programs. Other funds will support advanced technology and science that directly and indirectly increase productivity and national competitiveness.

It is the considered opinion of the Committee that enactment of this bill will not have an inflationary impact on prices and costs in the operation of the national economy. Further information on the purpose of the spending proposed in this bill can be obtained in other parts of this report. Also, a large amount of detailed statistical and financial information can be obtained in the hearings conducted in developing this bill.

Changes in the Application of Existing Law

The Committee submits the following statements in compliance with Clause 3, Rule XXI of the House of Represenatives, describing the effects of provisions proposed in the accompanying bill which

may be considered, under certain circumstances, to change the application of existing law, either directly or indirectly.

The Committee, in a number of instances, has found it necessary to recommend funding for ongoing activities and programs where authorizations have not been enacted to date. This includes some or all of the programs under the Department of Housing and Urban Development, the Consumer Product Safety Commission, the Environmental Protection Agency, the Federal Emergency Management Agency, the National Aeronautics and Space Administration, and the National Science Foundation.

In some cases, the Committee has recommended appropriations which are less than the maximum amounts authorized for the various programs funded in the bill. Whether these actions constitute a change in the application of existing law is subject to interpretation, but the Committee felt this should be mentioned.

The bill provides that several appropriations shall remain available for more than one year for which the basic authorizing legislation does not presently authorize such extended availability. Most of these items have been carried in previous appropriations Acts. The Committee deems such language desirable in order to provide for the effective use of the funds.

The Committee has included limitations for official reception and representation expenses for selected agencies in the bill.

The bill contains administrative provisions under the Veterans Administration, which could possibly be construed as changing the application of existing law.

Sections 401 through 414 of title IV of the bill, all of which are carried in the 1988 HUD—Independent Agencies Appropriations Act, are general provisions which place limitations on the use of funds in the bill and which might, under some circumstances, be construed as changing the application of existing law.

The bill includes, in certain instances, limitations on the obligation of funds for particular functions or programs. These limitations include restrictions on the obligation of funds for administrative expenses, the use of consultants, and programmatic areas within the overall jurisdiction of a particular agency.

The provision on pages 3 and 4, in connection with annual contributions for assisted housing, provides that highest priority in the use of funds in connection with the rental rehabilitation program shall be given to displaced families whose rents exceed 35 percent of income and permits vouchers of a five-year term to be used to assist public housing tenants whose units are demolished.

The provision on page 4, in connection with annual contributions for assisted housing, limits the use of funds for loan management activities for a contract term not to exceed five years.

The provision on page 5, in connection with annual contributions for assisted housing, provides that recaptured authority shall be rescinded.

The provision on page 5, in connection with annual contributions for assisted housing, gives discretion in the use of public housing funds for development or major reconstruction.

The provision on page 5, in connection with annual contributions for assisted housing, applies vacancy rate requirements to recaptured housing development grant funds.

The appropriation language on page 6, in connection with rental housing assistance, reduces the uncommitted balances of previously provided authority by not more than $2,000,000.

The provisions on pages 6 and 7, in connection with the housing for the elderly or handicapped fund, provide for certain loan conditions, provide borrowing authority for the Secretary, limit loans made in fiscal year 1989 to an interest rate which does not exceed 9.25 per centum, and provide that the receipts and disbursements of the funds shall be included in the totals of the Budget of the U.S. Government.

The language on pages 9 and 10, in connection with the flexible subsidy fund, permitting the use of excess rental charges and under certain circumstances assistance payments to an owner of a multifamily housing project assisted but not insured under the National Housing Act, could be construed as changing the application of existing law.

The provision on page 10, in connection with the Interagency Council on the Homeless, provides that regional support staff come from other Federal agencies.

The provision on page 10, in connection with the Federal Housing Administration Fund, limits additional commitments to guarantee loans.

The appropriation language on page 11, in connection with nonprofit sponsor assistance, limiting direct loans, could be construed as changing the application of existing law.

The appropriation language on page 11, in connection with guarantees of mortgage-backed securities, limits additional commitments to issue guarantees.

The language on page 12, in connection with community development grants, provides $350,000,000 of the appropriation by transfers of unobligated balances in the rehabilitation loan fund and the flexible subsidy fund.

The provision on page 12, in connection with community development grants, limiting expenses for planning and management development and administrative activities, could be construed as changing the application of existing law.

The provision on page 12, in connection with community development grants, earmarks $5,000,000 for a child care demonstration and could be construed as changing the application of existing law.

The language on page 12, in connection with community development grants, limiting commitments to guarantee loans, could be construed as changing the application of existing law.

The language on page 12, in connection with community development grants, permitting the use of certain state data, could be construed as changing the application of existing law.

The language on page 12, in connection with community development grants, establishes eligibility for payments of low-income persons' assessments for capital improvements.

The appropriation language on page 13, in connection with the rehabilitation loan fund, provides that the revolving fund shall consist of collections and unexpended balances of prior appropriations, and blocks the sale of loan assets.

The language on page 14, in connection with assistance for solar energy and energy conservation improvements, provides that recaptured 1988 funds shall remain available for reallocation.

The language on page 15, in connection with salaries and expenses, requires HUD to maintain a minimum average employment level in the public and Indian housing program.

The provision on page 17, in connection with the American Battle Monuments Commission, salaries and expenses, limits administrative support costs from the Korean War Memorial Fund.

The provision on page 17, in connection with the Consumer Product Safety Commission, salaries and expenses, limiting the availability of funds for commissioners, could be construed as changing the application of existing law.

The provisions on page 19, in connection with salaries and expenses of the Environmental Protection Agency, permits the use of receipts from a special fund and limits the use of funds for purposes of resource conservation and recovery panels.

The provisions on pages 19 and 20, in connection with abatement, control, and compliance, providing funds for administrative expenses and limiting the availability of funds, could be construed as changing the application of existing law.

The provisions on pages 20 and 21, in connection with the hazardous substance superfund, limiting the availability of funds for feasibility studies, natural resource damage claims, administrative expenses, and the Agency for Toxic Substances and Disease Registry, could be construed as changing the application of existing law.

The provision on page 21, in connection with leaking underground storage tank trust fund, limiting the availability of funds for administrative expenses, could be construed as changing the application of existing law.

The language on page 22, in connection with construction grants, limiting the availability of funds, may be construed as changing the application of existing law.

The language on page 22, in connection with the administrative provision, limits the use of funds for indemnity payments.

The provision on page 23, in connection with the Council on Environmental Quality, limiting the availability of funds, may be construed as changing the application of existing law.

The provisions on page 23, in connection with the Office of Science and Technology Policy, require reimbursement of detailed employees and limit the availability of funds.

The language on page 25, in connection with the National Flood Insurance Fund, transfers funds and limits certain fund expenses without prior notice to the Committees on Appropriations and could be construed as changing the application of existing law.

The language on pages 25 and 26, in connection with the emergency food and shelter program, limits administrative expenses.

The provisions on page 26, in connection with the Consumer Information Center, limit certain fund and administrative expenses, and could be construed as changing the application of existing law.

The language on page 27, in connection with the National Aeronautics and Space Administration, research and development, postpones the availability of funds pending a message from the President and provides for a rescission of $350,000,000 and a transfer of $150,000,000 in the absence of such a message.

The language on page 27, in connection with the National Aeronautics and Space Administration, research and development, rescinds funds appropriated in 1988.

The provisions on page 28 and 29, in connection with construction of facilities, extending the availability of certain project funds and limiting the use of funds for lease or construction of facilities, could be construed as changing the application of existing law.

The language on page 30, in connection with the National Credit Union Administration, central liquidity facility, limits new loans and administrative expenses.

The provisions on pages 31 and 32, in connection with research and related activities, earmark funds for an international agency and give discretion in the obligation of those funds and limit administrative expenses and contracts for various services.

The provisions on page 32, in connection with research and related activities, limit expenditures for certain activities and programs, provide for use of receipts for other research facilities and could require proportional reductions in legislative earmarkings.

The provisions on page 33, in connection with United States Antarctic program activities, provides that certain receipts may be credited to this appropriation and prohibits funds to be used for the purchase of certain aircraft and vessels.

The provision on pages 33 and 34, in connection with science education activities, could require proportional reductions in legislative earmarkings.

The provision on page 34, in connection with the Selective Service System, permits the President to exempt the agency from apportionment restrictions of the Budget and Accounting Act of 1921.

The provision on pages 36 and 37, in connection with Veterans Administration, medical care, limits administrative support staffing.

The language on page 37, in connection with the Veterans Administration, general operating expenses, provides for reimbursement to the Department of Defense for the cost of overseas employee mail. This language has been carried previously, and permits free mailing privileges for VA personnel stationed in the Philippines.

The language on pages 37 and 38, in connection with general operating expenses, requires VA to maintain minimum funding and average employment levels.

The language on pages 38 and 39, in connection with construction, major projects, establishes time limitations concerning the obligation of major construction funds, limits the use of funds and requires certification on project design.

The appropriation language for construction, minor projects on page 40, provides that unobligated balances of previous appropriations may be used for any project with an estimated cost of less than $2,000,000.

The provision on page 40, in connection with construction, minor projects, makes available funds for damage caused by natural disasters.

The language on page 41, in connection with the parking garage revolving fund, provides for operation and maintenance costs out of medical care funds.

The appropriation language on page 42, in connection with the direct loan revolving fund, limits loans and could, under certain circumstances, be construed as changing the application of existing law.

The language on page 42, in connection with the loan guaranty revolving fund, provides for the transfer of unobligated balances and does not require interest payments on transferred funds.

The provision on page 44, in connection with corporations, requires release in an appropriations Act of loans and mortgage purchase authority not otherwise required by law.

The language on page 45, in connection with the limitation on administrative expenses, Federal Home Loan Bank Board, provides funds for the training of state savings and loan examiners.

Permanent Obligational Authority—Federal Funds and Trust Funds

Substantial sums of new budget (obligational) authority are made available by permanent legislation for the continuation of certain government activities not subject to the annual appropriations process. Details of these activities for the agencies covered in this bill are reflected in appropriate tables appearing at the end of this report. The most significant are the life insurance programs of the Veterans Administration and the borrowing authority of the Federal Savings and Loan Insurance Corporation. The budget estimates that such permanent authorities will aggregate $5,716,499,000 in fiscal year 1989.

Comparison With Budget Resolution

Section 308(a)(1)(A) of the Congressional Budget and Impoundment Control Act of 1974 (Public Law 93-344), as amended, requires that the report accompanying a bill providing new budget authority contain a statement detailing how the authority compares with the reports submitted under section 302 of the Act for the most recently agreed to concurrent resolution on the budget for the fiscal year. This information follows:

[In million of dollars]

	Sec. 302(b)		This bill	
	Discretionary	Mandatory	Discretionary	Mandatory
Budget authority	43,688	16,024	43,686	16,024
Outlays	48,833	15,858	48,824	15,649
Direct loans	881	———	811	———
Primary guarantees	60,860	———	60,860	———

The bill provides no new spending authority as described in section 401(c)(2) of the Congressional Budget and Impoundment Control Act of 1974 (Public Law 93-344), as amended.

Balanced Budget and Emergency Deficit Control Act

During fiscal year 1989, for purposes of the Balanced Budget and Emergency Deficit Control Act of 1985 (Public Law 99-177), the following information provides the definition of the term "program, project, and activity" for departments and agencies carried in the accompanying bill. The term "program, project, and activity" shall include the most specific level of budget items identified in the 1989 Department of Housing and Urban Development-Independent Agencies Appropriations Act, the accompanying House and Senate Committee reports, the conference report or the joint explanatory statement of the managers of the committee of conference.

In applying any sequestration reductions, departments and agencies shall apply the percentage of reduction required for fiscal year 1989 pursuant to the provisions of Public Law 99-177 to each program, project, activity and subactivity contained in the budget justification documents submitted to the Committees on Appropriations of the House and Senate in support of the fiscal year 1989 budget estimates, as amended, for such departments and agencies as subsequently altered, modified or changed by Congressional action identified by the aforementioned Acts, resolutions and reports. Further, it is intended that in implementing the Presidential order, (1) no program, project, or activity should be eliminated, (2) no re-ordering of funds or priorities occur, and (3) no unfunded program, project, or activity be initiated. However, for the purposes of program execution, it is not intended that normal reprogramming between programs, projects, and activities be precluded *after* reductions required under the Balanced Budget and Emergency Deficit Control Act are implemented.

Five-Year Projections of Outlays

In accordance with section 308(a)(1)(C) of the Congressional Budget Act of 1974 (Public Law 99-344), as amended, the following information was provided to the Committee by the Congressional Budget Office:

Budget authority	$59,709,920,000
Outlays:	
1989	34,753,276,000
1990	11,827,936,000
1991	5,425,079,000
1992	2,189,880,000
1993 and future years	5,860,831,000

Financial Assistance to State and Local Governments

In accordance with section 308(a)(1)(D) of Public Law 99-344, the new budget authority and outlays provided by the accompanying bill for financial assistance to state and local governments are as follows:

Budget authority	$15,122,498,000
Outlays	1,341,304,000

COMPARATIVE STATEMENT OF NEW BUDGET (OBLIGATIONAL) AUTHORITY FOR FISCAL YEAR 1988 AND BUDGET ESTIMATES AND AMOUNTS RECOMMENDED IN THE BILL FOR FISCAL YEAR 1989—Continued

Agency and item	New budget (obligational) authority, fiscal year 1988	Budget estimates of new obligational authority, fiscal year 1989	New budget (obligational) authority recommended in bill	Bill compared with—	
				New budget (obligational) authority, fiscal year 1988	Budget estimates of new (obligational) authority, fiscal year 1989
GENERAL SERVICES ADMINISTRATION					
Consumer Information Center	1,279,000	1,354,000	1,354,000	+75,000	---
(Limitation on administrative expenses)	(1,652,000)	(1,736,000)	(1,736,000)	(+84,000)	---
DEPARTMENT OF HEALTH AND HUMAN SERVICES					
Office of Consumer Affairs	1,670,000	1,708,000	1,708,000	+38,000	---
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION					
Research and development	3,274,200,000	4,446,700,000	4,191,700,000	+917,500,000	-255,000,000
Rescission	---	---	-25,000,000	-25,000,000	-25,000,000
(By transfer)	(100,000,000)	---	---	(-100,000,000)	---
(By transfer, Department of Defense)	(70,000,000)	---	---	(-70,000,000)	---
Space flight, control and data communications	3,908,309,000	4,841,200,000	4,414,200,000	+505,891,000	-427,000,000
Construction of facilities	178,272,000	285,100,000	270,100,000	+91,828,000	-15,000,000
Research and program management	1,495,680,000	1,915,000,000	1,855,000,000	+359,320,000	-60,000,000
Total, National Aeronautics and Space Administration (net)	8,856,461,000	11,488,000,000	10,706,000,000	+1,849,539,000	-782,000,000
NATIONAL CREDIT UNION ADMINISTRATION					
Central liquidity facility:					
(Limitation on direct loans)	(600,000,000)	(600,000,000)	(600,000,000)	---	---
(Limitation on administrative expenses, corporate funds)	(813,000)	(880,000)	(880,000)	(+67,000)	---

Calendar No. 762

100TH CONGRESS } SENATE { REPORT
2d Session } { 100-401

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATION BILL, 1989

JUNE 24 (legislative day, JUNE 23), 1988.—Ordered to be printed

Mr. PROXMIRE, from the Committee on Appropriations, submitted the following

REPORT

[To accompany H.R. 4800]

The Committee on Appropriations to which was referred the bill (H.R. 4800) making appropriations for the Department of Housing and Urban Development, and for sundry independent agencies, boards, commissions, corporations, and offices for the fiscal year ending September 30, 1989, and for other purposes, reports the same to the Senate with various amendments and presents herewith an explanation of the contents of the bill.

AMOUNT OF NEW BUDGET (OBLIGATIONAL) AUTHORITY

	Fiscal year 1989
Amount of bill as recommended in House	$59,709,920,000
Amount of change by Committee	−633,447,000
Amount of bill as reported to Senate	59,076,473,000
Amount of appropriations to date, 1988	56,702,844,000
Amount of budget estimates, 1989	58,666,772,000
Over estimates for 1989	+409,701,000
Over appropriations for 1988	+2,373,579,000

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

1988 appropriation	$3,274,200,000
1989 budget estimate	4,446,700,000
House allowance	4,191,700,000
Committee recommendation	3,552,800,000

PROGRAM DESCRIPTION

The objectives of the National Aeronautics and Space Administration's [NASA] program of research and development are to extend our knowledge of the Earth, its space environment, and the universe; to expand the practical applications of space technology; to develop, operate, and improve unmanned space vehicles; to provide technology for improving the performance of aeronautical vehicles while minimizing their environmental effects and energy consumption; and to assure continued development of the aeronautics and space technology necessary to accomplish national goals.

The appropriations request would continue funding for a permanently manned space station, including development work on the hardware components and supporting development activities such as systems engineering and integration, and the technical and management information system. Definition and preliminary design of the Flight Telerobotic System Program would also be continued.

Another major area of activity is space transportation capability development including efforts related to the spacelab, the upper stages that place satellites in high altitude orbits not attainable by the shuttle, the engineering and technical base, payload operations and support equipment, advanced programs study and evaluation efforts, the development of the United States/Italy tethered satellite system, and development of the orbital maneuvering vehicle. Funding is included to continue definition and preliminary design activities on the crew emergency return vehicle and the advanced launch system.

The space science and applications program utilizes space systems supported by airborne and ground-based observations to conduct scientific investigations of the Earth and its space environment, the Sun, the planets, interplanetary and interstellar space, and the other stars of our

galaxy and universe. Results from these investigations contribute to our understanding of the universe, including the key questions of life, matter, and energy. In addition, this program conducts the research and selected technology developments to encourage the practical application of space technologies to needs on Earth. Funding is included to initiate design and development activities on the advanced x-ray facility which will allow astronomers to view the universe with an unprecedented degree of sensitivity.

Commercial programs include the technology utilization and commercial use of space. The Technology Utilization Program is designed to facilitate the transfer of NASA developed technology to the nonaerospace sectors of the U.S. economy. The commercial use of space is designed to increase private sector awareness of the opportunities in space. Private industry will be encouraged to invest and participate in high technology research and development utilizing the unique characteristics of space.

The objective of the aeronautical research and technology program is to provide the broad technology base essential to the preservation of U.S. leadership in aviation. The objectives of the space research and technology program are to provide the technology base necessary to support current and future space activities and to formulate and advance technology options for the future. These activities emphasize the longer-range aspects of generic research and technology development which are crucial in maintaining future U.S. leadership. Funding is included to initiate Project Pathfinder, which will develop technology underlying potential future space missions beyond the Earth's orbit and provide the advanced technology to continue U.S. leadership in space.

The overall objective of the advanced systems program is to perform studies to ensure capability for tracking and data acquisitions, communications, and data processing support required by all NASA flight projects in accomplishing their mission objectives.

COMMITTEE RECOMMENDATION

The Committee recommends an appropriation of $3,552,800,000 for research and development activities. This amount is $893,900,000 less than the budget estimate and $638,900,000 less than the House allowance.

The Committee recommends $200,000,000 for the space station program, a reduction of $767,400,000 below the administration's budget request and $702,400,000 below the House allocation. The Committee understands that the cost of simply maintaining the current space station teams is approximately $50,000,000 per month and that very little, if any, real progress can be made at this level of funding. Therefore, the Committee suggests that the funds recommended be used to phase out the current station program and plan for a scaled-down effort or, in the alternative, to sustain a bare-bones organization through the early part of calendar 1989 when a new administration will be in a position to determine the future direction of the program.

The Committee notes that the House included language in the bill with the intent of delaying the availability of $450,000,000 in space station funds until April 15, 1989. These moneys would become available unless the President submitted a special message after February 1, 1989, notifying the Congress that such funds will not be made available for the Space Station Program. This language gives the next President the option of proceeding with the space station or terminating the current program.

The Committee concurs with the House in recommending the following further adjustments in the administration's budget request:

—$11,000,000 from the advanced x-ray astrophysics facility [AXAF]. This reduces funding for AXAF to $16,000,000 in the coming fiscal year. The Committee concurs with the House directive that these funds be used to begin work on a high-resolution mirror assembly technology development program. This effort should take approximately 3 years and, if successful, will lead to a development start for the AXAF spacecraft in fiscal year 1992. The Committee commends NASA for its willingness to take this segmented approach to the AXAF project as a means of avoiding the kind of technical interface problems that plagued the Hubble space telescope. The Committee does not object to the use of advanced technology development funds to support continued phase B prime work on the AXAF spacecraft as well as the utilization of research and analysis dollars to continue a similar effort on the instruments. The Committee would expect to provide initial instrument development funding in fiscal year 1990. The Committee also directs the preparation and transmittal of the mirror assembly effort reports requested on a semiannual schedule by the House Appropriations Committee.

—$60,000,000 from the $100,000,000 requested for the Pathfinder Program. While such technology development efforts are crucial to future civil space initiatives, current budgetary constraints make such prudent investments impossible. Within those funds which can be sustained in this environment, however, the Committee recommends that the agency concentrate its efforts in those areas, such as advanced energy conversion technologies, which provide the greatest long-term potential for manned space exploration of our solar system. Such systems as the Sterling space engine, will greatly enhance the viability and efficiency of anticipated developments in new power sources now being developed by the other Federal agencies. The Committee notes that a substantial portion of the funds requested would be used to continue support for projects previously funded under other programs and also suggests that the amount provided be distributed in such a way as to minimize the disruption that would be caused by the termination of ongoing NASA contracts.

—$35,000,000 from the $631,100,000 requested for space transportation capability development with the reduction to be taken at the agency's discretion.

−$15,800,000 from the $84,400,000 requested for the national aerospace plane under the transatmospheric research and technology budget element. This reduction would leave a total of $68,600,000 for the program in fiscal year 1989, an increase of $16,100,000 above the current level of funding.

−$35,000,000 from the civilian space technology initiative, leaving a total budget of $121,800,000, an increase of $6,600,000 above the current appropriation.

−$35,000,000 from the $101,400,000 requested for the global geospace science mission. The recommended reduction will leave $66,400,000 for this initiative, more than three times the $20,000,000 currently available.

−$10,000,000 from the $97,800,000 requested for the ocean topography experiment. The remaining $87,800,000 is $12,800,000 more than is currently being spent on the program.

+$76,000,000 for the advanced communications technology satellite [ACTS]. The Committee understands that this project can be completed for a total of $499,000,000 with an additional $76,000,000 in fiscal year 1990 and $34,000,000 in fiscal year 1991 being sufficient to fulfill all Federal funding requirements.

+$10,000,000 for upper stages, making a total of $156,200,000 available for this activity. The added funding is required for ACTS, which is scheduled to be launched from a space shuttle orbiter.

−$25,000,000 appropriated in fiscal year 1988 for an industrial space facility. Although the Committee believes such a facility would provide substantial support for microgravity research in the relatively near future (1992 or 1993) at a reasonable cost, the Committee recommends the rescission of the funds in view of a lack of support from the House and Senate authorizing committees. The Committee is hopeful that a 9-month study to be conducted by the National Academy of Sciences will clarify the value of such a facility and will lay the groundwork for a further consideration of this approach in fiscal year 1990. In the meantime, the Committee directs that no agency issue a request for proposal for a commercially developed space facility unless the authority for such a program is established by law.

Although the Committee concurs with the House in providing $5,000,000 for a new total ozone mapping spectrometer [TOMS], the Committee recommends an increase in the NASA budget to accommodate this initiative. The Committee believes that requiring NASA to support this project from available resources places an undesirable burden on the agency in view of the deep cuts the Committee is recommending elsewhere. The Committee notes that this project will make a substantial contribution to the solution of a serious environmental problem and joins the House in suggesting that TOMS be considered for a bilateral mission in view of its importance to the international environmental community.

The Committee proposes the following adjustments in the House-approved amounts:

+$5,000,000 for aeronautical research and technology, making a total of $409,200,000 available for this activity, a reduction of $5,000,000 below the budget request.

The Committee recognizes the importance of the general aviation rotary engine research initiative and directs that the fiscal year 1989 aeronautical research and technology base program provide the $3,100,000 requested to continue this valuable effort.

+$10,000,000 for planetary exploration, providing the full budget request of $404,000,000. The Committee is concerned over the potential impact the House cut could have on the Mars Observatory program.

+$10,000,000 for space telescope operations, maintenance, and refurbishment, making available the full budget request of $111,300,000. The Committee is concerned that the House reduction might hinder efforts to fund new power systems for the telescope, which currently faces a power shortfall.

+$10,000,000 for technology utilization, commercial programs, and information systems, restoring these budgets to the full amount requested by the administration. The Committee is pleased that NASA is going forward with its plans to continue support for the AdaNET project ($2,700,000) which is intended to transfer Ada software to the commercial sector, and to conduct a definition/design study for a National Technology Transfer Center [NTTC] in West Virginia ($1,200,000). Such a center would be a central facility for access to most Federal data bases in order to provide access for the commercial sector to technologies developed by Federal funding at a variety of Federal agencies. The AdaNET effort is being supported in its initial phase on a cost-sharing basis with the intent that it will become a self-supporting commercial organization by 1992. The NTTC definition is intended to develop a technical and cost plan, and a cost-sharing plan involving both Federal and non-Federal sources, which will lead to a self-sustaining operation in approximately 5 years.

+$13,100,000 for life sciences, providing a total of $89,800,000 rather than $101,700,000 as proposed by the administration and $76,700,000 recommended by the House.

+$10,000,000 for a scatterometer to provide essential measurements for understanding the role of the world's oceans in determining the global climate. Without these additional funds, which would bring the program up to the requested budget of $15,700,000, there is an excellent possibility that the project would have to be terminated.

The Committee recognizes the importance of research on the greenhouse effect and global climate change and considers NASA's work in this area an important part of the agency's future and central to its mission. NASA recently reported to Members of Congress that the 4

warmest years in the past 130 years have occurred in this decade. Detecting the actual signal of global temperature trends which exceed the variability of normal climatic conditions is critical to the Congress as it considers appropriate responses to the buildup of greenhouse gases. Therefore, of the total sums made available to the Environmental Observation Program, $2,000,000 is provided for the Goddard Institute for Space Studies for the continuation of its work on global change, including temperature trends. In addition, NASA jointly with NOAA should report to Congress by March 1, 1989, on the significance of recent global temperature trends.

Of the amounts provided for research and development activities, $1,000,000 is provided for curriculum development activities for grades K–9 by ongoing nonprofit organizations. The Committee recognizes the value of these activities and their importance to the future competitiveness of the United States and feels that it is appropriate to provide transitional support to help such activities become self-sustaining. The Committee understands that funds will be awarded through a competitive solicitation.

The Committee directs that $1,000,000 be made available for the purpose of providing staff support and other assistance to any commission established by law during the 100th Congress for the purpose of (1) preparing a strategy for cooperation between the Soviet Union and the United States on unmanned Mars projects in anticipation of a joint manned mission; (2) devising strategies for such cooperation that would prevent the unwanted transfer of technology; and (3) preparing a detailed proposal for a joint manned Mars mission with the Soviet Union. These funds are made available subject to final passage of legislation creating the Commission before the end of the current Congress. If such an authorization is not enacted, the funds may be reprogrammed into other activities.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

1988 appropriation	$3,908,309,000
1989 budget estimate	4,841,200,000
House allowance	4,414,200,000
Committee recommendation	4,452,200,000

PROGRAM DESCRIPTION

The space flight, control and data communications appropriation provides for the production and operational activities for the space transportation system and the tracking, telemetry, command, and data acquisition support of all NASA flight projects.

Shuttle production and operational capability and space transportation operations are the key elements of the space transportation system that are contained within this appropriation. The shuttle production and capability development program provides for the national fleet of space shuttle orbiters including main engines, launch site and mission operational control requirements, initial structural and operational spares, production tooling, and related supporting activities. Funding is included to begin the design and development of the advanced solid rocket motor and the hardware necessary to extend the on-orbit staytime of the Space Shuttle to 14 to 16 days, and for expendable launch services for selected space science and applications missions consistent with implementation of the mixed fleet concept.

The space tracking and data acquisition program provides vital tracking, telemetry, command, and data acquisition support for Earth-orbital spacecraft, planetary missions, sounding rockets, balloons, and research aircraft. This support is currently provided by a worldwide network of NASA ground stations, and by the first of a system of three tracking and data relay satellites in geosynchronous orbit working with a single highly specialized ground station. Work will continue on the replacement tracking and data relay satellite spacecraft for the one lost in the *Challenger* accident. Facilities are also provided to process into meaningful form the scientific, applications, and engineering data which are collected from flight projects.

COMMITTEE RECOMMENDATION

The Committee recommends $4,452,200,000 for space flight, control, and data communications activities. This is $389,000,000 less than the budget request and $38,000,000 more than the House allowance.

The Committee concurs in the following House changes in the administration's budget request:

– $205,000,000 from the $3,610,400,000 requested for the space transportation system, popularly known as the space shuttle. The Committee agrees with the House decision to allow NASA to withhold the $227,000,000 payment due the Federal Financing Bank for costs associated with the financing of the tracking and data relay satellite system [TDRSS] until the fourth quarter of fiscal year 1989. The restaging of the payment schedule will give NASA the flexibility to deal with unavoidable space shuttle operations cost burdens in the coming fiscal year. However, the Committee expects NASA to make every effort to live within the total recommended for the space shuttle in fiscal year 1989 without compromising the safety of the system.

– $90,000,000 from the $1,035,300,000 requested for tracking and data acquisition. The request includes $78,800,000 for a TDRSS replacement spacecraft and $70,000,000 for a second TDRSS ground terminal. The reduction may be taken in part from either of these programs and/or in other activities at the agency's discretion.

– $60,000,000 requested for a Titan III expendable launch vehicle [ELV] for a TDRSS launch. The Committee urges NASA to construct the shuttle manifest so as to assure the availability of the shuttle for this launch, thus avoiding the need for a backup expendable launch vehicle.

– $12,000,000 from the $51,000,000 requested for Delta II ELV's. This reduction is taken in conjunction with the $35,000,000 reduction in the funds requested for the global geospace science mission

under the "Research and development" account, which will reduce Delta II requirements.

–$5,000,000 from the $88,000,000 requested for the advanced solid rocket motor [ASRM]. The Committee concurs with the House in recommending the transfer of $27,000,000 of the total remaining to the construction of facilities account for any construction costs that may be incurred should a Government-owned/ contractor operated facility be chosen for ASRM production.

+$10,000,000 for an extended duration orbiter [EDO]. The Committee concurs with the House in directing that these funds be used for the development of an EDO which can stay in orbit for approximately 30 days.

The Committee proposes the following adjustments in the House-approved amounts:

+$15,000,000 for a Titan III backup ELV for the Mars Observatory mission, the full amount requested. This will give the agency the needed flexibility to assure that this important mission gets off the ground in 1992 in support of the International Space Year, as part of our new space cooperation agreement with the Soviet Union and, most importantly, to restore the United States role in Mars exploration. The Committee opposes any delay in the Mars Observer mission beyond its scheduled 1992 launch and attaches the utmost importance to keeping to this date.

+$23,000,000 for a Titan IV ELV to be available in 1991 as a backup for the Magellan, Galileo, and Ulysses planetary missions currently manifested on the shuttle. The Committee's action provides the full budget request of $43,000,000. The Committee believes that it is particularly important to proceed with this procurement in view of the constraints the recent explosion of an ammonium perchlorate plant in Nevada is expected to place on shuttle operations.

CONSTRUCTION OF FACILITIES

1988 appropriation	$178,272,000
1989 budget estimate	285,100,000
House allowance	270,100,000
Committee recommendation	270,100,000

PROGRAM DESCRIPTION

This appropriation provides for the contractual services for the design, repair, major rehabilitation, and modification of facilities; the construction of new facilities; minor construction; the purchase of land and equipment related to construction and modification; and advanced design related to facilities planned for future authorization.

COMMITTEE RECOMMENDATION

The Committee recommends $270,100,000 for the construction of facilities. This is $15,000,000 less than the budget request and the same as the House allowance.

The reduction includes a cut of $27,900,000 requested for space station facilities in view of the tenuous funding situation confronted by the space station as outlined in the "Research and development" account. This reduction is virtually offset by a transfer of $27,000,000 from the "Space flight" account for the construction of a Government-owned/contractor operated ASRM facility as explained under that account heading in this report. The Committee concurs with the House in recommending a general reduction of $14,100,000 and notes that even with these alterations, the appropriation for construction of facilities will have increased by $91,828,000 above the current level of funding.

RESEARCH AND PROGRAM MANAGEMENT

1988 appropriation	[1] $1,495,680,000
1989 budget estimate	1,915,000,000
House allowance	1,855,000,000
Committee recommendation	1,870,000,000

[1] Does not include transfer of $242,438,000 agreed to in conference on the 1988 Appropriations Act. The conferees indicated that the formal transfer of some institutional costs would be made in a future Appropriations Act.

The research and program management appropriation supports the performance and management of research, technology, and test activities at NASA installations, and the planning, management, and support of contractor research and development tasks necessary to meet the Nation's objectives in aeronautical and space research. Specifically, this appropriation provides the technical and management capability of the civil service staff needed to conduct the full range of programs for which NASA is responsible; maintains facilities and laboratories in a state of operational capability and manages their use in support of research and development programs; and provides technical and administrative support for the research and development programs at NASA.

COMMITTEE RECOMMENDATION

The Committee recommends an appropriation of $1,870,000,000 for research and program management. This is $45,000,000 less than the budget request and $15,000,000 above the House-approved amount.

The Committee recommends that a substantial portion of this reduction be taken in space station staffing in view of the recommended phasedown of this program. The Committee suggests that the remainder of the reduction can be taken from the $77,950,000 increase requested for travel and operation of installations.

COMPARATIVE STATEMENT OF NEW BUDGET (OBLIGATIONAL) AUTHORITY FOR FISCAL YEAR 1988 AND BUDGET ESTIMATES AND AMOUNTS RECOMMENDED IN THE BILL FOR FISCAL YEAR 1989—Continued

[Amounts in dollars]

Item	1988 appropriation	Budget estimate	House allowance	Committee recommendation	Senate committee recommendation compared with (+ or -)		
					1988 appropriation	Budget estimate	House allowance
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION							
Research and development	3,274,200,000	4,446,700,000	4,191,700,000	3,552,800,000	+278,600,000	-893,900,000	-638,900,000
Rescission	---	---	-25,000,000	-25,000,000	-25,000,000	-25,000,000	---
(By transfer)	(100,000,000)	---	---	---	(-100,000,000)	---	---
(By transfer, Department of Defense)	(70,000,000)	---	---	---	(-70,000,000)	---	---
Space flight, control and data communications	3,908,309,000	4,841,200,000	4,414,200,000	4,452,200,000	+543,891,000	-389,000,000	+38,000,000
Construction of facilities	178,272,000	285,100,000	270,100,000	270,100,000	+91,828,000	-15,000,000	---
Research and program management	1,495,680,000	1,915,000,000	1,855,000,000	1,870,000,000	+374,320,000	-45,000,000	+15,000,000
Total, National Aeronautics and Space Administration (net)	8,856,461,000	11,488,000,000	10,706,000,000	10,120,100,000	+1,263,639,000	-1,367,900,000	-585,900,000

TITLE IV—GENERAL PROVISIONS

The Committee concurs with all of the general provisions that were included in the House-passed HUD-Independent Agencies Appropriations Act with the exception of section 415 which is intended to provide for drug-free workplaces. While the Committee strongly concurs with this goal, meaningful and effective legislation on this serious problem is needed. The Committee, therefore, recommends deletion of the House-passed rider and urges the authorizing committees of jurisdiction to expedite consideration of comprehensive legislation on this issue. In addition, the Committee recommends an amendment to section 401 of the House-passed bill to exempt certain Superfund-related travel from the travel restrictions set forth in that section.

The Committee has added a new section to the House-passed bill requiring the absorption of fiscal year 1989 pay raises within the levels appropriated in the bill.

COMPLIANCE WITH PARAGRAPH 7, RULE XVI, OF THE STANDING RULES OF THE SENATE

Paragraph 7 of rule XVI requires that Committee reports on general appropriations bills identify each Committee amendment to the House bill "which proposes an item of appropriation which is not made to carry out the provisions of an existing law, a treaty stipulation, or an act or resolution previously passed by the Senate during that session."

An authorization for programs funded by the National Aeronautics and Space Administration has not as yet passed the Senate.

100TH CONGRESS
2d Session
HOUSE OF REPRESENTATIVES
REPORT
100-817

MAKING APPROPRIATIONS FOR THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, AND FOR SUNDRY INDEPENDENT AGENCIES, BOARDS, COMMISSIONS, CORPORATIONS, AND OFFICES FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1989

AUGUST 3, 1988.—Ordered to be printed

Mr. BOLAND, from the committee of conference, submitted the following

CONFERENCE REPORT

[To accompany H.R. 4800]

The committee of conference on the disagreeing votes of the two Houses on the amendments of the Senate to the bill (H.R. 4800) making appropriations for the Department of Housing and Urban Development, and for sundry independent agencies, boards, commissions, corporations, and offices for the fiscal year ending September 30, 1989, and for other purposes, having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the Senate recede from its amendments numbered 4, 10, 11, 12, 14, 16, 20, 21, 25, 27, 28, 29, 31, 34, 35, 36, 37, 38, 39, 43, 47, 48, 53, 55, 59, 61, 65, 67, 72, 74, 77, 78, 79, 82, 83, 84, 85, and 86.

That the House recede from its disagreement to the amendments of the Senate numbered 5, 22, 26, 33, 41, 42, 49, 52, 54, 63, 66, 69, 71, and 80, and agree to the same.

Amendment numbered 2:

That the House recede from its disagreement to the amendment of the Senate numbered 2, and agree to the same with an amendment, as follows:

In lieu of the sum proposed by said amendment insert *$480,106,000*; and the Senate agree to the same.

Amendment numbered 7:

That the House recede from its disagreement to the amendment of the Senate numbered 7, and agree to the same with an amendment, as follows:

In lieu of the sum proposed by said amendment insert *$46,500,000*; and the Senate agree to the same.

strictions on personal services and percentage of state training courses pursuant to authorizing legislation.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

OFFICE OF CONSUMER AFFAIRS

The conferees agree that the Office of Consumer Affairs shall provide at least $300,000 for publication distribution costs as proposed by the Senate, instead of $350,000 as proposed by the House.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Amendment No. 54: Makes a technical change in the title of the research and development paragraph.

Amendment No. 55: Appropriates $4,191,700 for research and development as proposed by the House, instead of $3,552,800,000 as proposed by the Senate.

The conferees agree that if the administrator elects to exercise the option of transferring up to $30,000,000 of funding from the construction of facilities account, it is to be allocated relative to amounts provided in the House bill in the following priority order:

1. +$10,000,000 for planetary programs.
2. + *up to* $10,000,000 for the "scatterometer" instrument.
3. +$5,000,000 for the total ozone mapping spectrometer (TOMS) instead of $5,000,000 provided from within available funds as recommended by the House.
4. +$5,000,000 for space telescope operations.
5. +$2,000,000 for life sciences.
6. +$2,700,000 for the AdaNET software project.

The conferees direct that an operating plan reflecting these and other changes to the fiscal year 1989 budget be submitted to the Committees on Appropriations within 30 days of enactment of this bill.

The conferees did not include any funding for a National Technology Transfer Center in West Virginia. However, the conferees direct the Office of Commerical Programs to conduct a definition/design study of the five year master plan for the establishment of a national repository for federal research and development (technology transfer), which would be located in West Virginia, and to transmit the definition/design study along with five year cost estimates and a proposal for cost-sharing, to the Committees on Appropriations of the House of Representatives and the Senate by February 1, 1989.

The committee of conference is agreed that the $1,000,000 earmarked by the Senate for curriculum development activities for grades K-9 should be provided through competitive awards made under additional funding provided to the National Science Foundation's science and engineering education account.

The conferees also agree that $1,000,000 shall be available for distribution at the agency's discretion for studies associated with global climate change.

Finally, the conferees agree that no funds are made available for the administration of a joint US/USSR Mars Mission Commission.

Amendment No. 56: Reported in technical disagreement. The managers on the part of the House will offer a motion to recede and concur in the amendment of the Senate with an amendment as follows:

Restore the matter stricken by said amendment, amended to read as follows: , *of which $900,000,000 is for the space station program only: Provided, That $515,000,000 of the $900,000,000 for the space station program shall not become available for obligation until May 15, 1989, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: Provided further, That the aforementioned $515,000,000 shall become available unless the President submits a special message after February 1, 1989, notifying the Congress that such funds will not be made available for the space station program*

The managers on the part of the Senate will move to concur in the amendment of the House to the amendment of the Senate.

In connection with space station funding, the conferees direct NASA to continue work on solar dynamic power and satellite servicing to the extent practical within the limited funds available.

Amendment No. 57: Reported in technical disagreement. The managers on the part of the House will offer a motion to recede and concur in the amendment of the Senate with an amendment as follows:

In lieu of the sum proposed by said amendment, insert the following: *$4,364,200,000: Provided, That, notwithstanding any provision of this or any other Act, not to exceed $100,000,000 may be transferred to the National Aeronautics and Space Administration in fiscal year 1989 from any funds appropriated to the Department of Defense and such funds may only be transferred to the "Space flight, control and data communications" appropriation for space shuttle operations: Provided further, That the transfer limitation in the immediately preceding proviso shall not apply to funds transferred for advanced launch systems or under existing reimbursement arrangements: Provided further, That the funds appropriated under this heading are, together with funds permitted to be transferred hereunder*

The managers on the part of the Senate will move to concur in the amendment of the House to the amendment of the Senate.

The conferees agree that within the funds made available in this account, $5,000,000 shall be allocated for a TITAN III expendable launch vehicle for the Mars Observer Mission and $20,000,000 shall be allocated for a TITAN IV expendable launch vehicle for a planetary backup launch.

Amendment No. 58: Reported in technical disagreement. The managers on the part of the House will offer a motion to recede and concur in the amendment of the Senate with an amendment as follows:

In lieu of the matter inserted by said amendment, insert the following: *: Provided further, That in addition to sums otherwise provided by this paragraph, an additional $20,000,000, to remain available until expended: Provided further, That up to $30,000,000 of the funds provided by this paragraph may be transferred to and merged with sums appropriated for "Research and development" and/or "Research program management".*

SCIENCE, SPACE, AND TECHNOLOGY EDUCATION TRUST FUND

There is appropriated, by transfer from funds appropriated in this Act for "Construction of facilities", the sum of $15,000,000 to the "Science, Space, and Technology Education Trust Fund" which is hereby established in the Treasury of the United States: Provided, That the Secretary shall invest such funds in the United States Treasury special issue securities, that such interest shall be credited to the Trust Fund on a quarterly basis, and that such interest shall be available for the purpose of making grants for programs directed at improving science, space, and technology education in the United States: Provided further, That the Administrator of the National Aeronautics and Space Administration, after consultation with the Director of the National Science Foundation, shall review applications made for such grants and determine the distribution of such available funds on a competitive basis: Provided further, That such grants shall be made available to any awardee only to the extent that said awardee provides matching funds from non-Federal sources to carry out the program for which grants from this Trust Fund are made: Provided further, That of the funds made available by this Trust Fund, $250,000 shall be disbursed each calendar quarter for a ten-year period to the Challenger Center for Space Science Education: Provided further, That the Administrator of the National Aeronautics and Space Administration shall submit to the Congress an annual report on the grants made pursuant to this paragraph

The managers on the part of the Senate will move to concur in the amendment of the House to the amendment of the Senate.

The conferees have agreed to delete the language permitting the transfer of $27,000,000 for construction of an advanced solid rocket motor facility to the space flight, control and data communications account without prejudice.

The committee of conference has included bill language providing the Administrator of NASA with the option of transferring up to $30,000,000 from the construction of facilities account to the research and development and/or research and program management account. The use and relative priority of such funds is described above under the research and development account.

Amendment No. 59: Appropriates $1,855,000,00 for research and program management as proposed by the House, instead of $1,870,000,000 as proposed by the Senate. The conference agree that the reduction of 100 positions in NASA headquarters, which is specified by office and activity in the report accompanying the House bill, may be taken at the agency's discretion.

TITLE IV

GENERAL PROVISIONS

Amendment No. 79: Deletes language inserted by the Senate exempting travel performed to provide technical assistance for the Emergency Planning and Community Right to Know Act of 1986 from the general limitation on travel expenses.

Amendment No. 80: Deletes language proposed by the House and stricken by the Senate prohibiting the expenditure of funds in any workplace that is not free of illegal use or possession of controlled substances. The conferees understand that this matter will be addressed on a government-wide basis in another appropriations measure.

Amendment No. 81: Reported in technical disagreement. The managers on the part of the House will offer a motion to recede and concur in the amendment of the Senate requiring that all 1989 pay raises shall be absorbed within the levels appropriated in this Act.

Amendment No. 82: Deletes language inserted by the Senate reducing all agencies' appropriations to limit expenditures to 85 percent of the fiscal year 1987 level for management consulting services and to 95 percent for research, engineering, and technical consulting services. The conferees have ageeed to delete this bill language without prejudice. The conferees are concerned about reported abuses in this area of Federal activity and expect the Department and agencies funded through this Act to assiduously monitor and control these expenditures.

Amendment No. 83: Deletes language proposed by the Senate directing EPA to submit to the Congress a plan for the Agency to participate in the activities of the Pacific Northwest Hazardous Research, Development, and Demonstration Center. While the Senate bill language has been deleted, the conferees are in agreement that it would be useful for EPA to explore with the Pacific Northwest Center possible areas of collaboration and coordination which would be of mutual benefit. As indicated in the Senate language, this review should consider direct participation in research, in-kind personal exchange, interagency program coordination, and other measures to maximize the benefit of the Center to the public. A report should be submitted to the Congress by March 1, 1989.

Amendment No. 84: Deletes language inserted by the Senate directly EPA to report to the Congress within six months on the feasibility of using treated effluent waters from the Carson River Basin to improve the Lahontan Valley wetlands. While the conferees have agreed to drop the Senate bill language, the Agency is directed to reprogram funds as necessary to conduct the study and submit the report to the Congress no later than six months after enactment of this Act.

Amendment No. 85: Deletes language inserted by the Senate expressing the sense of the Senate that the President should call upon world leaders to begin negotiations on an international convention on the greenhouse effect. The conferees are concerned by the mounting evidence of global warming and have provided additional funds for research and policy studies to address this problem. The conferees hope that the next President will take a leadership role in seeking international coordination in addressing the range of issues related to both global climate change and strastospheric ozone depletion.

Amendment No. 86: Deletes language inserted by the Senate expressing the sense of the Senate that the HUD-Independent Agencies Subcommittee allocation be increased to permit development and production of the space station for deployment in the mid-1990's and to support other priority programs in the Department of Housing and Urban Development, the Veterans Administration, the Environmental Protection Agency, and the National Science Foundation.

Conference Total—With Comparisons

The total new budget (obligational) authority for the fiscal year 1989 recommended by the committee of conference, with comparisons to the fiscal year 1988 amount, the 1989 budget estimates, and the House and Senate bills for 1989 follow:

New budget (obligational) authority, fiscal year 1988	$57,359,891,000
Budget estimates of new (obligational) authority, fiscal year 1989	58,666,772,000
House bill, fiscal year 1989	59,709,920,000
Senate bill, fiscal year 1989	59,077,033,000
Conference agreement, fiscal year 1989	59,386,045,000
Conference agreement compared with:	
New budget (obligational) authority, fiscal year 1988	+2,026,154,000
Budget estimates of new (obligational) authority, fiscal year 1989	+719,273,000
House bill, fiscal year 1989	−323,875,000
Senate bill, fiscal year 1989	+309,012,000

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATIONS ACT, 1989

GENERAL SERVICES ADMINISTRATION

CONSUMER INFORMATION CENTER

For necessary expenses of the Consumer Information Center, including services authorized by 5 U.S.C. 3109, $1,354,000, to be deposited into the Consumer Information Center Fund: *Provided,* That the appropriations, revenues and collections deposited into the fund shall be available for necessary expenses of Consumer Information Center activities in the aggregate amount of $5,200,000. Administrative expenses of the Consumer Information Center in fiscal year 1989 shall not exceed $1,736,000. Appropriations, revenues and collections accruing to this fund during fiscal year 1989 in excess of $5,200,000 shall remain in the fund and shall not be available for expenditure except as authorized in appropriations Acts.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

OFFICE OF CONSUMER AFFAIRS

For necessary expenses of the Office of Consumer Affairs, including services authorized by 5 U.S.C. 3109, $1,708,000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

(INCLUDING RESCISSION OF FUNDS)

For necessary expenses, not otherwise provided for, including research, development, operations, services, minor construction, maintenance, repair, rehabilitation and modification of real and personal property; purchase, hire, maintenance, and operation of other than administrative aircraft, necessary for the conduct and support of aeronautical and space research and development activities of the National Aeronautics and Space Administration; $4,191,700,000, to remain available until September 30, 1990, of which $900,000,000 is for the space station program only: *Provided,* That $515,000,000 of the $900,000,000 for the space station program shall not become available for obligation until May 15, 1989, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further,* That the aforementioned $515,000,000 shall become available unless the President submits a special message after February 1, 1989, notifying the Congress that such funds will not be made available for the space station program.

Of the funds appropriated under this head in the Department of Housing and Urban Development—Independent Agencies Appropriations Act, 1988 (H.R. 2783), as enacted under the provision of section 101(f) of Public Law 100-202, an Act making further continuing appropriations for the fiscal year ending September 30, 1988, $25,000,000 are rescinded.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

For necessary expenses, not otherwise provided for; in support of space flight, spacecraft control and communications activities of the

National Aeronautics and Space Administration, including operations, production, services, minor construction, maintenance, repair, rehabilitation, and modification of real and personal property; tracking and data relay satellite services as authorized by law; purchase, hire, maintenance and operation of other than administrative aircraft; $4,364,200,000: *Provided,* That, notwithstanding any provision of this or any other Act, not to exceed $100,000,000 may be transferred to the National Aeronautics and Space Administration in fiscal year 1989 from any funds appropriated to the Department of Defense and such funds may only be transferred to the "Space flight, control and data communications" appropriation for space shuttle operations: *Provided further,* That the transfer limitation in the immediately preceding proviso shall not apply to funds transferred for advanced launch systems or under existing reimbursement arrangements: *Provided further,* That the funds appropriated under this heading are, together with funds permitted to be transferred hereunder, to remain available until September 30, 1990.

CONSTRUCTION OF FACILITIES

For construction, repair, rehabilitation and modification of facilities, minor construction of new facilities and additions to existing facilities, and for facility planning and design not otherwise provided, for the National Aeronautics and Space Administration, and for the acquisition or condemnation of real property, as authorized by law, $270,100,000, to remain available until September 30, 1991: *Provided,* That, notwithstanding the limitation on the availability of funds appropriated under this heading by this appropriations Act, when any activity has been initiated by the incurrence of obligations therefor, the amount available for such activity shall remain available until expended, except that this provision shall not apply to the amounts appropriated pursuant to the authorization for repair, rehabilitation and modification of facilities, minor construction of new facilities and additions to existing facilities, and facility planning and design: *Provided further,* That no amount appropriated pursuant to this or any other Act may be used for the lease or construction of a new contractor-funded facility for exclusive use in support of a contract or contracts with the National Aeronautics and Space Administration under which the Administration would be required to substantially amortize through payment or reimbursement such contractor investment, unless an appropriations Act specifies the lease or contract pursuant to which such facilities are to be constructed or leased or such facility is otherwise identified in such Act: *Provided further,* That the Administrator may authorize such facility lease or construction, if he determines, in consultation with the Committees on Appropriations, that deferral of such action until the enactment of the next appropriations Act would be inconsistent with the interest of the Nation in aeronautical and space activities: *Provided further,* That in addition to sums otherwise provided by this paragraph, an additional $20,000,000, to remain available until expended: *Provided further,* That up to $30,000,000 of the funds provided by this paragraph may be transferred to and merged with sums appropriated for "Research and development" and/or "Research and program management".

Contracts.

SCIENCE, SPACE, AND TECHNOLOGY EDUCATION TRUST FUND

42 USC 2467.

There is appropriated, by transfer from funds appropriated in this Act for "Construction of facilities", the sum of $15,000,000 to the "Science, Space, and Technology Education Trust Fund" which is hereby established in the Treasury of the United States: *Provided,* That the Secretary shall invest such funds in the United States Treasury special issue securities, that such interest shall be credited to the Trust Fund on a quarterly basis, and that such interest shall be available for the purpose of making grants for programs directed at improving science, space, and technology education in the United States: *Provided further,* That the Administrator of the National Aeronautics and Space Administration, after consultation with the Director of the National Science Foundation, shall review applications made for such grants and determine the distribution of such available funds on a competitive basis: *Provided further,* That such grants shall be made available to any awardee only to the extent that said awardee provides matching funds from non-Federal sources to carry out the program for which grants from this Trust Fund are made: *Provided further,* That of the funds made available by this Trust Fund, $250,000 shall be disbursed each calendar quarter for a ten-year period to the Challenger Center for Space Science Education: *Provided further,* That the Administrator of the National Aeronautics and Space Administration shall submit to the Congress an annual report on the grants made pursuant to this paragraph.

Grants.

Reports.

RESEARCH AND PROGRAM MANAGEMENT

For necessary expenses of research in Government laboratories, management of programs and other activities of the National Aeronautics and Space Administration, not otherwise provided for, including uniforms or allowances therefor, as authorized by law (5 U.S.C. 5901-5902); awards; lease, hire, purchase of one aircraft for replacement only (for which partial payment may be made by exchange of at least one existing administrative aircraft and such other existing aircraft as may be considered appropriate), maintenance and operation of administrative aircraft; purchase (not to exceed thirty-three for replacement only) and hire of passenger motor vehicles; and maintenance and repair of real and personal property, and not in excess of $100,000 per project for construction of new facilities and additions to existing facilities, repairs, and rehabilitation and modification of facilities; $1,855,000,000: *Provided,* That contracts may be entered into under this appropriation for maintenance and operation of facilities, and for other services, to be provided during the next fiscal year: *Provided further,* That not to exceed $35,000 of the foregoing amount shall be available for scientific consultations or extraordinary expense, to be expended upon the approval or authority of the Administrator and his determination shall be final and conclusive.

Contracts.

NATIONAL CREDIT UNION ADMINISTRATION

CENTRAL LIQUIDITY FACILITY

During fiscal year 1989, gross obligations of the Central Liquidity Facility for the principal amount of new direct loans to member credit unions as authorized by the National Credit Union Central

TITLE IV

GENERAL PROVISIONS

SECTION 401. Where appropriations in titles I and II of this Act are expendable for travel expenses and no specific limitation has been placed thereon, the expenditures for such travel expenses may not exceed the amounts set forth therefor in the budget estimates submitted for the appropriations: *Provided,* That this section shall not apply to travel performed by uncompensated officials of local boards and appeal boards of the Selective Service System; to travel performed directly in connection with care and treatment of medical beneficiaries of the Veterans Administration; to travel performed in connection with major disasters or emergencies declared or determined by the President under the provisions of the Disaster Relief Act of 1974; to site-related travel performed in connection with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended; to site-related travel under the Solid Waste Disposal Act, as amended; or to payments to interagency motor pools where separately set forth in the budget schedules: *Provided further,* That if appropriations in titles I and II exceed the amounts set forth in budget estimates initially submitted for such appropriations, the expenditures for travel may correspondingly exceed the amounts therefor set forth in the estimates in the same proportion.

SEC. 402. Appropriations and funds available for the administrative expenses of the Department of Housing and Urban Development and the Selective Service System shall be available in the current fiscal year for purchase of uniforms, or allowances therefor, as authorized by law (5 U.S.C. 5901-5902); hire of passenger motor vehicles; and services as authorized by 5 U.S.C. 3109.

SEC. 403. Funds of the Department of Housing and Urban Development subject to the Government Corporation Control Act or section 402 of the Housing Act of 1950 shall be available, without regard to the limitations on administrative expenses, for legal services on a contract or fee basis, and for utilizing and making payment for services and facilities of Federal National Mortgage Association, Government National Mortgage Association, Federal Home Loan Mortgage Corporation, Federal Financing Bank, Federal Reserve banks or any member thereof, Federal home loan banks, and any insured bank within the meaning of the Federal Deposit Insurance Corporation Act, as amended (12 U.S.C. 1811-1831).

SEC. 404. No part of any appropriation contained in this Act shall remain available for obligation beyond the current fiscal year unless expressly so provided herein.

SEC. 405. No funds appropriated by this Act may be expended—

(1) pursuant to a certification of an officer or employee of the United States unless—

(A) such certification is accompanied by, or is part of, a voucher or abstract which describes the payee or payees and the items or services for which such expenditure is being made, or

(B) the expenditure of funds pursuant to such certification, and without such a voucher or abstract, is specifically authorized by law; and

(2) unless such expenditure is subject to audit by the General Accounting Office or is specifically exempt by law from such audit.

SEC. 406. None of the funds provided in this Act to any department or agency may be expended for the transportation of any officer or employee of such department or agency between his domicile and his place of employment, with the exception of the Secretary of the Department of Housing and Urban Development, who, under title 5, United States Code, section 101, is exempted from such limitation.

SEC. 407. None of the funds provided in this Act may be used for payment, through grants or contracts, to recipients that do not share in the cost of conducting research resulting from proposals not specifically solicited by the Government: *Provided,* That the extent of cost sharing by the recipient shall reflect the mutuality of interest of the grantee or contractor and the Government in the research.

SEC. 408. None of the funds provided in this Act may be used, directly or through grants, to pay or to provide reimbursement for payment of the salary of a consultant (whether retained by the Federal Government or a grantee) at more than the daily equivalent of the maximum rate paid for GS-18, unless specifically authorized by law.

SEC. 409. No part of any appropriation contained in this Act for personnel compensation and benefits shall be available for other object classifications set forth in the budget estimates submitted for the appropriations.

SEC. 410. None of the funds in this Act shall be used to pay the expenses of, or otherwise compensate, non-Federal parties intervening in regulatory or adjudicatory proceedings. Nothing herein affects the authority of the Consumer Product Safety Commission pursuant to section 7 of the Consumer Product Safety Act (15 U.S.C. 2056 et seq.).

Contracts. Public information.

SEC. 411. Except as otherwise provided under existing law or under an existing Executive order issued pursuant to an existing law, the obligation or expenditure of any appropriation under this Act for contracts for any consulting service shall be limited to contracts which are (1) a matter of public record and available for public inspection, and (2) thereafter included in a publicly available list of all contracts entered into within twenty-four months prior to the date on which the list is made available to the public and of all contracts on which performance has not been completed by such date. The list required by the preceding sentence shall be updated quarterly and shall include a narrative description of the work to be performed under each such contract.

Contracts. Reports.

SEC. 412. Except as otherwise provided by law, no part of any appropriation contained in this Act shall be obligated or expended by any executive agency, as referred to in the Office of Federal Procurement Policy Act (41 U.S.C. 401 et seq.) for a contract for services unless such executive agency (1) has awarded and entered into such contract in full compliance with such Act and the regulations promulgated thereunder, and (2) requires any report prepared pursuant to such contract, including plans, evaluations, studies, analyses and manuals, and any report prepared by the agency which is substantially derived from or substantially includes any report prepared pursuant to such contract, to contain information concerning (A) the contract pursuant to which the report was prepared, and

(B) the contractor who prepared the report pursuant to such contract.

SEC. 413. Except as otherwise provided in section 406, none of the funds provided in this Act to any department or agency shall be obligated or expended to provide a personal cook, chauffeur, or other personal servants to any officer or employee of such department or agency.

SEC. 414. None of the funds provided in this Act to any department or agency shall be obligated or expended to procure passenger automobiles as defined in 15 U.S.C. 2001 with an EPA estimated miles per gallon average of less than 22 miles per gallon.

SEC. 415. Such sums as may be necessary for fiscal year 1989 pay raises for programs funded by this Act shall be absorbed within the levels appropriated in this Act.

This Act may be cited as the "Department of Housing and Urban Development—Independent Agencies Appropriations Act, 1989".

Approved August 19, 1988.

LEGISLATIVE HISTORY—H.R. 4800:

HOUSE REPORTS: No. 100-701 (Comm. on Appropriations).
SENATE REPORTS: No. 100-401 (Comm. on Appropriations).
CONGRESSIONAL RECORD, Vol. 134 (1988):
June 22, considered and passed House.
July 12, 13, considered and passed Senate, amended.
Aug. 9, House agreed to conference report; receded and concurred in Senate amendment, in others with amendments. Senate agreed to conference report; concurred in House amendments.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 24 (1988):
Aug. 20, Presidential statement.

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