National Aeronautics and Space Administration

Chronological History Fiscal Year 1988 Budget Submission

Prepared by:
Comptroller
Institutional Program Analysis Division
Code BI

KEY TO PAGE NUMBERS UNDER LEGISLATIVE REFERENCE

National Aeronautics and Space Administration

Fiscal Year 1988

Item	Statistics	Authorization Page Numbers: House Auth Comm	Authorization Page Numbers: Senate Auth Comm	Authorization Page Numbers: Auth Conf Comm	Appropriations Page Numbers: House Approp Comm	Appropriations Page Numbers: Senate Approp Comm	Appropriations Page Numbers: Approp Conf Comm
Legislative Reference							
Summary by Appropriation	1,2,3	9, 21	139		202		209,210
Research and Development	1,2,4	9,21	139		202	204	210
253 Space Station	2,4	10,21,22	139,142	193	202	205	210
253 Industrial Space Facility	2,4				203	206	210
253 Space Transportation Capability Developement	2,4	10,21,25	139,144	193	202	206	
254 Physics and Astronomy	2,4	10,21,32	139,147	193	202	206	210
254 Life Sciences	2,5	10,21,39	139,151	193			
254 Planetary Exploration	2,5	10,21,42	139,152	193	202	206	210
254 Space Applications	2,5	10,21,47	140,156	193	202	206	210
254 Technology Utilization	2,5	10,21,60	140	193			
254 Commercial Use of Space	2,5	10,21,62	140,164	193	203	206	210
402 Aeronautical Research and Technology	2,5	10,21,63	140,166	193		207	210
254 Transatmospheric Research and Technology	2,5	10,21,80	140,169	193	203	207	210
254 Space Research and Technology	2,5	10,21,81	140,170	193	203	207	210
254 Safety, Reliability, and Quality Assurance	2,6	10,21,101	140,172	193			
255 Advanced Systems	2,6	10,21,102	140,173	193			
Space Flight, Control and Data Communications	1,2,6	10,103	139-40,174		203	207	210
253 Shuttle Production and Operational Capability	2,6	10,103	140,174	193	203	207	
253 Space Transportation Operations	2,6	10,107	140,177	193	203	208	
255 Space and Ground Network Communications and Data Systems	2,6	10,109	140,179	193	203	208	210
253 Expendable Launch Vehicles	2,6		140,180	193	203	206,208	210

National Aeronautics and Space Administration

Fiscal Year 1988

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
Construction of Facilities	1,3,7	10,118	139-40,181		203	208	211
Space Station Facilities	3,7	7	182		203	208	
Space Flight Facilities	3,7	10,119	181	193			
Goddard Space Flight Center	3,7	10,119	181	193			
Ames Research Center	3,8	10,119	181	193		208	211
Dryden Flight Research Center	3,7	10, 119-20	181	193			
Langley Research Center	3,7	10,119-20	181	193			
Lewis Research Center	3,7	10,119,121	181	193			
Various Locations	3,8	10,119,121	181	193			
Repair	3,8	10,119,122	181	193			
Rehabilitation and Modification	3,8	10,119,122	181	193			
Minor Construction	3,8	10,119,122	181	193			
Facility Planning and Design	3,8	10,119,123	181	193			
Environmental Compliance and Restoration	3,8	119,123	181	193			
General Reduction	3,8	3,8			203		
Research and Program Management	3,8	10,124	139-40,182	193	203	208	211

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Chronological History of the FY1988 Budget Submission
(in thousands of dollars)

Item	Initial Budget Submission to Congress	Budget Ammendment	Revised Budget Submission to Congress	AUTHORIZATION House Comm. H. R. 2782 Rpt. 100-204 7-7-87 Appd. 7-9-87	AUTHORIZATION Senate Comm. S. 1164 Rpt. 100-87 5-14-87 Appd. 7-10-87	AUTHORIZATION Conf. Comm. P. L. 100-147 Appd. 10-30-87	Difference From Revised Budget Submission	APPROPRIATION House Comm. H. R. 2783 Rpt.100-189 6-25-87 Appd. 9-22-87	APPROPRIATION Senate Comm. H. R. 2783 Rpt. 100-192 9-25-87 Appd. 10-15-87	APPROPRIATION Conf Comm. P. L. 100-498 Appd. 12-21-87	Difference From Initial Budget Submission	Difference From Revised Budget Submission
Total Appropriation												
Research and Development	3,623,200	0	3,623,200	3,697,200	3,721,000	3,719,000	95,800	3,661,200	3,378,100	3,374,200*	-249,000	-249,000
Space Flight, Control and Data Communications	4,064,300	28,000	4,092,300	4,034,300	4,081,300	4,045,300	-47,000	4,000,300	3,978,300	3,908,309	-155,991	-183,991
Construction of Facilities	195,500	0	195,500	185,500	210,700	216,500	21,000	169,700	185,700	178,272	-17,228	-17,228
Research and Program Management	1,598,000	0	1,598,000	1,605,000	1,608,000	1,593,000	-5,000	1,558,000	1,558,000	1,495,680	-102,320	-102,320
Total NASA	9,481,000	28,000	9,509,000	9,522,000	9,621,000	9,573,800	64,800	9,389,200	9,100,100	8,956,461	-524,539	-552,539
R & D Appropriation :												
OSS	767,000	0	767,000	767,000	767,000	767,000	0	767,000	458,700	450,000	-317,000	-317,000
OSF	568,600	0	568,600	538,600	592,600	553,600	-15,000	549,600	549,600	549,600	-19,000	-19,000
OSSA	1,508,300	0	1,508,300	1,598,300	1,625,100	1,628,100	119,800	1,598,300	1,630,700	1,625,300	117,000	117,000
OCP	54,000	0	54,000	49,000	49,000	49,000	-5,000	46,000	50,000	50,000	-4,000	-4,000
OAST	691,000	0	691,000	715,000	653,000	687,000	-4,000	666,000	654,800	665,000	-26,000	-26,000
OSRMQA	16,200	0	16,200	16,200	16,200	16,200	0	16,200	16,200	16,200	0	0
OSTDS	18,100	0	18,100	13,100	18,100	18,100	0	18,100	18,100	18,100	0	0
Total Research and Development	3,623,200	0	3,623,200	3,697,200	3,721,000	3,719,000	95,800	3,661,200	3,378,100	3,374,200	-249,000	-249,000
SFC&DC Appropriation :												
OSF	3,115,400	28,000	3,143,400	3,120,400	3,136,400	3,120,400	-23,000	3,106,400	3,064,400	3,014,409	-100,991	-128,991
OSTDS	948,900	0	948,900	913,900	944,900	924,900	-24,000	893,900	913,900	893,900	-55,000	-55,000
Total SFC&DC	4,064,300	28,000	4,092,300	4,034,300	4,081,300	4,045,300	-47,000	4,000,300	3,978,300	3,908,309	-155,991	-183,991
C of F Appropriation :												
OSS	25,800	0	25,800	0	0	0	-25,800	0	0	25,800	0	0
OSF	17,000	0	17,000	22,800	17,000	22,800	5,800	17,000	17,000	17,000	0	0
OSSA	11,500	0	11,500	11,500	11,500	11,500	0	11,500	11,500	11,500	0	0
OAST	29,900	0	29,900	39,900	70,900	70,900	41,000	29,900	45,900	45,900	16,000	16,000
OSTDS	6,400	0	6,400	6,400	6,400	6,400	0	6,400	6,400	6,400	0	0
other	104,900	0	104,900	104,900	104,900	104,900	0	104,900	104,900	104,900	0	0
general reduction	---	0	0	0	0	0	0	0	0	-33,228	-33,228	-33,228
Total C of F	195,500	0	195,500	185,500	210,700	216,500	21,000	169,700	185,700	178,272	-17,228	-17,228
R & PM Appropriation :	1,598,000	0	1,598,000	1,605,000	1,608,000	1,593,000	-5,000	1,558,000	1,558,000	1,495,680	-102,320	-102,320
Total NASA	9,481,000	28,000	9,509,000	9,522,000	9,621,000	9,573,800	64,800	9,389,200	9,100,100	8,956,461	-524,539	-552,539

* Reflects transfer to FY 1988 for Space Station from FY 1987

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Chronological History of the FY1988 Budget Submission (in thousands of dollars)

Item	Initial Budget Submission to Congress	Budget Ammendment	Revised Budget Submission to Congress	AUTHORIZATION: House Comm. H. R. 2782 Rpt. 100-204 7-7-87 Appd. 7-9-87	AUTHORIZATION: Senate Comm. S. 1164 Rpt. 100-87 5-14-87 Appd. 7-10-87	AUTHORIZATION: Conf. Comm. P. L. 100-147 Appd. 10-30-87	AUTHORIZATION: Difference From Revised Budget Submission	APPROPRIATION: House Comm. H. R. 2783 Rpt. 100-189 6-25-87 Appd. 9-22-87	APPROPRIATION: Senate Comm. H. R. 2783 Rpt. 100-192 9-25-87 Appd. 10-15-87	APPROPRIATION: Conf. Comm P. L. 100-498 Appd. 12-21-87	APPROPRIATION: Difference From Initial Budget Submission	APPROPRIATION: Difference From Revised Budget Submission
Research and Development	3,623,200	0	3,623,200	3,697,200	3,721,000	3,719,000	95,800	3,661,200	3,378,100	3,374,200	-249,000	-249,000
253 Space Station	767,000	0	767,000	767,000	767,000	767,000	0	767,000	458,700	425,000 *	-342,000	-342,000
253 Industrial Space Facility	0	0	0	0	0	0	0	0	0	25,000	25,000	25,000
253 Space Transportation Capability Developement	568,600	0	568,600	538,600	592,600	553,600	-15,000	549,600	549,600	549,600	-19,000	-19,000
254 Physics and Astronomy	567,100	0	567,100	577,100	591,800	581,800	14,700	567,100	577,100	577,100	10,000	10,000
254 Life Sciences	74,600	0	74,600	74,600	74,600	74,600	0	74,600	74,600	74,600	0	0
254 Planetary Exploration	307,300	0	307,300	342,300	307,300	320,300	13,000	322,300	350,700	332,300	25,000	25,000
254 Space Applications	559,300	0	559,300	604,300	651,400	651,400	92,100	634,300	628,300	641,300	82,000	82,000
254 Technology Utilization	18,300	0	18,300	18,300	18,300	18,300	0	18,300	18,300	18,300	0	0
254 Commercial Use of Space	35,700	0	35,700	30,700	30,700	30,700	-5,000	27,700	31,700	31,700	-4,000	-4,000
402 Aeronautical Research and Technology	375,000	0	375,000	399,000	375,000	387,000	12,000	375,000	377,000	377,000	2,000	2,000
254 Transatmospheric Research and Technology	66,000	0	66,000	66,000	66,000	66,000	0	56,000	45,000	53,000	-13,000	-13,000
254 Space Research and Techoology	250,000	0	250,000	250,000	212,000	234,000	-16,000	235,000	232,800	235,000	-15,000	-15,000
254 Safety, Reliability and Quality Assurance Program	16,200	0	16,200	16,200	16,200	16,200	0	16,200	16,200	16,200	0	0
255 Advanced Systems	18,100	0	18,100	13,100	18,100	18,100	0	18,100	18,100	18,100	0	0
Space Flight, Control and Data Communications	4,064,300	28,000	4,092,300	4,034,300	4,081,300	4,045,300	-47,000	4,000,300	3,978,300	3,908,309	-155,991	-183,991
253 Shuttle Production and Operational Capability	1,229,600	0	1,229,600	1,174,600	1,150,600	1,174,600	-55,000	1,190,600	1,150,600	1,100,609	-128,991	-128,991
253 Space Transportation Operations	1,885,800	0	1,885,800	1,945,800	1,985,800	1,885,800	0	1,885,800	1,885,800	1,885,800	0	0
253 Expendable Launch Vehicles	0	28,000	28,000	0	0	60,000	32,000	30,000	28,000	28,000	28,000	0
255 Space and Ground Network Communications and Data Systems	948,900	0	948,900	913,900	944,900	924,900	-24,000	893,900	913,900	893,900	-55,000	-55,000

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Construction of Facilities	195,500	0	195,500	185,500	210,700	216,500	21,000	169,700	185,700	178,272	-17,228	-17,228
253 Johnson Space Center	19,200	0	19,200	0	0	0	-19,200	0	0	0	-19,200	-19,200
253 Kennedy Space Center	20,600	0	20,600	22,800	17,000	22,800	2,200	17,000	17,000	17,000	-3,600	-3,600
253 Marshall Space Flight Center	3,000	0	3,000	0	0	0	-3,000	0	0	0	-3,000	-3,000
254 Goddard Space Flight Center	11,500	0	11,500	11,500	11,500	11,500	0	11,500	11,500	11,500	0	0
402 Langley Research Center	3,100	0	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0	0
402 Dryden Flight Research Center	10,500	0	10,500	10,500	10,500	10,500	0	10,500	10,500	10,500	0	0
402 Lewis Research Center	16,300	0	16,300	16,300	16,300	16,300	0	16,300	16,300	16,300	0	0
402 Ames Research Center	0	0	0	10,000	41,000	41,000	41,000	0	16,000	16,000	16,000	16,000
255 Various Locations	6,400	0	6,400	6,400	6,400	6,400	0	6,400	6,400	6,400	0	0
255 N-Repair of Facilities	25,000	0	25,000	25,000	25,000	25,000	0	25,000	25,000	25,000	0	0
255 N-Rehabilitation and Modification of Facilities	32,000	0	32,000	32,000	32,000	32,000	0	32,000	32,000	32,000	0	0
255 N-Minor Construction and Additions to Facilities	8,000	0	8,000	8,000	8,000	8,000	0	8,000	8,000	8,000	0	0
255 N-Facility Planning and Design	16,000	0	16,000	16,000	16,000	16,000	0	16,000	16,000	16,000	0	0
255 Environmental Compliance and Restoration Program	23,900	0	23,900	23,900	23,900	23,900	0	23,900	23,900	23,900	0	0
General Reduction	0	0	0	0	0	0	0	0	0	-7,428	-7,428	-7,428
Research and Program Management	1,598,000	0	1,598,000	1,605,000	1,608,000	1,593,000	-5,000	1,558,000	1,558,000	1,495,680	-102,320	-102,320
total	9,481,000	28,000	9,509,000	9,522,000	9,621,000	9,573,800	64,800	9,389,200	9,100,100	8,956,461	-524,539	-552,539

* Reflects transfer of $100M to FY 1988 for Space Station from FY 1987

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Chronological History of the FY1988 Budget Submission
(in thousands of dollars)

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	Research and Development	3,623,200	0	3,623,200	3,697,200	3,721,000	3,719,000	95,800	3,661,200	3,378,100	3,374,200	-249,000	-249,000
	Office of Space Station	767,000	0	767,000	767,000	767,000	767,000	0	767,000	458,700	425,000*	-342,000	-342,000
253	Space Station	767,000	0	767,000	767,000	767,000	767,000	0	767,000	458,700	425,000*	-342,000	-342,000
	Development	733,000	0	733,000	733,000	733,000	733,000	0	733,000	733,000	733,000	0	0
	Pressurized Modules	196,500	0	196,500	196,500	196,500	196,500	0	196,500	196,500	196,500	0	0
	Assembly Hardware/Subsystems	204,000	0	204,000	204,000	204,000	204,000	0	204,000	204,000	204,000	0	0
	Platforms and Servicing	59,000	0	59,000	59,000	59,000	59,000	0	59,000	59,000	59,000	0	0
	Power System	88,000	0	68,000	88,000	68,000	88,000	0	88,000	88,000	88,000	0	0
	Operations Capability/Utilization	52,000	0	52,000	52,000	52,000	52,000	0	52,000	52,000	52,000	0	0
	Management and Integration	133,500	0	133,500	133,500	133,500	133,500	0	133,500	133,500	133,500	0	0
	Flight Telerobotic System	22,000	0	22,000	22,000	22,000	22,000	0	22,000	22,000	22,000	0	0
	Operations	7,000	0	7,000	7,000	7,000	7,000	0	7,000	7,000	7,000	0	0
	Transition Definition	5,000	0	5,000	5,000	5,000	5,000		5,000	5,000	5,000	0	0
	Congressional Action							0		-308,300	-342,000	-342,000	-342,000
253	Industrial Space Facility	0	0	0	0	0	0	0	0	0	25,000	25,000	25,000
	Office of Space Flight	568,600	0	568,600	538,600	592,600	553,600	-15,000	549,600	549,600	549,600	-19,000	-19,000
2	Space Transportation												
	Capability Developement	568,600	0	568,600	538,600	592,600	553,600	-15,000	549,600	549,600	549,600	-19,000	-19,000
	Spacelab	73,500	0	73,500	73,500	73,500	73,500	0	73,500	73,500	73,500	0	0
	Upper Stages	159,700	0	159,700	159,700	181,700	159,700	0	159,700	159,700	159,700	0	0
	Engineering and Technical Base ...	139,800	0	139,800	139,800	139,800	139,800	0	139,800	139,800	139,800	0	0
	Payload Operations and							0					
	Support Equipment	83,400	0	83,400	73,400	85,400	73,400	-10,000	83,400	83,400	83,400	0	0
	Advanced Programs	24,900	0	24,900	24,900	24,900	24,900	0	30,900	30,900	30,900	6,000	6,000
	Tethered Satellite System	7,300	0	7,300	7,300	7,300	7,300	0	7,300	7,300	7,300	0	0
	Orbital Maneuvering Vehicle	80,000	0	80,000	60,000	80,000	75,000	-5,000	55,000	55,000	55,000	-25,000	-25,000
	Office of Space Science												
	and Applications	1,508,300	0	1,508,300	1,598,300	1,625,100	1,628,100	119,800	1,598,300	1,630,700	1,625,300	117,000	117,000
	General Reduction												
254	Physics and Astronomy	567,100	0	567,100	577,100	591,800	581,800	14,700	567,100	577,100	577,100	10,000	10,000
	Hubble Space Telescope												
	Development	98,400	0	98,400	98,400	98,400	98,400	0	93,400	93,400	93,400	-5,000	-5,000
	Gamma Ray Observatory												
	Development	49,100	0	49,100	49,100	49,100	49,100	0	49,100	49,100	49,100	0	0
	Spacelab/Space Station Payload							0					
	Developement and Mission							0					
	Management	95,400	-20,000	75,400	95,400	95,400	75,400	0	80,400	80,400	80,400	-15,000	5,000
	Explorer Development	60,300	0	60,300	70,300	80,300	70,300	10,000	60,300	70,300	70,300	10,000	10,000
	Mission Operations and Data							0					
	Analysis	128,100	0	128,100	128,100	128,100	128,100	0	128,100	128,100	128,100	0	0
	Research and Analysis	60,100	0	60,100	60,100	60,100	60,100	0	60,100	60,100	60,100	0	0
	Suborbital Program	75,700	0	75,700	75,700	80,400	80,400	4,700	75,700	75,700	75,700	0	0
	Space Station Planning	0	20,000	20,000	0	0	20,000	0	20,000	20,000	20,000	20,000	0

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254 Life Sciences	74,600	0	74,600	74,600	74,600	74,600	0	74,600	74,600	74,600	0	0
Life Sciences Flight Experiments	32,900	0	32,900	32,900	32,900	32,900	0	32,900	32,900	32,900	0	0
Research and Analysis	41,700	0	41,700	41,700	41,700	41,700	0	41,700	41,700	41,700	0	0
Congressional Action							0					0
254 Planetary Exploration	307,300	0	307,300	342,300	307,300	320,300	13,000	322,300	350,700	332,300	25,000	25,000
Galileo Developement	55,300	0	55,300	55,300	55,300	55,300	0	55,300	55,300	55,300	0	0
Magellan	59,600	0	59,600	59,600	59,600	59,600	0	59,600	78,000	59,600	0	0
Ulysses	10,800	0	10,800	10,800	10,800	10,800	0	10,800	10,800	10,800	0	0
Mars Observer (MGCO)	29,300	0	29,300	64,300	29,300	42,300	13,000	44,300	54,300	54,300	25,000	25,000
Mission Operations and							0					
Data Analysis	77,000	0	77,000	77,000	77,000	77,000	0	77,000	77,000	77,000	0	0
Research and Analysis	75,300	0	75,300	75,300	75,300	75,300	0	75,300	75,300	75,300	0	0
254 Space Applications	559,300	0	559,300	604,300	651,400	651,400	92,100	634,300	628,300	641,300	82,000	82,000
Solid Earth Observations	76,800	0	76,800	76,800	80,800	80,800	4,000	76,800	76,800	76,800	0	0
Environmental Observations	393,800	0	393,800	393,800	393,800	393,800	0	378,800	378,800	378,800	-15,000	-15,000
Materials Processing in Space	45,900	0	45,900	45,900	50,000	50,000	4,100	65,900	45,900	65,900	20,000	20,000
Communications	20,500	0	20,500	65,500	104,500	104,500	84,000	90,500	104,500	97,500	77,000	77,000
Information Systems	22,300	0	22,300	22,300	22,300	22,300	0	22,300	22,300	22,300	0	0
Office of Commercial Programs	54,000	0	54,000	49,000	49,000	49,000	-5,000	46,000	50,000	50,000	-4,000	-4,000
254 Technology Utilization	18,300	0	18,300	18,300	18,300	18,300	0	18,300	18,300	18,300	0	0
Product Development	1,920	0	1,920	1,920	1,920	1,920	0	1,920	1,920	1,920	0	0
Acquisition, Dissemination and							0					
Network Operations	4,730	0	4,730	4,730	4,730	4,730	0	4,730	4,730	4,730	0	0
Program Development, Evaluation							0					
and Coordination	2,380	0	2,380	2,380	2,380	2,380	0	2,380	2,380	2,380	0	0
Technology Applications	6,620	0	6,620	6,620	6,620	6,620	0	6,620	6,620	6,620	0	0
Industrial Outreach	2,650	0	2,650	2,650	2,650	2,650	0	2,650	2,650	2,650	0	0
254 Commercial Use of Space	35,700	0	35,700	30,700	30,700	30,700	-5,000	27,700	31,700	31,700	-4,000	-4,000
Commercial Applications R&D	31,000	0	31,000	26,000	26,000	26,000	-5,000	31,000	27,000	31,000	0	0
Commercial Development Support	4,700	0	4,700	4,700	4,700	4,700	0	4,700	4,700	4,700	0	0
Congressional Action							0	-8,000				
General Reduction										-4,000	-4,000	-4,000
Office of Aeronautics and Space Technology	691,000	0	691,000	715,000	653,000	687,000	-4,000	666,000	654,800	665,000	-26,000	-26,000
402 Aeronautical Research and Technology	375,000	0	375,000	399,000	375,000	387,000	12,000	375,000	377,000	377,000	2,000	2,000
Research and Technology Base	285,200	0	285,200	305,200	285,200	297,200	12,000	285,200	287,200	287,200	2,000	2,000
Systems Technology Programs	89,800	0	89,800	93,800	89,800	89,800	0	89,800	89,800	89,800	0	0
Congressional Action												
254 Transatmospheric Research and Technology	66,000	0	66,000	66,000	66,000	66,000	0	56,000	45,000	53,000	-13,000	-13,000
Research and Technology Base	66,000	0	66,000	66,000	66,000	66,000	0	56,000	45,000	66,000	0	0
General Reduction										-13,000	-13,000	-13,000
254 Space Research and Technology	250,000	0	250,000	250,000	212,000	234,000	-16,000	235,000	232,800	235,000	-15,000	-15,000
Research and Technology Base	115,900	0	115,900	115,900	115,900	115,900	0	115,900	115,900	115,900	0	0
Systems Technology Programs	0	0	0	0	0	0	0	0	0	0	0	0
Civil Space Technology												
Initiative (CSTI) program	134,100	0	134,100	134,100	96,100	118,100	-16,000	119,100	116,900	119,100	-15,000	-15,000
Congressional Action											0	0

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Office of Safety, Reliability, Maintainibility and Quality Assurance	16,200	0	16,200	16,200	16,200	16,200	0	16,200	16,200	16,200	0	0
254 Safety, Reliability and Quality Assurance Program	16,200	0	16,200	16,200	16,200	16,200	0	16,200	16,200	16,200	0	0
Office of Space Tracking and Data Systems	18,100	0	18,100	13,100	18,100	18,100	0	18,100	18,100	18,100	0	0
255 Advanced Systems	18,100	0	18,100	13,100	18,100	18,100	0	18,100	18,100	18,100	0	0
Space Flight, Control and Data Communications	4,064,300	28,000	4,092,300	4,034,300	4,081,300	4,045,300	-47,000	4,000,300	3,978,300	3,908,309	-155,991	-183,991
Office of Space Flight	3,115,400	28,000	3,143,400	3,120,400	3,136,400	3,120,400	-23,000	3,106,400	3,084,400	3,014,409	-100,991	-128,991
253 Shuttle Production and Operational Capability	1,229,600	0	1,229,600	1,174,600	1,150,600	1,174,600	-55,000	1,190,600	1,150,600	1,100,609	-128,991	-128,991
Orbiter Operational Capability	403,200	0	403,200	348,200	324,200	348,200	-55,000	384,200	324,200	403,200	0	0
Launch and Mission Support	249,300	0	249,300	249,300	249,300	249,300	0	249,300	552,100	552,100	302,800	302,800
Propulsion Systems	552,100	0	552,100	552,100	552,100	552,100	0	552,100	249,300	249,300	-302,800	-302,800
Changes and System Upgrading	25,000	0	25,000	25,000	25,000	25,000	0	25,000	25,000	25,000	0	0
General Reduction			0	0	0	0	0	0	0	-128,991	-128,991	-128,991
253 Space Transportation Operations	1,885,800	0	1,885,800	1,945,800	1,985,800	1,885,800	0	1,885,800	1,885,800	1,885,800	0	0
Flight Operations	561,100	0	561,100	561,100	561,100	561,100	0	561,100	561,100	561,100	0	0
Flight Hardware	923,100	0	923,100	923,100	923,100	923,100	0	923,100	923,100	923,100	0	0
Launch and Landing Operations	401,600	0	401,600	401,600	401,600	401,600	0	401,600	401,600	401,600	0	0
Expendable Launch Vehicle Ops	0	0	0	60,000	100,000	0	0	0	0	0	0	0
253 Expendable Launch Vehicles	0	28,000	28,000			60,000	32,000	30,000	28,000	28,000	28,000	0
Office of Space Tracking and Data Systems	948,900	0	948,900	913,900	944,900	924,900	-24,000	893,900	913,900	893,900	-55,000	-55,000
255 Space and Ground Network Communications and Data Systems	948,900	0	948,900	913,900	944,900	924,900	-24,000	893,900	913,900	893,900	-55,000	-55,000
Space Network	481,500	0	481,500	446,500	481,500	457,500	-24,000	426,500	446,500	426,500	-55,000	-55,000
Ground Network	257,100	0	257,100	257,100	257,100	257,100	0	257,100	257,100	257,100	0	0
Communications and Data Systems	210,300	0	210,300	210,300	210,300	210,300	0	210,300	210,300	210,300	0	0
Congressional Action					-4,000	0	0	0	0	0	0	0

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Construction of Facilities	195,500	0	195,500	185,500	210,700	216,500	21,000	169,700	185,700	178,272	-17,228	-17,228
Space Station Facilities at Various Locations	25,800	0	25,800	0	0	0	-25,800	0	0	25,800	0	0
253 Johnson Space Center	15,800	0	15,800	0	0	0	-15,800	0	0	15,800	0	0
SS - Construction of Addition to the Mission Control Center	15,800	0	15,800	0	0	0	-15,800	0	0	15,800	0	0
253 Johnson Space Center	3,400	0	3,400	0	0	0	-3,400	0	0	3,400	0	0
SS - Construction of Addition to the Simulator/Training Facility	3,400	0	3,400	0	0	0	-3,400	0	0	3,400	0	0
253 Kennedy Space Center	3,600	0	3,600	0	0	0	-3,600	0	0	3,600	0	0
SS - Construction of Space Station Processing Facility	3,600	0	3,600	0	0	0	-3,600	0	0	3,600	0	0
253 Marshall Space Flight Center	3,000	0	3,000	0	0	0	-3,000	0	0	3,000	0	0
SS - Modifications of Process Technology Facility	3,000	0	3,000	0	0	0	-3,000	0	0	3,000	0	0
Space Flight Facilities at Various Locations	17,000	0	17,000	22,800	17,000	22,800	5,800	17,000	17,000	17,000	0	0
253 Kennedy Space Center	17,000	0	17,000	22,800	17,000	22,800	5,800	17,000	17,000	17,000	0	0
SF - Construction of LC 39 Operations Support Building	17,000	0	17,000	22,800	17,000	22,800	5,800	17,000	17,000	17,000	0	0
254 Goddard Space Flight Center	11,500	0	11,500	11,500	11,500	11,500	0	11,500	11,500	11,500	0	0
E - Construction of Spacecraft Systems Development and Integration Facility	8,600	0	8,600	8,600	8,600	8,600	0	8,600	8,600	8,600	0	0
E - Modifications for Utility Reliability	2,900	0	2,900	2,900	2,900	2,900	0	2,900	2,900	2,900	0	0
402 Langley Research Center	3,100	0	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0	0
R - Modifications to Hypersonic Propulsion Facility	3,100	0	3,100	3,100	3,100	3,100	0	3,100	3,100	3,100	0	0
402 Dryden Flight Research Center	10,500	0	10,500	10,500	10,500	10,500	0	10,500	10,500	10,500	0	0
R - Construction of Integrated Test Facility	10,500	0	10,500	10,500	10,500	10,500	0	10,500	10,500	10,500	0	0
402 Lewis Research Center	16,300	0	16,300	16,300	16,300	16,300	0	16,300	16,300	16,300	0	0
R.- Construction of Addition to the Research Analysis Center ...	9,800	0	9,800	9,800	9,800	9,800	0	9,800	9,800	9,800	0	0
R - Modifications for Fan/Compressor Research, Engine Research Building	6,500	0	6,500	6,500	6,500	6,500	0	6,500	6,500	6,500	0	0
402 Aeronautics Centers	0	0	0	10,000	0	0	0	0	0	0	0	0
R - Rehabilitation of Aeronautical Test Facilities	0	0	0	10,000	0	0	0	0	0	0	0	0

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402 Ames Research Center	0	0	0	0	41,000	41,000	41,000	0	16,000	16,000	16,000	16,000
R - Repair and Modernization of the 12 ft. pressure wind tunnel ...	0	0	0	0	41,000	41,000	41,000	0	16,000	16,000	16,000	16,000
255 Various Locations	6,400	0	6,400	6,400	6,400	6,400	0	6,400	6,400	6,400	0	0
T- Construction of Communications Development Antenna, Goldstone, Ca.	6,400	0	6,400	6,400	6,400	6,400	0	6,400	6,400	6,400	0	0
255 N-Repair of Facilities	25,000	0	25,000	25,000	25,000	25,000	0	25,000	25,000	25,000	0	0
255 N-Rehabilitation and Modification of Facilities	32,000	0	32,000	32,000	32,000	32,000	0	32,000	32,000	32,000	0	0
255 N-Minor Construction and Additions to Facilities	8,000	0	8,000	8,000	8,000	8,000	0	8,000	8,000	8,000	0	0
255 N-Facility Planning and Design	16,000	0	16,000	16,000	16,000	16,000	0	16,000	16,000	16,000	0	0
255 Environmental Compliance and Restoration Program	23,900	0	23,900	23,900	23,900	23,900	0	23,900	23,900	23,900	0	0
General Reduction										-33,228	-33,228	-33,228
Research and Program Management	1,598,000	0	1,598,000	1,605,000	1,608,000	1,593,000	-5,000	1,558,000	1,558,000	1,495,680	-102,320	-102,320
By Installation :												
Johnson Space Center	249,046	0	249,046	249,046	249,046	249,046	0	249,046	249,046	249,046	0	0
Kennedy Space Center	220,643	0	220,643	220,643	220,643	220,643	0	220,643	220,643	220,643	0	0
Marshall Space Flight Center	232,512	0	232,512	232,512	232,512	232,512	0	232,512	232,512	232,512	0	0
National Space Technology							0					
Laboratories	13,916	0	13,916	13,916	13,916	13,916	0	13,916	13,916	13,916	0	0
Goddard Space Flight Center	231,025	0	231,025	231,025	231,025	231,025	0	231,025	231,025	231,025	0	0
Ames Research Center	145,247	0	145,247	145,247	145,247	145,247	0	145,247	145,247	145,247	0	0
Langley Research Center	168,208	0	168,208	168,208	168,208	168,208	0	168,208	168,208	168,208	0	0
Lewis Research Center	169,995	0	169,995	169,995	169,995	169,995	0	169,995	169,995	169,995	0	0
Headquarters	158,866	0	158,866	158,866	158,866	158,866	0	158,866	158,866	158,866	0	0
Inspector General	8,542	0	8,542	8,542	8,542	8,542	0	8,542	8,542	8,542	0	0
Aeronautical Increase	0	0	0	7,000	0	0	0	0	0	0	0	0
Space Grant College/Fellowship	0	0	0	0	10,000	10,000	10,000	0	0	0	0	0
General Reduction			0			-15,000	-15,000	-40,000	-40,000	-102,320	-102,320	-102,320
By Function :												
Personnel and Related Costs	1,111,631	0	1,111,631	1,111,631	1,111,631	1,096,631	-15,000	1,111,631	1,111,631	1,111,631	0	0
Travel	43,312	0	43,312	43,312	43,312	43,312	0	43,312	43,312	43,312	0	0
Facilities Services	232,548	0	232,548	232,548	232,548	232,548	0	232,548	232,548	232,548	0	0
Technical Services	89,980	0	89,980	89,980	89,980	89,980	0	89,980	89,980	89,980	0	0
Management and Operations							0					
Support	120,529	0	120,529	120,529	120,529	120,529	0	120,529	120,529	120,529	0	0
Aeronautical Increase			0	7,000	7,000	0	0					
Space Grant College/Fellowship			0	0	10,000	10,000	10,000				0	0
General Reduction								-40,000	-40,000	-102,320	-102,320	-102,320
NASA TOTAL	9,481,000	28,000	9,509,000	9,522,000	9,621,000	9,573,800	64,800	9,389,200	9,100,100	8,956,461	-524,539	-552,539

* Reflects transfer of $100M to FY 1988 for Space Station from 1987

100TH CONGRESS | HOUSE OF REPRESENTATIVES | REPORT
1st Session | | 100–204

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, FISCAL YEAR 1988

JULY 7, 1987.—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, MINORITY AND ADDITIONAL VIEWS

[To accompany H.R. 2782]

[Including cost estimate of the Congressional Budget Office]

The Committee on Science, Space, and Technology, to whom was referred the bill (H.R. 2782) 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, report favorably thereon with an amendment and recommend that the bill as amended do pass.

The amendment (stated in terms of the page and line numbers of the introduced bill) is as follows:

Page 17, line 23, strike "or" where it first appears and insert "if".

PURPOSE OF THE BILL

TITLE I

The purpose of title I is to authorize appropriations to the National Aeronautics and Space Administration for fiscal year 1988 as follows:

Programs	Estimated [1] fiscal year 1987	Authorization fiscal year 1988	Page No.
Research and development	$3,127,700,000	$3,697,200,000	30
Space flight, control and data communications	5,815,000,000	4,034,300,000	193
Construction of facilities	166,300,000	185,500,000	224
Research and program management	1,425,000,000	1,605,000,000	236
Total	10,534,000,000	9,522,000,000	

[1] The estimated fiscal year 1987 data used in this table and throughout this report are given for comparison purposes. Actual fiscal year 1987 spending will differ slightly from these data.

TITLE II

The purpose of Title II is to authorize the development, construction, operation, and use of a permanently manned Space Station. It authorizes the construction of the Space Station, prioritizes its major uses, requires its development and operation to support and not infringe on other science and space activity, requires the development of advanced technologies to enhance its operations, requires appropriate use and support by the private sector, and requires the promotion of international cooperation in the development, construction and operations of the Space Station.

Title II also authorizes a Space Station capital development for the fiscal year 1988 through 1995 and requires that the amount requested by the President for Space Station development shall not exceed 25 percent of the total NASA budget for any year. It also requires the Administrator to provide yearly reports to Congress certifying compliance with provisions of this section.

Section 203 limits the funding authorized for operation and enhancement of the Space Station after it is developed to no more than 10 percent of the NASA budget for any year. It authorizes the Administrator to separately request additional funds necessary for utilization of the Space Station pursuant to policies set forth in section 201.

Section 204 requires the launching and servicing of the Space Station to be carried out by the most cost-effective use of both the Space Shuttle and expendable launch vehicles and requires the Administrator to submit a report on the cost-effective use of space transportation systems by January 15, 1988.

Sections 205 and 206 require the assessment of and collection of certain capacity charges and fees for non-NASA users of the Space Station. Section 207 requires the Administrator to submit to the President and the Congress by January 15, 1988, a detailed plan for the development, operations, and utilization of the Space Station pursuant to the provisions of this Act.

Section 208 requires that no agreement between the United States and any foreign entities involving the detailed design, development, construction, operation or use of the Space Station may be effected until a period of 30 days during which the House or Senate is in session has passed after the proposed agreement has been submitted to the Congress.

AMENDMENT

SECTION 201 (b)

H.R. 2782, as introduced, prohibited the use of the Space Station by or on behalf of any department or agency for the conduct on the Space Station of the operational testing or deployment of any offensive or defensive weapon or weapons system or in contravention of United States laws or treaty obligations. The Committee recommends an amendment to this language which changes the world "or" before the last clause of "if". This change limits the prohibi-

EXPLANATION OF THE BILL

TITLE I—NASA AUTHORIZATION

Title I provides authorization of appropriations for the National Aeronautics and Space Administration for fiscal year 1988 (explained in the chart below) and related provisions.

Sections 101 (a), (b), (c), and (d) contain authorization levels for NASA programs for fiscal year 1988, which are reflected in the chart below.

FISCAL YEAR 1988 NASA AUTHORIZATION

SUMMARY

	Authorization fiscal year 1988
Research and development:	
Permanently Manned Space Station	$767,000,000
Space transportation capability development	538,600,000
Physics and astronomy	577,100,000
Life sciences	74,600,000
Planetary exploration	342,300,000
Space applications	604,300,000
Technology utilization	18,300,000
Commercial use of space	30,700,000
Aeronautical research and technology	399,000,000
Transatmospheric research and technology	66,000,000
Space research and technology	250,000,000
Safety, reliability and quality assurance	16,200,000
Tracking and data advanced systems	13,100,000
Subtotal, Research & Development	3,697,200,000
Space flight, control and data communications:	
Space Shuttle production and operational capability	1,174,600,000
Space Shuttle operations	1,885,800,000
Expendable launch vehicle operations	60,000,000
Space and ground network, communications, and data systems	913,900,000
Subtotal Space Flight, Control and Data Communications	4,034,300,000
Construction of facilities:	
Construction of LC 39 Operations Support Building, Kennedy Space Center	22,800,000
Construction of Spacecraft Systems Development and Integration Facility, Goddard Space Flight Center	8,600,000
Modifications for utility reliability, Goddard Space Flight Center	2,900,000
Construction of Integrated Test Facility, Dryden Flight Research Center	10,500,000
Modifications to Hypersonic Propulsion Facility for Vacuum Systems, Langley Research Center	3,100,000
Construction of addition to the Research Analysis Center, Lewis Research Center	9,800,000
Modifications for Fan/Compressor Research, Engine Research Building, Lewis Research Center	6,500,000
Construction of Communications Development Antenna, Goldstone, California, Jet Propulsion Laboratories	6,400,000
Repair of facilities at various locations, not in excess of $750,000 per project (or not in excess of such higher amount up to $2,000,000, in the case of any particular project, as the Administrator may find to be required by special circumstances)	25,000,000

ations require otherwise, a contract concerns a product that will be completely assembled in the United States; when completely assembled, not less than 50 percent of the final product will be domestically produced; and the difference between foreign and domestic bids is not more than 5 percent. The Administrator shall report to Congress on contracts entered into with foreign entities during the years 1982–1987 by January 15, 1988.

Section 107 states the sense of the Congress that the Space Shuttle is a critical national resource that should be preserved and used primarily for missions requiring manned presence. To complement the Space Shuttle, a diversified family of expendable launch vehicles should be incorporated by use into the Nation's civilian space flight program. The bill directs the Administrator to establish a program for launching payloads by means of expendable launch vehicles, and, if available, by commercial launch services. The Administrator is directed to take the steps necessary to ensure that certain payloads are launched according to scheduled launch dates, including the Mars Observer, in 1992; Roentgen Satellite (ROSAT), in 1990; Tracking and Data Relay Satellite (TDRS)-F, or a planetary mission, in 1991; and Extreme Ultraviolet Explorer (EUVE), in 1991. Expendable launch vehicles will carry the aforementioned payloads, and the Administrator is directed to obtain the vehicles, or commercial launch services, in order to meet the launch schedules identified herein. A report on the actions taken to carry out this section shall be submitted to Congress by October 1, 1987. A minimum of $60,000,000 is authorized in section 101(b) to carry out this section.

Section 108 recognizes and protects the national capital investment in space satellites and vehicles through the establishment of a system of servicing, rehabilitation and repair capabilities in orbit.

The Committee's view toward satellite servicing is as a cost-effective and economic approach to extending our operations in space. Thus the merits of satellite servicing would be judged according to the comparable cost of the servicing operations versus the cost of building and launching expendable satellites. The Committee envisions that this servicing concept may become most cost effective when permanent presence and hardware basing in space is achieved.

The Administrator is required to conduct a study on satellite servicing capability and present the report to Congress by January 15, 1988

Section 109 directs the Administrator to review the findings and recommendations of the National Commission on Space and to recommend, within 60 days after enactment, a long range implementation plan.

Section 110 directs the Administrator to institute competition in the Solid Rocket Motor project by undertaking the competitive design and development of an Advanced Solid Rocket Motor (SRM). In the event NASA does not proceed with an Advanced SRM, the Administrator is directed either to conduct a competition to select a qualified second source of supply for flight sets of the redesigned SRM currently under development, or to recompete the current source of supply for flight sets of the redesigned SRM. The Administrator is directed to consult with the Comptroller General concerning the competition. The Committee intends that NASA carry out this section in accordance with general procurement law.

Section 111 amends the National Aeronautics and Space Act to require that the position of Administrator and Deputy Administrator not be simultaneously occupied by retired commissioned officers of the armed forces unless a period of ten years have passed since active duty.

Section 112 directs the Administrator to keep the Congress fully informed with respect to all activities of the Administration.

TITLE II: SPACE STATION

The Committee adopted title II of the bill to establish policy and specific guidelines for the Space Station program. In this part of the bill policies, and priorities for the development, construction, operation and use of the Space Station are established.

SECTION 201: CONSTRUCTION OF SPACE STATION; DECLARATION OF POLICY

Section 201(a) sets forth the priority of purposes for the Space Station. This priority establishes science as the highest priority objective. The design and configuration should reflect these priorities.

Section 201(b) emphasizes the research character of the Space Station by specifically providing that the Space Station may be used for research, experimentation and exploratory development. The Committee has further provided that the Space Station may not be used by or on behalf of any department or agency for the purpose of conducting on such Station the operational testing of deployment of any offensive or defensive weapon or weapons systems if in contravention of United States laws or treaty obligations.

Section 201(c) expresses the principle that other science and space activities must remain healthy and retain their program integrity during the development and operation of the Space Station. The Committee intends that science and engineering programs should remain funded at an appropriate level and they should utilize or interact with the Space Station only if technically justified.

Section 201(d) encourages the Administration to undertake advanced technologies such as automation with the objective of reducing the cost of operating the Space Station.

Section 201(e) directs the Administrator to seek private commercial contributions to the Space Station infrastructure. These contributions may encompass both construction and operation of appropriate hardware elements. The Committee intends that the Administration assume an active role in identifying and soliciting such contributions.

Section 201(f) recognizes the important role of the Space Station in securing cooperative relationships with international partners. The Administrator is directed to develop and operate the Station in conjunction with international partners.

Section 201(g) recognizes that the evolutionary character of the Space Station must be a prime design objective.

SECTION 202: CAPITAL DEVELOPMENT PROGRAM

Section 202(a) requires the Administrator to submit budget requests each fiscal year for the development phase of the Space Station from fiscal year 1988 through fiscal year 1997. Each budget request must be accompanied by budget estimates for the next two fiscal years. The Committee intends that the development phase so defined include as a minimum, achievement of a permanent manned capability. Enhancements beyond this, either during the development operations phase, should remain as a program goal.

Section 202(b) requires that the annual request for the total Space Station development (as defined in Section 202(c)) not exceed 25 percent of the total NASA budget. This budgetary ceiling is envisioned to permit the achievement of a permanently manned infrastructure by 1997 within a reasonable projection of the NASA budget while at the same time preserving funding "wedges" in other essential space activities. In other words this provision is one means for achieving the policy goals of Section 201(c).

Section 202(c) defines the scope of the development program for the purpose of this title. Development includes but is not limited to the research and development activities associated with the space and ground systems and collateral equipment (e.g., flight telerobotic servicer, operations and transition definition) and all direct expenses for Space Flight Control and Data Communications, Construction of Facilities and Research and Program Management. These direct expenses are intended to include marginal costs of transportation and tracking and data services, launch facilities, payload processing facilities, simulator facilities, and all other enabling facilities including their collateral equipment, and all laboratory and technical services provided by NASA Centers.

Section 202(d) requires the Administrator to certify compliance (i.e., account for all station costs) with Section 202(b) using the special accounting definitions provided by subsection (c). This certification is intended to substitute for and preclude the need for any formal restructuring of the normal NASA budget submittal that would otherwise be required by subsection (b) and (c).

SECTION 203: OPERATION AND ENHANCEMENT

Section 203(a) requires that the annual budget submission after FY 1997 for the basic operation and enhancement of the Station and its associated ground systems not exceed 10 percent of the total NASA budget. The Committee envisions that, by specifying such an operations cost target, Station planners can more clearly define the cost effectiveness of specific technologies and weigh their development costs against their operations costs and cost savings.

Section 203(b) permits additional expenditures (beyond the basic operating costs which are provided for in Section 203(a)) for utilization of the Space Station. The Committee further intends that these utilization expenditures such as for flight hardware, operation of the experiments, data transmission costs, be justified in programmatic terms. For example, if the Station is to be used as a platform for a particular science experiment, this use and the associated costs must be justified in terms of the science programs, not the Station program. Similarly, the costs must be carried in the budget request of the science program, and authorized accordingly.

Section 203(c) and 203(d) define, respectively, the scope of the operations costs and enhancement costs for the purposes of this title. These include all direct expenses such as marginal transportation costs, all ground facility operating costs, all marginal tracking and data transmission costs, and all hardware, software, and facility improvements and all other identifiable associated costs.

In adopting this section, the Committee fully recongizes that this limitation may pose a challenge to NASA, especially if large scale enhancements are envisioned early in the operations phase. The Committee envisions four ways under which enhancements can be accomplished.

First, overall growth in the NASA budget will result in benefits to all NASA programs including the proportional amount for Space Station.

Second, NASA can reduce operations costs and thereby divert relatively more toward enhancements.

Third, NASA can collect user fees under section 206 and utilize these for enhancements resulting in a demand driven system.

Fourth, NASA can submit additional requests for specific enhancements (e.g., for a major Mars mission) that do not have the potential to attract user fees.

The reduction in operation costs should be a major design objective of the Station. Although the Committee is aware of some hardware programs, such as solar dynamic power, that are specifically intended to accomplish this goal, there is no cost framework whereby systematic trade studies can be made and some cost reducing technologies are not receiving proper emphasis. For example, the General Accounting Office, in the report entitled "Space Operations: NASA's Use of Information Technology," stated:

> NASA may soon be making important tradeoff decisions that could significantly affect the cost and operation capabilities of the station, possibly for its estimated life span of 30 years. In light of the large investment that the Space Station will likely require, NASA and the Committee may wish to consider addressing several key questions, including:
>
> If NASA remains committed to its cost and timeframe goals for designing and developing the station, will it have to use a "minimal risk approach," which would involve, in large part, the use of existing technologies for most station systems?
>
> If a minimal risk approach is taken, will this force NASA to rely primarily on proven, existing information technology that may be seriously outdated by the time the station is placed in operation?
>
> Will NASA be incurring the risk of building a less effective station with excessive operating costs an extensive dependence on ground station for its long life?

SECTION 204: LAUNCH OF SPACE STATION ELEMENTS

Section 204(a) expresses the sense of Congress that the Space Station assembly and operation should be based on the most cost effective system available considering both the Space Shuttle and expendable launch vehicles (ELV's).

Section 204(b) requires a report on cost effective launch systems by January 15, 1988. The report should address existing ELV's, future ELV's now under consideration for development and the requirements for Shuttle services for other programs and users.

The Committee intends that particular attention be paid to the role of heavy lift vehicles and the relative advantages of a Shuttle derived vehicle and an advanced launch system. Inasmuch as NASA's current program commitments primarily address only the advanced launch system, the Committee will entertain reprogramming requests if additional funds are required to study Shuttle derived vehicle technologies for the purposes of this section. The Committee believes that any study assessing the mission and merits of a Shuttle derived vehicle include participatior by the Department of Defense in the same manner as NASA now participates in studies of the advanced launch system. In addition to the launch of Space Station elements, this study should address the broader uses of the Shuttle derived vehicle in cooperation with or independent of the Department of Defense.

SECTION 205: CAPACITY CHARGES TO OTHER FEDERAL AGENCIES DESIRING TO ENHANCE THE SPACE STATION

Section 205 requires the Administrator to assess charges against non-NASA users if such users wish to make specific enhancements to the Station in order to fulfill their utilization requirements. These charges are exclusive of the user fees of Section 206 which are incurred as a result of sharing power, astronaut services, and other common commodities. Funds transferred pursuant to the assessment are to be used to construct the desired capacity.

SECTION 206: NON-NASA USER FEES

Section 206(a) requires the Administrator to collect user fees from all non-NASA users of the Station.

Section 206(b) establishes the objective for user fees as promotion of the Station, costs recovery, and efficient allocation of resources. The Committee intends that user fees be indexed to a realistic economic valuation which reflects the costs of deploying and maintaining these resources.

Section 206(c) gives the Administrator the authority to waive or modify user fees on a case-by-case basis when such waiver or modification will advance the purposes of the civilian space program.

SECTION 207: SUBMISSION OF PLAN

Section 207(a) requires the submission of a report which outlines the total cost of Station development, a review of the possible configurations of the Space Station, and a plan for collecting capacity charges and user fees.

Section 207(b) restricts the obligation of any funds in excess of $250,000,000 until the report in subsection (a) is submitted. This allows about one-third of the funds to be obligated in the one-third of a year that will pass before the report is submitted.

Section 207(c) sets the reporting date for subsection (a) as January 15, 1988.

SECTION 208: AGREEMENTS WITH FOREIGN ENTITIES

Section 208 requires that any agreements with foreign entities be submitted to Congress before they become effective.

COMMITTEE VIEWS

SCIENCE ON THE SPACE STATION

The Committee is not satisfied that NASA is fully addressing the issue of science utilization of the Space Station. It is clear from the report of the Space and Earth Sciences Advisory Committee (SESAC) entitled "Crisis in the Space and Earth Sciences" that science objectives should determine the use of any particular platform selection. The Committee is thus disturbed by the widespread apprehension in the science community that science may be forced inappropriately onto the Station in order to justify its existence. The Committee intends to ensure that the proper balance among science programs is maintained and the Shuttle and Station are utilized only when appropriate.

On the other hand, the Station will have some inherently beneficial characteristics for the conduct of "man-in-the-loop" science. It is incumbent on the science community to continue to make an input to the design process and make good use of the research opportunities that will result. The Committee recognizes that the development of a meaningful science mission model has been made difficult by recent events. The *Challenger* accident and the resulting constraints on the Shuttle schedule and performance have vastly reduced the opportunity to define meaningful research programs in materials science and life science, the two prime utilization categories for the manned element. The role of satellite servicing is now ill-defined. In addition, a favorable environment for attached payloads will evidently not occur until the final stages of assembly. Finally, the uncertainty in the West Coast Shuttle capability may require a fundamental reassessment of the approach to servicing the polar platforms.

Notwithstanding these difficulties the Committee believes that all feasible steps should be taken to develop the science mission of the Station. As a minimum, the following should be undertaken:

NASA should take positive steps toward acquiring an extended duration capability Orbiter as recommended by the Task Force on the Scientific uses of the Space Station.

Announcements of opportunity should be issued for various classes of experiments within the pressurized volume and for attached payloads as soon as the availability and technical characteristic of these opportunities can be baselined.

A prioritization of specific materials science and life science activities should be developed such that meaningful planning of resources aboard the manned element can be facilitated.

An organizational focal point within the Office of Space Science and Applications should be established to integrate the needs of the various science disciplines and develop a unified science utilization plan.

NASA should commit to a Science Applications Information System and the interface with this system should be an explicit part of the design baseline.

NASA should establish science test beds to develop expert systems, teleoperation, and robotic capabilities. These should emphasize science disciplines most in need of automated technologies such as materials science.

The Committee requests that NASA keep the Committee informed on the progress toward satisfying these recommendations.

CRISIS IN SPACE AND EARTH SCIENCE

The combined effects of the loss of the *Challenger*, the two hiatus in flight opportunities, and the cancellation of the Shuttle Centaur program have resulted in an unprecedented loss of vitality in the space and earth sciences. NASA has been unable to fulfill some of the basic mandates embodied in the National Aeronautics and Space Act.

It is clear, however, that the crisis in space and earth science that was brought to light by these events had been developing long before the *Challenger* accident and was rooted in management and budgetary decisions over the past decade.

The November 1986 report by the NASA Advisory Council entitled "The Crisis in Space and Earth Sciences" has provided a meaningful context for the new commitment that will be required to revitalize NASA's science program. This report makes four general recommendations intended to provide long term stability for the space and earth science community and foster those conditions which have in the past led to great achievements in science.

1. The Space and Earth Science Program must continue to incorporate a diverse range of activities, participants and facilities.
2. The scientific requirements of a particular mission must be the dominant factor in selecting the launch vehicle, instruments and spacecraft to be employed.
3. All aspects of the Space and Earth Science Program, and their total requirements for resources must be thoroughly and realistically understood through rigorous planning.
4. Carefully specified criteria must be used in setting priorities and deciding among proposed major space research projects and missions.

Underlying these recommendations, it is clear that NASA's commitment to research and development must be cast in terms of scientific objectives rather than the need to justify institutional initiatives or hardware programs.

The Committee requests that by October 1, 1987, NASA prepare a comprehensive report in response to the recommendations made by the NASA Advisory Council. The Committee expects this report to form the seminal basis for the agency's new commitment to its fundamental science mandate.

SMALL PAYLOAD OPPORTUNITIES

A continuing concern to the Committee has been the adequacy of flight opportunities for small and medium class science payloads. This situation, which existed prior to the *Challenger* accident, has become intolerable in the post-*Challenger* environment. The Committee has, therefore, augmented the Explorer program to encourage more frequent flight opportunities in this payload class.

The Committee fully recognizes that this problem has resulted from a number of factors some of which are difficult to control. It is clear that the promise of frequent small payload opportunities on the Shuttle may never be fulfilled. Like the Spacelab program, users of Spartan, Hitchhiker, and other Shuttle-based small payload carriers will face increasingly severe performance and schedule constraints. It is evident that EVL's and suborbital programs must play a much greater role in the future.

There are, however, institutional and management factors that have also played a role in limiting small and medium class payload opportunities. The perceived lack of engineering challenge in developing and flying many small payloads may present an inherent bias against such programs. Yet, the cost effectiveness and scientific return from satellites such as the Infrared Astronomy Satellite (IRAS) and International Ultraviolet Explorer (IUE) have been hallmarks in NASA's heritage and it is essential that NASA continue to solicit proposals for scientific programs in this payload class.

In soliciting proposals for these scientific programs, however, NASA must carefully lay out cost and flight opportunity factors. A key element in the stress which now characterizes the space and earth sciences is the inability of NASA to follow through on the good ideas which are generated by announcements of opportunity. That is, the "opportunity" being announced must be realistic. All too often such announcements of opportunity for both small and major flight programs have simply created more pressure for new starts and program augmentations that cannot be met within available resources.

As pointed out by the National Academy of Sciences, the NASA Advisory Council, and others, the Explorer program is now in critical need of management attention. The impact of the *Challenger* accident, the failure of the Explorer funding to keep pace with inflation, and the evolving complexity of Explorer missions have resulted in a situation which scarely resembles the original goal of providing frequent low cost flight opportunities. The Committee requests that by January 15, 1988, NASA submit a plan which establishes funding requirements and describes management initiatives necessary to provide for an Explorer program baseline of one flight per year.

NASA's Applications Mandate

The Committee notes with concern that NASA's new goals and objectives which were intended to set the direction toward recovery from the *Challenger* accident have failed to identify clearly an agency mission for space applications. The dual mandate for space science and applications had been fundamental to the support Congress and the public have given to the space program over the past 25 years. For example, the economic stimulus which has resulted from NASA's role in communications research has been one of the great successes of our investments in space. Future programs in materials science and remote sensing applications could yield similar benefits.

The Committee is mindful, however, of the complex relationship that exists between the Government and the private sector in carrying out applications research and development. The Government can neither compete with the private sector nor perform research that might otherwise be done by the private sector. Thus, the approach to carry out its applications mission must be based on fundamentally different mechanisms than for scientific research. NASA's focus must be not only on achieving technical results but also on achieving technology transfer. The Committee urges NASA to exploit fully the authority given it by the Space Act and develop legal and institutional mechanisms which can identify appropriate applications research activities and interactions with the private sector.

Over the past several years, it has become clear that such applications areas as communications research have not been strongly supported. If, as has been asserted, the private sector should take on a larger burden of this type of research, it is incumbent on NASA to actively work with the private seactor to effect a reasonable and responsible transition. The Committee will not accept NASA's abandonment of these activities as being in the public interest. The Committee further wishes to make clear that any shift to the private sector will be supported only if there is clear and convincing evidence that traditional American leadership will be assured through industry efforts.

With respect to the Advanced Communications Technology Satellite (ACTS) program, the Committee has once again restored funds deleted by the Administration. Through its advanced technology, the ACTS Program will enable the United States to successfully respond to the European and Japanese challenge for preeminence in the world satellite communications market. In order for the United States to meet this competition in a timely way, NASA should ensure that ACTS be launched before comparable satellites by other countries. The Committee is pleased to note that NASA provided additional funds for the program in FY 1987. The Committee requests that NASA keep the Committee informed on its progress toward this goal and identify to the Committee the specific mission schedule. The Committee would state that it will not accept further NASA abrogation of agency leadership and responsibility in this area.

In order that the long-range competitive benefits of ACTS technology be disseminated most effectively within the U.S. economy, NASA should assure that a broad spectrum of U.S. interests—large and small business conerns, universities, and non-profit organzations—be able to participate cost-effectively in the experiment activities. This should be accomplished by developing a reasonable policy for use of NASA ground stations, the ACTS flight system, and basic engineering data.

Civil Space Technology Initiative

The Committee is pleased with NASA's proposal that the agency reinvigorate its Space Research and Technology program by beginning a Civil Space Technology Initiative. This effort will go a long way to reversing a trend toward erosion and neglect that has continued for too long in NASA's space technology endeavors.

For more than a decade, the percentage of NASA's budget that has been devoted to the development of advanced space technologies has been running at a level that is only about one-third of what it was during the 1960s. Though these activities consume only a few percent of NASA's overall budget, they are critically important to maintaining American preeminence in space. Historically, these investments have also paid handsome dividends by providing technologies that have been useful throughout the economy and in keeping U.S. companies competitive in world markets.

Oversight of Shuttle Recovery Effort

The Committee is generally pleased with the overall thrust and results of NASA's Shuttle recovery efforts to date. In our view, the agency appears to be dealing in a conscientious manner with the concerns raised in the Committee Report, Investigation of the *Challenger* Accident, House Report, No. 99–1016 and the report of the Rogers Commission. Nevertheless, the Agency must be aware that the Committee is not yet fully satisfied with NASA's response, only with the progress to date; and that the Committee will continue its close oversight.

We are particularly pleased with the efforts of the Office of Safety, Reliability, Maintainability, and Quality Assurance to develop a series of "indicators" of Space Shuttle launch pressure. This development is so significant because of the conclusion the Committee reached as a result of its accident investigation that the driving pressure to achieve an ever increasing Space Shuttle launch rate was the overriding cause of the *Challenger* accident.

The Committee plans hearings to closely review and scrutinize the work being done by NASA and its contractors to return the Shuttle to safe flight operations.

Space Shuttle Flight Rate

Prior to the *Challenger* accident, NASA had established a goal to increase the number of Space Shuttle flights to 24 per year. The high flight rate was viewed as necessary to reduce costs per flight and to achieve more routine access to space. The highest Shuttle flight rate achieved was 10 for the 12 month period ending just prior to the accident. The 1986 Committee report on the *Challenger* accident, House Report No. 99-1016, concluded that pressure to increase the Shuttle flight rate was a primary factor contributing to the accident.

The Committee recommends in the strongest possible terms that NASA not accord such high priority to Shuttle flight rate in the future. The flight rate must be consistent with available resources, the technical maturity of the Shuttle, and the flexibility desired in scheduling payloads. NASA management should ensure the efficient use of resources but cannot impose a artificial flight rate on the system. Future planned flight rates must be derived from a rational analysis of resources and needs. The flight rate should be determined from the "bottom up" rather than the "top down."

NASA's written response to the Committee accident report and some statements by NASA officials during the fiscal year 1988 budget authorization hearings indicate that the agency is establishing a new flight rate goal of 16 flights per year assuming a four Orbiter fleet. A recent National Research Council report concluded that a maximum steady state launch rate of only 11 to 13 Shuttle flights per year (with 4 Orbiters) would be possible, which is inconsistent with the maximum flight rate being planned by NASA.

The Committee is not trying to decide for the Agency whether 12 or 16 flights per year is the appropriate flight rate level. That is for NASA to determine. Rather, the Committee wishes again to emphasize that Shuttle flight rate must not become a goal in and of itself. NASA must derive the Shuttle flight rate by taking into account the availability of Shuttle resources, the planned use of expendable launch vehicles, and Shuttle-unique payload requirements. The Committee intends to closely monitor this situation during the flight recovery period and after flights begin again.

NASA's Emphasis Should Be On Understanding Phenomena (Rather Than On Procedures and Paperwork)

The Committee report on the *Challenger* accident concluded that a fundamental problem contributing to the accident was poor technical decisionmaking by top NASA and contractor personnel, who failed to act decisively to solve the increasingly apparent and serious anomalies in the solid rocket booster joints. In spite of the many procedures NASA had developed and implemented to identify potential safety problems, responsible officials did not appear to thoroughly understand fundamental physical and engineering phenomena, which could limit the performance of critical hardware, or cause an accident. The Committee cited the need for a more rigorous risk assessment approach to critical hardware evaluation that would result in quantitative predictions of performance characteristics and safety margins. A January 1987 letter report of the National Research Council Panel on Redesign of the Space Shuttle Solid Rocket Booster reemphasized the need for NASA to ensure a better understanding of the basic phenomena governing hardware performance.

Since the accident, NASA has made considerable progress in implementing new or improved procedures to identify and evaluate potential safety problems with critical flight hardware. These paperwork-intensive procedures must be supplemented by the development of analytical models that will enable an improved understanding of flight system performance characteristics and limitations. The models should be systematically used to predict the results of experimental tests and to analyze flight data. All NASA staff affiliated with the Shuttle and other flight programs must also develop a more safety-conscious attitude that will help ensure that adequate attention is paid to identifying potential safety problems and understanding the phenomena underlying those problems.

The Committee intends to continue to monitor the progress being made by NASA in ensuring a better understanding of the performance characteristics and limitations of flight hardware. This issue will be further addressed at future hearings and periodic reviews of NASA flight programs and safety, reliability, maintainability and quality assurance activities.

Space Shuttle Utilization Policy

The Committee believes that the time is right to begin to readdress the basic goals and philosophy of the Space Shuttle program. Specifically, in this post-accident environment, how should the Shuttle be viewed and what should it be used for?

Prior to the accident, the Shuttle was viewed by NASA and this Committee as the "be all and do all" in space transportation. Indeed, the system was even given the name "The National Space Transportation System." Clearly, this is no longer the case. The Space Shuttle will be part of a "mixed fleet" of launch systems within NASA as well as the Defense Department.

On the other hand, it is not yet clear to all experts just how the Space Shuttle should be used in the future. Some have suggested that the Shuttle should be flown as much as possible and that expendable launch vehicles (ELVs) should then be used to carry payloads that cannot make it onto the Shuttle manifest. Others have recommended that the Shuttle should be used only to carry payloads that require man and that everything else should be launched by ELVs.

On the basis of the testimony received at committee hearings, it is the evolving sense of the Congress that the Space Shuttle is a critical national resource that should be preserved for those missions that require manned presence and that expendable launch vehicles should be used to place most other spacecraft into orbit. The only exceptions to this general rule should be when: (1) it would be exceedingly expensive to reconfigure a satellite for an ELV launch; (2) the spacecraft is so expensive or of such national importance that it is imperative to utilize the higher launch reliability provided by the Space Shuttle; and (3) if a launch accident or some other similar event has "grounded" a particular launch vehicle (or class of vehicles) and it is necessary to use the Space Shuttle as a "backup" launch vehicle to replace the grounded expendable launch vehicle in order to place a high priority payload into orbit.

Exceptions such as those indicated above could be incorporated into an agency policy or definition of what constitutes a "Shuttle-unique" payload. Such was a recent recommendation of the Commercial Space Transportation Advisory Committee (to the Department of Transportation Office of Commercial Transportation). A clear definition by NASA of what constitutes Shuttle-unique payloads qualifying for STS launch would provide valuable guidance to the commercial community and assist in business planning. The Committee concurs with the advisory group that NASA take such steps to articulate a definition by publishing, for industry comment, the criteria by which such determinations are made.

In a similar vein, serious questions have been raised as to whether performance improvements that have been planned for the Space Shuttle would be worth either their cost or the potential added risk that might pose to the crew. Still other experts have suggested that for safety reasons consideration should be given to significantly lowering the maximum permissible thrust setting for the Main Engine (i.e., well below the currently planned 104 percent). Any changes along these lines would have significant impacts on the payload carrying capability of the Space Shuttle, but, if ELVs are capable of picking up the slack, such changes may be safer and cheaper in the long run.

The Committee currently plans to look into these and related issues in thorough hearings later in the year. Accordingly, we request that NASA begin now to address these issues in a comprehensive manner so that the agency wil be prepared to answer the Committee's questions at those hearings.

Utilization of Orbiting Shuttle External Tanks

The Committee notes that the Space Shuttle External Tank (ET) is a potentially valuable resource that should be considered for possible space development. Qualified academic research groups could be awarded ET resources for space-based research much like the land grant concept of the past. Using orbiting ETs, universities working cooperatively with industry might be able to increase scientific research opportunities, expand our Nation's space infrastructure and broaden the spectrum of private space enterprise.

In response to the Committee's request in House Authorization Report 99-829, NASA has delivered to the Committee a report specifying the technical, operational, cost, and safety requirements for ET orbit insertion. The NASA report "External Tank Utilization on Orbit" states: "The engineering and operating problems involved with this objective are basically within the current state-of-the-art of Shuttle operations, support system and technology." The report also specifies the impact on Shuttle payload, propellant requirements for station keeping, requirements for accessibility to orbiting ETs, probability of space debris or micrometeoroid damage, and NASA's estimate of the cost of ET modifications and operations. The Committee appreciates the delivery of this detailed report in response to the Committee's specific request.

The Committee is pleased to be informed of progress acheived by university groups and NASA in the past year toward realizing the potential value of ET resources: (1) The Universty Corporation for Atmospheric Research (UCAR), a 25-year old group of 57 universities and research institutions, is leading the "Space Phoenix" program to obtain orbiting ETs and develop them for scientific and commercial purposes using non-government funds; (2) NASA has created a high level committee to work with UCAR on the Space Phoenix program; (3) UCAR and the Government are making good progress toward an agreement concerning transfer of one or more ETs to UCAR; (4) NASA is supporting studies of a Gamma Ray Imaging Telescope (GRIT) which could be installed in an orbiting ET; (5) Zero gravity simulations of GRIT telescope assembly procedures are being conducted at the Marshall Space Flight Center; (6) A symposium of space scientists has been convened by university groups to consider science experiments that can be conducted in and from space using ETs.

U.S.-U.S.S.R. Cooperation in Civilian Space

The Committee notes with approval the signing on April 15, 1987, of a formal agreement between the United States and the Soviet Union concerning cooperation in the exploration and use of outer space for peaceful purposes. The agreement will facilitate co-operative ventures in the fields of space science, including solar system exploration, space astronomy and astrophysics, earth science, solar-terrestrial physics and space biology and medicine.

Following a October 1985 visit to Moscow at the invitation of the U.S.S.R. Academy of Science, a Committee delegation concluded that a formal framework for civilian space cooperation would be a desirable means of enhancing space cooperation with the Soviet Union . . . "by lending structure for cooperation, strengthening channels for communications, and providing leverage for assuring a return on the national investment in the relationship" ("Visit to Sweden and the Soviet Union," Report, Committee on Science and Technology, Serial I, 1985). The agreement marks a significant step toward cooperation.

In keeping with the spirit of the renewed agreement, the Committee would urge NASA to consult with its NASA Advisory Committee on areas identified for cooperation with the U.S.S.R., with particular emphasis on Mars exploration. Particular areas of emphasis could include joint calibration of instruments, coordination of landing sites, and sharing of data.

The International Geosphere Biosphere Program

The International Geosphere Biosphere Program is a new initiative in science that will address major environmental problems that are common to all who live on the Earth. It will do this by taking a bold new approach: harnessing the power of remote sensing of the Earth from space, the emerging technology of new generations of computers to process and comprehend the awesome amounts of data that will be involved, and the co-operation and collaboration of many scientific disciplines and the national efforts of more than 100 countries of the world. The goal of the program is to describe and understand the interactive physical, chemical and biological processes that regulate the unique environment that the Earth provides for life; the global changes that are now occurring in this system; and the role of human actions in perturbing the natural balances of the system. The IGBP will begin in earnest in 1992, and last at least a decade.

The IGBP was an idea that took shape over the last three years in this country through actions in the National Research Council. During that time, the Committee had encouraged the idea of an IGBP. The critical, international link was forged last September in Switzerland when the IGBP was unanimously and enthusiastically endorsed, after two years of study, by the 21st General Assembly of the International Council of Scientific Unions (ICSU)) in Berne. ICSU is the highest council of science: an international, non-governmental scientific organization whose principal objective is to encourage international scientific activity for the benefit of humankind. The United States is represented there by our National Academy of Sciences, and by U.S. members of the 20 international scientific unions that are also represented. The IGBP has the potential to be the most ambitious, and the most promising, endeavor in man's long history of understanding the planet on which he lives.

The U.S. contribution to IGBP will consist of coordinated efforts in many federal agencies, under the general rubric of "Global Change". The National Science Foundation has already begun its own, contributing program, called "Global Geosciences" that ties together related programs in the biological sciences, atmospheric science, oceanography, solid earth studies, and polar programs. The NASA Advisory Council commissioned in 1983 a major study of "Earth System Sciences" that has provided, and will continue to provide, both the intellectual framework and the down-to-earth requirements of the coordinated programs of measurement and monitoring that will be required. NOAA has now under study a new contributing program, called "Global Climate Change", that would make use of the expertise and experience of that agency, focusing on changes in the atmosphere and ocean components of the Earth system. The Department of Energy is now contemplating its proper role in the effort, as is the Department of Defense, through research activities of the Office of Naval Research. The connection of U.S. programs in Global Change with the ICSU IGBP will be made through the National Research Council. In addition there will soon be a coordinating mechanism to link the principals involved in all the major U.S. scientific agencies who will work on this global program.

The Committee welcomes this progress and these plans: they tell of powerful and altruistic efforts to respond to the challenge of a rapidly-changing world, with plans for providing the fundamental knowledge that can serve as a basis for assessing likely, future changes on the Earth during the next 100 years.

The Committee urges the National Aeronautics and Space Administration to continue to cooperate fully with other agencies and with international activities. The Committee requests to be kept fully informed of further progress and new plans.

Phase B of the Advanced Solid Rocket Motor Program

The Administrator shall proceed with Phase B of the advanced solid rocket motor program as an alternative design and report to the Committee on Science, Space and Technology of the House and the Committee on Commerce, Science and Transportation of the Senate, the status of the program at the time of the submission of the 1989 budget request.

Solar System Plasma Physics

The Committee recognizes and endorses the study of solar system plasma physics as an important branch of science, concerned with problems of true intellectual significance that may be studied effectively in space and whose importance extends to laboratory physics as well as large-scale astrophysics. Proposed as an attached payload for the Space Station to perform detailed studies of the sun, the High Resolution Solar Observatory (HRSO) is of great importance to the next generation of solar studies. The Committee notes that HRSO would respond to the Committee's concern expressed in

Report No. 99-829 accompanying H.R. 5495 that the science objective of the cancelled Solar Optical Telescope program be reintroduced. A descoped version of the SOT, the HRSO will provide sufficient resolution to observe levels in the solar atmosphere ranging from the photosphere to the transition region. The critical problems to be studied include plasma-magnetic field interactions related to the solar dynamo and studies of energy transport in the solar atmosphere. The Committee wishes to encourage NASA to pursue studies that will lead to a new start for HRSO in the near future.

Providing for Future International Cooperation in Manned Spaceflight

With the passage of time, a growing number of nations are considering manned spaceflight and the United States and the Soviet Union will be conducting manned flights with increasing frequency.

This increasing level of manned spaceflight activity raises the issue of whether it would be worthwhile for the United States and other nations to begin to design and develop standardized docking modules and related equipment so that the manned spacecraft that are flown by these nations can rendezvous and dock with each other while in space. Such equipment would be required to conduct cooperative manned missions involving spacecraft of different countries, and could prove invaluable should it ever be necessary to conduct international rescue operations to save the crew onboard a crippled manned spacecraft.

Recognition of the value of standardized docking equipment was one of the principal motivations behind the Apollo-Soyuz test project in 1975. This joint U.S.-Soviet space mission was intended to further the growing detente between the two nations and to demonstrate a piece of hardware that could conceivably be used for rescue missions. A subsequent cooling in the relations between the two super powers, however, brought further pursuit of these endeavors to an end.

The tide in the relationship between the United States and the Soviet Union again seems to be moving towards a point that it may be possible to consider the development of standardized docking equipment for use on manned spaceflight systems. Indications of this change were apparent during the visit of the Committee to the Soviet Union in late 1985. The Committee understands that both countries have continued to show interest in cooperative space ventures in recent bilateral negotiations.

The Committee believes that the potential for cooperative manned missions involving spacecraft of different countries is an important topic that deserves the attention of NASA as it begins the development of a permanently manned Space Station. Accordingly, the Committee requests that NASA undertake a conceptual study of the potential uses for, engineering approaches to, and cost of a universal docking module that could be employed on the Space Station, Space Shuttle, Soviet manned spacecraft, and future manned space systems developed by all nations. This report should be forwarded to the Congress by February 15, 1988.

NASA's Planetary Exploration Program

A key finding of the 1983 report by the Solar System Exploration Committee (SSEC) entitled Planetary Exploration Through the Year 2000 was that in order to carry out a robust and continuous program of planetary exploration, the cost of individual missions needs to be carefully controlled. The SSEC identified key management and technical factors that could be used to control these costs. The planetary observer program which embodied these recommendations was intended to be based on a series of missions utilizing a continuous line of high-inheritance spacecraft.

These missions, if carried out on a regular and reliable basis would provide a continuum of planetary data that would sustain the health of the planetary exploration community.

The Committee is concerned over NASA"s recent decision to delay the first mission in this series, the Mars Observer. There is no doubt that the Challenger accident and the resulting budget situation has presented a difficult environment for managing a balanced space science program. The Mars Observer program, however, provided an important opportunity for NASA to make a commitment, not only to a balanced science program, but also to a mixed fleet that would ensure stability in our access to space.

The Committee recommends that NASA should use this two year delay in the Mars Observer mission to establish a strong and cost effective planetary observer program. Specifically, NASA should:

1. Begin procurement of an expendable launch vehicle service for the 1992 Mars Observer launch;
2. Establish a logistics base of spares and spacecraft long lead items for the planetary observers;
3. Maintain adequate funding for the Mars Observer mission that will avoid the additional costs of a stretched out program.
4. Begin a program of ground based simulation for spacecraft and science operations to accumulate experience on the assembled Mars Observer spacecraft prior to launch.
5. Commence planning for the next observer mission, the Lunar Polar Orbiter in 1994.

The Committee believes that these actions will not only reduce the risk for the Mars Observer mission, but will also build a foundation for a robust and low-cost planetary observer program as envisioned by the SSEC.

Space Station Plans

The Committee recognizes that building a manned Space Station is a high priority for NASA and for the United States' future in space. The Committee's recommendation of full funding for NASA's FY 1988 request for the Space Station is intended as a clear statement of the Committee's strong commitment to the concept of a Space Station program.

In section 207 of the NASA authorization bill, the Committee recognizes that although it endorses the Space Station as an idea or concept there also must be a well-designed plan for its implementation. The ultimate future of and schedule for the funding of the Space Station will depend on congressional approval of a practical plan for the Station's mission, design, development, and construction.

The Committee notes that funding for the civilian space program may be affected by competing demands within the entire federal budget. Given this fiscal reality, the plan for the Station should also reflect an appropriate balance in NASA's long-term budget among the Space Station and its other responsibilities and missions.

Thus, the Committee adopted section 202(b) which provides a proportional limit to the annual request level for the Space Station program. NASA planning for the Space Station should therefore recognize that as an integral and major part of the future space program, the Space Station will directly benefit from stability and growth in the NASA budget as a whole.

Study on New Directions for U.S.-Latin American Cooperation in Science and Technology

The National Academy of Sciences' Office on International Affairs, through the Board on Science and Technology for International Development (BOSTID), has received an NRC Program Initiative Fund (PIF) grant in 1987, to explore opportunities for Inter-American cooperation. An initial meeting was held on February 3, 1987, with the federal civilian research and development agencies, and selected professional societies to receive input on agency programs and experiences on science, space, and technology inter-American cooperation. In March, at a second NASA meeting, an ad hoc program planning meeting of scientists was to discuss opportunities for cooperation.

Due to the importance of NASA involvement in international science, the current and future potential opportunities for inter-American cooperation, and the strategic need for intercontinental relations, the Committee directs NASA to work with other appropriate federal R&D agencies, including DOE, and NSF, and other independent bodies to chart new directions for U.S.-Latin American cooperation.

The Committee directs that an independent study, with inter-agency support, of current activities, an evaluation of the effectiveness of different mechanisms for cooperation, and suggestions of appropriate new action, federal and non-federal to further enhance science, space, and technology intercontinental collaboration, is an appropriate course of action.

Furthermore, a study combining this information should also address why the U.S. should be concerned with scientific cooperation in the hemisphere and which present U.S.-Latin American activities would help further cooperation.

The study should examine opportunities, identify priority countries and fields of action, and recommend, where appropriate mechanisms—bilateral, multilateral and private which have been effective in the past (providing reason why they were effective), as well as those which have promise in the future.

Not later than June 30, 1988, the Committee requires a final report. The Committee anticipates that funds for this study will come from private sources and the appropriate federal government agencies, and would not exceed a total cost of $250,000.

NASA Technology Utilization Program

The NASA Technology Utilization Program was created to ensure that technology developed for NASA aerospace research could be transfered to other areas. One of those areas in which technology transfers have been successful is in adapting aerospace technology to meet the unique needs of individuals with physical disabilities. This has resulted in advancement in voice controlled wheelchairs, communication aids, and prosthestic devices, etc, which have allowed individuals with physical disabilities to have greater access to education, employment, housing and recreation resulting in greater independence and productivity for these individuals.

The Committee therefore urges NASA's Technology and Technology Utilization Program to maintain and strengthen its activities in bioengineering and rehabilitation, with a particular emphasis on technology transfers which permit more independent lifestyles for persons with disabilities, as well as the dissemination of information on those transfers to persons and organizations working with the disabled. Additionally, the Committee directs NASA's Technology Utilization Program to report back to Congress within 180 days on specific projects they are curently undertaking in applied technologies in to employment, housing and education for the disabled, and how they are disseminating information on such technology transfers.

Aerospaceplane

The Committee supports enthusiastically the national effort to develop the technologies needed for hypersonic flight. The task will be extremely challenging; but, if successful, the result will be U.S. preeminence in this flight regime.

The Committee believes success may well depend on preserving the project's research character. Mission requirements for the experimental aircraft must be kept to the minimum necessary to demonstrate the key technologies. Accordingly, the Committee urges NASA and DOD to resist burdening the project's cost and chances for technical success with "nice-to-have" features and capabilities. Such additions will increase its complexity and cost, and should be left to follow-on programs aimed at developing specific applications.

Aeronautical Research

The Committee is concerned about the confluence of two trends: the eroding position of the U.S. aviation industry in international trade and the level of NASA's aeronautical budget which has been flat during this decade, when inflation is considered. The Committee believes that a stronger emphasis on aeronautics is needed within NASA to reverse these interrelated trends.

Accordingly, the Committee requests the Administrator of NASA to examine the advantages and disadvantages of various steps aimed at elevating the emphasis, visibility and stature of aeronautics. Such steps should include, as a minimum, creation of a Deputy Administrator for Aeronautics and a corresponding organizational realignment designed to enhance the advocacy and execution of aeronautical programs. The Committee requests the Administrator report the results of this examination not later than September 30, 1987.

DETAILED EXPLANATION OF THE BILL

Title I

The bill authorizes Research and Development in section 101(a), Space Flight, Control and Data Communications in section 101(b), Construction of Facilities in section 101(c), and Research and Program Management in section 101(d). These activities are explained below. The bill also provides NASA with certain reprograming authority, subject to appropriate reporting requirements, in sections 102-104. Sections 105-110 make various amendments to the National Aeronautics and Space Act of 1958 and express the sense of the Congress on a number of issues. Title III of the bill authorizes appropriations for the Department of Transportation, Office of Commercial Space Transportation. Each of these provisions is fully explained in detail below.

RESEARCH AND DEVELOPMENT

NASA REQUEST $3,623,200,000

AUTHORIZATION $3,697,200,000

SUMMARY

		Estimated fiscal year 1987	Authorization fiscal year 1988	Page No.
1	Space Station	$420,000,000	$767,000,000	31
2	Space transportation capability development	495,500,000	$538,600,000	38
3	Physics and astronomy	522,800,000	$577,100,000	51
4	Life sciences	72,200,000	74,600,000	66
5	Planetary exploration	358,400,000	$342,300,000	72
6	Space applications	569,700,000	604,300,000	82
7	Technology utilization	15,700,000	18,300,000	108
8	Commercial use of space	25,600,000	30,700,000	112
9	Aeronautical research and technology	376,000,000	399,000,000	114
10	Transatmospheric research and technology	45,000,000	66,000,000	148
11	Space research and technology	171,000,000	250,000,000	150
12	Safety, reliability, and quality assurance	9,200,000	16,200,000	189
13	Tracking and data advanced systems	17,100,000	13,100,000	191
	Total	3,127,700,000	3,697,200,000	

1. SPACE STATION

NASA REQUEST, $767,000,000

AUTHORIZATION, $767,000,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Definition	$250,000,000	0
Development	150,000,000	$733,000,000
Flight telerobotic system	20,000,000	22,000,000
Operations definition	0	7,000,000
Transition definition	0	5,000,000
Totals	420,000,000	767,000,000

The Space Station will provide a unique capability to enhance the Nation's space science and applications program, and to further the commercial utilization of space while stimulating advanced technologies. Development of the U.S. permanently manned Space Station, as directed by President Reagan, will follow a deliberately-paced program plan which will permit us to maintain the preeminence in space our Nation has attained through various manned and unmanned programs.

The U.S. Space Station will be a multi-purpose, national facility, providing a permanent human presence in space to conduct essential scientific and technical research, to support unique commercial activities, and to perform operational tasks more efficiently in space. International participation with the U.S. Space Station program has been encouraged by the President. Canada, member states of the European Space Agency (ESA), and Japan have responded enthusiastically. Memoranda of Understanding (MOU) for the definition and preliminary design phase were executed with Canada, ESA, and Japan in the spring of 1985 concurrent with the initiation of the NASA definition contracts. These international partners have undertaken parallel definition and preliminary design studies to identify Space Station elements that each of them may consider for development. Negotiations for the development phase of the program are currently underway with our current international partners.

The Space Station will be designed to permit the system to evolve, as warranted over time, to provide greater user utility and operational capabilities. Its manned and unmanned elements will be designed to facilitate on-orbit maintainability/restorability, operational autonomy, human productivity, and simplified user interfaces. Implicit in these objectives is the recognized need to optimize man/machine systems in space via automation, robotics, and artificial intelligence technologies. During the definition period, NASA conducted trade studies to evaluate various subsystems changes to the Space Station options. The baseline configuration has been selected and is commonly known as the "dual keel" configuration. It is from this baseline, which was derived using the findings of the preliminary design and definition studies, as well as the advanced technology work, that the detailed design will begin in late FY 1987.

The Station and its platforms will be placed and maintained in low-Earth orbit by the Space Transportation System, thereby building upon the previous national investment in space.

The definition and preliminary design phase will continue through FY 1987 and will provide the technical and programmatic plan for the Space Station development program, including the completion of the detailed definition and preliminary design, the analysis and integration of national and international user community requirements, and the advanced development of technology options. A continuing emphasis on user requirements and operations will be maintained as the engineering design evolves through subsystem advanced development and testing in dedicated test beds.

DEVELOPMENT

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Pressurized modules	$40,000,000	$196,500,000
Assembly hardware/subsystems	27,000,000	204,000,000
Platforms and servicing	6,000,000	59,000,000
Power system	19,000,000	88,000,000
Operations capability/utilization	13,000,000	52,000,000
Management and integration	45,000,000	133,500,000
Totals	150,000,000	733,000,000

The development phase, which will begin in FY 1987, includes the prime contractor effort on the work packages, which will provide the major hardware components, as well as supporting development activities such as the systems engineering and integration (SE&I), the program's Technical and Management Information System (TMIS) and Software Support Environment (SSE), and the evolvement of operational planning including user accommodations and interfaces.

Pressurized Modules

The design and development activities of the hardware elements and systems will be initiated in FY 1987. In FY 1988, the prime activities will commence with program requirements reviews (PRR) for the pressurized modules and related elements. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contact negotiations and source evaluation board activities. PRR's are scheduled to begin three months after contract start date. Near the end of FY 1988, program design reviews (PDR) will be conducted for hardware elements and systems including the structure for the modules (laboratory, habitation and logistics) and resource nodes; the outfitting of the modules; the environmental control and life support system; the manned systems and the internal components of the thermal control system and audio/video system; and related launch package integration activities. These PDR's will provide an evaluation of the current design approach of the work packages, taking into consideration the interfaces with other elements of the program including those being developed by our international partners. Successful completion of the PDR's will result in the authorization to proceed with detailed design in accordance with the reviewed design approach and interface requirements.

Those efforts beginning in FY 1987 that provide capabilities for independent assessments of contracted work that develop necessary in-house capabilities required to accomplish development responsibilities will continue. These activities include the maintenance of data management activities to provide for transfer of data between the work packages, contractors, and other parties involved in the development process; the development of tools and analyses that will provide independent assessment capabilities in areas such as commonality and man/system integration effectiveness. Also, work in the materials area relative to hardware responsibilities of developing the modules for the Station will continue. The work in this area involves the establishment of a materials data base that will serve as a resource during the design and development of the Station's hardware elements. Efforts will also be undertaken in the international integration area to ensure the compatibility of the international hardware with the Space Station.

Assembly Hardware/Subsystems

The development efforts which were initiated in FY 1987 in this area will continue to concentrate on completing the design of the hardware elements as well as the various subsystems and related activities including: the truss; the mobile base for the mobile servicing center; the outfitting of the airlocks and nodes; the external thermal control; extravehicular activity; data management; communications and tracking; guidance, navigation, and control; propulsion; and related launch package integration activities.

In FY 1988, the prime activities will commence with PRR's for the assembly hardware/subsystems areas. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contract negotiations and source evaluation board actions. These PRR's are scheduled to begin three months after the contract start date. The PDR, which is currently planned for the end of FY 1988, will be conducted using the data developed by the contractors as well as that data available from the in-house activities supporting those efforts and will allow for the evaluation of the design approach planned for the interfaces.

Continued work in the outfitting of facilities being prepared for the Station will provide capabilities to conduct tests of the advanced technology to be utilized in the development of the Station. Designing the outfitting of the resource nodes, a recent configuration change, will commence as well as the designing and outfitting of the airlocks and the interfaces with the extravehicular activity system. The identification of requirements for each subsystem will continue and trade studies will be conducted to assure that proper interfaces are maintained with the additional hardware being developed by other NASA centers as well as the international partners. For example, examination of various design alternatives of distributed processing architectures for the guidance, navigation and control subsystem will be continued. The technology work required to provide for information for a possible new space suit will progress to enable a timely decision about the design of that suit.

Platforms and Servicing

The platforms and servicing responsibilities include the development and production of two unmanned platforms, one multi-purpose servicing facility, the payload accommodation equipment (PAE) and the course pointing systems. The platforms, one co-orbiting and one polar, will be used for scientific research and Earth and astronomical observations. The servicing facility will be positioned on the Station structure and will provide maximum access for servicing payloads and free-flyers. The PAE is attached to the structure and will provide for the mounting of various scientific instruments. Electrical power and other utilities are provided to the payloads through the PAE. The course pointing systems are provided for payload instruments requiring a high degree of pointing accuracy, typically instruments for observing Earth and celestial bodies.

The initial design and development activities initiated in FY 1987 will continue in FY 1988. Currently planned for three months after the contract start date, the PRR will update the program to include those management decisions and design changes which occurred as a result of contract negotiations, and source evaluation board actions. The major thrust of the development activities will be to ensure that the requirements, design, configuration, and interfaces of the platforms, servicing bay, and attached payload accommodations are defined and identified in sufficient detail to support the PDR, which is currently planned for the end of FY 1988. This review will result in the authorization to proceed with further design in accordance with the reviewed designed approach and interface requirements. Specifications will be baselined, procurement activities will accelerate, and the technology development effort, associated with the platform thermal and data management systems will continue. Emphasis will also be placed upon maintaining an effective interface with potential users of the Station, thus ensuring that their requirements are adequately accommodated. Prime contractor activities will be argumented by extensive in-house efforts in materials testing and evaluation, systems engineering and integration, product assurance and parts evaluation, and transportation planning. The acquisition of the unique test equipment, payload interface simulators, and other related equipment required to implement and support these in-house efforts will also begin in FY 1988.

Power System

The Space Station will utilize a 20 kHz hybrid power system, with 87.5 kw of power produced by photovoltaic arrays and solar dynamic converters. The polar and co-orbiting platforms will have photovoltaic arrays for power production and batteries for energy storage. The Space Station power system requirements include the design, development, and production of electrical power system hardware and software, the integration, assembly, and checkout of power module elements, the provision of support equipment to other work packages, support to Space Station systems engineering and integration, and launch package integration of power module elements.

The power system effort is directed toward the production of photovoltaic (PV) and solar dynamic (SD) modules, common components for the polar and co-orbiting platform power systems, a power management and distribution subsystem (PMAD) and components, and flight, application and ground support software. Flight, applications, ground support, and test software for the PV and SD modules, the PMAD subsystem, and the platform power systems will be designed, produced, and tested.

The prime contractor's efforts will be directed toward baselining specifications and commencing initial design and purchase activities. Additional activities will include outfitting test cells in preparation for energy storage tests, and preparations for photovoltaic array, PMAD and materials tests.

In FY 1988, the prime activities will commence with program requirements reviews (PRR) for the power system elements. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contract negotiations, source evaluation board actions, etc. PRR's are scheduled to begin three months after the contract start date. During FY 1988, procurement activities will increase, and qualification, fabrication, and testing of some of the PV components will be conducted. Software design and development will also be initiated.

Toward the end of the fiscal year the preliminary design reviews (PDR) for the power system elements will be held. These are held in support of the program PDR, and are intended to ensure that the design approaches and configurations interface properly. The program PDR will result in the authorization to proceed with further design in accordance with the reviewed design approach and interface requirements. Additional activities will essentially be an extension of those activities which commenced in FY 1987, with energy storage, thermal cycle, and power distribution and management tests to be conducted. The Power Systems Facility will be outfitted, and project control and delegated systems engineering and integration activities will be increased.

Operations Capability/Utilization

Operational capability development efforts include the detailed design and development of the hardware and software necessary to outfit the operational facilities, exclusive of those items which are provided under the Constitution of Facilities appropriation. Outfitting of the Space Station Support Center, the Space Station training facilities, and the launch site ground processing facilities are representative of this type of development effort. Another supporting development activity is in the utilization area. This effort builds upon the utilization activity conducted during definition. It includes the development of procedures, tools and equipment to integrate the user fully into the design and operation of the flight and ground systems of the Space Station. User requirements and user selection processes will also be developed.

Management and Integration

Systems Engineering and Integration (SE&I) activities will be managed by the newly established Program Office with support from the Program Support Contractor (PSC). Some effort will be distributed at each major center involved in the Space Station program. The proposals received in response to the request for proposal for the program support contractor are anticipated and a selection is scheduled for the mid-1987 time frame. These efforts include the development of integrated engineering models of the Station, the continuation of trade studies on resource allocation by element, the allocation of requirements among program elements, and the establishment of design requirements. Key system level schedules and documentation will be expanded and maintained, systems level assembly and check out logic will be refined, and systems level verification requirements and procedures will be established.

Data management and information systems efforts include the Technical and Management Information System (TMIS) and the Software Support Environment (SSE) which are the initial elements of the Space Station Information System. TMIS is an integrated system of technical and management processes, automatic data processing hardware and software, communications networks, and procedures supporting the design and development, as well as the operations of the Space Station. Award of the TMIS development contract is expected in mid-FY 1987 and the first increment of the system is scheduled to be in place by the end of FY 1987 to support the early development efforts of the program. The system will be designed incrementally to allow for advances in state-of-the-art technologies. This approach will also allow for requirements to be accommodated as they become known in lieu of replacement of obsolete hardware, software, and processes. The SSE will provide the infrastructure for the development of common applications software required for flight and ground systems. Planned activities include the completion of the requirements analysis effort, the completion of the software productive facility preliminary design document, the completion of the facility contract end item list, and bringing the facility on-line to support the preliminary and critical design reviews.

Safety, reliability, and quality assurance activities will be emphasised for development, and operations. Early emphasis will be on the development of criteria to perform critical reviews of station design for safety issues at the black box and system level, application of the criteria to assess the safety of the proposed design during the preliminary design review, and establishment of quality assurance standards. Program support activities will provide management, technical, and institutional support from the individual centers necessary to sustain the development activities of the Space Station.

Flight Telerobotic System

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Flight telerobotic system:	
Estimated Fiscal Year 1987	$20,000,000
Authorization Fiscal Year 1988	22,000,000

The Flight Telerobotic System (FTS) will be a highly automated telerobotic device capable of precise manipulations in space. It will operate with a mix of remote and supervisory controls by astronauts and will be used to assist in assembly and servicing operations. The FTS will improve the efficiency and safety of Space Station related operations. Initially intended for relatively simple tasks, the FTS capabilities will evolve over time to accommodate increasingly sophisticated operations for wide application in space as well as the technology application on the ground.

The FTS program is structured to provide a flight telerobotic system with phased capabilities based on assembly, servicing, and maintenance needs, to support the Station launch and operations schedules. In FY 1987, a definition and preliminary design effort with multiple contracts will be pursued. Work was also begun on the design of both the flight and ground systems that will support the FTS program and the definition of requirements for the flight demonstration. The integration of NASA-developed technology from the Office of Aeronautics and Space Technology is being reviewed for possible FTS applications.

In FY 1988, the definition and preliminary design contracts will continue. These contracts will culminate in the selection of a preliminary design for the FTS which will be developed by a single contractor. Work will continue in the design of the flight and ground systems and the requirements definition for the flight demonstration. Current plans are to have it available for flight on the second assembly launch of the Space Station. A Shuttle flight demonstration of the FTS will precede the second assembly launch and will be conducted in the early 1990's.

Operations Definition

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Operations definition:	
Estimated Fiscal Year 1987	0
Authorization Fiscal Year 1988	$7,000,000

Operations definition funding begins in FY 1988 and builds on the work initiated in the definition phase of the program. It includes a variety of operations-oriented study activities that are required to support the development of flight hardware and operational facilities. The key FY 1988 operations activities will be in the integrated logistics arena. Logistics requirements must be defined early in the development phase and factored into the work package and KSC detailed design and development efforts to ensure an efficient design and reasonable life cycle costs. Other activities in FY 1988 include studies of automation and robotics applications for operations, and other studies that may be recommended by the Space Station Operations Task Force.

Transition Definition

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Transition definition:	
Estimated Fiscal Year 1987	0
Authorization Fiscal Year 1988	$5,000,000

In order to assure that the initial Station design will facilitate evolution to greater capacities and capabilities to accommodate users, transition definition efforts must be conducted in parallel with the development phase. With a start in FY 1988, the transition definition program will provide the minimum lead time required to demonstrate major new technologies prior to being incorporated into the Space Station System, thereby avoiding decisions based on conceptual studies with no substantive engineering data as support.

The transition definition initiative encompasses evolution and transition technology definition studies. The definition studies: include mission and systems analyses to define Station evolution requirements; operations analyses to establish growth modes that will optimize user accommodations; and technology forecasts that will enable upgrades to increase the efficiency and productivity of the Station. The studies will provide a knowledge base to allow the Space Station Program to respond to new requirements as they develop as well as to enhance accommodations of current user requirements.

2. SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

NASA REQUEST, $568,600,000

AUTHORIZATION, $538,600,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacelab	$73,900,000	$73,500,000
Upper stages	160,500,000	159,700,000
Engineering and technical base	133,400,000	139,800,000
Payload operations and support equipment	44,500,000	73,400,000
Advanced programs	27,600,000	24,900,000
Tethered satellite system	10,600,000	7,300,000
Orbital maneuvering vehicle	45,000,000	60,000,000
Total	495,500,000	$538,600,000

A reduction of $20,000,000 was made in the funds requested by NASA for the Orbital Maneuvering Vehicle. These reductions would provide a slip in the schedule for this program that are consistent with the launch delays being experienced by the spacecraft (such as the Space Telescope) that will utilize the OMV.

In adopting the reduction from the request level in development funds for the Orbital Maneuvering Vehicle, the Committee recognizes that a delay in delivery of 4 to 6 months and a potential increase in total cost may accrue. These program impacts are undesirable and the Committee does not intend that such actions signal any lack of support for this program. Due to the delay in resuming Shuttle flight activity in 1988, it is likely that the Space Telescope, which is the first flight requirement for the OMV, may be delayed by up to eight months. Thus, the delay in OMV delivery date can be accommodated. The Committee recognizes, however, that a variety of factors related to Shuttle performance and solar cycle variability may lead to an earlier requirement than has been projected. The Committee urges NASA to develop contingency plans for alternative reboost and servicing scenarios.

The principle 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 of the Orbital Maneuvering Vehicle.

Spacelab is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The development program which has been carried out jointly by NASA and the European Space Agency (ESA) continues with the procurement of hardware for the Hitchhiker System, the Spacelab Pallet System, the Space Technology Experiment Platform and the lay-in of spares to support the flight program. Operational missions for the next few flights include a number of Spacelab module and Spacelab Pallet System missions.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle 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 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 (MFSC), and the National Space Technology Laboratories (NSTL) for research and development activities.

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.

The Advanced Programs effort identifies potential future space initiatives and provides technical as well as programmatic data for their definition and evaluation. Activity is focused on six major areas: advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Advanced development activities are conducted to provide a basis for obtaining significant performance and reliability improvements and reducing future program risks and development costs through the effective use of new technology. Extensive studies are being conducted jointly with DOD on future launch vehicle requirements.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reuseable 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.

The first Spacelab reimbursable flight, Deutchland-1 (D-1), was successfully flown during the first quarter of FY 1986 and the first GSFC Spacelab Hitchhiker was successfully flown in the second quarter of FY 1986. In FY 1986, preparations were completed for the Spacelab Astro-1 mission that was scheduled for March 1986. This mission would have been the first Igloo Pallet Configuration of the Spacelab Pallet System (SPS). This mission has been rescheduled for the first quarter of 1989.

The balance of the hardware for the Dedicated Discipline Laboratory, the Spacelab Pallet System, the Space Technology Experiment Platform, and the Hitchhiker system is being procured.

In Upper Stages the commercially developed Payload Assist Modules (PAM) provide low cost transportation from the Shuttle's low Earth orbit. The Delta class PAM-D is capable of injecting up to 2,750 pound payloads into geosynchronous transfer orbit. The PAM-DII is capable of placing a 4,100 pound payload into geosynchronous transfer orbit and was used for the first time in launching an RCA payload for STS 61B in November 1985. The Atlas-Centaur class PAM-A is capable of inserting 4,400 pound payloads into the same orbit and was system-qualified in late 1984. Forty PAM's have been launched on the Delta, Atlas, and Space Shuttle. There have been 20 consecutive successful PAM missions.

The Inertial Upper Stage (IUS) was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The FY 1988 Budget includes funds for production, launch, flight support, and integration costs for vehicles to accommodate the TDRS C, D, E and F missions, and the Galileo, Ulysses (including a PAM-S vehicle), and Magellan planetary missions.

The Transfer Orbit Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use in the Shuttle or on Titan. It will have the capability of placing 6,000 to 13,000 pounds into geosynchronous transfer orbit. The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage which has completed preliminary design and is under consideration for commercial development by Orbital Sciences Corporation for use in the Shuttle. It will have the capability to place 5,200 pound payloads into geosynchronous transfer orbits when used alone or 6,500 pounds into geosynchronous orbit when combined with a TOS. Production of a TOS vehicle for the Mars Observer mission and an AMS for the Global Geospace Science mission is included in the FY 1988 budget.

The Solid Rocket Motor Integrity Program objectives are to provide confidence in existing flight systems, and to generate an urgently needed engineering data base for design, analysis, and testing of solid rocket motor components. The 19 contracts in 11 states have made excellent progress in determining root causes of persistent problems plaguing motor nozzles and the results are contributing to the Shuttle Solid Rocket Motor redesign effort. Investigation of other motor components in addition to the nozzle is being considered.

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 six major areas—advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Advanced planning and analysis efforts will be increasingly focused on long range manned mission options in and beyond Earth orbit. Satellite servicing systems will continue definition and advanced development work in remote and proximity operations. Continued efforts will be made in the areas of platform systems and servicing and advanced tether applications. Advanced transportation concepts will be studied, including orbit transfer vehicles (OTV's), propellant management, advanced launch vehicles, and advanced STS analytical tools. The joint NASA/DOD studies of future launch vehicle requirements will be continued. Systems supporting human presence in space as well as generic work in space structures, orbital debris management and retrieval, and artificial intelligence applications will be investigated.

The Tethered Satellite System (TSS) hardware development was initiated in FY 1984 following the completion of an advanced development phase initiated in FY 1983. 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 and a cooperative first flight is presently scheduled for 1990.

The Orbital Maneuvering Vehicle (OMV) completed early study and feasibility efforts in FY 1985. FY 1986 was devoted to phase C/D RFP/SEB activities. The Administrator selected TRW as the OMV contractor and negotiations were completed in FY 1986. TRW was given authority to proceed on October 1, 1986, with contract award in December 1986. The OMV will be 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. Based on current planning, this capability will be available for use with the STS in 1991.

SPACELAB

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Development	$21,100,000	$14,400,000
Operations	52,800,000	59,100,000
Total	73,900,000	73,500,000

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 reusable 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 components; consisting of a pressurized module and unpressurized pallet segments, igloo, command and data management subsystem, environment control subsystem, power distribution systems, instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

Additional hardware to complete the Spacelab system is in the Spacelab development budget, including such major elements as the crew ground support equipment, hardware modifications, system recertification and a training simulator. Support software and procedures development, testing, and training activities not provided by ESA, which are required to demonstrate the operational capability of Spacelab, are also included in NASA's funding. NASA has procured an additional Spacelab unit from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. Additional Spacelab hardware including the initial lay-in of spare 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 near completion.

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, 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, planned for observation of Halley's comet, was delayed to 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 1987. Operation of the depot maintenance program for U.S.-provided and European-supplied hardware and the procurement of replenishment spares will continue in FY 1987.

The FY 1988 development funds are required to complete the Hitchhiker and STEP programs, complete the lay-in of both U.S. and European source spares, and to make the necessary hardware and GSE modifications and upgrades for return-to-flight recertifications as recommended by the Rogers' Commission, in preparation for re-flight in 1989.

The FY 1988 operations program reflects significant restructuring and rescheduling of Spacelab missions resulting from the Challenger accident. 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 the Materials Science Laboratory (MSL–3 and MSL–4) and two to three Hitchhiker systems in FY 1989 and the first Spacelab Life Science Laboratory (SLS–1), the International Microgravity Laboratory (IML–1), MSL–5, and four Hitchhiker systems in FY 1990. The support for these missions includes analytical integration, configuration management, hardware integration and software development and integration. Funding is also included to operate and maintain the MSFC and JSC Payload Operations Control Centers (POCC) required to support the Spacelab manifest. 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 1988 request also reflects significant program restructuring and rescheduling of Spacelab missions resulting from the standdown of the Shuttle. The current program provides for launching one to two major Spacelab missions per year beginning in 1989 as compared to three to four missions planned previously.

In addition to these NASA missions Spacelab reimbursable missions are scheduled to support DOD, Germany (D–2) and Japan (J).

Upper Stages

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Development	$14,200,000	$17,100,000
Procurement and operations	146,300,000	142,600,000
Total	160,500,000	159,700,000

The STS upper stages are required to deploy Shuttle-launched payloads to orbits not attainable by the Shuttle 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 on the STS. Several other upper stages now being commercially developed, including the Transfer Orbit Stage (TOS), will become available for use with the STS.

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 first IUS was successfully launched in October 1982 on a Titan 34–D booster. The first IUS/STS launch in April 1983 carried the TDRS–1 spacecraft. The IUS failed to operate nominally during the second stage boost. The IUS anomalies were resolved by joint USAF/NASA action, and the DOD/NASA/Industry Anomaly Investigating Team determined that the IUS was again ready for flight. The IUS operated nominally when deployed from STS–51C in January 1985. The second IUS/TDRS was lost during the Challenger accident. Four IUS vehicles were procured by NASA for launch of the initial four Tracking and Data Relay Satellite System spacecraft; the first three were funded through the TDRSS contract while the fourth is funded under this budget element.

The objective of the PAM program is to provide low cost transportation from the Shuttle's low Earth orbit to geosynchronous transfer orbit. The Delta class PAM–D is capable of injecting up to 2,750 pound payloads into geosynchronous transfer orbit. The PAM–DII was developed commercially and is capable of injecting 4,100 pound payloads into geosynchronous transfer orbit. Its first mission, on STS–61B in November 1985, deployed an RCA satellite. The Atlas-Centaur class (PAM–A) is capable of inserting 4,400 pound payloads into the same orbit. PAM's are being developed commercially, but NASA monitors the development and production to assure that the PAM is technically adequate and will be available when needed. Forty PAM's have been lauched on the Delta, Atlas, and Shuttle with 20 consecutive successes.

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 vehicle is being procured for the Mars Observer mission and FY 1987 funding is included to procure a second TOS for the ACTS mission. The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage that has completed preliminary design with development under consideration for initiation in 1987. The AMS will also be developed commercially by the Orbital Sciences Corporation for use with the Shuttle. It will have the capability to place a 5200 pound payload into geosynchronous transfer orbit when used alone or 6500 pounds into geosynchronous orbit when combined with TOS. The Global Geospace Science mission will require three PAM–D and one AMS class upper stages.

The solid rocket motor 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. Motor testing will be conducted to verify analyses and create an engineering data base. The results of this program are contributing to the redesign of the Shuttle Solid Rocket Motor.

Production and operations funds in FY 1988 are required to continue production of three IUS's and one PAM-S vehicle to support the Galileo, Ulysses and Magellan missions, and upper stages for the Mars Observer, TDRSS-E and TDRSS-F Missions. Monitoring of the PAM-D, PAM-DII and TOS programs will continue. Funds are also required to support continuation of the solid rocket motor integrity program. Consistent with the FY 1987 recission request submitted by the President, funding for the upper stage for ACTS has not been provided in FY 1988. Funding starts in FY 1988 on four upper stages, three PAM-D class and one AMS class, for the Global Geospace Science Missions.

Engineering and Technical Base

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Research and test support	$67,400,000	$72,500,000
Data systems and flight support	22,600,000	26,100,000
Operations support	38,600,000	36,100,000
Lauch system support	4,800,000	5,100,000
Total	133,400,000	139,800,000

The Engineering and Technical Base (ETB) provides the core capability required to sustain an engineering and development base for various NASA programs at the manned space flight centers. Additional center program support requirements above the core level are funded by the benefiting programs, such as Shuttle Operations and Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Fight 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. The funding for center operations base support is split between the ETB and Shuttle Operations budget elements in accordance with the principle that ETB will provide the core level and the benefitting program is responsible for funding additional support requirements. At KSC, due to its operational character, the core level provides for future studies and ground systems research and development. 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, including security.

The requested funding for the ETB in FY 1988 provides for a continuation of the FY 1987 level of support for institutional research and development facilities and services at the centers.

In research and test support, effort will be continued to provide increased computation capabilities at MSFC for engineering and science projects through the acquisition 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. Safety, reliability and quality assurance activities will also be provided.

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 technical facilities and equipment, chemical cleaning, engineering design, technical documentation and analysis, telecommunications, component fabrication, photographic support, and logistics support. Examples of specific services to be provided in FY 1988 include: (1) operation and maintenance of specialized electrical and cryogenic systems, and maintenance of test area cranes; (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) photographic services, including still and motion picture processing, and audio-visual mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; (6) technical documentation services, telecommunications, and graphics; (7) technical services in support of center operations including receipt, storage, and issue of research and development supplies and equipment and transportation services; and (8) management services in support of center operations, including data management, microfilming, and preparation of technical documentation. In addition, FY 1988 funds will provide a basic level of institutional support at NSTL for continuing main engine testing activities.

In Launch Systems Support, funds are required to continue work in the development of beneficial application of new technology to the solution of operational problems and development of improved operational capabilities for launch site hardware, ground processing and support systems.

Payload Operations and Support Equipment

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Payload operations	$37,000,000	$68,300,000
Payload support equipment	7,500,000	15,100,000

	Estimated fiscal year 1987	Authorization fiscal year 1988
General reduction		10,000,000
Total	44,500,000	73,400,000

The Payload Operations and Support Equipment objectives are to centralize the provisioning of payload services, both unique and common, which are required beyond the basic 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 reusable 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 payloan services for currently scheduled NASA launches. As a result of the Challenger accident and the decision to cancel the Centaur program for planetary launches, there have been major changes in payload integration requirements. Major NASA payloads receiving support during this year include Hubble Space Telescope, Galileo, Ulysses, Magellan, Astro, and Tracking and Date Relay Satellites (TDRS). The change to IUS upper stages for the planetary launches of Galileo, Ulysses and Magellan require substantial new integration. The significant change in launch dates for all NASA payloads will require a thorough reassessment of the payload integration into the Shuttle. 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. These demonstrations will provide the experience necessary for realization of the Shuttle's potential for satellite servicing missions and on-orbit assembly functions.

Payload support equipment estimates reflect the requirement to modify and upgrade selected payload integration facilities for safer, more efficient operations. FY 1988 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 1987 AND 1988 FUNDING LEVELS

Advanced programs:	
Estimated fiscal year 1987	$27,600,000
Authorization fiscal year 1988	24,900,000

Advanced Program's principal objectives are to conduct mission requirements analyses, conceptual system definition, detailed system definition, and advanced supporting developments to acquire the technical and programmatic data for the evaluation of new space flight initiatives. Future space program and systems requirements, configurations, costs, and capabilities are identified to provide the basis for development decisions on new space flight systems. Past program efforts have provided such information for new major Agency programs and systems including Apollo, Skylab, the Space Transportation System and Space Station. Subsystem studies and advanced and supporting development efforts are conducted to demonstrate the required performance and reliability. Improvements to reduce future systems program cost and schedule risks while increasing performance will also be investigated.

In FY 1987, the Advanced Programs effort is focused in six major areas—advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Definition studies as well as advanced development efforts are being continued in the areas of satellite servicing systems, manned extravehicular activity, spacecraft and platform resupply, maintenance and repair, rendezvous and proximity operations, satellite maintenance and repair in low and geostationary Earth orbit, and autonomous capabilities. In spacecraft systems, definition activities continue for free flying and tethered space platforms in low and geostationary orbits operating from the Shuttle. Advanced transportation studies are focused on study of potential future reusable orbit transfer vehicles (OTV), space-based operations of OTV's, competitive aeroassist braking techniques for OTV, Shuttle-derived launch vehicle concepts, propellant scavenging, and aft cargo carrier concepts. Crew systems efforts will focus on definition and advanced development related to future space flight systems. Generic space system capabilities will include studies related to space debris. Preliminary definition and ground simulation evaluations of assembly and construction operations for large space systems and orbital structures will be pursued.

NASA, in conjunction with the DOD, is investigating future space transportation and operational support requirements including heavy lift launch capability and associated advanced technology. These studies were initiated during FY 1986 to identify the necessary requirements and supporting technologies for future space transportation systems. Studies, definition, and a limited amount of advanced development effort will be devoted to key subsystems for a Shuttle-derived Heavy Lift Launch Vehicle (HLLV). Preliminary studies have already been initiated for engines, precision recovery devices, propulsion/avionics modules, advanced structures, avionics and other contributory technologies.

The objective of efforts to be initiated in the advanced manned mission area will be the planning and analysis of potential follow-on programs to exploit the STS and the Space Station. Integrated program options involving low Earth orbit, geostationary orbit, lunar and planetary missions will be investigated, with the multi-year purpose to develop goals, planning information, and infrastructure requirements.

In FY 1988, major emphasis will be placed on system concept definition and key advanced technology in crew systems, geostationary Earth orbital unmanned platforms, reusable OTV's, new capability mission kits for orbital maneuvering vehicles, future tethered systems applications, satellite servicing systems near and remote from the orbiter, and second generation shuttles. A major goal continues to be the conceptual definition of the systems architecture and space elements needed for space operations over the next twenty years.

The satellite servicing program element will continue to explore effective manned servicing concepts to extend STS operational capability for Earth orbit support of spacecraft, platforms, and constellation aggregates. The spacecraft systems program element will focus on geostationary platform capability, definition and delineation of critical mechanisms, and designs which require advanced development efforts. Detailed engineering systems analysis will be continued to determine the efficiency of future tethered platform applications. Second generation shuttle concept studies and advanced developments will continue. In the crew systems area, new life support system concepts and advanced developments will continue focusing on post-Space Station era manned missions. Also, in the crew systems area, new capabilities for EVA will be pursued. Generic studies regarding orbital debris, large structures, and system applications will be continued. Advanced manned missions beyond the Space Station will continue to be studied with expanded scope and increased depth. Studies will be conducted to identify potential lunar/Mars missions and their potential demands on the STS.

Tethered Satellite System

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Tethered satellite system:	
Estimated fiscal year 1987	$10,600,000
Authorization fiscal year 1988	7,300,000

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 mechansim. 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 1988 funding of $7.3 million reflects a phase down of the hardware design and development consistent with a delay in the engineering verification flight from 1988 to 1990 caused by the Challenger accident. Current plans call for completion of hardware assembly in FY 1987 and delay in systems qualification until FY 1989. Contractor manpower levels will be minimized consistent with science and Italian interface requirements. Late FY 1988 will see the start of preparations for completion of deployer qualifications efforts. Mission Operation Planning and Dynamic Simulations of on-orbit tethered satellite operations are planned to continue throughout FY 1988.

Orbital Maneuvering Vehicle

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Orbital maneuvering vehicle:	
Estimated fiscal year 1987	$45,000,000
Authorization fiscal year 1988	60,000,000

The Orbital Maneuvering Vehicle (OMV) will provide a new STS reusable 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 spacebaseable resuable 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 of satellite to original operational altitudes or higher; delivery of 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.

3. PHYSICS AND ASTRONOMY

AUTHORIZATION, $577,100,000

NASA REQUEST, $567,100,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Hubble space telescope development	$101,300,000	$98,400,000
Gamma ray observatory development	50,500,000	49,100,000
Spacelab/Space Station payload development and mission management	90,100,000	95,400,000
Explorer development	56,700,000	70,300,000
Mission operation and data analysis	125,700,000	128,100,000
Research and analysis	53,400,000	60,100,000
Suborbital program	75,100,000	75,700,000
Total	552,800,000	577,100,000

The objectives of the Physics and Astronomy program are to increase understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. The objects under study include the most distant clusters and galaxies, stars and structures in nearby galaxies, and the interstellar medium in our galaxy. The most unusual and exotic phenomena exhibited as quasars, black holes, neutron stars, and pulsars are of particular interest. We also include our own Sun, with its multitude of time varying phenomena at all scales of spatial resolution. Space research allows observations in wavelength regions, such as the infrared, ultraviolet, or x-rays and gamma rays, which are absorbed by the earth's atmosphere; or in the visible region, where ground based work is limited by atmospheric distorting effects. We also couple these observations to those of cosmic ray particles, which have their origin in energetic acceleration processes occurring in sites such as solar flares and supernovae.

The objectives of the program are accomplished with a mixture of large, complex free flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights, retrievable Spartans, and suborbital opportunities. The latter include balloons, aircraft, and sounding rocket flights. In the future, the Space Station will provide an opportunity for both attached payloads and major free-flying observatories requiring assembly, maintenance, and refurbishment on-orbit. 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 Physics and Astronomy missions undertaken to date have been extraordinarily successful. Recently, these include the High Energy Astronomical Observatories (HEAO, 1977–1979), the International Ultraviolet Explorer (IUE, 1978), the Solar Maximum Mission (SMM, 1980) and the Infrared Astronomy Satellite (IRAS, 1983). The IUE and the SMM are still operating, and new scientific results are continually emerging from these, as well as the high quality data sets archieved from the HEAO's and the IRAS.

The Hubble Space Telescope, to be launched by the Space shuttle in late 1988, 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 special features by a factor of ten better than the typical ground based optical telescope, and will observe the universe at approximtely 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 as the origin, evolution, and disposition of galaxies, quasers, 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, supernovae, and the nature of the mysterious cosmic gamma-ray bursts.

Definition studies of the advanced technology will continue on the other observatories, i.e. the Advanced X-Ray Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). The AXAF will provide a capability some 10 times more sensitive than the HEAO-2 to understand the multi-million degree thermal and non-thermal processes which occur in quasars, clusters of galaxies, supernovae remnants, binary stellar systems involving compact objects, and stellar corona. Many of these objects are end points of cosmic evolutionary cycles. SIRTF, on the other hand, will 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 the most distant ones.

The Explorer program, since the inception of the U.S. space 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 at over a million degrees, which the IRAS, a joint U.S./U.K./Netherlands project, has detected and cataloged over 300,000 sources on the sky, and has shown star formation in other galaxies is a more prevalent and important activity than previously thought. At least one quaser has been shown to have its dominant energy release in the infrared spectral region. Since the IRAS completed operations in late 1983, these discoveries have come from analysis of archieval data, and many more results can be expected.

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 the Combined Released and Radiation Effects (CRRES) experiment for flight in 1992 on a Department of Defense spacecraft. Finally, we have concluded the selection of a U.S. team which will participate in the Japanese Solar-A mission (an explorer 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 involvement in the Shuttle/Spacelab program will continue, with the flight of the Astro-1, a set of ultra-violet and soft x-ray telescopes and spectrometers, scheduled for 1989. The Astro-1, whose first flight, scheduled to observe Comet Halley in March 1986, was cancelled due to the Challenger accident, will investigate the interstellar medium by following up on discoveries made with the IUE. Many of the investigations originally scheduled for Shuttle/Spacelab opportunities, such as Cosmic-Ray Nuclei Experiment (CRNE), the Heavy Nuclei Collector (HNC), the Shuttle High Energy Astrophysics Lab (SHEAL), and the Spartan program have been cancelled, deferred or rescoped as a consequence of the loss of the Challenger.

During the shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-flying aircraft will take on increased significance. This enhanced effort will provide observations and instrument development opportunities for research groups. Furthermore, activities in the Research and Analysis (R&A) and the mission Operations and Data Analysis (MO&DA) areas will also be augmented in order to maintain this vital reseach base in Physics and Astronomy.

The committee added $10,000,000 to the NASA request to augment the Explorer development.

Hubble Space Telescope Development

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft	$87,600,000	$85,000,000
Experiments	13,700,000	13,400,000
Total	101,300,000	98,400,000

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. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The Hubble Space Telescope design will permit on-orbit maintenance and repair, and/or retrieval by the Space Shuttle for return to Earth for required refurbishment and then relaunch by the Space Shuttle.

During FY 1986, the Hubble Space Telescope (HST) Program completed the series of comprehensive functional and environmental tests that had begun in FY 1985. The test series culminated in a highly successful thermal/vacuum test, which verified performance of the spacecraft, the science instruments, and the HST ground system under simulated orbital conditions. The results of these tests indicate that the flight and ground support elements of the HST system will meet or exceed the scientific performance objectives. The HST was on schedule for an October 1986 launch until the Challenger accident forced a replanning of the program to meet a launch date of November 1988.

After the completion of the thermal/vacuum testing, the scientific and engineering manpower assigned to the HST Program was reduced to the minimum cadre needed to retain the critical skills and knowledge required to sustain the program through FY 1987. During the first half of FY 1987, this reduced level of effort will be used to bring the spacecraft to a final state of launch readiness and to complete functional verification of the ground system, whose development has been stretched out to permit the inclusion of measures to increase the on-orbit efficiency of the HST and provide capabilities originally scheduled for the post-launch period. After a systems validation test, the spacecraft will be retained in environmentally-controlled storage until reactivated for pre-ship preparations. In addition, the program will participate in a Failure Modes and Effects Analysis/Critical Item List re-review as required by the Space Transportation System.

The FY 1988 funding level is required to maintain the irreplaceable skilled experts who have hands-on experience with the spacecraft. During FY 1988, the HST Program will be performing additional safety and spacecraft review work as a consequence of the shuttle accident, as well as returning to the program manning levels needed to support pre-ship functional testing of the HST system, transporting the spacecraft to Kennedy Space Center, and conducting launch preparations and operations at KSC.

GAMMA RAY OBSERVATORY DEVELOPMENT

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft	$34,500,000	$34,100,000
Experiments and ground operations	16,000,000	15,000,000
Total	50,500,000	49,100,000

The Gamma Ray Observatory (GRO) has as its objective the measurement of 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. The 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. Scientific involvement in the GRO cuts across university, government and industry. The international involvement, with a complete Principle 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 represents 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. The orbit selected allows possible refueling through the STS or reboost by the Orbital Maneuvering Vehicle (OMV) to obtain an extended lifetime.

In FY 1986, the detailed design of the spacecraft primary structure was completed at TRW, the prime contractor, and manufacturing and assembly of the structure was initiated. In addition, fabrication and assembly of instrument hardware was continued.

In FY 1987, instrument calibration and testing will continue. Assembly of the spacecraft structure will be completed, electronic manufacturing will continue, and all government furnished property subsystems for GRO will be delivered.

FY 1988 funding is required for completion of the spacecraft modal survey and static load testing. In addition, the fabrication and testing of the spacecraft attitude control and power system electronics will be completed. The development of the GRO mission operations and data systems will be continued 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.

SPACELAB/SPACE STATION PAYLOAD DEVELOPMENT AND MISSION MANAGEMENT

FISCAL YEAR 1987 AND 1988 FUNDING LEVELS

Spacelab/Space Station payload development and mission management:

Estimated fiscal year 1987	$90,100,000
Authorization fiscal year 1988	95,400,000

A primary objective of the Spacelab Payload Development and Mission Management program is to develop instruments used for Shuttle/space flight investigations in the disciplines of physics and astronomy on board the Space Shuttle or Spacelab carriers. These science payloads include sounding rocket class experiments for flight on the Space Shuttle.

A second objective is to initiate the necessary planning, definition and development of payloads and missions as the Office of Space Science and Applications (OSSA) begins its preparations as a future major user of the Space Station complex. This new focus includes the study definition of integration and operational requirements of potential Space Station payloads and missions, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Another major objective is to manage the mission planning, integration, and execution of all NASA Spacelab and attached 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; data dissemination to experimenters, and initial analysis of flight data from physics and astronomy science payloads. Similar mission management activities will be carried out for Space Station payloads as they enter the development phase and interface requirements become well defined.

Instruments are currently under development for several Shuttle/Spacelab missions with primary emphasis on physics and astronomy. Each of these instruments is typically developed by a principal investigator to carry out a specific scientific investigation; several instruments with closely allied or compatible objectives will generally be flown as an integrated mission. In many cases, the principal investigator heads a team of coinvestigators. Investigators are generally members of the university community, but may also represent government or industry research facilities, or foreign cooperative research activities.

Development is essentially complete for the three ultraviolet telescopes and two wide-field cameras to be flown on the Astro-1 mission. This mission is designed to conduct investigations in ultraviolet imaging, spectrophotometry, and polarimetry at very high resolution. It will be able to observe a broad range of objects, from nearby comets and planets to the most distant quasars. This mission is scheduled for flight in early 1989.

Work is proceeding on instruments for the Shuttle High Energy Astrophysics Lab (SHEAL). This mission, planned for flight in 1992, will study the diffuse X-ray background and measure X-ray spectra of point and extended sources.

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 will fly in early 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 Science 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 ongoing 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 of ongoing Spacelab missions will continue in FY 1988. For non-physics and astronomy missions, such as the Spacelab Life Sciences missions (SLS) and the International Microgravity Lab (IML), this includes all spacelab efforts except instrument development and data analysis. Development of instruments will continue for the Space Plasma Lab as well as for the Shuttle High Energy Astrophysics Lab. For the Astro-1 mission, final integration and test activities will resume, in preparation for a planned flight in early 1989. FY 1988 funding will support the continued development of low-cost sounding rocket class payloads which will be flown on the Space Shuttle to provide more flight opportunities for the science community.

In addition, FY 1988 funding is required to continue ongoing Space Station payload development and planning activities. FY 1988 funding will support continued early definition, design and development activities for payloads selected for early Space Station flights. Other planning activities will address concerns or issues that typically cut across OSSA disciplines, and will include continued science operations concept development, information systems concept and architecture studies, servicing studies, platform utilization studies as well as other special systems engineering and integration support studies.

EXPLORER DEVELOPMENT

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Cosmic background explorer	$31,500,000	$16,000,000
Extreme ultraviolet explorer	14,700,000	31,400,000
Roentgen satellite experiments	2,700,000	2,500,000
Combined release and radiation effects satellite	2,200,000	2,200,000
Other Explorers	2,600,000	2,800,000
Solar-A (formerly HESP)	3,000,000	5,400,000
General augmentation		10,000,000
Total	56,700,000	70,300,000

Investigations selected for Explorers are usually of an exploratory or survey nature, or have focused 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 ultraviolet observations.

Recent Explorers have performed active plasma experiments on the magnetosphere, made *in-situ* measurements of the comet Giacobinni-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. These data elements have proven to be some of the most important signatures of the nature of these phenomena. The Explorer program also provides a means of implementing instruments on "target of opportunity" missions, such as those involving international collaboration, or other Federal agencies.

Solar-terrestrial and atmospheric Explorers provide a means for conducting studies of the Earth's near space environment. The International Sun Earth Explorer (ISEE–1977), International Cometary Explorer (ICE–1978), Dynamics Explorer (DE–1981), and Advanced Magnetic Particle Trace Experiment (AMPTE–1984), have provided data on plasmas and fields, near the earth and throughout the interplanetary medium. The ISEE and ICE data sets have directly confirmed, by *in-situ* observation, magnetic merging in space plasmas, as well as several plasma wave instabilities and kinetic effects which cannot be reproduced in the laboratory. The ICE encounter with Comet Giacobinni-Zinner and the AMPTE artificial comet releases late in 1985 prepared the Halley armada for their historic encounters. The IMP-8 satellite, now almost 13 years old, is the only existing monitor for the solar wind as a plasma input to the geospace environment, and provides a near-earth baseline for missions to the other planets.

Astrophysics explorers have been the principal means for conducting the first sky surveys in the gamma ray, X-ray, ultraviolet, infrared, and low frequency radio regions of the electromagnetic spectrum. The IUE (1978) is still operating, and has shown that our Galaxy has an extended hot halo, that the local interstellar medium is much more tranparent and less homogeneous than expected, and determined the spectra of hundreds of hot stars which are losing mass. The IRAS (1983), in nearly a year of operation, performed a complete sky survey over the 10–100 micron region, locating over 300,000 sources. A major discovery is a dust ring around a nearby star, Vega, which is believed to be a proto-planetary nebula. IRAS has also catalogued many new asteroids, discovered properties of star-forming regions in ours as well as external galaxies, and has provided new data on energetics and processes in active galaxies, including quasars.

A number of small or cooperative activities are also included in the Explorer budget. The Heavy Nuclei Collector (HNC), which consists of an array of passive cosmic ray detectors developed for inclusion on the Long Duration Exposure Facility (LDEF), has been cancelled due to budgetary and launch opportunity constraints. Scheduled for launch in 1987 on a Scout expendable launch vehicle, is the San Marco-D mission. A cooperative effort with Italy, 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) is to be completed for inclusion in the Combined Release and Radiation Effects Satellite (CRRES), an Air Force Mission now scheduled for 1992. 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 (formerly High Energy Solar Mission, HESP), 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 be the first simultaneous observations of these phenomena from space.

In FY 1987, 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, a slip of 9 months from the original launch date of July 1988. Funding in FY 1987 will be used to continue development and testing of the three COBE instruments and to redesign the COBE spacecraft to fit on the Delta 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 X-ray imaging instrument being provided by the U.S. will be delivered in the second quarter of FY 1987. Although ROSAT is currently manifested for a 1994 Shuttle launch, a possible launch on an expendable launch vehicle in late 1989 or early 1990 is also under consideration.

Definition and design will continue in FY 1987 on the X-ray Timing Explorer. 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 these will be evaluated in FY 1987, but selection for further study will depend on the availability of future launch opportunities for the Explorer program.

During FY 1988, the reconstruction, integration and test of the COBE spacecraft structure and its instruments will be completed, and the spacecraft will begin pre-launch preparations. The major activity will be on the EUVE development. Activities on ROSAT, and the development of the U.S. instrument for the Japanese Solar-A will also continue.

Mission Operations and Data Analysis

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
High energy astronomy observatory extended mission	$3,800,000	$3,000,000
Solar maximum mission extended mission	8,500,000	9,000,000
Hubble space telescope operations	47,000,000	51,600,000
Hubble space telescope maintenance and refurbishment	45,000,000	42,100,000
Explorers	21,400,000	22,400,000
Total	125,700,000	128,100,000

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 have been achieved, for purposes of conducting specific investigations that have continuing, high scientific significance. The funding suports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and solar terrestrial 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.

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.

The FY 1988 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 first quarter of FY 1989.

Mission operations data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM) and the International Ultraviolet Explorer (IUE). Funding will also continue for the High Energy Astronomical Observatories (HEAO 1-3), and the Infrared Astronomy Satellite (IRAS) data analysis. These programs have produced valuable data sets which are used by a wide segment of the astronomy community.

RESEARCH AND ANALYSIS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Supporting research and technology	$39,800,000	$46,500,000
Advanced technology development	13,600,000	13,600,000
Total	53,400,000	60,100,000

This 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.

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) the continued 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 solar and heliospheric physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. The work in solar and heliospheric physics involves the study of the solar atmosphere, solar flares, and the influence of the Sun on interplanetary phenomena. The theory activities are related to all the Physics and Astronomy disciplines and are critical to the correlation of available information. The SR&T funding will provide for continuation of definition work on Gravity Probe-B. 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.

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 new potential 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 for subsystem/elements critical to enventual mission development in order that technical readiness and resoruces requirements may be adequately defined before the missions are proposed for implementation.

Candidate missions for the 1980s and early 1990s that require ATD activities include the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). The AXAF mission, which is the first priority new mission recommendation in astronomy by the National Academy of Sciences, 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 Specelab 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 1987, major emphasis will be on completing the AXAF definition and deepening the technological and system understanding of science instruments selected for definition. Technological preparation for SIRTF will also continue.

During FY 1988, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for a viable physics and astronomy program. FY 1988 funding will also support continued studies on potential candidate missions such as the Advanced X-ray Astrophysics Facility and the Space Infrared Telescope Facility. In the data analysis activities to be carried out at university and government research centers in FY 1988, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). The Gravity Probe-B activities in FY 1988 are designed to verify the entire GP-B design, leading to confidence in the information necessary to decide the feasibility of progressing into the next phase of design and development activities.

Suborbital Programs

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Sounding rockets	$30,900,000	$32,100,000
Airborne science and applications	31,600,000	30,300,000
Balloon program	7,900,000	8,200,000
Spartan	4,700,000	5,100,000
Total	75,100,000	75,700,000

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 on 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 FY 1987. Included in this number are eight NASA launches in Greenland as a follow-up to the FY 1985 effort. Of significant interest in FY 1986 were two rocket launches to observe Halley's Comet which were recovered, field refurbished, and reflown for a total of four flights. These flights produced some of the data originally planned to be obtained from the Astro-1 Shuttle flight which was postponed as a result of the 51-L accident. An equivalent number of flights is scheduled for FY 1988.

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 observation into the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1986, the C-141 flew 73 science flights to make far-infrared observations, including exploration of the star-forming regions and of other areas in our own galaxy and solar system. An expedition to New Zealand in the spring provided the only detailed study of infrared emissions from Comet Halley as it became visible shortly after perihelion. In FY 1987, about 70 missions are planned, including five flights from Hawaii, and a planned expedition to make celestial observations from the southern hemisphere. FY 1987 activities also include initiation of a study to develop and evaluate alternatives for developing 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, presumably a Boeing 747.

The Airborne Science and Applications program also operates an ER-2, two U-2Cs, and a C-130. In addition, an aircraft has been acquired to replace the CV-990 research facility, "Galileo II", which was destroyed in 1985. The replacement, a DC-8, is undergoing modifications and is expected to be ready for science operations in late 1987. Acquisition of a second ER-2, to replace the aging U-2Cs is under way. These aircraft support other major segments of the Space Science and Applications programs 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-2Cs acquire stratospheric air samples and conduct *in-situ* measurements at altitude ranges above the capability of more conventional aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

Balloon programs.—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 3500 pounds, and to realize 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. Six Spartan missions are currently under development, each with a different scientific instrument. 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, manifested for FY 1991, will consist 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.

FY 1988 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 for potential long-duration balloon flights. In FY 1988, the Airborne Science and Applications funding will be used to continue flights of the Kuiper Airborne Observatory. Requested FY 1988 funding will allow operation of the DC-8, the ER-2's, and the C-130. Operation of these aircraft will allow continuation of airborne infrared astronomy exploration, collection and analysis of stratospheric air samples, testing of newly developed instrumentation, and the demonstration of new sensor concepts.

4. LIFE SCIENCES PROGRAM

NASA REQUEST, $74,600,000

AUTHORIZATION, $74,600,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Life sciences flight experiments	$30,400,000	$32,900,000
Research and analysis	41,800,000	41,700,000
Total	72,200,000	74,600,000

The Committee adopted the request level for the Life Sciences program. The Committee recognizes, however, that the development of plans for research on the Space Station and the recent signing of an agreement with the Soviet Union for cooperation in the exploration and use of outer space for peaceful purposes must necessarily be reflected in future budget requirements. The Committee considers the life sciences to be an integral part of any planning for future initiatives in manned exploration.

The goals of the Life Sciences program are to provide a sound scientific, medical, and technical basis for safe and effective manned space flight, and to advance the understanding of the basic mechanisms of biological processes by using the unique capabilities of the space program. Results from the research program are applied to: the immediate needs in the maintenance and health of the astronauts; understanding biological mechanisms and the response of biological systems to weightlessness; the design of the advanced life support systems for use on future missions; and understanding the biosphere of the planet Earth, as well as the origin, evolution, and distribution of life in the universe.

The Life Sciences program is the key to developing a capability to sustain a permanent manned presence in space and to utilize the space environment to study living systems. These activities include both ground-based and space research efforts which are mutually supportive and integrated, and use a composite of disciplines and techniques in both biology and medicine to address space-related medical problems and fundamental biological processes.

The Life Sciences Research and Analysis program includes five major elements: (1) space medicine, which is focused on the health and well-being of space crews by understanding and preventing any adverse physiological changes which occur in space flight and upon return to Earth; (2) advanced life support systems, which is a program of research and technology development for life support systems necessary to maintain life in space autonomously for long periods of time; (3) gravitational biology, which consists of flight and ground-based experiments that focus on using microgravity as a biological research tool to understand basic mechanisms of the effects of microgravity on plants and animals; (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 is directed toward understanding the interaction between life on Earth and its physical and chemical environment.

The goals of the Space Medicine program are to assure space crew members' health and ability to function effectively in the space environment. In the future, experience gained from medical operations in space flight will allow a broader segment of the population to participate in all aspects of space missions. Particular emphasis is being placed on testing countermeasures designed to prevent physiological problems associated with exposure to the space environment. It is essential that long-term monitoring of space flight crews be performed in a standardized and organized fashion in order to develop risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. In addition, biomedical research is designed to understand the physiological basis for problems encountered in manned space flight. Areas of emphasis include: vestibular dysfunction, cardiovascular deconditioning, immunology, bone and muscle loss, and radiation damage. This research concentrates on trying to define potential flight protocols and countermeasures, first as space flight experiments and ultimately on an operational basis.

The Advanced Life Support System program seeks ways to develop technologies for more efficient life support systems for the space program. It also undertakes the scientific work in chemistry and biology necessary to understand how life can be maintained in closed systems which receive only energy from the external environment. All are aimed at potential future needs of long duration manned space flight and lunar colonization.

The goals of the Gravitational Biology program are to further our understanding of basic physiological mechanisms and the effects of microgravity on plants and animals through the use of the space environment. Research, which includes both ground-based and space flight experiments, is focused on clarifying gravity-sensing systems; the effects of microgravity on reproduction, development, physiology, and behavior; and gravity's influence on the evolution of life on Earth. These studies are aimed at providing information essential to the long-term survival of plants and animals in space as well as an understanding of gravity's past and present effect on life.

The Exobiology efforts are concentrated on studies of life's origin, with particular emphasis on developing sound hypotheses which could lead to discovering the relationships which may link the formation of the solar system and the origin of life. Ground-based research on model systems and analysis of extraterrestrial materials, coupled with the results of planetary flight experiments, are clarifying the mechanisms and environments responsible for the chemical evolution leading to life's origin. Studies of life's origin and evolution will be extended to enhance our understanding of the interaction of the biota with the Earth's present environment, and thereby provide a more comprehensive picture of life—its past, present, and future.

The Biospherics Research Program seeks to utilize NASA technology in remote sensing, combined with ground-based research and mathematical modeling, to study the biosphere (the thin layer around the Planet that contains all of terrestrial life). The goal of the program is to understand the structure and function of the biosphere in order to understand how global biological processes and planetary properties modify and modulate one another. Knowledge of these interactions will ultimately allow predictions of how the habitability of the Earth can be affected by human activities or natural phenomena.

Life Sciences Flight Experiments

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Life sciences flight experiments:	
Estimated fiscal year 1987	$30,400,000
Authorization fiscal year 1988	32,900,000

The objective of the Life Sciences Flight Experiments program is to assimilate information and scientific questions from the various life sciences disciplines and translate them into payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation to weightlessness. The program includes selection, definition, inflight execution, data analysis, and reporting on medical and biological investigations involving humans, animals and plants. Past experience indicates that humans clearly undergo physiological changes in weightlessness. Thus far these changes appear to be reversible upon return to Earth, however, many of the observed changes are physiologically significant and are not well understood. With weightless exposure beyond several months, these changes may prove irreversible. Shuttle/Space lab missions are suitable for gaining a greater understanding of the early response to weightlessness, which will improve the management of several existing problems (e.g., space adaptation syndrome) and will enhance the confidence of estimating the physiological consequences of more sustained weightless exposure (e.g. Space Station).

Current activities include the development of life sciences flight experiments to be flown on the first dedicated Life Sciences mission (Space Life Sciences-1 (SLS–1)) which is scheduled for late 1989 and will concentrate on human investigations. Many of the experiments and associated flight hardware flown on earlier Shuttle flights have supported and enhanced the preparations for SLS–1 and subsequent missions. In addition, experiment development activities are currently underway to support the flight of the first International Microgravity Laboratory-1 (IML–1) mission in early 1990. Human vestibular experiments, plant investigations, and animal support hardware test and checkout are planned.

The investigations planned for SLS–1 and IML–1 explore the known problems of manned space flight through the use of both human and animal subjects, and also include key investigations in gravitational biology. Principal investigators will examine cardiovascular adaptation, space adaptation syndrome, muscle atrophy, bone demineralization, early anemia in weightlessness, and the effects of weightlessness on plant and animal development. The SLS–1 mission will be unique in several respects: it will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space.

In addition to the preparation and flight of previously selected experiments, increasing activity and emphasis will be directed towards the study and definition of experiments which can be conducted on the Space Station.

FY 1988 funding is required for the final preparation and flight of approved experiments and the continued definition and development of new experiments and hardware that will be flown on future Spacelab/Shuttle missions—i.e., Shuttle middecks, Japanese-J mission, the second dedicated life sciences mission (SLS-2), German D-2 mission, IML-2, and SLS-3. The selection of new experiments through the Announcement of Opportunity (AO) process is continuing. In addition, increasing activities are planned to support the development of Space Station Life Sciences experiments.

Research and Analysis

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Life sciences research and analysis:	
Estimated fiscal year 1987	$41,800,000
Authorization fiscal year 1988	41,700,000

The Life Sciences Research and Analysis program is concerned with ground-based and pre-flight research in basic biology and in those medical problem areas that affect manned spaceflight. The program is comprised of five elements: (1) space medicine; (2) advanced life support systems research; (3) gravitational biology; (4) exobiology; and (5) biospheric research.

The Life Sciences Space Medicine program is responsible for bringing the technology and practice of medicine to bear on solving the problems of sustaining, supporting, and protecting individuals working in the space environment. The program provides the means for assuring the physical welfare, performance, and adequate treatment of in-flight illnesses or injuries to spaceflight crews. Such conditions as spatial disorientation, fluid shifts and endocrine changes which can decrease performance, cardiovascular tolerance, and possibly aggravate latent diseases, will be carefully evaluated to determine preventive measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the time required for adaptation to the space environment will be continually undertaken. The supporting applied science element of the Space Medicine program is accomplished through a biomedical research program and seeks to develop the basic medical knowledge needed to enable men and women to operate more effectively in space. The program is organized into discrete elements, each designed to rectify a particular physiological problem known or expected to affect the human organism in space. Such problems as motion sickness, bone loss, and electrolyte imbalances are under intense scrutiny not only to provide a better understanding of their underlying causes, but also to develop more effective preventive measures. The program will make extensive use of ground-based simulation techniques which evoke, in both humans and animals, physiological changes similar to those seen in space.

The Advanced Life Support Systems research program concentrates on enhancing our ability to support a long-duration manned presence in space and optimizing the productivity of the Space Transportation System (STS) crews. Improvements are sought in spacecraft habitability and man-machine system engineering methods as well as a means to provide air, water, and food to support life directly. The program has developed technology for building apparatus to regenerate spacecraft air and water supplies in flight and is investigating the scientific basis for new systems such as food recycling for long-term missions. Research is in progress on space suits for quick reaction situations and on innovative approaches to designing space tools and work stations.

The Gravitational Biology program explores the role of gravity in life processes and uses gravity as an environmental tool to investigate fundamental biological questions. Specific objectives are to: (1) investigate and identify the role of gravity in plant and animal behavior, morphology and physiology; (2) identify the mechanisms of gravity sensing and the transmission of this information within both plants and animals; (3) identify the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the development and metabolism of organisms; (4) use gravity to study the normal nature and properties of living organisms; and (5) extend the limits of knowledge about plant and animal growth as well as long-term survival and reproduction in space.

The Exobiology program is directed toward understanding the origin and evolution of life, and life-related molecules, on Earth and throughout the universe. Research encompasses the cosmic history of the biogenic elements, prebiotic chemistry, early evolution of life, and evolution of advanced life. Understanding these processes in the context of the planetary and astrophysical environments in which they occurred will be emphasized. Flight experiments on planetary missions and in Earth orbit 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 the biota and the contemporary environment to develop an understanding of global bio-geochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modeling efforts are focused on integrating biology with atmospheric, climate, oceanic, terrestrial, and bio-geochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

The Space Medicine program will collect information on occupational exposures in zero-gravity on each Shuttle flight and conduct inflight clinical testing of countermeasures, especially in the areas of cardiovascular deconditioning, vestibular problems and muscle atrophy. The program will also develop health care procedures, equipment, and facilities compatible with the space environment. Medical selection standards will continue to be reviewed with an aim of gradually making space flight opportunties available to more of our population. The biomedical research element will begin to expand its research on physiological changes associated with longer exposure to weightlessness. Bone demineralization, muscle atrophy and cardiovascular deconditioning will be studied so that appropriate countermeasures can be devised. At the same time, problems associated with the initial adaptation to weightlessness, such as vestibular dysfunction and fluid shifts, will continue to be vigorously investigated. Furthermore, increased emphasis will be placed on radiation biology so that it will be possible to precisely measure dosages and effects of cosmic and solar radiation. This information will be required to determine the proper radiation shielding of humans in space. The performance and efficiency of flight crews will be emphasized by research in psychology and human factors.

The Advanced Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environments of manned spacecraft, and will continue development of data acquisition systems and computer technologies to analyze and simulate human physical activities. Laboratory plant growth methods developed in recent years will be scaled up to obtain a capability to produce plant material at efficiency and productivity level high enough for space life support applications.

The Gravitational Biology program will focus on expanding the investigation of plant and animal gravity serving systems and gravitational effects on plant and animal reproduction and development. Research which leads to or includes space flight experiments will be emphasized with the objective of resolving discrete biological problems.

The Exobiology program will emphasize the development of new flight experiment concepts to clarify the non-biological mechanisms for the synthesis of biologically significant molecules in space, and completing definition of systems required before a search for extraterrestrial life can be initiated. These concepts will be crucial to our understanding of the origin of life on earth as well as assessing the possibility of these processes occurring elsewhere in the universe.

The Biospheric Research program will place emphasis on improving estimating techniques for determining the functional and structural state of the terrestrial biomass by combining ground-based measurements with remote sensing data. Additional emphasis will be placed on characterizing biogenic gas fluxes of key atmospheric constituents. This information is required for the development of a better understanding of global bio-geochemical cycles.

Emphasis will also be placed on the formulation of improved approaches to the operational management of space adaptation syndrome. In-flight evaluation of these approaches will be conducted to provide the basis for the development of more effective countermeasures. There will be an expanded interdisciplinary approach to determining how to enhance the capabilities, performance, and efficiency of spaceflight crews. The object of this effort will be to allow humans, to the fullest extent possible, the opportunity to explore and work in space by improving the working environment and by facilitation of the human interaction with the automated devices that can be placed at their disposal.

5. PLANETARY EXPLORATION PROGRAM

NASA REQUEST, $307,300,000

AUTHORIZATION, $342,300,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Galileo development	$71,200,000	$55,300,000
Magellan	92,600,000	59,600,000
Ulysses	10,300,000	10,800,000
Mars Observer	35,800,000	64,300,000
Mission operations and data analysis	80,000,000	77,000,000
Research and analysis	68,500,000	75,300,000
Total	358,400,000	342,300,000

The Committee added $35,000,000 to the NASA request to accelerate the development of the Mars Observer so that it can be launched in 1992, on an expendable launch vehicle.

The Committee has also directed that, within the planetary exploration program, $64,000,000 may be used only for the planetary observer program. This program, as recommended by the Solar System Exploration Committee, is intended to provide low cost continuous planetary exploration flight opportunities by establishing a series of missions based on high inheritance spacecraft and instruments. The Committee is disappointed that the first mission in this series, the Mars Observer, has been delayed past its original launch date of 1990.

The Committee intends that this mission be strengthened by providing spares for the Mars Observer and establishing a manifest baseline on an expendable launch vehicle. The Committee intends that NASA give preference to a commercially available ELV in carrying out this section. Furthermore, the spares procurred pursuant to this section should be used for a 1994 launch of the Lunar Polar Orbiter the next in the observer series, if they are not utilized by the Mars Observer.

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 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.

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 meteorites 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 relatively 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 carrying it to an encounter with the planet 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.

Both the Galileo orbiter/probe mission to Jupiter and the Ulysses mission to the Sun had been ready for launch in May 1986 on the Space Shuttle/Centaur Upper Stage. The Challenger accident in January 1986 forced a postponement of these launches and subsequent cancellation of the Centaur launch stage resulted in further re-evaluations of these missions. The Magellan mission was also adjusted to accommodate a one-year launch delay caused by the Challenger accident and cancellation of the original Centaur upper stage.

Present plans now call for Galileo to be launched on a Shuttle/Inertial Upper Stage (IUS) combination in the 1989–1990 timeframe. 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 Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, 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 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 the 1989–1990 timeframe using the Shuttle and IUS/PAM-S launch stages.

Magellan, formerly the Venus Radar Mapper mission, 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 determine accurately 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 now 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. Mars Observer will utilize a modified Earth-orbiting spacecraft, thereby benefiting from aerospace industry's earlier investment in development.

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 inquires 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. In addition, we are conducting preliminary design and advanced technology for development of a new class of spacecraft, Mariner Mark II. At the same time we are studying a Comet Rendezvous/Asteroid Flyby (CRAF) mission in which this spacecraft would hard-land a probe on the nucleus of an active comet, with potential for close encounters of one or more asteroids en route to the target comet.

The Planetary Exploration program is also founded on a coordinated research and analysis effort. Research and Analysis 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 an technology needed for future missions.

Galileo Development

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft	$35,100,000	$20,200,000
Experiments	16,100,000	12,700,000
Ground operations	20,000,000	22,400,000
Total	71,200,000	55,300,000

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.

Current plans call for the orbiter and probe to be launched together in the 1989–1990 timeframe 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. 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 surface and the dynamic magnetosphere will be comprehensively mapped. During this time ten close flybys of Jupiter's 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 1987, major activities of the Galileo program will include the implementation of thermal control design modifications to the spacecraft since, in passing Venus, it will be going closer to the Sun than originally planned. In addition, several critical parts changeouts will be made in order to improve the reliability of the spacecraft computers. All the scientific instruments will be updated and recalibrated preparatory to reinstallation on the spacecraft.

FY 1988 funds will provide for completion of the reassembly, integration and initial testing of the reintegrated spacecraft system. Modification of the flight software and mission operations system will be continued.

Magellan

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft	$58,100,000	$38,300,000
Experiments	25,600,000	7,900,000
Ground operations	8,900,000	13,400,000
Total	92,600,000	59,600,000

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 of about 150 meters.

During 1986, the mission was readjusted to accommodate a one-year launch delay caused by the Challenger accident and cancellation of the Centaur upper stage. Good progress was made in initiating the necessary hardware changes. During FY 1987, major activities will include the assembly, testing and delivery of a test version of the radar instrument flight model. Spacecraft assembly and integration of the flight spacecraft will be completed. Also the final design reviews will be held for the mission operations system.

In FY 1988, the flight model of the radar instrument will be delivered for integration with the spacecraft and environmental testing will be initiated for the entire system. Integration of the mission operations system will be completed to be followed by initiation of operations testing and training preparatory for launch.

ULYSSES

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft	$4,800,000	$3,300,000
Experiments	4,000,000	5,900,000
Ground operations	1,500,000	1,600,000
Total	10,300,000	10,800,000

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.

Because of the Challenger accident and subsequent cancellation of the Centaur upper stage, the Ulysses launch is currently planned for the 1989-1990 timeframe, using the Shuttle and IUS/PAM-S launch stages. During 1986, spacecraft prelaunch testing at the Kennedy Space Center (KSC) was completed, the spacecraft was returned to ESA for storage and the instruments were returned to the investigators for storage and recalibration. Mission design activities were initiated to support the new mission profile and launch date. During 1987, effort will continue on studying the details of the new mission and mission operations planning. Support to ESA will continue in order to make the spacecraft compatible with the new upper stage configuration.

FY 1988 funding will provide for completion of the documentation of the new spacecraft/launch vehicle interface, launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments.

MARS OBSERVER MISSION

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spacecraft development	$11,600,000	$7,800,000
Experiments	22,800,000	18,100,000
Ground operations	1,400,000	3,400,000
General augmentation		35,000,000
Total	35,800,000	64,300,000

The Mars Observer mission is the first in a series of planetary missions utilizing a new low-cost approach to inner solar system mission exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well-defined and focused science objective and makes use of high-inheritance, modified production-line Earth-orbital spacecraft. The objective of the Mars Observer mission is 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 characterize their interaction with the Martian environment.

The limitation on the number of launch opportunities through 1990 and the further restrictions placed on scheduling by the 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 using the Space Shuttle 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 1987, it is planned to complete the detailed design of the instrument hardware and to initiate fabrication of the Payload Data Subsystem. Detail design of the spacecraft will be continued.

The FY 1988 funding is required to initiate instrument hardware fabrication and assembly and to maintain a minimum level of support in spacecraft and ground operations subsystem developments.

MISSION OPERATIONS AND DATA ANALYSIS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Voyager extended mission	$2,800,000	$2,800,000
Pioneer programs	8,300,000	8,500,000
Voyager/Neptune mission	31,800,000	26,100,000
Planetary flight support	37,100,000	39,600,000

	Estimated fiscal year 1987	Authorization fiscal year 1988
Total	80,000,000	77,000,000

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 traveling through 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. The observatory phase of this encounter, which began in November 1985, included 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 will 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 and it provided 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.

FY 1987 funding is providing operational support for the Voyager and Pioneer operations, as well as for the extension of the Voyager 2 mission to a 1989 encounter with the planet Neptune. Activities are also continuing in multimission support development activities.

FY 1988 funding is required for the continued operation and data analysis activities in support of the Voyager and Pioneer missions. Development activities will also be continued in FY 1988 on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

Research and Analysis

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Supporting research and technology	$46,400,000	$47,900,000
Advanced programs	15,200,000	20,700,000
Mars data analysis	2,900,000	3,700,000
Halley's Comet co-investigations and watch	4,000,000	3,000,000
Total	68,500,000	75,300,000

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 to Halley's Comet.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, and instrument definition.

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 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 activity continues to ensure that we capitalize on the wealth of data provided by Viking and earlier missions and that we are scientifically prepared for the next phase of Mars exploration. While continuing to support a variety of scientific investigations, the major emphasis of this program will address the origin and evolution of Martian volatiles.

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.

During FY 1988, 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, in FY 1988, 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 1988 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Within Advanced Programs, instrument definition and advanced technology development for potential future missions will also be continued with emphasis on the Mariner Mark II spacecraft.

The FY 1988 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 1988 funding is also required to continue operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

6. SPACE APPLICATIONS

NASA REQUEST, $559,300,000

AUTHORIZATION, $604,300,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Solid earth observations	$75,600,000	$76,800,000
Environmental observations	323,900,000	393,800,000
Materials processing in space	45,400,000	45,900,000
Communications	103,500,000	65,500,000
Information systems	21,300,000	22,300,000
Total	569,700,000	604,300,000

Solid Earth Observations

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Shuttle/Spacelab payloads	$21,600,000	$21,100,000
Geodynamics research	32,100,000	33,100,000
Research and analysis	21,900,000	22,600,000
Total	75,600,000	76,800,000

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.

Specific land surface objectives include determination of the terrestrial landscape including the biosphere and the hydrosphere, and understanding 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 climatic system, and the composition and evolution of crustal rock systems 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 variability of the Earth's geopotential fields.

The objective of the Shuttle/Spacelab payload development project 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, 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, involving use of SIR-B components and a multi-polarized, dual frequency instrument is under development for flight in the early 1990's. 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.

Shuttle/Spacelab Payload Development

The objective of this program is to develop, test, and evaluate Earth-viewing remote sensing instruments and systems to obtain data for land remote sensing research.

Preparations are continuing for commercialization of the Large Format Camera (LFC). 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. SIR-C is in the development phase; System Requirements Review and Antenna Preliminary Design Review are complete.

Advanced Spectrometer technology development 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 plane will continue.

FY 1988 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, microwave interferometry and the Global Positioning Satellites 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 America 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. In 1982, 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.

In FY 1988, measurements of plate motion between North America and Europe will be continued in cooperation with NOAA and several European countries. Measurements of the motions of the Pacific Plate will also be continued in cooperation with DoD and Japan and will be extended to include China. In addition, regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. Similar measurements will be initiated in Europe in cooperation with a consortium of 10 European, North African, and Mid-East countries. The Caribbean studies will be continued in FY 1987 and are expected to involve some eight countries in 1988.

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 joint LAGEOS-2 mission with Italy will be launched by the U.S. in 1993.

Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1988. In addition, system studies of a second magnetic field satellite for long-term measurements of the Earth's field, studies of geopotential research and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

Research and Analysis

The major objectives of the Solid Earth Research and Analysis program are to characterize the physical, geological and biological state of the Earth's surface, explore its variation with time and to understand the processes which control its state and its interactions with the atmospheric and hydrologic systems.

Existing operational and research sensor systems are used to gather data on land surface properties and their variations. Observations are also conducted using experimental systems on airborne and space-based platforms. Theoretical models are formulated and validated using these observational systems with the resulting algorithms being used in the analysis of land surface properties and processes. Observational systems are used which operate in the visible, infrared and microwave regions of the spectrum, and both active and passive systems are used. Much of the emphasis is on quantification of changes to the land surface, whether it be from natural or anthropogenic causes.

The Geologic Processes program addresses the study of the evolution of the Earth's crust on a global basis with multispectral remote sensing techniques. The relative distribution of rock types, spectral properties of rocks, regional tectonics, rock weathering processes and geobotanical relationships are important research topics that are being addressed for many types of geologic environments. Multispectral remote sensing data analysis studies are supported by laboratory and field spectrometry and field mapping efforts to verify spectral properties and interactions.

The Biochemical Processes program conducts studies through global and continental scale observation programs using operational satellite data products and analytical techniques developed for this purpose. Additionally, high spectral resolution studies are conducted using aircraft platforms and regional scale studies are conducted using the Landsat Thematic Mapper. The areal extent and temporal variability of ecosystems are investigated, and the causal, mechanism sought.

In FY 1988 emphasis will continue on investigations of the Earth's systems which are undergoing stress, in order to better understand the processes which control such systems. Specific regions will be identified for study, long-term observations will be initiated and data will be assembled from existing satellite data, and intensive field measurement programs will be defined. Pilot studies to validate methodologies will be conducted and global to regional scale process models will be developed and utilized for processing the data. A mixture of biomes and stress factors will be identified; initial emphasis will be on semi-arid to arid regions undergoing seasonal or multi-year drought and on forest biomes under stress from acid rain and conversion. The activities are closely associated with the International Satellite Land Surface Climatology Project (ISLSCP) and the International Global Change Program.

The FY 1988 activities will also emphasize studies to determine continental rock type and erosion processes in semi-arid regions in sedimentary basins. Sensor systems such as the Advanced Visible-Infrared Imaging Spectrometer, quad-polarization L- & C-Band imaging radar and the Thermal Visible-Infrared Imaging Spectrometer will be used in these investigations, and will serve as prototypes for shuttle instruments now under development and for future Space Station polar platform instruments. The thematic mapper on the operational Landsat will continue to serve as the focal instrument for multidisciplinary investigations, with particular emphasis on the tectonic structure of continental highlands.

ENVIRONMENTAL OBSERVATIONS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Upper atmosphere research and analysis	$33,400,000	$34,400,000
Atmospheric dynamics and radiation research and analysis	31,900,000	32,900,000
Oceanic processes research and analysis	20,800,000	21,500,000
Space physics/research and analysis	21,000,000	21,500,000
Payload and instrument development	12,000,000	19,400,000
Extended mission operations	33,600,000	26,800,000
Interdisciplinary research and analysis	1,100,000	1,100,000
Tethered satellite payloads	1,000,000	3,100,000
Scatterometer	32,900,000	22,700,000
Upper atmosphere research satellite mission	114,200,000	95,400,000
Ocean topography experiment	19,000,000	90,000,000
Global geospace science		25,000,000
Total	320,900,000	393,800,000

The objectives of the Environmental Observation program are to improve our understanding of the processes in the magnetosphere, 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, plasma acceleration, and dynamic processes occurring in the magnetosphere, 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; improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction; and enabling a comprehensive understanding of solar terrestrial processes and a detailed determination of the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

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 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 1988 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 1988 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. With the apparent decision by the U.S. Navy to cancel their Navy Remote Ocean Sensing System (N-ROSS) satellite, the planned spacecraft for NSCAT, studies and plans are underway for alternatives.

Development of the Ocean Topography Experiment (TOPEX) began in FY 1987 and will continue in FY 1988; 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.

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. The Dynamics Explorer spacecraft continues to collect valuable data on magnetosphere-ionosphere coupling processes. In addition, the International Sun Earth Explorer (ISEE-3) spacecraft, renamed International Cometary Explorer (ICE), has completed an exploration of the Earth's geomagnetic tail. On September 11, 1985, ICE accomplished the first encounter with a comet as it passed through the tail of Giacobini-Zinner. ICE also provided supporting solar wind measurements for the March 1986 Halley missions. In March–May 1986, the Polar Region and Outer Magnetosphere International Study (PROMIS) coordinated six satellites (ISEE 1 and 2, ICE, Active Magnetospheric Particle Explorer (AMPTE), Interplanetary Monitoring Platform (IMP-8), Dynamics Explorer (DE-1) and the Swedish Viking satellites to provide unique data on magnetospheric processes.

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 Atmospheric Trace Molecules Observed by Spectroscopy (ATMOS), Active Cavity Radiometer (ACR), Light Detection and Ranging (LIDAR), and 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 Global Geospace Science (CGS) program is proposed as an FY 1988 new start. It is a complementary science mission to the FY 1987 approved Collaborative Solar-Terrestrial Research (COSTR) initiative, in which the U.S. moves from a supporting to a leadership role in solar terrestrial physics. 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. Together with COSTR, GGS represents research of the highest scientific merit.

Along with the Solid Earth Observations program, the Environmental Observation 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.

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 manmade 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 have been 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 1988, 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 1988 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1988 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 1988 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 phenomenon, the UARP is planning a major aircraft mission 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.

Atmospheric Dynamics and Radiation Research and Analysis

The research and analysis activities within the Atmospheric Dynamics and Radiation program comprise a core effort which is fundamental to using space technology to solve problems in atmospheric science. The program's three main thrusts are in the areas of global-scale tropospheric processes research, mesoscale processes research 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 meteorological 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 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. In addition, special attention has been devoted to developing active lidar techniques to provide detailed profiles of atmospheric 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 over local to regional size 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. A joint NASA-NOAA project of this type was completed and is known as the Centralized Storm Information System. In the area of remote sensor development, successful flights of instrumentation on the ER-2 aircraft to observe cloud top dynamics and lightning have been completed, and a feasibility study of a potential lightning mapper has been completed. NASA is currently working with NOAA to determine the practical value of lightning mapping from geostationary orbit and the possibility of incorporating experimental lightning mapping observations on a GOES spacecraft.

The Climate Research program seeks to develop a space capability for global observations of climate parameters which will contribute to our understanding of the processes that influence climate and its predictability. Research is focused in accordance with the National Climate program priorities wherein NASA has the role of lead agency for solar and Earth radiation research. Future study thrusts will be aligned with programs of solar irradiance monitoring, Earth radiation budget monitoring and analysis, the global distribution and effect of cloud systems and stratospheric aerosols on the radiation budget, and on selected process studies which relate to monitoring of climate change. The past year's activities have stressed data analysis and model studies of the effects of the El Chichon volcano on climate. The first results of the data phase of the International Satellite Cloud Climatology Project (ISCCP) have been successfully archived and elements of the First ISCCP Regional Experiment (FIRE) have been completed. Data from ISCCP and FIRE will be analyzed in conjunction with the Earth Radiation Budget Experiment (ERBE) data to improve our knowledge of cloud-radiation interactions which effect 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 on developing the capability to observe rainfall from space has been initiated. This includes studies of instrumentation, sampling requirements, algorithm development and modeling to determine the feasibility of remotely sensing rainfall from space.

FY 1988 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in 3-dimensions. 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 Microburst in Severe Thunderstoms Experiment (MIST), the first ISCCP Regional Experiment (FIRE) and the Satellite Precipitation and Cloud Experiment (SPACE). 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 1988.

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. As such, the program operates in concert with a variety of federal agencies (e.g., Navy, NOAA, NSF) and foreign countries (e.g., Canada, Europe, Japan).

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 seaice cover and the details of its motion.

The Oceanic Process R&A program is actively pursuing scientific research with other federal agencies and foreign countries 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 Flux Experiment (GFE), and a Program for International Polar Oceans Research (PIPOR).

In FY 1988, the physical oceanography research activities will include implementation planning for WOCE and TOGA, as well as the development of numerical models and associated data assimilation techniques for use in determining the general circulation of the oceans. In biological oceanography, the analysis of data from Nimbus-7 will be continued in order to estimate global ocean productivity, as well as to help with the conceptual design of the Global Flux Experiment. In addition, accommodation studies will be performed with EOSAT for potential flight of an ocean-oriented color scanner 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 in Alaska of SAR data from the European Space Agency's ERS-1 and from the Japanese JERS-1 spacecraft due for launch in the 1989-1991 time frame. The NASA Ocean Data System is now functioning as a scientific support facility for the ocean research community. Coordination activities with the Office of Naval Research, NSF, and NOAA are being pursued 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.

Space Physics Research and Analysis

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. These studies include: the complex coupling of the atmosphere with the ionosphere and the magnetosphere; the solar wind and how it interacts with planetary magnetospheres and ionospheres; and how variations in the solar wind are coupled into planetary environments and neutral atmospheres. This discipline also includes the conduct of active experiments to extract information under controlled conditions, and the use of space as a laboratory for the study of plasmas in parameter regimes that are unattainable on Earth. The understanding of the plasmas in the solar system, the only naturally occurring plasmas to which we have direct access, will also enable us to refine theories regarding astrophysical plasma processes.

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 and for the Earth sciences community, but also there are 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.

This field of research is one of relative maturity, with emphasis on multipoint, *in situ* measurements and on active perturbation experiments rather than isolated exploratory observations. For example, there are presently four spacecraft systems—the Interplanetary Monitoring Platform, the International Sun-Earth Explorer (ISEE), Dynamics Explorer (DE), and the Active Particle Tracer Explorer (AMPTE) taking such measurements. AMPTE has carried out a program of coordinated chemical releases and plasma diagnostics to investigate solar wind plasma entry into the magnetosphere and energization of plasmas directed both towards and away from the atmosphere. The campaign called PROMIS (Polar Region and Outer Magnetosphere International Study) took full advantage of these satellite systems during March–May 1986 when the Swedish Viking satellite contributed toward a unique opportunity for correlative measurements of the Earth's magnetosphere on a large scale. In addition to the *in situ* measurements of natural plasma environments as discussed above, a second major thrust of the Space Physics program is to use these natural environments as unique laboratories for basic plasma physics, especially through the use of active experiments to simulate plasma phenomena under controlled conditions. There is an active program of sounding rocket and balloon investigations aimed principally at spatially or temporarily isolated atmospheric, ionospheric or magnetospheric phenomena. Theoretical modeling and supporting laboratory activities are also being conducted.

Advanced Technology Development (ATD) provides for the definition of advanced missions and supporting instrument technologies. FY 1987 ATD efforts were directed at extending the definition of the WIND and POLAR missions including instruments, spacecraft, and ground systems of the Global Geospace Science (GGS) program and performing accommodation studies for incorporating continuous realtime solar wind data capability on WIND to meet USAF Air Weather Service's statement-of-need as a joint mission.

The Solar Terrestrial Theory activity continues to provide a strong basis for all of the programs in both solar physics and space plasma physics. Theoretical groups are engaged in research on virtually every aspect of solar-terrestrial physics by using both fundamental process calculations and numerical models of large-scale phenomena. The active phase of AMPTE also provided controlled perturbations of the geospace environment, including a full-scale simulation of solar wind-comet interactions.

During FY 1988, the space physics research and analysis activities will be continued with particular emphasis on the analysis of data obtained from the 1986 PROMIS campaign and from the International Cometary Explorer (ICE) which collected unique data in the Earth's distant magnetotail before going on to an encounter with the comet Giacobini-Zinner in September 1985. Definition studies will be conducted during FY 1988 for advanced missions such as the follow-on for the U.S.-Italian Tethered Satellite System, which will investigate atmospheric and electrodynamics effects, a solar probe mission to study the unexplored region between four and sixty radii from the Sun, and Space Station payloads including the Solar Terrestrial Observatory.

The Solar Terrestrial Theory program will be continued during FY 1988. In addition, a comprehensive and quantitative aggregate model of solar-terrestrial interactions will continue to be developed.

PAYLOAD AND INSTRUMENT DEVELOPMENT

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Measurement of Air Pollution from Satellites (MAPS)	$800,000	$700,000
Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS)	2,100,000	2,500,000
Active Cavity Radiometer (ACR, ACRIM)	1,100,000	1,100,000
Light Detection and Ranging (LIDAR)	3,000,000	100,000
Collaborative solar terrestrial research (COSTR)	5,000,000	15,000,000
Total	12,000,000	19,400,000

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.

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 inter-hemispheric 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.

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. The emphasis is on developing scientific instruments that have been conceived through the Space Plasma and Solar Physics Research and Analysis programs and through the Sounding Rocket program. The development and selection of opportunities will be coordinated and focused to answer questions identified in the National Academy of Sciences Committee on Solar and Space Physics report on priorities in solar system space physics. Most of the instruments developed through this program will provide a U.S. contribution to an international thrust in solar-terrestrial research in the 1989–1995 timeframe.

FY 1988 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 initial flight of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) instrument was completed in 1985, with greater than expected science results. The FY 1988 funding is required to support the ground observation program of ATMOS as well as continued science team activities, data processing and analysis, and limited refurbishments.

FY 1988 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.

Development activities will continue on the international (U.S. and French) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of conceptual definition, breadboard laboratory activities, and preliminary design reviews for this multi-phase user program. In this advanced state-of-the-technology 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.

In FY 1988, 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. While ISAS will provide the Geotail Spacecraft and the majority of the instruments, NASA will provide instruments requiring unique capabilities to measure the hot, low density plasmas, energetic plasmas, low intensity waves and weak magnetic fields in the deep magnetic tail. In addition, NASA will begin development of U.S. provided instruments and mission support equipment for the ESA/NASA joint CLUSTER and SOHO missions. These missions will provide detailed measurements of solar variability and solar oscillations, the origin and flow of the solar wind, the interaction of the solar wind with the terrestrial magnetosphere, and the resultant space plasma microprocesses. ESA will provide the SOHO and CLUSTER satellites, and the majority of the instruments. NASA will provide instruments for solar oscillations and solar corona measurements and several space plasma instruments that are unique in their capabilities and performance.

Extended Mission Operations

The objectives 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 atmosphere 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 1988 to support the strong demand for data.

The Solar Mesosphere Explorer (SME), launched in October 1981, is providing major input to our overall atmospheric parameter data base. SME is producing simultaneous measurements needed to understand the complex chemical processes taking place in the mesosphere, including data measurements of ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties. A ground truth program to aid in the validation of the SME data is also being undertaken. SME is providing excellent data on the effect of volcanoes on the Earth's atmosphere.

Solar terrestrial research activities rely on data received from the International Sun-Earth Explorers, (ISEE-1 & 2), the Interplanetary Monitoring Platform (IMP), the Active Magnetospheric Particle Trace Explorer (AMPTE), and the Dynamics Explorers which are still operational. 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).

By 1988 funding is required to support continuing mission operations and data analysis activities for ISEE-1 and 2, IMP, DE, ICE and AMPTE. 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 1988; these *in situ* observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, FY 1988 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

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 1988, 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.

Tethered Satellite Payloads

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 TSS will allow unique science to be undertaken such as observations of atmospheric processes occurring within the lower thermosphere (below 180 km altitute), observations of crustal geomagnetic phenomena, and direct observation of magnetospheric-ionospheric-atmospheric coupling processes in the 125-180 kilometer region. In addition, the satellite, coupled to the conducting tether, can generate large amplitude hydromagnetic waves and electrodynamic waves in the local space plasma, thus enabling active space plasma and magnetospheric physics experiements to be performed. The objective of the initial TSS mission is to verify the controlled deployment, retrieval and on-station stabilization of the satellite tethered from the orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter.

The TSS is an international cooperative project with the Italian government. The United States is developing the tether deployment and retrieval system, is responsible for overall project management and system integration, development and integration of the 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. An Announcement of Opportunity for investigations was issued in April 1984. Selection of investigators was completed in late 1985 and instrument design initiated in 1986.

The FY 1988 funding is required to continue development of U.S.-provided instruments on TSS-1 and core equipment development and integration.

Scatterometer

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for other 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 1990-1991 will provide an overlap of data gathering with the World Ocean Circulation Experiement, 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 requirements 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 Scattterometer was to have been flown on the Navy Remote Ocean Sensing System (N-ROSS) satellite in late 1990. With the apparent decision by the Navy to cancel N-ROSS development, the program is seeking an alternate, compatible flight option. As the Navy is still interested in Scatterometer data, it is assisting the agency in obtaining an alternate flight.

During FY 1987, various hardware components will be delivered, construction of the radio frequency subsystem will continue, the procurement of the second of two computer systems will begin, and a Critical Design Review will be conducted. Planned FY 1988 activities will include the continuation of hardware development leading to testing and integration of the Scatterometer Flight Model, delivery of the second computer system and beginning of its testing, and continued refinement of post launch research and verification plans.

Upper Atmosphere Research Satellite Program

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 which 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-real-time interactive utilization of data by the twenty-one design and theoretical investigator teams, is underway.

The FY 1988 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. In addition, the spacecraft development and hardware fabrication activities will continue.

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 1988 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.

Current plans call for NASA and the French Space Agency (CNES) to collaborate 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 1987 a satellite contractor and a science team was selected, and sensor and ground data system development began. In FY 1988, preliminary design of the satellite and ground data systems will be well underway. Sensor development will continue through the Critical Design Review phase leading to the initiation of fabrication by late FY 1988. At the same time the science team will be refining their research plans and will assist in assessing design options as they relate to achieving scientific success with TOPEX.

Global Geospace Science

The Global Geospace Science (GGS) is proposed as a FY 1988 new initiative and 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.

The GGS is a complimentary mission to the Collaborative Solar Terrestrial (COSTR) program initiated in FY 1987 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 would be greatly enhanced by the addition of the two spacecraft proposed in the GGS program. The combined program would include five spacecraft missions: two U.S. spacecraft, WIND and POLAR; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft; GEOTAIL. NASA will launch and provide upper stages for all spacecraft except SOHO. ESA will provide for launch and associated costs for SOHO. Initiation of GGS in FY 1988 will move the U.S. from a supporting to a leadership role in this international cooperative program.

The Global Geospace Science (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 measurements in key plasma source and storage regions, multi-spectral 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. Approval of the GGS will allow the United States to become a full partner in the ISTP program reinforcing our commitment to international cooperation and is essential to maintaining continued leadership in solar terrestrial physics.

Definition studies are complete and FY 1988 funds are required to initiate development of GGS spacecraft instruments and ground system. FY 1988 funding will allow initiation of these efforts in time to take advantage of simultaneous measurements provided by the Collaborative Solar Terrestrial Research (COSTR) program and other solar-terrestrial research efforts.

MATERIALS PROCESSING IN SPACE

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Research and analysis	$13,900,000	$14,400,000
Microgravity Shuttle/Station payloads	34,000,000	31,500,000
Total	47,900,000	45,900,000

The Materials Processing in Space program emphasizes the science and technology of processing materials to understand constraints imposed by gravitational forces and the unique capabilities made possible by controlling these processes in the space environment. Ground-based research, technology development, and payload definition activities in FY 1988 are being concentrated on six major processing areas: metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. These activities will provide the scientific basis for future space applications of materials processing technology as well as provide a better understanding of how these processes occur on the ground. Definition studies will be performed for Shuttle and Space Station experiment candidates in areas such as containerless experiments, combustion science, solidification and crystal growth, and blood storage. Also included are maintenance of capabilities for experimentation in drop tubes, towers, and aircraft. Studies and science support for Joint Endeavor and Technical Exchange Agreements are included in this program.

Microgravity Shuttle/Space Station payloads is a consolidaton of ongoing activities which provide a range of experimental capabilities for all scientific and commercial participants in the Microgravity Science and Applications program. These include Shuttle mid-deck experiments, the Materials Experiment Assembly and the Materials Science Laboratory, which is carried in the orbiter bay. These capabilities will enable users to develop different experiments in a cost-effective manner and allow a better understanding of the technical risks associated with experiment concepts before attempting to develop more complex hardware; define and implement Microgravity Science experiment equipment development and conduct key in-space experiments in support of current Space Station activities and future microgravity Space Station Laboratory work in Materials Science. In addition, reflight of investigations on Shuttle/Spacelab missions and the mid deck is provided for in Materials Experiment Operations.

Research and Analysis

The research and analysis activity provides the scientific foundation for all current and future projects in the Mic~ogravity 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. The FY 1987 funding is being used to support ongoing research.

Ground-based research and analysis will be continued in FY 1988 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 Microgravity Shuttle/Space Station payloads program provides a wide range of opportunities for scientific and commercial experiments in microgravity science and applications. Development of Shuttle mid-deck and cargo bay experiments and Space Station experiments are supported under this activity. Preliminary data analysis on Shuttle experiments already flown has shown promising results.

FY 1988 funding is required to continue basic and applied research activities using mid-deck and cargo bay experiments leading to several flights over the next few years. Investigations will be planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will begin on a number of Physics and Chemistry Experiments (PACE) as well as continued development of several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metallic casting, and levitation.

Funding will also support definition activity for Space Station hardware development.

COMMUNICATIONS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Advanced Communications Technology Satellite (ACTS)	$85,000,000	$45,000,000
Research and analysis	13,000,000	$14,400,000
Search and rescue	1,000,000	1,300,000
Technical consultation and support studies	3,200,000	3,400,000
Experiment coordination and operations support	1,300,000	1,400,000
Total	103,500,000	65,500,000

The committee added $45,000,000 in funds to the NASA request to complete development of the Advanced Communications Technology Satellilte.

The Communications Research and Analysis program 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 utilization, satellite switching, and intersatellite link technologies, 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 at the end of the decade.

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. A five satellite system is now in service (two U.S. and three U.S.S.R. satellites) and has been credited with saving over 675 lives in numerous worldwide incidents. The operational responsibility for this program was referred to NOAA in 1985.

The technical consultation and support program will continue to 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 (WAR's) is continuing.

The experiment coordination and operations support program 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) is continuing through contracts with the University of Miami.

Advanced Communications Technology Satellite

The objective of the Advanced Communications Technology Satellite (ACTS) program is to prove the feasibility of certain advanced communications satellite technologies through a flight test program. The specific technologies to be validated include: (1) the use of multiple fixed and scanning spot antenna beams; (2) frequency reuse; (3) beam interconnectivity at both intermediate frequencies and at baseband; (4) advanced system network concepts; and (5) dynamic rain-compensation techniques. These technologies will be applicable to a wide range of communications systems in the 1990's.

The ACTS spacecraft will be launched from the Shuttle into geostationary orbit. The spacecraft will consist of a commercial communications bus and a multibeam communications package, including a multibeam antenna, baseband processor, RF matrix switch, traveling wave tube amplifier, and low noise receiver. The ground segment will consist of a NASA ground station and a master control station. Following launch and checkout, a two-year program of user-funded experiments will be initiated, during which time ACTS system technologies will be tested, evaluated, and validated. Over 40 organizations, including DOD, have requested consideration for experiment opportunities on ACTS to date.

FY 1987 funding continued the design and development of the spacecraft bus, the communications electronics package, the baseband processor, the multibeam antenna, and the development of the NASA ground station and the software needed for the master control station.

Research and Analysis

The Communications Research and Analysis program emphasizes the development of high-risk technology required to maintain U.S. pre-eminence in the international satellite communications market, to enable new and innovative pubic services, and to meet the communications needs of NASA and of other government agencies. This program focuses on the "interconnectivity technologies" of on-board switching, intersatellite links, and antennas, as well as advanced radio frequency (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 1987, work is continuing on advanced communications technologies. The laser intersatellite communications technology will permit improved 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 encourage industry participation was signed in FY 1985 as the basis for the program, and in early FY 1986, the NASA technology program received the support of industry at a major government/industry briefing. Recently the Federal Communications Commission allocated a frequency for domestic mobile satellite service. In FY 1986, system design studies were completed and hardware development was initiated. In FY 1987 field tests of selected hardware elements will be conducted.

During FY 1988, advanced studies and selected technology development will continue in the high risk areas of microwave and optical technology, satellite switching, RF systems, and intersatellite links. Work in these technology areas will support U.S. industry, NASA, and other government agencies and address national economic and security interests.

In FY 1988 all prototype components for the mobile communications experiment will be completed and field testing of the full mobile terminal will begin.

Search and Rescue

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 and marine vessels during emergencies. The Search and Rescue satellite system has met all specifications and was declared operational in July 1985. The system has received world-wide acclaim and has been credited with saving over 675 lives to date. In addition, the system is demonstrating the potential to save millions of dollars annually in search logistics costs.

In FY 1987, work is continuing to improve system software efficiency, develop low-cost 406 MHz hardware, and initiate development techniques that will enhance the ability of the system to locate quickly those in distress.

In FY 1988, an experiment using geostationary satellites for instant alert will be completed and the results analyzed. Work to impove cost and performance of emergency beacons will continue.

Technical Consultation and Support Studies

Technical Consultation 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 1986, a geostationary orbit arc allotment planning concept was developed as part of the U.S. preparations for the 1988 Space World Administrative Radio Conference (SWARC). Proper preparation is critical to U.S. objectives for maintaining flexibility in the use of orbiting and operating communications satellites. During FY 1987, work will proceed to obtain an international frequency allocation for mobile satellite operation.

In FY 1988, work will be completed on the geostationary orbit arc allotment planning method and support will continue for the second session of SWARC. Studies will continue for the purposes of identifying techniques to increase the efficient use of the limited orbit/spectrum resources and to understand and alleviate the adverse effects of propagation phenomena on space communications.

Experiment Coordination and Operations Support

The objectives of this program 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) ATS-3, continues to support the National Science Foundation, the National Oceanic and Atmospheric Administration, the Department of Commerce, the Department of the 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.

In FY 1988, operational support for ATS-3 will continue. NASA will maintain approval and policy control of the ATS program. NASA will continue planning support for educational, scientific, and public service communications experiments for organizations within the Western hemisphere, and will support similar experimental activities of Pacific basin organizations within the footprint of the ATS-3 coverage.

INFORMATION SYSTEMS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Data systems	$9,400,000	$9,700,000
Information systems	11,900,000	12,600,000
Total	21,300,000	22,300,000

The objectives of the Information Systems program are to: develop and demonstrate advanced capabilities of managing, distributing, and processing data and information; implement information system standards and provide common software in order to lower data system costs; and develop the basis for data services to provide improved access to, and rapid delivery of, space data and advanced data systems in support of the nation's satellite programs and space science and applications projects.

This program provides for timely development of data system capabilities to meet the needs of flight missions and major space science and applications programs. The early demonstration of capabilities has a high potential for reducing ground data system development risks and for providing timely delivery of data to researchers.

The FY 1988 Information Systems funding is required to provide support for space science and applications programs. Funds are required: to continue development of planetary, earth resources, and astrophysics data systems projects which are being implemented at the Jet Propulsion Laboratory, the Goddard Space Flight Center, and participating academic institutions; to continue implementation of on-line data directories and catalogs; to operate the large-scale computers in the Space and Earth Sciences Computing Center (SESCC) and the archives at the National Space Science Data Center (NSSDC) (both facilities located at the Goddard Space Flight Center); to develop common software to support ongoing research in the space and earth sciences; and to continue development of data management and data archiving to support flight projects, discipline program offices, and other NASA program offices. The FY 1988 funding levels will also provide the university/research community with improved access to NASA computational facilities and data archives by expanding network communications links, by increasing online data storage capacities, and by developing standards for data and protocols.

7. TECHNOLOGY UTILIZATION

NASA REQUEST, $18,300,000

AUTHORIZATION, $18,300,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Product development	$1,500,000	$1,920,000
Acquisition, dissemination and network operations	4,100,000	4,730,000
Program development, evaluation and coordination	1,780,000	2,380,000
Technology applications	5,950,000	6,620,000
Industrial outreach	2,370,000	2,650,000
Total	15,700,000	18,300,000

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 transer 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: (1) 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; (2) to encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist; and (3) 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 to *NASA Tech Briefs* which now exceeds 130,000 readers. This 60% 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 20 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 1987 and on into FY 1988. An additional milestone was reached in late 1986 when the Federal Laboratory Consortium (FLC) for Technology Transfer (formerly established under P.L. 99-502) and NASA elected to enter into an agreement which establishes formal linkages between the NASA IAC network and the various Federal laboratories. Based on the successful completion of an experimental program between the NASA 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 should spur and accelerate the process for the 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 groundbased opportunities and exploitation of available technology. The IAC are a natural focal point for increasing awareness of available technology and opportunities.

Several important events occurred during the past year 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 which culminates several years of intensive collaborative effort between NASA, JHU Applied Physics Laboratory, and various private sector firms, initiates a two-year clinical test period in which 20 or more implantations will occur. All of the scheduled applications during the test period will be for patients with chronic diabetes.

Finally, NASA authorized an experimental technology transfer program at the Jet Propulsion Laboratory as a means to enhance access to that laboratory's technology by the private sector. In May 1986, NASA entered into a cooperative agreement with the nonprofit 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 cofounding 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 royalities from patent licensing, and reverse technology transfers to NASA/JPL from industry.

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 1988. These resources will provide for evaluation and packaging of these technologies for publication to become available to industry to stimulate active interest in participating in NASA's Technology Utilization and Commercial Use of Space programs.

Acquisition, dissemination and network operations

In FY 1988, NASA plans to strengthen 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 FY 1988. 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. Moreover, the system will enable technology transfer managers to maintain appropriate controls over the process to insure overall program effectiveness and management accountability.

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) and Commercial Use of Space (CUS) programs. 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/CUS program 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 1988 to strengthen program development, evaluation and coordination on an internal as well as external basis to support the national technology transfer network and commercial use of space outreach efforts.

Technology applications

In FY 1988, a broadening of application team responsibilities is anticipated to assist NASA Industrial Applications Centers in brokering 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 1988, 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. 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. 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 commercialization of advanced technologies resulting from NASA's R&D programs. The technological needs of industry—and of NASA—would benefit from this synergistic approach designed to bring engineering resources of both in closer proximity.

Successful technology transfer occurs most frequently in an environment where knowledge is shared easily and advantages through cooperative endeavors are explained and understood. It is this role that the NASA dissemination center network can readily fulfill.

8. COMMERCIAL USE OF SPACE

NASA REQUEST, $35,700,000

AUTHORIZATION, $30,700,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Commercial applications R&D	$22,600,000	$26,000,000
Commercial development support	3,000,000	4,700,000
Total	25,600,000	30,700,000

The Committee reduced NASA's request by $5 million in view of the inevitable delays in commercial activity in space as a result of the shuttle down-time. The impact on the program as a result of the reduction is expected to be minimal.

The goal of the Commercial Use of Space program is to provide a national focus in support of the expansion of U.S. private sector investment and involvement in civil space activities, while emphasizing new high technology commercial space ventures and promoting the development of new markets for civil space services. The specific objectives of the program are to: (1) 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, and radiation for commercial purposes; (2) facilitate private sector space activities through improved access to available NASA capabilities; (3) encourage an increase in private sector investment in the commercial use of space independent of NASA funding; and (4) develop and implement commercial space policy NASA-wide.

Nine Centers for the Commercial Development of Space (CCDS) have been established since the start of the program. A solicitation is underway to obtain proposals for as many as five new CCDS in 1987. Average cost of a CCDS is just under $1 million per year.

The Office of Commercial Programs (OCP) is building multi-user, multi-use government hardware 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. The total estimated cost of the present program will be approximately $50 million with hardware delivery starting in 1987.

The OCP has assumed responsibility for integration and mission management of unique Joint Endeavor Agreement flight experiments.

Work will start in FY 1987 to prepare experiments for flight and thus have them in a flight-ready status when the 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.

The Committee notes with growing concern the disparity between the space flight requirements of secondary payloads and NASA's capability (through the Space Shuttle) to meet these requirements. Since many of the seconday payloads involve research essential for maintaining U.S. leadership in space, the Committee strongly supports NASA's efforts to reduce the backlog of secondary payloads. To this end, the Committee endorses the effort of the Ames Research Center to study the feasibility of developing a reusable re-entry satellite that can help in reducing this backlog of micro-gravity and life sciences secondary payloads.

Commercial applications R&D

In order to maintain momentum in commercial use of space activities, NASA will continue to establish Centers for the Commercial Development of Space (CCDS). Institutions with strong research capabilities in sciences and engineering, in collaboration with industry and/or industrial associations, will be encouraged to participate. The Centers are joint undertakings involving, to the extent practicable, teams of industrial corporations and/or government agencies (other than NASA) and/or non-profit institutions. Resources support and technical assistance will be partially furnished by NASA with the remainder furnished by the Center members. In FY 1985, NASA provided partial funding to establish five Centers for the Commercial Development of Space. In FY 1986, NASA funded four additional Centers for a total of nine CCDS in operation. Awards are planned for FY 1987 and FY 1988 for an eventual total of up to 18 Centers simultaneously operating. NASA's individual CCDS funding is planned for five years in order to stimulate and stabilize the Centers' activities. Nevertheless, NASA's support, on a year-to-year basis, will depend on a favorable annual review of the Centers' progress in stimulating commercial use of space. There is a mandatory requirement for industry participation in each Center, including the expenditure of corporate resources. NASA support will be reduced and finally discontinued at the end of five years as the successful Centers achieve self-sufficiency.

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, 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 is placed on building the required technical infrastructure. The main thrust of the effort will be directed by the private sector in coordination with NASA. 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 Hitchhiker-M or Materials Science Laboratories, as well as mid-deck augmentation racks or derivatives thereof. 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 micro-gravity environment for certain commercial experiments. Sounding rocket use will allow proof-of-concept testing and hardware check-out in a limited duration microgravity environment.

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. Short and long range plans and agency policy are adjusted based on the results of the studies. Support services and equipment hardware maintenance are the other elements of commercial development support.

9. AERONAUTICAL RESEARCH AND TECHNOLOGY

NASA REQUEST, $399,000,000

AUTHORIZATION, $399,000,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Research and technology base	$272,900,000	$305,200,000
Systems technology programs	103,100,000	93,800,000
Total	376,000,000	399,000,000

The goal of the NASA Aeronautical Research and Technology program is to conduct effective and productive aeronautical research and develop technology which contributes materially to the enduring preeminence of U.S. civil and military aviation. This goal is supported by five comprehensive program objectives: (1) identify and concentrate on those emerging technologies with potential for order-of-magnitude advances in aircraft capability and performance that will enhance U.S. industrial competitiveness; (2) sustain the excellence of NASA's research centers by modernizing and enhancing the efficiency of national facilities, advancing scientific and engineering computational capabilities, and enhancing staff technical excellence by selecting highly qualified personnel and providing them with challenging career opportunities; (3) ensure timely and efficient transition of research results to the U.S. aerospace community through reports, conferences, workshops, and active participation of industry in contractual and cooperative 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 NASA Aeronautical Research and Technology program is intended to provide results well in advance of specific applications through long-term independent research and technology which is not driven by the development and operational pressures often encountered by the DOD and industry. Fundamental research in the traditional aeronautical diciplines is pursued concurrently with systems research directed at interaction among disciplines, components, and subsystems. Ongoing and planned research in the program represents a major contribution to the technological foundation for securing and maintaining world leadership in aeronautics for the United States.

NASA requested $375,000,000 for Aeronautical Research and Technology. This amount represents a $1,000,000 decrease from the Fiscal Year 1987 Appropriation. Furthermore, in constant 1988 dollars, it is about $10 million less than the amount actually spent in 1981.

The significance of the long-term trend is reflected in a worsening international trade picture for aerospace products, the largest component of which is civil aircraft and parts. During the 1980's, a serious foreign challenge to U.S. leadership emerged, resulting in a first-ever, downward trend in the aerospace balance of trade. Indicative of this pattern was a four-fold increase in European penetration of the large transport market within the United States itself, previously a virtual United States monopoly.

Thus, it is clear the United States must run harder if it wishes to remain competitive in the world aviation market, one of the few remaining sectors that still produces a net positive balance of trade.

Technology is an essential element of success in aviation, both civil and military. Breakthroughs in performance have always been the sought-after goal that could change the outcome in air warfare situations or commercial 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 substantially if the trends in world aviation trade are to be reversed. Accordingly, it recommends a $20 million augmentation to the Research and Technology Base, to be applied to basic research in aerodynamics, propulsion, materials and structures, and controls and guidance. Within this amount, $2 million is earmarked for general aviation rotary engine research. The Committee is interested in recent advances in the two-stroke rotary vee engine and believes the engine may have the potential to provide greater power-to-weight efficiencies than conventional rotary engines. The Committee directs NASA to conduct a technical assessment of rotary vee engine performance and possible applications of high temperature ceramics to rotary vee engine design. The Committee recommends $250,000 for rotary vee engine activities in FY 88. In addition, $2 million is recommended to augment the High Angle of Attack System Technology Program and $2 million to augment the engine hot section work under the Advanced High Temperature Engine Materials Systems Technology Program. The total recommended authorization is $399,000,000.

The FY 1988 research and technology program has been redirected to emphasize and focus on those technological opportunities which have potential for order-of-magnitude increases in vehicle capabilities and substantive impact on U.S. competitiveness. Previous progress in hypersonic technologies has led to the creation of the joint DOD/NASA National Aero-space Plane program. This program is being supported over the entire spectrum of fundamental disciplinary research and technology in the aeronautics program. The ongoing turbine engine Hot Section Technology (HOST) and the Ceramics for Turbine Engines Systems Technology programs have been combined and augmented into a High-temperature Propulsion Materials program aimed at revolutionary advances in engine thrust-to-weight ratio applicable to a broad range of aerospace vehicles. The demand for NASA's unique aeronautics research and test facilities is growing with the emergence of the National Aero-space Plane program and a new generation of military aircraft requiring extensive wind tunnel testing. In order to meet growing demand for development and new research needs with aging facilities, NASA is accelerating its wind tunnel modernization program, while also launching a broad study to identify the highest priority needs to guide future facilities enhancements. A brief summary of the key elements of the research and technology base and systems technology programs follows.

In fluid and thermal physics, research will focus on aerodynamic benchmark experiments to provide the data base for validating recent breakthrough computational fluid dynamic analyses for three-dimensional viscous flows and for developing models of complex flow phenomena. Activities will emphasize linking gas dynamics and chemical kinetics in advanced simulation codes for application to viscous, real-gas, external flows about hypersonic flight vehicles. In the fundamental flow physics area, emphasis is focused on the experimental and computational analysis of turbulence, turbulent flows, and vortical flows capitalizing on pathfinding advances in numerical aerodynamic simulation technology. Devices and design techniques to reduce viscous drag for supersonic aircraft will be developed from this research.

Applied aerodynamics will concentrate on high angle-of-attack aerodynamics, developing techniques to control vortex instabilities to enhance the maneuverability of future high-performance aircraft. Emphasis also will be placed on rotorcraft acoustics, air load prediction, and augmented flight dynamics. The 40x80-foot wind tunnel will become fully operational, supporting many joint programs with the DOD and industry, as well as NASA specific research.

In the propulsion area, research is providing a fundamental technology base for advanced propulsion systems. Emphasis will be placed on detailed flow measurements in the large, low-speed centrifugal compressor facility to verify three-dimensional viscous flow codes for turbomachinery and on thin-film sensors for use on propulsion components made of high-temperature composite materials, including ceramics. Development and verification of analytical codes for supersonic combustion ramjets, variable geometry inlets, and propulsion/airframe integration will also be pursued for very high-speed flight.

Materials and structures activities will include fundamental research in high-temperature materials; advanced design concepts and processing technology to exploit the unique properties of composites; computational methods development for analysis of loads and structural response of advanced vehicle configurations and engine systems; and structural concepts for hypersonic vehicle applications, including methods for active and passive thermal management. A focused effort will continue in rotorcraft air loads to develop and validate noise and vibration prediction technology.

In information sciences research, multiple process architectures, operating systems, programming languages, and algorithms for very high performance applications will be explored. Special emphasis will be placed on fundamental research related to software systems that perform with ultra-high reliability in spite of either hardware or software faults.

Controls and guidance research will investigate active controls technology for structural weight reduction and control of aeroelastic response, techniques for dynamic integration of structures and controls to optimize performance and identify problems early in the design process, and application of artificial intelligence and expert systems to achieve advanced cockpit automation. Emphasis on analytical modeling and airborne detection of wind shear will address technology for safer adverse weather operations.

Human factors research will pursue technology advances to enhance the overall capability, safety, and reliability of the crew-cockpit system. Emphasis will be placed on flight crew procedure monitoring with automated error detection and correction, flight validation of rotorcraft workload prediction methods, computer-based modeling of crew performance, vision systems requirements for automated nap-of-the-earth rotorcraft flight, and field studies of pilot error in automated aircraft.

Flight systems research will be directed at improving safety of flight in severe weather conditions. This includes technology for safe operation of aircraft and helicopters in icing conditions and for design of aircraft better able to survive encounters with severe weather. Improvements of analytical and experimental techniques for high-speed aircraft, including powered-lift aircraft with vertical or short takeoff and landing capabilities, will continue.

In systems analysis, studies will continue toward identifying the most promising aircraft concepts for future high-speed civil transportation.

Rotorcraft systems technology activities will include development of a comprehensive helicopter data base in loads, vibration, acoustics, and performance to validate predictive methodologies and completion of a cooperative research program with the U.S. rotorcraft industry. Active controls and advanced rotorcraft configuration research, such as tilt rotor and X-wing, will accelerate with the promise of dramatic improvements in speed, agility, maneuverability and productivity for civil and military operations.

The turbine engine hot section technology program and the ceramics for turbine engines program will be combined and augmented to develop a fundamental high-temperature materials technology base for advanced propulsion systems. The principal focus will be on ceramics, carbon-carbon and metal matrix composite materials. These advanced materials will enable much higher temperatures than present turbines and engine hot section components can withstand, with prospects for totally eliminating the need for cooling air—currently a costly penalty to engine performance. This technology will allow sustained supersonic cruise, high thrust-to-weight engines for advanced vertical takeoff and landing concepts, and much higher fuel efficiency.

High-performance aircraft research will concentrate on the application of integrated propulsion and flight controls to enhance military aircraft mission effectiveness, selection of the most promising supersonic vertical takeoff and landing configuration(s) for focused technology development, and extended verification of the advanced technologies incorporated into the X-29A forward-swept-wing aircraft. Detailed design fabrication, aircraft modification, and flight qualification testing will continue on the oblique wing technology program, leading to flight tests in FY 1989.

The advanced turboprop program will emphasize increased fundamental understanding of source noise, cabin acoustics, and installation aerodynamics encompassing both single- and counter-rotation propellers. The general aviation and commuter engine research program will continue to provide the technology base for small gas turbine engines to improve fuel consumption through advanced high-pressure ratio, mixed-flow component technology and innovative cycle concepts.

The Numerical Aerodynamic Simulation (NAS) initial operating configuration will be fully operational in the new facility in 1987. The second high-speed processor will be integrated into the system, and the support subsystem will be upgraded for the extended operating configuration, which will be operational in mid-1988. Operation support will be combined with NAS development in systems technology to increase the efficiency of managing the NAS and to enhance its development in an integrated fashion.

RESEARCH AND TECHNOLOGY BASE

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Fluid and thermal physics research and technology	$39,500,000	$29,000,000

	Estimated fiscal year 1987	Authorization fiscal year 1988
Applied aerodynamics research and technology	56,100,000	61,000,000
Propulsion and power research and technology	38,700,000	41,000,000
Materials and structures research and technology	39,000,000	42,000,000
Information sciences research and technology	23,800,000	26,000,000
Controls and guidance research and technology	24,100,000	27,600,000
Human factors research and technology	24,000,000	26,000,000
Flight systems research and technology	21,900,000	26,100,000
Systems analysis	5,800,000	6,500,000
General Increase		20,000,000
Total	272,900,000	305,200,000

Fluid and Thermal Physics Research and Technology

The Fluid and Thermal Physics Research and Technology program is a combined analytical and experimental research effort directed at external aerodynamics. One of its principal objectives is the development of computational methods, which will increase the speed and efficiency of three-dimensional (3-D) flow solvers by two orders of magnitude, for the prediction and simulation of complex fluid flows over aircraft. A second objective is the validation of prediction and simulation methods by means of a coordinated experimental test program with particular focus on accurate 3-D 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. Drag reduction research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag by up to 60 percent. Rapid progress is being made in the development and validation of computational techniques that will lead to reduced development time and costs for future aircraft and will provide the basis for achieving new and higher levels of aircraft and missile performance.

The goal of computational fluid dynamics (CFD) research is to predict and simulate the aerodynamic flow field for complete aircraft or missile configurations in any flight condition. To this end, the program includes the development of computer codes for simulating turbulence and for solving complex fluid dynamics problems, including steady and unsteady, inviscid, and viscous flow over two- and three-dimensional geometries from low subsonic to hypersonic speeds. Improved algorithms for Euler and Navier-Stokes codes were developed for efficient use of new supercomputer technology to make possible early utilization of the advanced capabilities provided by the initial operations of the Numerical Aerodynamic Simulation (NAS) program. Significant progress has been made in the application of CFD techniques to complete aerodynamic configurations. For the first time, viscous flow over an entire aircraft has been computed and validated for realistic flight conditions. In addition, gas dynamic and chemical kinetic effects have been incorporated into computational codes that simulate the viscous, real-gas external flows about hypersonic vehicles.

The advancement and confidence in CFD research relies heavily on a detailed understanding of flow physics which provides input for more accurate mathematical modeling of the flow. Increased effort has, therefore, been devoted to the modeling of turbulence and to the validation of CFD codes.

Detailed benchmark data bases are being acquired to provide the flow field and boundary conditions for the validation of computational codes. A vortical flow data base was generated from detailed low-speed experiments of a delta wing model at high angles of attack for CFD code validation. The understanding and control of viscous flow phenomena are vital in the development of advanced aerodynamic configurations. Significant progress has been made in viscous flow research, particularly in the drag reduction area. Wind tunnel and flight tests have proven the riblet as an effective device for turbulent drag reduction, providing a 6-percent reduction in skin friction drag. Also, the large eddy break-up concept has been computationally analyzed and redesigned for application to transonic flows. Active laminar flow control research on the Jetstar aircraft is nearing completion, and results have proven that wing flow suction in a small region at the leading edge is effective in establishing laminar flow over a large portion of the wing. It was demonstrated that severe environmental effects, tested under realistic operational conditions, do not adversely affect the drag reduction. Natural laminar flow research flight testing was begun on the F-14 aircraft where the effects of sweep and Mach number on boundary layer transition will be explored.

Experimental and analytical aerodynamics research efforts have resulted in a number of low- and medium-speed airfoil designs being transferred to industry. The National Transonic Facility (NTF) was heavily utilized in experimental research and problem-solving testing. Extensive tests were conducted on a modified EA-6B model in the NTF where low-speed stability and lift were significantly improved. These modifications provided an 18-percent increase in lift at low speed. Advances in analytical aerodynamics included the development of an accurate thin-layer Navier-Stokes method for transonic, high-Reynolds number flows of isolated wings. Construction of the fluid mechanics laboratory at the Ames Research Center was completed. This laboratory contains a number of small research facilities that are used for fundamental fluid physics investigations. Theory and experiments are being closely coupled in this environment in turbulence modeling, vortical flow studies, high angle-of-attack flows, and for other complex fluid phenomena. Advances were made in the understanding of vortex-thrust and vortex-lift phenomena through testing of wing leading-edge extensions and cavity flaps.

In FY 1988, the CFD program will continue to improve 3-D configuration analysis and design. This will be accomplished principally through the development of numerical algorithms with an order-of-magnitude improvement in speed and efficiency over current solvers. Particular focus will be given to validating Navier-Stokes prediction codes for unsteady rotorcraft aerodynamics and codes incorporating real-gas effects and finite-rate chemistry to predict aerodynamic performance, heat transfer, and engine/exhaust flows for hypersonic vehicle concepts. Development of applications codes will be broadened to include greater integration of aerodynamics, structures, propulsion, and controls.

Aerodynamic benchmark experiments designed to validate CFD techniques and provide data for flow modeling will be conducted. Data will be acquired to improve the modeling of complex flows that experience separation, vortical motions, and streamwise or transverse curvature.

Viscous flow research in FY 1988 will focus on improving the understanding of the physics of turbulent flows and the development of techniques and devices to reduce or eliminate turbulence induced aircraft drag. Development of the holographic velocimeter concept will be pursued as a means of exploring fundamental turbulence phenomena and gathering turbulence modeling data. The modification and extension to supersonic speeds of existing subsonic turbulent skin friction reduction devices will be carried out. An analysis technique will be developed for predicting hypersonic boundary-layer transition. Methods will be developed for reducing induced drag. Research in turbulence control will be performed where sensors and logic circuitry will be used in controlling the adverse effects of turbulence. The F-14 variable-sweep transition flight experiment with natural laminar flow wings will be completed. The concept of hybrid laminar flow control, where laminar flow control and natural laminar flow techniques are combined, will be explored.

Research in experimental and analytical aerodynamics will focus on the analysis of vortical flows. Vortex formation, breakdown, and control will be studied in a series of wind tunnel tests. Additionally, wind tunnel tests of high-alpha leading-edge and trailing-edge separation phenomena will be conducted to understand the flow physics and investigate possible mechanisms for controlling vortex formation. A large panel aerodynamics computer code will be enhanced with advanced flow solvers to handle transonic flows. National Transonic Facility correlation model test results will be used in calibrating three transonic wind tunnels. Fundamental skin friction experiments on laminar flow concepts, leading-edge breakup devices (LEBUs) and riblets will be performed in flight at subsonic and supersonic speeds to build the technology base for drag reduction. Boundary-layer transition control on low- and medium-speed airfoils will be investigated in wind tunnel tests.

Applied Aerodynamics Research and Technology

The objective of Applied Aerodynamics Research is to generate advanced technology to improve the performance and flight dynamics of future aircraft and missiles through analytical and experimental programs. The effort is directed at specific technology goals associated with each class of vehicle: (1) increased efficiency for subsonic aircraft through airframe and propulsion integration, greater stall-spin resistance, improved takeoff and landing performance using powered lift, and a 60-percent reduction in cruise drag; (2) accurate prediction of the aerodynamic sources of rotorcraft noise and vibration, and the improvement of rotorcraft performance and flight dynamics for doubled productivity and agility; (3) high angle-of-attack maneuverability, sustained supersonic performance, and short takeoff and vertical landing (STOVL) capabil-

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operation. For supersonic cruise, new nonlinear approaches to laminar flow and airfoil shapes are being developed to double cruise efficiency. In high angle-of-attack research, active and passive control of vortex flow has shown promise for improving the control problems associated with this maneuver condition. In addition, the use of multiaxis thrust vectoring is being explored after successful free-flight tests in the 30x60-foot wind tunnel. These fundamental efforts are developing the research base for flight experiments to be conducted under the systems technology element for high-performance flight research. In the supersonic fighter STOVL program, an ejector lift-vectored thrust fighter model is being constructed in large scale by Canada for testing by NASA in a cooperative program. In addition, in-house studies of other supersonic STOVL concepts are underway to support an early decision to choose the most attractive approach.

Activities in hypersonics were expanded in FY 1987 in both the experimental and theoretical areas. Experimental wind tunnel tests were conducted on advanced aerospace configurations that show promise for atmospheric cruise flight applications and air-breathing accelerator launch vehicles. The application of computational fluid dynamics to the simulation and analysis of complex flow fields was carried out using a newly developed computer code which simulates viscous hypersonic flows about realistic configurations.

Research leading to new testing capability and techniques continues to be pursued to support aerodynamics research. The National Transonic Facility is continuing to demonstrate capability for cryogenic wind tunnel testing in order to simulate full-scale conditions with independent control of compressibility, viscosity, and aeroelasticity parameters. Models tested to date include the Space Shuttle, the EA-6B for the Navy, and the Pathfinder I, a generic transport with interchangeable components. Nonintrusive measurement devices, such as laser anemometers which provide large payoffs in accuracy and productivity, will continue to be improved.

In aeroacoustics research, model tests which quantify the effects of the acoustic fatigue loads on the aft end of high-performance fighters have been completed. Flight tests of twin-plume resonance are underway to confirm these loads and investigate a method of detuning the jets to reduce acoustic fatigue.

In FY 1988 subsonic aerodynamics research will develop technology to reduce induced drag and minimize interference drag. High lift systems that are applicable to advanced, low-drag, natural laminar flow wings will be designed. The benefits and limitations of unconventional configurations using forward sweep and canards will be demonstrated by wind tunnel testing.

Activities in rotorcraft aerodynamics research will include an intensive schedule of large-scale tests in the 40x80-foot wind tunnel, focusing on the aerodynamic phenomena that cause noise, vibration, loads, and unstable rotor dynamics behavior. A bearingless main rotor will be tested to define high-speed dynamic stability and loads for this advanced configuration. A simplified method of higher harmonic control for vibration reduction will be tested on a full-scale rotor. The aerodynamic interference between a main rotor, fuselage, and a tail rotor will be investigated in another test. Each of these tests seeks to validate a portion of an analysis code that predicts the aerodynamic behavior involved. Small-scale tests will also be conducted to understand the strong influences of the rotor wake on airloads prediction. In flight dynamics research, a new activity will be started in cooperation with the U.S. Army's development of a variable-stability research helicopter. This new research tool will have higher harmonic pitch control, a flexible research control system, and a highly maneuverable rotor system. Such capabilities are key to understanding the potential for advanced control on highly maneuverable combat rotorcraft.

High-performance aerodynamic research in sustained supersonic cruise will translate the improvements predicted in airfoil and laminar flow into carefully constructed wind tunnel experiments. High angle-of-attack research will investigate stability and control at angles up to 80 degrees to support the planned flight research on the F-18 vehicle and will provide the aerodynamic data base necessary for piloted simulations of maneuvers using thrust vectoring for control. In powered-lift technology, the large-scale fighter model of an ejector lift/vectored thrust model will be tested in the 40x80-foot wind tunnel in a cooperative effort with Canada. Several studies and tests on critical technology areas, such as sustained supersonic cruise and ground-effect penalties in hover, will be undertaken in support of the U.S./United Kingdom program in supersonic STOVL. Simulation of the proposed STOVL concepts will determine required levels of control power and flying qualities criteria.

In the area of test techniques and instrumentation, development of advanced cryogenic instrumentation with emphasis on accurate boundary layer diagnostics, sensing of model attitude and structural deformation, and the development of an ultra-high force balance will continue in the National Transonic Facility. In other test techniques activity, the laser holography visualization effort will focus on measurement of turbulence quantities in order to provide detailed data bases to support turbulence modeling and CFD validation efforts. Adaptive walls will become operational in the Langley Research Center 0.3-meter and the Ames Research Center 2-foot wind tunnels. Fluorescent techniques will be developed for simultaneously sensing temperature, velocity, density, and skin friction parameters. The recently developed liquid crystal coatings for boundary layer research will be extended to supersonic and hypersonic flows.

Additional emphasis will be placed on modernizing and improving the test efficiency of NASA's major wind tunnels to meet increasing research and development demand. Specific focus will be on test instrumentation and data acquisition systems to increase the productivity of national wind tunnels. Additional investments will be made in maintenance and operations to assure reliability and availability of these national resources for major development programs.

The FY 1988 aeroacoustics research will focus on the development of three-dimensional flow prediction of near-field acoustics in the tip region of supersonic propellers.

Hypersonic cruise/transatmospheric concepts will be designed, tested, and analyzed to establish a data base for this evolving aerospace vehicle class. Wind tunnel models will be constructed and tested over a wide speed range (through hypersonic Mach numbers) to simulated high altitudes over a range of Reynolds numbers at the Langley Research Center. The computational fluid dynamics program at the Ames Research Center will be expanded to include real-gas effects and the effects of flow-field separation on realistically complex aerodynamic shapes.

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 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 performed on 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 of the component and subsystem level. These research efforts will lead to major propulsion system improvements for all types of aircraft.

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 number range of 3 to 6. A Mach 5 inlet has been designed using two-dimensional codes and was tested at small scale using flow visualization to obtain qualitative information and attractive instrumentation placements subsequent to large-scale experiments. The flow was found to be highly three-dimensional, showing that two-dimensional codes will be inadequate for design of high-speed inlets. Analytical development includes a time-dependent, three-dimensional, fully elliptical Navier-Stokes code to analyze complex flow fields and subsequently serve as a design tool.

For high-performance applications, the goal is to develop technology to support propulsion systems capable of vertical takeoff and landing using powered lift and in-flight thrust vectoring capability. Fabrication of the powered-lift test rig has been completed at the Lewis Research Center. In 1987, the rig will be used for evaluation of the U.S./Canadian ejector concept to obtain system performance and loss data. Fabrication of the hot gas ingestion model will be completed in 1987, and testing will begin in the low-speed 9x15-foot wind tunnel at the Lewis Research Center to determine the extent and effect of hot gas ingestion into the inlet during powered-lift operations. These results will be used to verify hot gas injection computer codes that are currently under development.

The objective of small engine research is to achieve a fuel consumption reduction of 50 percent and multifuel capability for intermittent combustion engines. Research emphasis for stratified-charge rotary engines, offering possible multifuel capability, includes improved understanding of the physics that will enable accurate prediction of advanced engine performance and operating boundaries. The computer modeling of rotary engine flow fields has been completed along with the fabrication of a rig to perform detailed flow measurements. At Deere and Company, a 40-cubic-inch single-rotor engine obtained 160 horsepower, the highest power density ever attained in a rotary engine. In 1987, new fuel injection schemes and advanced rotors are being investigated for improved fuel consumption. For small gas turbines, a large, low-speed centrifugal compressor facility is currently scheduled for completion and initiation of research in FY 1987. The facility will be used to investigate boundary layers and secondary flows and verify advanced three-dimensional viscous flow codes for turbomachinery.

In supersonic cruise, the objective is to develop technology for lightweight, efficient propulsion concepts for supersonic cruise conditions. Research is being focused on the analysis and experimental verification of the supersonic throughflow fan. This system 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 rig is nearing completion using advanced three-dimensional Euler and Navier-Stokes codes. In 1987, the rig will be fabricated and checked out in preparation for test of the supersonic throughflow fan.

Instrumentation and control research is aimed at developing advanced high-temperature sensors and optical nonintrusive measurement systems for research applications and engine sensors and controls for future propulsion systems. The first optical instrumentation system, that allows nonintrusive flow measurement of all three velocity components through a single viewing port, has been used to map a turbine stator cascade to develop verfication data for secondary flows. Bench tests have started on an advanced anemometer that has the capability of measuring detailed flow characteristics very near fixed surfaces. In support of high-temperature electronics development, a silicon carbide-based diode was demonstrated at 300°C, and the final major step in device fabrication capability was completed by demonstrating plasma etching. Studies are underway to eliminate the occurrence of antiphase boundaries, discovered during the past year, during production of silicon carbide crystals. Unchecked, this could degrade the performance of devices fabricated from the crystals. In FY 1987, the performance of a control sensor failure accommodation control on an F-100 engine will be demonstrated at the Lewis Research Center over the flight envelope.

Internal computational fluid mechanics (ICFM) is an increasingly important tool for understanding flow phenomena and as a basis for 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. A quasi three-dimensional Navier-Stokes code has been developed for turbomachinery, and a full three-dimensional code will be operational in 1987. The potential to describe the flows in more than one stage of turbomachinery was recently demonstrated with a new multistage code which reduces computer time significantly. An experiment was performed using laser diagnostics to develop a unique data set describing the structure of a normal shock interacting with a boundary layer and the flow field downstream of the shock. This flow field is typical of those found in high-speed inlets and transonic turbomachinery. The data set is currently being used to verify two- and three-dimensional Navier-Stokes analysis codes.

Hypersonic propulsion activities will continue with development of the analytical and experimental data base for supersonic combustion and Mach 3 to 6 high-speed cruise systems. Code development will continue for the complex flow fields in scramjet combustors, variable geometry inlets, and high-speed propulsion and airframe integration. Algorithms for high-speed flows (up to Mach 20) that reduce required computer time will be extended to three-dimensional capability and to include chemical heat release. Experimental efforts will 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. In addition, the Mach 5 two-dimensional inlet test will be completed at the Lewis Research Center in the 10x10-foot supersonic wind tunnel which will be used to verify advance three-dimensional Navier-Stokes codes that will be capable of analysis of practical high-speed inlets.

High-performance aircraft will include an evaluation of a complete simulation of a supersonic advanced short takeoff and vertical landing aircraft and propulsion system. A General Dynamics E-7 ejector system test on the power-lift rig will be completed to determine the detailed pressure drop and flow distribution on a representative configuration. Short diffuser inlets will be evaluated to determine potential performance at high angle-of-attack operation for supermaneuvering capability.

Supersonic cruise research will continue to focus on the supersonic throughflow fan concept. The tests will be completed on the inlet and diffuser portions of the test rig and compared to analytical predictions to help verify the codes being used for the design of supersonic inlets and ducts. The fan will be fabricated and tests initiated by the conclusion of 1988. The results of the fan experiments will be used to verify three-dimensional viscous analysis codes and help guide the development of off-design analysis codes. Systems studies will be conducted to determine critical technologies required for a propulsion system that incorporates a supersonic throughflow fan for various high-speed applications.

Small engine research includes rotary engines and increased emphasis on gas turbines. Laser anemometer flow measurements will be used to verify a generalized multidimensional rotary engine computer program that will be used to design the aerodynamic shape of a lightweight rotor for incorporation into the experimental program at Deere and Company. Gas turbine research efforts will concentrate on developing an experimental data base using the large low-speed centrifugal rig completed in 1987. The rig will allow 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 flow structure in the compressor.

Advanced instrumentation and controls research will continue to focus on nonintrusive measurement and high-temperature structural phenomena for code verification and optical sensors and actuators for propulsion systems application. The four-spot laser anemometer will measure near-wall boundary-layer flow in a warm turbine facility to verify advanced codes. A second nonintrusive optical flow measurement system, an electronic heterodyne holographic interferometer, will be used to define flow structure in highly accelerating regions, such as shocks in a transonic cascade. High-temperature applications will include the demonstration of a thin-film heat flux sensor and characterization of a silicon carbide-based metal-oxide semiconductor field effect transistor at 400°C. Preliminary designs of functional fiber optic sensor and actuator systems will be completed for an integrated propulsion/flight control system.

Research emphasis in internal computational fluid mechanics will continue on advance prediction capabilities for high-speed propulsion. For both existing codes and new codes under development, predictions of the aerodynamic flow field will be combined with reacting flow, combustion, and heat transfer to yield the capability of describing the total process taking place within a propulsion system. An advanced algorithm for simulating shocks in high-speed flows will be tested in three-dimensional Navier-Stokes code. An advanced three-dimensional Navier-Stokes testbed solver will be completed with the capability for replacing algorithms without restructuring the code. Analytical and experimental efforts will continue on unsteady flows with shear layers to investigate the effect of shear layer excitation on mixing control in highspeed combustion systems. A multistage turbomachinery code will be improved to include viscous effects and fundamental experiments will begin for data required to enable use of the average-passage approach necessary to model the real turbomachinery case where the flow is not averaged.

Materials and Structures Research and Technology

The objectives of the Materials and Structures Research and Technology program are to: (1) investigate 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, and economy in aircraft. 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 at higher temperatures with increased reliability and reproducibility. A new ceramic design code that accounts for the brittle material behavior has been successfully developed and transferred to industry. Improvement of ceramic material strength at high temperature has been successfully accomplished with a new sintering process using silicon nitride. The development of ceramic composites is expected to provide a material system that is of sufficient strength and durability to have a wide range of design applications in advanced turbine engines.

In aircraft materials research, studies are being conducted in advanced materials systems for very lightweight and very high temperature applications to understand mechanisms of damage, the environmental effects on the properties of composites, the prediction of microstructure, and the bulk properties of materials. Significant advances have been made in understanding alloy chemistry and secondary processing of advanced fiber-reinforced aluminum alloy; strong, high-temperature, silicon-carbide fiber-reinforced intermetallics for aircraft propulsion systems; and a new process for three-dimensional, woven, thermoplastic composites for airframe structures.

Computational structural mechanics (CSM), a major thrust in FY 1987, 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. A CSM software testbed concept has been developed to accelerate the development and evaluation of new computational methods and computer systems utilization. CSM analysis methods have already made important contributions to the understanding and improvement of the Shuttle solid-rocket motor clevis/tang joint design.

Research in aircraft structures emphasizes the development of design and analysis technology for efficient damage-tolerant advanced composite structural components and innovative structural concepts. Thermomechanical structural analysis has been developed for high-temperature complex engine structures. Methodology for solving interdisciplinary design problems, including design optimization, is continuing. The prediction of structural loads due to intense acoustic radiation in advanced turboprop applications is being pursued. Significant accomplishments made in 1987 include the development of advanced geodesic composite panel design concepts with filament-wound isogrid panel construction, proven construction and fabrication technique of a half-scale fuel strut for a scramjet engine concept, and validated three-dimensional stress analysis of cracked structures which allowed improved redesign of the blades of large wind tunnel drive fans.

In the aeroelasticity program, new and more efficient unsteady aerodynamic computational methods, with emphasis on transonic flow, are being developed and verified with experiments. A comprehensive transonic unsteady aerodynamic and aeroelastic analysis code has been transferred to industry and the Air Force for application. A new concept for an actively controlled flexible wing has been successfully tested in the transonic dynamics tunnel, and this concept represents a breakthrough for future advanced high-speed aircraft design to alleviate maneuver loads with improved roll rates. Aeroelastic analysis performed on the X-wing aircraft revealed new design aspects which will improve the operational aeroelastic stability.

In rotorcraft research, an augmented effort starting in 1987 is focused on measuring and understanding the detailed rotor airloads through wind tunnel and shake tests. Initial airload data will be acquired with the UH-60 helicopter in flight. Whirl testing and flight tests of the Boeing Model 360 will extend the airload and structural dynamic data base to airspeeds beyond 180 knots. A new test apparatus is being constructed for the 40x80-foot wind tunnel to test both of these rotors to compare with the flight test results. A better definition of difficult-to-model fuselage components is being pursued to overcome the large prediction errors for airframe vibratory response.

Hypersonic research continues to explore innovative new materials and structures concepts for airframe and propulsion systems for advanced aerospace vehicles. In both areas, studies are directed toward the development of new lightweight material systems and structural concepts that will withstand the extreme high temperature and loads encountered in the hypersonic flight regime. An integrated flow/thermal/structural analysis methodology has been developed and verified with experimental results. Current research in hypersonic materials has established the feasibility for three-dimensional woven carbon-carbon fiber-stiffened structure and an arc spray processing technique for advanced metal matrix fabrication. A new vehicle sizing methodology has been developed for vehicle weight assessment and optimized for both structural loads and failure criteria.

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. Strong emphasis will be placed on advanced high-temperature metallic and nonmetallic materials. New and tougher resin/fiber composites, high-temperature polyimides (700°F), 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 brittle materials will be pursued. Generalized, multiaxial constitutive models for composites will be developed for prediction of environmental effects, cyclic damage, and rate dependence.

In the structures area, emphasis will be placed on development of innovative structural concepts for composites using advanced filament winding and pultrusion, as well as design concepts using high-temperature brittle materials. Analytical and experimental studies will continue to develop advanced structural concepts and configurations that exploit the advantages of composites. Structural analysis will concentrate on nonlinear methods for predicting the structural response under complex thermomechanical load histories. Synthesis and optimization methodology will be used to obtain high-performance aircraft structures. Efforts in structural response under acoustic loads will continue. Facilities for high-temperature structural fatigue will be developed to increase the experimental capabilities in fatigue/failure assessment on advanced structural materials.

The dynamics and aeroelasticity program will emphasize the development of improved analytical tools for predicting unsteady aerodynamic loads for transonic flow with particular emphasis on three-dimensional flow for the total vehicle configuration. Innovative flutter suppression research will be pursued together with the development of novel flight deflection measurement techniques, such as electro-optical sensor systems. New aeroelasticity concepts, such as the flexible actively controlled wing developed in FY 1987, will be refined through systematic wind tunnel tests, and data will be correlated with analysis.

In the area of integrated analysis and design optimization, efforts will concentrate on the development of efficient methods in CSM for the analysis of complex aerospace vehicles and propulsion systems. Emphasis will be placed on nonlinear analysis of high-temperature engine structures and nonlinear transient dynamics of multibody problems and rotating shafts. Large displacement procedures will be developed for analyzing stiffened composite panels required for composite airframe design. CSM analysis methods development will continue in the areas of concurrent computing methods with multiple and parallel processor computers and efforts in software testbed development will be expanded. Research will also be initiated to exploit the Cray 2 supercomputer of the numerical aerodynamic simulator for CSM research applications.

Research in subsonic transports, commuter airplanes, and general aviation aircraft will be focused on safety issues for ground operation and crash load alleviation. Structural and dynamic analysis will be conducted to understand ground handling problems, including friction and rolling effects on tires. Work will continue on the development of airframe subfloors using the energy absorbing composite structural concepts. Advanced tire testing activities will utilize the aircraft landing dynamics facility recently modified to obtain 220-knot test speed capability.

The rotorcraft activity will continue to concentrate on the detailed airloads and airframe structural dynamics. The large rotor test rig for the 40x80-foot wind tunnel will be completed and ready for use to test the UH-60 and Boeing Model 360 rotors planned in FY 1989. A model 360 helicopter with extensively instrumented rotor blades will begin flight testing to augment the data base obtained with wind tunnel and shake tests. Effective approaches for active vibration suppression, as well as structural detuning, will be studied. The fuselage vibration analysis will be extended to include rotor/fuselage coupled vibration.

In FY 1988, more emphasis will be directed toward hypersonic materials and structures research. 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 concepts and methodology for controlling the aeroservoelastic behavior at hypersonic speeds will be pursued. Actively cooled primary structural concepts will be investigated. Hypersonic materials research will be focused on carbon-carbon control surfaces; constitutive behavior and characterization of high-temperature, lightweight composites; fabrication of intermetallic composites with low density matrices; and oxidation-resistant and thermal barrier coatings.

Information Sciences Research and Technology

The objectives of the Information Sciences Research and Technology program are to increase NASA's capabilities in advanced aerospace computing and to exploit key computer science disciplines to meet the agency's unique computing requirements. Support for computational fluid dynamics (CFD) and other aerospace research disciplines is provided by developing a fundamental understanding of the relationships between essential algorithms and advanced architecture and exploiting the potential of concurrent processing to significantly increase computing power. Software engineering to support aerospace research includes research and development of concepts for advanced operating systems, programming languages, and user interfaces for distributed and parallel architectures. Another key objective is to establish the technology base for cost-effective, reliable computing in complex, mission-critical hardware and software systems.

Significant progress toward enabling efficient computation of aerospace algorithms was made in the last year. The most fruitful approach has been to ensure that computer architectures and the computational algorithms are well matched. It was demonstrated that multiple instruction/multiple data stream architectures with common (shared) memory, such as the Cray XMP and Cray 2, can efficiently process CFD algorithms. By use of an approximate factorization, three-dimensional flow problems were split into separate one-dimensional problems which ran on independent processors, with the three-dimensional grid data accessible through common memory.

The usual mapping of data to the hypercube architecture for performing fast Fourier transforms is not efficient when performing nearest neighbor mesh computations on the same data. Since these computations are used together in many CFD algorithms, it is important to use a mapping which is good for both. This year, a code mapping which shows promise in greatly increasing the efficiency of CFD calculations on the hypercube is being investigated. Other algorithms currently being investigated on the hypercube architecture include multigrid Navier-Stokes solvers.

A special purpose architecture for solving Navier-Stokes processor, has been designed and a prototype was built this year. The high performance of this system has been achieved in a very cost-effective design which will enable supercomputing capability for NASA flow codes without use of expensive general purpose supercomputers.

Research on the implementation and application of sparse distributed memory (SDM) was initiated this year. It is theoretically capable of learning to recognize similar events and conditions by experience and training without the need for programming by software. Simulations are underway to verify essential capabilities of SDM. Intelligent systems based on SDM might include avionics that are able to effectively manage unanticipated events which, in turn, would increase the reliability of highly automated aerospace vehicles.

There have been significant research results this year which support NASA's goal of establishing a technology base for reliable, fault-tolerant computer system in mission-critical applications. A reconfigurable concurrent architecture has been defined which provides significantly higher reliability with less redundancy than previous approaches. This kind of architectural research will ultimately enable flight-crucial computer systems to automatically reconfigure in order to maintain adequate performance and to degrade gracefully upon further failure.

A high-speed mainframe computer networking subsystem (CNS) has begun operation to help NASA achieve its goal of improving the effectiveness and productivity of large mainframe computers which are essential for aeronautic research and technology programs. Using the program support communications network (PSCN), the CNS has achieved a transmission rate of 1.544 million bits per second. The network enables efficient transmission of large data and program files between NASA's geographically distributed research centers.

Research in matching computer architectures and algorithms will continue to serve NASA's needs for efficient processing of aerospace algorithms. Investigations of the most advanced supercomputers, such as the Cray 2, and their use for computational fluid dynamics research and similar problems will continue. In addition, more comprehensive approaches may be established in cooperation with the Defense Advanced Research Projects Agency (DARPA) and the National Science Foundation (NSF). One approach under consideration is the formation of a center for advanced architectures which could bring together application scientists, computer architects, and software specialists to study the utility of specific architectures for specific algorithms. This center would allow sharing of advanced computers and research results.

A hardware prototype of sparse distributed memory (SDM) will be built. This will be used to conduct application studies to test the theory with real pattern recognition problems. A study will be conducted to determine the feasibility of a modified SDM for performing simulations of dynamic gases at far greater resolution than currently possible.

In the area of redundant software, studies will quantify the reliability gained as a function of redundancy and will develop strategies for reducing errors. The cost and reliability of very large aerospace software projects will hinge on intergrated, comprehensive, and automated software management tools. For this reason, increasing emphasis will be placed on software support environments. This work will concentrate on management of the software life cycle.

NASA is working with other federal agencies to identify the issues and devise a plan for interconnecting the NASA PSCN and other research-oriented networks, including those from the NSF, DARPA, National Academy of Sciences, and the Department of Energy. This will establish a consistent mechanism to allow sharing of both computing and network resources.

Controls and Guidance Research and Technology

The objectives of the Controls and Guidance Research and Technology program are to: (1) investigate emerging controls, guidance, artificial intelligence, and display technologies which offer automation/system integration for aviation effectiveness and efficiency; (2) develop architectures for flight-crucial systems for future aircraft and devise analytical methods and techniques for assessing their reliability and performance; (3) develop methods to alleviate the threat of wind shear and heavy rain through airborne detection and avoidance; (4) develop controls and guidance theories and analysis methods for extending the performance envelope and reliability of highly augmented future aircraft; and (5) explore new concepts for achieving integration of multidisciplinary technologies.

Control theory research includes activities on analytical methods, controls modeling, and applications. Methods for analyzing and simulating reconfigurable/restructurable control systems continue to be a major focus with the objective of achieving automatic failure detection and identification in order to accommodate unanticipated failures in real time. A control law was developed for damping shock-induced flutter. A new research thrust is the development of the theory for closed-loop control by symbolic processing to allow the use of high-level mission goals for effective and safe flight management and control.

Guidance and display concepts research is directed toward enabling flight and ground systems tolerant of human error. In the guidance concepts area, progress has been made in formulating approaches to utilize and apply artificial intelligence and expert systems technology in various aircraft applications. For military airplanes, the main thrust involves flight evaluations of automated wingman and advanced lead-pilot advisor concepts; for civil aircraft, the main emphasis is on the air traffic controller associate. A controller descent advisor and expert system schedule advisor have been demonstrated in air traffic control simulations. A technique for high-resolution stereo displays in 3-D has been demonstrated. A new approach for increasing thin-film electroluminescent display brightness by an order of magnitude has been conceived and will be evaluated in prototype hardware.

Flight-crucial systems research has concentrated on the development of a technology base for the design, validation, and assessment of highly reliable guidance and control systems. The avionics integration research laboratory facility at the Langley Research Center is the focus for a significant part of this research, which has extensive industry and university involvement. Activities in fault injection, computer synchronization, and software reliability have been completed to validate reliability estimation computer programs. Three reliability prediction computer codes have been effectively transferred to industry.

Controls and guidance research directly applicable to subsonic transports includes activities on advanced transport operating systems, airborne Doppler radar wind-shear detection, advanced digitial control systems architectures, and flight safety. The joint NASA/Federal Aviation Administration airborne wind shear program was initiated in 1986. A takeoff and landing monitor was developed and successfully evaluated by over 30 pilots. The monitor provides pilots with an integrated display of aircraft state during takeoff/landing, including safety warnings and indications of optional stopping positions on the runway.

Rotorcraft guidance and controls research involves unique concepts to enable automated nap-of-the-earth (NOE) flight. Flight tests were completed on a highly portable low-cost beacon landing system. It shows great promise for use in a battle-damaged airfield misson scenario for both fixed-wing and rotorcraft application. A real-time terrain-following and terrain-avoidance trajectory coupler was developed for low-altitude rotorcraft flight.

Controls and guidance research directly applicable to high-performance aircraft includes the integrated airframe and propulsion control system architecture program aimed at the development of validation methodology for complex integrated control system and the integration of aerodynamic, structural, propulsive, and control system dynamics. A comprehensive set of control system design metrics has been selected based upon analytical studies of nonlinear aerodynamics and flexible aircraft models. These metrics are being evaluated in piloted real-time simulations.

Hypersonic vehicle controls and guidance research is directed toward guidance and outer-loop control concepts which can significantly affect the performance and efficiency of hypersonic cruise vehicles operating at very high altitudes. Conventional guidance and control techniques may not be optimum in the upper atmospheric environment at which these vehicles will operate, and new considerations, such as extremely high-temperatures, may dictate completely new primary guidance and control modes. Initial studies are underway for evaluating active controls concepts for future aerospace vehicle concepts.

In the applied aircraft control theory area, a key goal is to develop robust control algorithms which are resistant to vehicle or environmental uncertainties. The prime technical challenge is to develop a completely restructurable controls algorithm for unanticipated failures. Future thrusts will be directed toward bringing viable theories into simulated flight environments for evaluation. Additionally, nonlinear modeling and systems identification methods are being developed to support high angle-of-attack controls requirements.

Guidance and display concepts research includes the application of artificial intelligence technology to military and civil aircraft operations. One planned focus is the automated wingman program undertaken in cooperation with Defense Advanced Research Projects Agency. The automated wingman concept has the potential for making substantial improvements in the effectiveness of multiaircraft strike forces through the application of artificial intelligence technology. The approach for conducting flight research in this program, involving a ground computational facility and a remotely augmented vehicle, offers the potential for validating artificial intelligence flight systems and the capability for stimulating complex aircraft and multiaircraft systems in a cost-effective manner.

In the flight-crucial systems area, research will stress validation techniques, assessment technology, software reliability, lightning effects, and advanced architectures. Recent software reliability research has indicated a potential fallacy in classical software reliability assumptions. Increased emphasis will be applied to develop a credible software reliability model based on validated assumptions. In the advanced architecture area, the proof-of-concept hardware and software of the advanced information processing system, a distributed fault- and damage-tolerant architecture designed for real-time aerospace applications, will complete test and validation.

Controls and guidance research directed at subsonic transports includes advanced transport operating systems, highly reliable digital control systems architectures, and safety. The major focus in advanced transport operating systems will be evaluation of air traffic control automation aids for unequipped and four-dimensional (4-D) flight management equipped aircraft operations within the national airspace system. Research will establish preliminary algorithms needed to allow a transport to automatically fly the optimized trajectory from cruise to the terminal area metering fix, flight crew interfaces, and ground controller procedures to intermix 4-D and non-4-D equipped aircraft. This research will be performed in close coordination with the Federal Aviation Administration.

Rotorcraft controls and guidance research involves the application of artificial intelligence and expert systems technology to the difficult military rotorcraft mission of all-weather NOE operations. The objective of this research is to develop flight path management and planning concepts for terrain following and avoidance and manually controlled helicopter NOE flight, leading to automated flight. An expert system will be developed for onboard mission replanning during NOE flight, and concepts for providing the interface between the pilot and the system will be formulated. This research will be performed in cooperation with the U.S. Army.

Controls and guidance research directed at high-performance aircraft applications will stress development of a supermaneuverability technology base for high angle-of-attack research. Proposed design methods will be evaluated and honed in piloted simulation.

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. This is necessary for safety, efficiency, and increased capability in transcentury rotorcraft and transports and, ultimately, in the National Aerospace Plane. This is accomplished by developing an understanding of crew capabilities, limitations, and tendencies in interacting with these systems and by delineating guidelines for implementing that understanding. There are four areas of emphasis: flight management, human engineering methods, rotorcraft, and subsonic transports.

The flight management research program continues to emphasize: (1) determination of the relationship between human performance and advanced automation, (2) information management for advanced cockpits, (3) computer-aided interface design tools, and (4) evaluation and modeling of pilot sensory and information transfer performance. Operational incidents, such as those collected by the Federal Aviation Administration (FAA)/NASA aviation safety reporting system, continue to provide researchers with guidance about the most critical areas requiring investigation. The rapid advancement of onboard computers has dramatically altered the nature of the piloting task.

An expert system which automatically detects crew procedure errors was completed and readied for testing in full mission simulation. The system contains information about expected behaviors, phase of flight, and other operational details. It is a key component in a more fully capable system which will be human error tolerant.

An intelligent cockpit aid was developed for fault monitoring and diagnosis utilizing a knowledgebased approach to system description.

The subsonic air carrier research program concentrates on: (1) determination of sources of pilot error in operational aviation environments and evaluation of systems and operating procedures, (2) improved pilot selection and training methods, and (3) investigation of methods for improving information transfer in the national airspace system. This year, a major, full-mission simulation study of the human factors aspects of the FAA's traffic alert and collision avoidance system (TCAS) was initiated at the request of the FAA and the Air Transport Association.

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, Department of Defense, and Federal Aviation Administration (FAA). The program is organized into the following main categories: (1) aviation safety, (2) flight instrumentation and test techniques, (3) high-performance 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, wind shear, lightning, turbulence, and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of previously unobtainable 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.

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. They involve 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, development of ice protection concepts, establishment of a flight-validated lightning strike data base, and development of an understanding of the effects of heavy rain on aircraft aerodynamic and propulsion system performance. A program has been initiated to develop an intercolated graphite thermal anti-deicing concept for composite aircraft surfaces. Development of an airfoil ice accretion computer code has been completed, and research efforts related to advanced aircraft applications have been initiated. In the area of heavy rains, a Critical Design Review was successfully completed for the planned use of the aircraft landing dynamics facility for heavy rainfall simulation using a large-scale wing model. The instrumented F-106 severe storms research aircraft completed its lightning strike flight research activity. The resulting first-of-a-kind data base is providing the basis for the development of lightning strike effects models for use by FAA and industry for materials and avionics protection. Wind tunnel investigations of heavy rain effects are providing an initial data base for modeling the resulting degradation of aircraft performance.

The objectives of the high-performance aircraft program are 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. Negotiations have been conducted with the United Kingdom for cooperative investigations of several design concepts for an aircraft with supersonic and advanced short takeoff and vertical landing (ASTOVL) capability.

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 has been initiated.

In FY 1988, the aviation safety program will emphasize coordinated wind tunnel and analytical investigations with ice accretion and its effects on fixed- and rotary-wing aircraft performance and handling qualities. Research to establish a flight-validated severe storms and lightning effects data base will be completed and the results reported to the FAA and industry. Wind tunnel and analytical investigations will be continued to establish a data base for analysis and understanding of the effects of heavy rain on aircraft aerodynamic and propulsion system 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 the potential integration of aerodynamic and propulsive flight controls on the NASA F-18 high-alpha research vehicle. In the U.S./United Kingdom ASTROVL program, propulsion system and airframe design studies will be completed to identify the advantage and disadvantages of alternative propulsion system concepts for a supersonic ASTOVL aircraft. The study results will be used to guide the research activities required to develop the technology base for the most promising aircraft/propulsion system concepts.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft. In the main, these standard aircraft 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). The test support activity also provides for flight crew training, maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

Systems Analysis

The objective of the Systems Analysis effort is 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, and provide potential economic benefits. Conceptual designs are performed incorporating new technologies, and sensitivity analyses and tradeoff studies are conducted to quantify the benefits of the emerging technologies.

Systems analysis studies of subsonic aircraft, which include general aviation, commuter, and transport aircraft, concentrate on the impact of very advanced materials and structures for propulsion systems on a 150-passenger class of transports powered by advanced turboprops and on a 500-passenger class of transports powered by turbofans.

In FY 1987, data collected from a joint program between the American Helicopter Society and NASA was used to identify the highest payoff technologies that enable helicopter noise reduction with minimum performance penalty. Also, conceptual studies were performed to quantify noise reduction achievable through advanced technologies, such as rotorcraft without tail rotors.

A major study effort has been initiated to identify the most promising vehicle and propulsion system concepts for high-speed civil transportation (from Mach 2.0 up to transatmospheric speeds). The studies address the advanced vehicle concepts enabled by emerging technologies, including those from the National Aerospace Plane program. These studies are being conducted by major airframe and propulsion system manufacturers with airline consultants.

An ongoing study effort is assessing the potential of new technologies for high-performance aircraft. In FY 1987, the studies focused on the advanced short takeoff and vertical landing (ASTOVL) aircraft. As part of a cooperative U.S./United Kingdom program, second-generation conceptual design studies were conducted with emphasis on advanced propulsion concepts and their intergration into the vehicle. These in-house studies support major contractual efforts with propulsion system and airframe manufacturers that are funded in the flight systems area. Together these studies will form the basis for selecting the most promising concept for technology development in FY 1988.

Studies in FY 1987 for hypersonic vehicles consisted of in-house development of models to assess hypersonic propulsion systems and contractual development and assessment of unique propulsion concepts for both hypersonic cruise and transatmospheric flight.

In FY 1988, rotorcraft efforts will assess the impact of advanced technologies on high-speed tilt rotor configurations and X-wing concepts. For the tilt rotor, technology needs will be identified for folded tilt rotor configurations with speeds in excess of Mach 0.7. Also, the potential benefits and technology needs of autonomous remotely piloted rotorcraft will be studied.

The high-speed civil transportation studies will continue through FY 1988. Design criteria will be established, and sensitivity studies will be performed to assess the benefits and technical risks of configuration options in terms of civil potential. Also, for each configuration, issues such as environmental impact, safety, fuel, and airport infrastructure will be examined. The national-scale significance of these issues and their sensitivity to emerging technologies will be determined.

Systems studies for advanced high-performance aircraft will focus on new capabilities enabled by key technology developments in high thrust-to-weight ratio propulsion, propulsive control, and systems integration. The thrust-to-weight ratio of engines is exepcted to double over the next decade. Combined with advances in lightweight materials, advanced structural concepts, and reliable flight/propulsion controls, a small lightweight fighter with short takeoff and vertical landing capability that is supermaneuverable could result. In FY 1988, thrust vectoring and other propulsive control concepts will be assessed.

Hypersonic speed and high-altitude capability in both airplanes and missiles have obvious advantages for national defense, as well as hypersonic transports and transatmospheric vehicles. Vehicle concepts incorporating projected technology advances are required to determine the performance potential and technology needs. Prospective vehicles and their mission capabilities will be assessed, along with their sensitivity to technology options. In FY 1988, the emphasis will be on determining the most promising propulsion concepts and associated technology needs for hypersonic cruise and transatmospheric vehicles. These formulations will employ the synergistic integration of aerodynamics, aerothermal, propulsion, structural, and controls technologies.

SYSTEMS TECHNOLOGY PROGRAMS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Rotorcraft systems technology	$18,700,000	$5,000,000
High-performance aircraft systems technology	26,000,000	16,600,000
Advanced propulsion systems technology	28,400,000	32,500,000
Numerical aerodynamic simulation	30,000,000	39,700,000
Total	103,100,000	93,800,000

Rotorcraft Systems Technology

The Rotorcraft Systems Technology program consists of research conducted on two fronts. The first element focuses on advanced technology applicable to the broad class of rotorcraft, with a present focus on reducing noise and vibration and increasing the performance of helicopters. The second element consists of research leading to new, enabling rotorcraft concepts with vastly greater capabilities, such as triple the speed, range, and altitude of current generation helicopters. In FY 1987, the emphasis is on completing the initial flight investigations of an X-wing rotor on the rotor systems research aircraft (RSRA) under a joint program with the Defense Advanced Research Projects Agency (DARPA).

In the noise program conducted with U.S. industry, an updated, comprehensive noise prediction code was made operational. Accuracy is expected to be ±3 decibels in most cases for existing designs. Broadband noise prediction was completed, and good correlation of blade-vortex interaction noise was made from a limited data base. A flight test of a two-speed rotor on a McDonnell Douglas 500E helicopter that dramatically demonstrated the importance of rotor speed control for low noise operation was conducted. In addition, since many helicopters have noise signatures dominated by the tail rotor, several promising concepts for tail rotor noise reduction are being analyzed for future testing.

In the joint DARPA/NASA RSRA/X-wing rotor investigation, the goal is to demonstrate a stoppable circulation-control rotor concept which could increase the operational capability for future rotorcraft into the high subsonic flight regime. The prime objective of this test program is to perform an X-wing conversion from rotary to stopped-rotor flight and return to rotary-wing flight. The flight research program will also investigate the dynamic stability, performance, and rotor control characteristics of the X-wing rotor system. The testbed aircraft modifications have been completed, and in FY 1987 the RSRA/X-wing basic flight test program for flight envelope clearance will be initiated. The program will also include obtaining ground-based piloted simulation data, conducting propulsion systems testbed evaluations, and generating vehicle management systems data in support of the flight investigation of the X-wing rotor on the RSRA. The RSRA/X-wing basic 40-hour flight test program will be initiated.

The NASA/American Helicopter Society (AHS) cooperative industry noise research program will conclude with the release of the operational version of the comprehensive noise prediction code called ROTONET. New subroutines for rotor loads, rotor wakes, and aerodynamic interference will be incorporated. Prediction accuracy is expected to approach ±1.5 decibels for takeoff and flyover conditions for existing designs. A full-scale test in the 40x80-foot wind tunnel of a modified S-76 rotor designed for reduced blade-vortex interaction noise using technology developed in the NASA/AHS program will take place. A final task of this program will be a design exercise for a low noise rotor with practical operational limitations with a view toward validating improvements in the technology.

An effort will be accelerated to gather a modern data base on rotor airloads with comprehensive measurement of pressures, structural shears, pilot control activity, and acoustics. This effort is fundamental to the needs of noise and vibration prediction and will supplant the previous data base that is outdated in terms of airfoils, platform, and aeroelasticity and is limited in speed, fidelity, and depth. The flight data will be accompanied by full-scale and small-scale wind tunnel testing to correlate scaling laws and wind tunnel wall interference effects.

Active pitch control for improvements in vibration, noise, performance, and maneuvering has been demonstrated in small scale under applied aerodynamics basic research. A test is planned in the 40x80-foot wind tunnel to verify results and reduce uncertainty due to scaling effects. Simulation research will investigate the augmented control available with this approach. The use of active controls will also be investigated with a goal of enabling relaxed aeroelastic stability on a future tilt rotor to reduce wing thickness, hence drag, and push speeds from the current 300 knots to 400 knots. Additional efforts will examine blade airloads and more modern hub designs for speed and maneuverability. As a first step, a test will be conducted in the transonic dynamics tunnel for feasibility and proof of analysis.

In FY 1988, the RSRA/X-wing basic 40-hour flight test program will be completed. No further funding has been requested. These tests will concentrate on the flight mode in which the aircraft converts from rotary to stopped rotor at speeds near 200 knots. Ground-based tests and analysis of advanced X-wing technology, such as improved airfoils developed with computational flight dynamics and improved control laws, will be conducted.

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-alpha research vehicle has been modified to a research configuration for support of flights research operations in FY 1987, with the goal of obtaining a flight-validated data base for the design of highly maneuverable aircraft. Initial flight tests are focusing on the measurements of high angle-of-attack aerodynamics for correlation with wind tunnel and analytical predictions. In the NASA/Air Force advanced fighter technology integration (AFTI) program, the AFTI/F-111 mission adaptive wing project has completed envelope expansion and will initiate the flight test of an automatic camber control system for its variable camber airfoil to demonstrate the performance improvements which may be obtained in maneuvering flight. In the F-15 highly integrated digital electronic control (HIDEC) program, which builds on the capability developed during the digital electronic engine control and F-100 engine model derivative programs, flight research testing to validate 10- to 15-percent aircraft performance improvements through integrated digital electronic controls will be completed. Fuel flow reductions of 14 percent have been demonstrated in high-speed flight with afterburner and acceleration times to supersonic flight have improved substantially. Flight test data will be obtained on the F-106 aircraft equipped with leading-edge vortex flaps to validate the predicted improvements on aircraft takeoff, landing, and maneuvering flight performance. Flight testing of a YAV-8B Harrier is continuing for validation of wind tunnel, analytical, and simulator predictions of vertical/short takeoff and landing aircraft aerodynamic, propulsion, and control characteristics. In the NASA/DARPA X-29A forward-swept-wing flight demonstration program, the aircraft completed the envelope clearance flights in 1986, demonstrating the capabilities of the advanced technologies designed in the experimental aircraft.

During FY 1987, the turbine engine hot section technology (HOST) program continues to focus on the issues involved in engine durability. The objective is to establish predictive methods for the structural response and life of hot section components through developments in analysis, instrumentation, and verification methodology. The new high-temperature structures and fatigue laboratory at Lewis Research Center has completed its first year of operation. Studies of the turbine blade and burner liner materials under realistic, complex, thermomechanical loading conditions have led to accurate prediction of combustor liner failure. Improved analysis for 3-D aerothermal flow interaction in turbine cascades has been developed and benchmark tests conducted. Constitutive laws have been developed and validated to predict single crystal turbine blade response. Improved theories of salt deposition on rotating airfoils are being developed, thus leading to better models for hot corrosion performance in the turbine environment. The environmental and average turbine engine stress effects on cyclic damage accumulation for life prediction models is continuing.

As part of the activity to develop higher performance, longer life turbine blade materials, the ceramics for turbine engines program has continued to make progress in FY 1987. The relationship between microstructure and properties for silicon nitride will be established and toughening mechanisms identified. Studies of high-temperature function and wear are ongoing. New fibers produced by chemical vapor deposition processes are being studied for higher performance ceramic composites. In FY 1987, an advanced brittle design code, developed in-house at Lewis Research Center, will be extended to include multiaxial response.

The objective of the oblique wing technology program is to establish a flight-validated data base for application of the technology to future civil and military aircraft. For over forty years, NASA has investigated oblique wing technology, including wind tunnel tests, simulations aircraft design studies, and low-speed manned and unmanned flight tests. These studies have indicated significant performance advantages for an oblique wing aircraft, as compared to a conventional swept wing, for missions requiring both efficient subsonic cruise and supersonic dash performance. In addition, the concept offers significant improvement in carrier spotting ratio for Navy operations.

The final step in the oblique wing technology program is the design, construction, and flight evaluation of an aeroelastically tailored composite oblique wing at transonic and supersonic speeds. The NASA F-8 digital fly-by-wire (DFBW) test aircraft will be utilized as the research testbed for the flight program. This aircraft provides for easy installation of the oblique wing, as well as a well defined, readily modifiable, highly flexible, digital flight control system. An oblique wing preliminary design contract has been awarded and will provide the basis for the final design of the wing and required modifications to the F-8 DFBW testbed. This activity will lead to the start of the flight test program in 1989.

The flight research activity in FY 1988 will involve a variety of high-performance aircraft to investigate advanced concepts. Several projects will continue their flight phases during this period. The F-15 HIDEC flight test validation of performance improvements resulting from propulsion system variable operating line control will be completed. A program to further develop the technologies for the integration of flight and propulsion controls will be initiated with the F-15. These performance seeking control flights will validate the performance potential of real-time, inflight optimization. The NASA/DARPA X-29A aircraft program will be expanded to include Air Force participation in the follow-on flight research program. One of the X-29A aircraft will be modified to include a spin chute to enable flight research testing of the forward-swept wing technologies above 20 degrees angle of attack. The F-106 aircraft will conduct flight tests of the vortex flap concept for correlation with wind tunnel and analytical predictions. The YAV-8B Harrier flight test program will complete the baseline aerodynamic and engine bleed flow experiments and initiate flight investigations to support supersonic short takeoff and vertical landing aircraft control design studies.

In FY 1988, the contracts for final design, fabrication, and ground qualification testing of the oblique wing and F-8 DFBW aircraft system interfaces/modifications will be under way. In-house wing aerodynamic design and research and technology activities in support of the oblique wing program will be continued, including wind tunnel investigations, simulations, and the application of advanced aerodynamic and structural analysis computer codes.

In FY 1988, the turbine engine hot section technology element and the ceramics for turbine engines element have been combined and augmented to form the advanced high-temperature engine materials program in the Advanced Propulsion Systems Technology program. The programs were combined to focus the efforts on developing fundamental technology for revolutionary advances in high-temperature materials for advanced propulsion systems and will be reported under Advanced Propulsion Systems Technology.

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 will be obtained for verification of analysis codes and to support the gathering and analysis of experimental data under actual flight conditions using aircraft testbeds. The 9-foot-diameter large-scale advanced propeller was successfully tested in a wind tunnel for aeroelastic stability and cleared for flight test. The single-rotation flight propulsion system, which includes the large-scale advanced propeller, forward nacelle, gearbox, and gas generator completed a static ground test. The system passed functional tests and completed a 50-hour endurance test to complete its checkout for flight testing. In 1987, the propulsion system will be installed on a modified production aircraft to perform structural, aeroelastic, and acoustic verification for propellers at large scale. Additional small-scale experiments in support of the flight test included one-ninth scale model low-speed tests of the propfan test assessment flight test aircraft which determined the aircraft to have acceptable stability and control characteristics. A semispan version on the model is also being tested to gather detailed aerodynamic data behind the propeller to aid in the analysis of the large-scale results. Ground tests of the General Electric unducted fan engine, a gearless counter-rotation profan concept, were successfully completed. The engine is currently undergoing flight tests on a modified production aircraft under industry sponsorship. Aerodynamic and acoustic data are being gathered for both gearless and geared counter-rotation concepts in a two-foot-diameter scale-model size. The performance results are good and the acoustic results show that the proper design of the propellers will result in acceptable noise levels for airport operations.

In the general aviation and commuter engine technology program, with the objective of raising the performance level of small turbine engines to more nearly match that of large engines, the work continues to be focused on providing fundamental experimental data to obtain a detailed understanding of the design parameters that affect component performance as size is reduced. Small engine component technology studies have been completed. It was determined that high-temperature materials, such as ceramics for the hot section, improved aerodynamics of components, and advanced cycles, including recuperators, have the potential of reducing small engine fuel use by 20–50 percent with a corresponding reduction in direct operating costs of 12–20 percent. The scaled centrifugal compressor program was completed, proving that after the effects of tip clearance, blade thickness, and surface roughness were properly accounted, the performance of small centrifugal compresssors depended on Reynolds number, which is the nondimensional parameter used for aerodynamic scaling. In addition, the experimental evaluation of an advanced ceramic matrix combustor liner was completed and a full analysis of the data will be accomplished in 1987. Ceramics offer the potential of eliminating cooling requirements for combustor liners, thus increasing engine cycle efficiency. During 1987, the new small turbine facility checkout will be completed and subsequently used to evaluate turbine performance penalties associated with inlet boundary layer size and blade surface finish.

In FY 1988, advanced turboprop systems research will emphasize source noise, cabin environment, turboprop installation aerodynamics, and the devlopment 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, aerodynamics, aeroelastics, propeller source noise, and an untreated cabin environment. The combination of aerodynamic 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. Analytical and experimental ground and flight research will be performed cooperatively with industry to develop approaches and determine their effectiveness for controlling cabin noise in various turboprop aircraft configurations. Experimental installation aerodynamics research will be performed on a variety of turboprop/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 under development for predicting aircraft flow fields. Advanced propeller research will include code development for predicting aircraft flow fields. Advanced propeller research will include code development and verification using three-dimensional viscous transonic methods that consider counter-rotation interaction and evaluation of advanced concepts.

The general aviation and commuter engine technology effort will continue to focus on developing fundamental understanding and obtaining an analytical and experimental data base for use in future advanced small engines. Advanced turbine technology will be emphasized in FY 1988, with the experimental evaluation of a cooled, high work radial turbine and a mixed-flow turbine. Radial turbines are capable of very high work capability per stage. Successful cooling of small radial rotors will yield a very high-power compact turbine that can be used in high-pressure-ratio engines which provides system efficiency improvements. In another approach, the need for cooling can be potentially eliminated by using high-temperature materials such as ceramics; however, 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 fabricated to evaluate the maximum stress levels during rig tests in preparation for fabrication and test of a ceramic rotor at a later date. In addition, a centrifugal compressor evaluation will be completed, yielding a detailed laser velocimetry flow field description of a high-speed rotor.

Advanced high-temperature engine materials technology research will develop fundamental technology to enable very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life hot section components. Key to these applications are materials capable of operating at much higher temperatures and strength levels than now possible. These advanced materials will provide for a 30-percent decrease in weight, while allowing an increase in maximum operating temperature and a doubling of life. Only minor performance gains are possible with the existing high-temperature materials, such as titanium and superalloys, which are currently being used. The key advanced materials include ceramics and ceramic composites, metal matrix composites, and carbon-carbon composites.

Two ongoing systems technology programs currently in high-performance aircraft systems technology, turbine engine hot section technology and ceramics for turbine engines, have been combined and augmented to form the advanced high-temperature engine materials program for FY 1988. The objective of this new program is to develop the necessary fundamental technology to provide for the revolutionary advances in high-temperature materials for high-performance propulsion systems. These advanced materials will enable higher turbine inlet temperatures for sustained supersonic cruise, high thrust-to-weight engines for advance high-performance concepts, and engine hot section component operations without cooling air for higher fuel efficiency. The program includes process development and research to understand how these materials respond to the complex thermomechanical loads encountered to allow determination of their life in service. Development of the technology to improve structural ceramic reliability to permit its use in engines will be continued, as will development of the analytical tools and experimental data base necessary for accurate life prediction and durability assessment of turbine blades, vanes, and combustors using current materials 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 computional physics by developing a preeminent capability for numerical simulation or aerodynamic flows. This program will provide the computional capabilities required to obtain solutions to problems which are currently intractable. Ongoing research and technology base efforts in computional aerodynamics will benefit significantly from the advanced computional capabilities to be provided by the NAS program. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations, providing first-principle prediction of viscous flow about simple aerodynamical shapes, and enabling the prediction of performance of complete aircraft. The NAS program will develop an extensive, user-friendly system to assist engineers and scientists in all aspects of problem solution from problem formulation through graphical presentation of results. The heart of this system is the high-speed processors, which will be upgraded when new supercomputer systems at least four to six times more powerful than existing machines become available. These machines will provide the large-capacity/high speed computational capability required in advanced fluid dynamic research and applications.

Since NAS is both a development and an operational system, two high-speed processors are necessary. One processor will be devoted exclusively to production computing. The second, newer and more powerful machine, will be integrated into the system while software for production use is being developed. The first high-speed processor (HSP-1), a Cray 2 supercomputer, reached operational status in the NAS initial operating configuration (IOC) on July 21, 1986. For IOC operations, over 180 researchers nationwide used the NAS resources to numerically simulate complex flow phenomena. Construction of the NAS facility has been completed, and occupancy began in the first quarter of FY 1987. Full operations commence in the second quarter of FY 1987 when the NAS system relocation into the NAS facility is completed. During FY 1987, the second high-speed processor will be acquired in preparation for receiving the planned extended operating configuration (EOC).

FY 1988 will be an important year in the development of the NAS system. The second high-speed processor (HSP-2), which will be four to six times more powerful than HSP-1, will be installed and integrated into the NAS system. Secure (classified) processing will be initiated with the completion of the secure processing area in the new building. The addition of HSP-2, which constitutes the NAS EOC, will reach the full planned architecture of the NAS system. The major subsystems will be expanded as appropriate to support EOC operations. The mass storage subsystem will be expanded to handle the additional archival storage required for support of the HSP-2. The advanced graphics subsystem development will be completed to accommodate both high-speed processors. During this period, system software development will continue, and all new components will undergo extensive test and integration. Application software developed during IOC will continue to be modified to provide pathfinding viscous flow solutions for advanced configurations. In FY 1988, NAS operations support funding has been consolidated in the NAS program from the Research and Technology Base. This consolidation of funding simplifies management and reporting of NAS progress.

10. TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

NASA REQUEST, $66,000,000

AUTHORIZATION, $66,000,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Transatmospheric research and technology:	
Estimated fiscal year 1987	$45,000,000
Authorization fiscal year 1988	66,000,000

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 this 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 low-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 long-duration heat loads; and complete integration 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 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.

Ongoing activities in the National Aero-Space Plane program include technology development in subsonic, supersonic, and hypersonic hydrogen-fueled propulsion technology; advanced high-temperature materials and lightweight, high-strength, thermal structural concepts; and computational fluid dynamics, which remain the three critical technologies for all transatmospheric vehicle applications. The engine and airframe contracted efforts will be supported by an extensive focused technology effort at NASA centers (Ames, Langley and Lewis) and other government laboratories. Work will continue on computational fluid dynamics calculations, including the refinement of computer models based on test data. Modeling using supercomputers will include external/internal aerodynamics, aerothermodynamics, kinetics and thermal-structural considerations, and nozzle/plume computer codes for analyzing chemically reacting hypersonic nozzle/plume flows. Work will continue on development of, and manufacturing technology for, lightweight, high-temperature advanced materials. For example, processing techniques for fabricating ceramic matrix composite panels will be demonstrated. Engine component and subsystem testing will continue over the wide speed range of interest, and flight research vehicle test planning will be initiated. Tests will be conducted on subscale component integration models of scramjet concepts over the speed range of Mach 3.5 to Mach 8. Contractors will concentrate on developing and refining their vehicle concepts, the construction and testing of critical structural components of the airframe cryogenic tankage and vehicle, and propulsion/airframe integration of both engines into their respective vehicle configurations. In addition, the airframe contractors will focus on critical technologies including nose cap and leading-edge materials, actively cooled structures, computational fluid dynamics code validation, and flight instrumentation.

Due to the nature of this national program, a significant portion of the funding will be the responsibility of the Program Management Office which will distribute the funds to support the critical technology maturation contracted activities. NASA research center personnel will be responsible for the technical management of these technology efforts.

11. SPACE RESEARCH AND TECHNOLOGY

NASA REQUEST, $250,000,000

AUTHORIZATION, $250,000,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Research and technology base	$133,600,000	$115,900,000
Systems technology programs	37,400,000	0
Civil Space Technology Initiative (CSTI) program	0	134,100,000
Total	171,000,000	250,000,000

The goal of the Space Research and Technology program is to retain national preeminence in space by advancing the technology base that supports the civil space program. The specific objectives are to provide a broad base of advanced technology for vehicle and subsystem concepts, components, devices and software; to develop the underlying analyses methods, materials behavior, and discipline technologies; and to perform ground and in-space experiments to provide basic data and verify concepts through ground and in-space experiments so that new technology can be utilized with confidence.

An enhanced technology program is required to assure that advance space transportation systems provide reliable access to, and operations in, space; that science missions can continue to expand understanding of the universe through missions of increased capability; and that human presence in space expands systematically within and beyond earth orbit.

In FY 1988, the program will continue to support agency goals in space transportation, Space Station, and Space Science and Applications, as well as to provide synergistic support to military and commercial space user needs. In FY 1988, the Space Research and Technology program has been restructured into two parts. The first part, which retains the space research and technology base title, contains the generic, fundamental research aspects of the program. The second part, the Civil Space Technology Initiative (CSTI) program, includes focused systems technology programs supporting transportation, operations, and science consistent with the goals of the U.S. space program. The CSTI supports research in propulsion, vehicle concepts, information systems, large structures and control, power, and automation and robotics. CSTI contains research activities from the former research and technology base and systems technology programs, which have been reoriented and augmented toward the goals of the CSTI program.

The research and technology base portion of the program is conducted in the disciplines fundamental to space endeavors. In aerothermodynamics, increased emphasis will be given to obtaining the data base for code validation/verification covering the entire atmospheric spectrum from continuum to rarefied/free molecular flows. Continued emphasis will be placed on investigating aerodynamic and aerothermodynamic performance of hypersonic and entry vehicle configurations. The space energy conversion program will explore concepts which increase the capability and life of small and large utility-type power systems and for spacecraft and rover applications. Propulsion technology will increase the performance, life, and reliability of liquid oxygen/liquid hydrogen and liquid oxygen/hydrocarbon propulsion systems for earth-to-orbit and orbit transfer vehicles, stressing components, integrated diagnostic instrumentation, and fault-tolerant concepts. Research on auxiliary propulsion will develop concepts for gaseous oxygen and hydrogen propellant systems for growth stations and vehicles. Electric propulsion will address low-thrust propulsion applications, with attention on fundamental life- and performance-limiting features. Materials and structures activities will investigate the static and dynamic response of large-area space structures, including erectable and deployable construction concepts and analysis of dynamic response and controls interaction. The work on thermal protection systems and related thermal-structural analysis methodology for advanced transportation vehicle concepts will continue. The effects of the space environment, particularly atomic oxygen interaction on lightweight materials for spacecraft and platforms, will continue as a major thrust. In space data and communications, emphasis will be on advanced memory concepts, fault-tolerant general purpose computer architectures, and microwave and optical communications technology. The information sciences program will emphasize software technology, reliable computing, concurrent processing, radiation-tolerant electronics, and sensing technology for spacecraft and Space Station applications. Controls and guidance research will lead to the ability to precisely control large, flexible space structures; precision pointing of large spacecraft; and adaptive guidance concepts for future transportation systems. Human factors efforts are aimed at the enhancement of astronaut productivity through crew stations with "human engineered" information management techniques and extravehicular work stations.

Efforts in space flight research and technology will be focused on: (1) orbiter experiments to validate experimental and predictive techniques for the design and development of future space transportation systems, (2) a cryogenic fluid management flight experiment, and (3) in-space experiments. The systems analysis area will focus on the identification of high-leverage technologies for future space missions.

The CSTI program will focus on technology development in propulsion, vehicle concepts, information systems, large structures and control, power, and automation and robotics.

The CSTI propulsion program includes earth-to-orbit (ETO) and booster technology. Research on ETO propulsion will be expanded to assure a mid-1990 capability to enable development of reusable, high-performance, liquid oxygen/hydrogen, and high-density fuel propulsion systems for next-generation space transportation vehicles beyond shuttle. A booster technology program will develop the options for both pressure-fed liquid rocket propulsion and large-scale hybrid (solid propellant with liquid oxygen) systems. For vehicle technology, analytical and wind tunnel research on aerobraking and aeromaneuvering will be expanded to include the design, development, and flight of an aeroassist flight experiment (AFE). The AFE will be conducted by delivering a highly instrumented aerobrake configuration to earth orbit with the shuttle, accelerating the vehicle propulsively into the atmosphere at geosynchronous entry velocity, performing the atmospheric drag braking maneuver, and skipping back to low earth orbit for shuttle recovery. The information science program is focused on sensor devices for earth and astrophysical observations in spectral bands where present measurements cannot be made. The program also will build an optical disk buffer breadboard and demonstrate unique computer architectures for processing high-speed and large-volume radar and imaging sensing data. These computer capabilities will exploit applicable Department of Defense (DOD) and commercial processor technology to enable the effective management of the exponential growth of data from future science missions.

In large structures and control, the control of flexible structures (COFS) program will emphasize development of the first and second flight configurations and definition of the third configuration. A new element, precision segmented reflector technology, will be conducted in parallel. It will be directed at validating design concepts for lightweight composite, multisegment, precision reflectors. This technology program will include structural concepts for segmented surfaces, assembly methods, advanced material development and characterization, and control methods for multisegmented surfaces leading to tests of a seven-element subassembly. In the CSTI power program, enhancement of the high-capacity, high-efficiency, thermal-to-electric power conversion program will accelerate the development of components and subsystems for a ground test of the conversion systems to verify efficiency and life potential. The CSTI program in automation and robotics will build on the ongoing program directed at spacecraft and platform systems to develop and apply expert systems technology to prelaunch and in-space transportation operations.

Research and Technology Base

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Aerothermodynamics research and technology	$11,400,000	$11,100,000
Space energy conversion research and technology	20,400,000	14,600,000
Propulsion research and technology	21,000,000	14,500,000
Materials and structures research and technology	18,900,000	17,900,000
Space data and communications research and technology	13,600,000	8,900,000
Information sciences research and technology	10,200,000	8,000,000
Controls and guidance research and technology	7,500,000	6,300,000
Human factors research and technology	2,300,000	4,900,000
Space flight research and technology	22,200,000	23,200,000
Systems analysis	6,100,000	6,500,000
Total	133,600,000	115,900,000

Aerothermodynamics Research and Technology

Future aerospace vehicles, such as aeroassist orbit transfer vehicles (AOTV), the aero-space plane, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in rarefied atmospheres. The design of these vehicles presents some formidable performance prediction challenges. To meet these challenges, the aerothermodynamics program is pursuing the following objectives: (1) development of advanced numerical algorithms for the whole range of continuum, transitional, and rarefied flow regimes; (2) development of accurate and detailed finite-rate chemistry and turbulent flow models; (3) establishment of benchmark quality, experimental data for code validation/verification; (4) correlation of calculations with ground and flight (shuttle orbiter experiments) experimental data; (5) establishment of a detailed aerothermal loads data base and development of integrated analysis techniques; and (6) provision of integrated aerospace vehicle design and analysis capability to support future vehicle/mission requirements.

For the continuum flow regime, significant progress recently has been made for three-dimensional viscous flows about hypersonic flight vehicles. An upwind differenced viscous flow code was developed for slender, winged flight vehicles and demonstrated for Mach numbers up to 25. This code provides the base for the analysis and prediction of aerodynamic and aerothermodynamic flows about transatmospheric vehicles. Additionally, a three-dimensional viscous flow code was developed and demonstrated for blunt aeroassist vehicles. The code was used to analyze the flow and heat transfer to the base region of the aeroassist flight experiment (AFE) vehicle under simulated reentry conditions where it was determined that flow reattachment in the base region caused localized high heating areas.

For rarefied flow regimes, the direct simulation Monte Carlo (DSMC) technique continues under development to better understand and model complex flow problems as represented by the interaction of vehicle airframe, ambient rarefied atmosphere, propulsion system exhaust, and material outgassing. Recently completed modification to the DSMC computer codes allows for the modeling of nonequilibrium thermodynamics under rarefied conditions. This improvement enables the prediction of nonequilibrium heating to aeroassist and planetary return vehicles operating at high speeds at high altitudes. The DSMC technique has been used to explain the shuttle glow phenomena experienced on shuttle flights. STS-3, -4, and -5. Excellent qualitative agreement between the DSMC calculations and flight data supports the hypothesis that the glow is due to collisionally excited molecules (N_2) from the free stream and not to surface contamination effects.

Computational chemistry, in which the chemical and physical properties of matter are computed from first principles, is making significant contributions to the fundamental understanding of the chemical and physical processes that occur in the low-density shock layer gases that surround the airframes of high-altitude high-speed vehicles. In FY 1987, the exact production mechanism of excited molecular species by electron impact was established through application of first principle calculations. It is now understood that these excited molecular species are the principal source of nonequilibrium radiation expected to dominate AOTV designs.

The development of a fully integrated fluid-thermal-structural analysis technique is essential to permit proper vehicle structural design while avoiding the tendency to overdesign, which can result in significant mass/volume penalties. In FY 1987, the program achieved a significant milestone with the unique demonstration of a single calculation which successfully coupled fluid dynamics, thermal analysis, and structural response for shock-induced localized high heating on a simulated scramjet engine strut.

Continued emphasis will be placed on developing computer codes capable of simulating external flows relevant to aerospace transportation systems and on providing analysis and design capability with respect to aerodynamic and aerothermodynamic loads. Toward this end, in FY 1988, chemical nonequilibrium real-gas models will be incorporated into the viscous, three-dimensional, continuum flow codes for blunt bodies, allowing for accurate prediction/simulation of the high-altitude high-velocity thermal environment encountered by aeroassist orbit transfer vehicles during atmospheric maneuvers. In addition, real gas equilibrium thermodynamic properties will be incorporated into the slender hypersonic winged vehicle viscous flow codes to enable accurate high Mach number, moderate altitude flight conditions to be simulated. These codes will then be utilized to analyze the thermal environment encountered by transatmospheric vehicles during both ascent and reentry flight.

Software will be developed in FY 1988 to enable establishment of a readily accessible national data base for the storage of aerodynamic and aerothermodynamic data. Existing and newly acquired ground- and flight-test results will be incorporated into this data base. This will provide the validated technology required to rapidly evaluate future conceptual aerospace vehicle configurations. The experimental data base for verifying the predictive capability of the fluid-thermal-structural analysis technique will be completed in FY 1988. Predictions will be compared to data obtained both at Langley Research Center (Mach 6.3/8-foot high temperature tunnel) and at CalSpan (Mach 6.3 to 18).

In FY 1988, the reliability of the nonequilibrium flow radiation models that have been developed for the direct simulation Monte Carlo method will be established. This will be accomplished by comparing the calculated results with available laboratory and flight data.

Additionally, benchmark hypersonic experiments will be carried out in FY 1988 in the newly reactivated 3.5-foot tunnel from Mach 7 to 12 in order to establish an accurate data set with which hypersonic winged-body flow codes can be validated. These tests will provide the first comprehensive data for a generic but realistic hypersonic configuration that can be easily modeled by recently developed computational codes.

Space Energy Conversion Research and Technology

The objectives of this program are to explore concepts and components to improve the performance, lifetime, and cost effectiveness and to reduce the size and weight of power and life support systems for large manned space systems, small earth-orbiting and planetary exploration spacecraft, and other ambitious future space missions.

In FY 1986, two significant advances in photovoltaic cell technology were achieved. A gallium arsenide (GaAs) solar cell demonstrated over 23-percent efficiency when exposed to a 100-to-1 solar concentration of air mass zero (AMO) spectrum at 25 degrees centigrade. This is the highest performance yet achieved for a space photovoltaic cell, and, when combined with data indicating that GaAs degrades from radiation damage less than half as much as silicon, this shows the near-term potential for a considerable decrease in solar array areas. An indium phosphide (InP) cell with an efficiency of 14.2-percent AMO was demonstrated and shows potential for considerably higher efficiencies. These cells also have demonstrated a substantial improvement in ability to maintain efficiences in a radiation environment relative to either silicon or gallium arsenide. Because some spacecraft operate for extended periods in regions of high natural radiation, the ability to achieve relatively high efficiencies with good resistence to damage by radiation is more important than just high efficiency. An advanced photovoltaic array design was completed which demonstrated an array power-to-weight ratio in excess of 130 watts per kilogram, and a technology demonstration contract was awarded. This would be over a twofold increase in the power-to-weight ratio of 60 watts/kilogram demonstrated in the shuttle array experiment as recently as late 1984. Doubling of the power-to-weight ratio of photovoltaic power systems will provide additional scientific capability on weight-limited geosynchronous and planetary spacecraft. Integrated pressure vessel (IPV) nickel-hydrogen batteries with energy densities two times those of conventional nickel-cadmium batteries achieved cycle life in excess of 20,000 hours at 80 percent depth of discharge, leading to their selection as the electrical energy storage device for the initial operating configuration (IOC) Space Station.

In the power management and distribution area, a facility was put on line for the evaulation of newly developed high-power (100 kilowatts) 20-kilohertz electrical components, such as transformers, capacitors, transmission lines, and radiation-hardened high-temperature electronics.

As part of the space nuclear power research effort, the largest free-piston Stirling engine ever built demonstrated 22.5KWe, which is over 90 percent of full design power. The free-piston Stirling engine, in conjunction with a linear alternator, offers the potential to provide high efficiency and long life. The testing of the Stirling engine developed a valuable data base from which design codes were updated and validated. Deep impurity double-injection (DI)[2] silicon devices have been shown to exhibit insigificant electrical degradation after gigarad level irradiations 100 times that tolerated by conventional silicon devices. These devices also exhibit a high-temperature stability at temperatures twice those of conventional silicon devices. Dramatic improvements in both the fundamental understanding and the demonstrated lifetimes were made in the porous molybdenum electrodes used in the alkali metal thermoelectric coverter (AMTEC). AMTEC is a thermally regenerative electrochemical conversion device, which is both static and modular and which has had experimentally measured efficiencies. An important first step was made in the development of technology for high-efficiency liquid-droplet and liquid-belt radiator concepts by demonstrating continuous generation of uniform droplets with low vapor pressure fluids. High-strength graphite fiber-reinforced copper matrix composites, which have the potential to substitute for beryllium in radiator panels, have been fabricated and tested. A low-power reusable organic iodide laser has been successfully operated to demonstrate power transmission at power levels commensurate with those achievable with a solar concentrating parabolic dish.

Prior to FY 1988, the space energy conversion program had the broad focus of addressing the technology needs of all advanced space applications. In FY 1988, a systems program in high-capacity nuclear power will be established as part of the new CSTI program. Nuclear technologics needed to meet the high-capacity power systems requirements for evolutionary space station(s), lunar and planetary bases, and for high-power demand electric propulsion systems will be developed in this program. The FY 1988 space energy conversion research and technology program will develop concepts and component technologies that will: (1) dramatically reduce the weight of relatively low-power spacecraft power systems; (2) enable substantial reduction in the size and weight of high-capacity, nonnuclear power systems; and (3) increase the degree of closure, reduce power requirements, and increase the life of environmental control and life support systems.

For photovoltaic spacecraft power systems technologies, the goal is to improve the total system performance enough to permit a 50-percent increase in payload weight. Techniques for increasing the purity of indium phosphide crystals will be investigated and are expected to yield indium phosphide cells with a 30-percent improvement in efficiency relative to current indium phosphide cells, while maintaining a high resistence to radiation damage. Experimental efforts, started in FY 1987, to improve doping techniques for amorphous silicon materials will be continued in FY 1988. Amorphous silicon can be produced in very thin sheets, and consequently, very lightweight photovoltaic materials could be produced if planned efforts to improve the efficiency and life are successful. In FY 1988, testing of a spacecraft silicon photovoltaic array with a power-to-weight ratio of 130 watts per kilogram (more than twice the current state of the art) will be completed. Experimental studies to understand the life-limiting mechanism of electrode erosion in very high energy density lithium batteries will continue. Finally, new ways of intergrating components with lightweight structures into a long-life, low-weight, reliable, and efficient solar power system will be demonstrated. Work initiated in FY 1987 on a small reactor spacecraft power system will continue in FY 1988. Dynamic conversion concepts and high-temperature rare-earth chalcogenides and boron carbide thermoelectric materials suitable for use with a small, lighweight, reactor power system will be evaluated to establish their current-producing capability as a function of temperature ratio. Design and materials development efforts for high-strength metal matrices, lightweight heat pipes, and radiation-hardened electronic components will be continued.

Technologies being pursued to improve the performance of high capacity power systems (greater than 50 kWe) include advanced solar dynamics, photovoltaic concentrator arrays, and high capacity batteries. In FY 1988, a compact Stirling engine, with a high-temperature, heat pipe heater head suitable for use with a solar concentrator, will be fabricated and performance testing will be initiated. Efforts to design high-performance solar concentrators, including new concepts such as prismatic designs, will continue. Techniques to reduce thermal distortions and off-pointing losses in concentrator photovoltaic systems will continue, as will efforts to develop very high efficiency (greater than 30 percent) photovoltaic cells for operation at concentration ratios greater than 100. In the energy storage area, long-life, very high energy density batteries such as bipolar nickel-hydrogen batteries are being developed.

In the life support area, work will continue on the development of hollow fiber membranes as a low energy approach to humidity condensate removal. Performance testing of reverse osmosis/hyperfiltration technology for wash-water recovery will be initiated as an alternative to the energy intensive phase change technology. The development of a basic technology associated with supercritical water oxidation, which would permit further closure of the life support loop by recovery of organic wastes, will be continued and feasibility tests initiated.

Propulsion Research and Technology

The objective of the Propulsion Research and Technology program is to establish a base of design concepts and analytical tools that will allow the design and development of advanced propulsion systems with the known performance, life, and operational characteristics essential for next generation space transportation systems. This base will also reduce the risk of costly, unanticipated design deficiencies and schedule delays during the development and certification of flight hardware. Specific objectives include developing a sound understanding and broad base of knowledge in the area of resuable engine component life prediction and extension; improving high-pressure ignition/combustion performance, stability, heat transfer, and cooling models; developing unique, nonintrusive diagnostic sensors for use in interactive engine condition monitoring/control systems; establishing an understanding of the chemical and physical processes associated with very high-performance, low-thrust propulsion systems, as well as developing corrosion-resistant high-temperature materials necessary for achieving extremely long life and reliability; and evaluating potential breakthrough propulsion concepts and related research and technology issues that could lead to quantum leaps in future propulsion capabilities.

For life prediction/extension, the effort has been primary directed toward the turbomachinery to understand and analytically simulate the hostile environments to which these components are subjected. The program includes developing techniques for reducing the severity of those environments by analytically simulating them and determining configuration changes that will reduce thermal and mechanical loads resulting from the environments. Advanced design concepts that can provide greatly increased fatigue life are also being developed. Advanced materials and coatings which will contribute to the reduction of thermal transients to aid in increasing life expectancy of turbomachinery components and systems are also in the program. A rotordynamics model has been developed for investigating design changes, such as dampers on Space Shuttle main engine (SSME) rotors for alleviating vibration and for studying interactions and resulting failure mechanism. A bearing model has been completed which has enabled the analytical determination of SSME bearing problems. This model has revealed that in addition to wearing problems, thermal loading has also contributed to failure mechanisms. Thus, analytical designs, using various contact angles in conjunction with new and augmented cooling techniques, are being investigated. Damping seal analytical models have led to the design of new concepts and will be evaluated in the size and speed range of interest for the SSME using a unique test facility. Advanced computational fluid mechanics techniques are being used to define the flow of hot gases through the turbine blades and to define the resultant thermal and mechanical stresses on the blades. The results of such anaylses will provide inputs to structural analyses as well. Probabilistic structural analysis theories have been developed and are being used by both NASA and industry to predict the fatigue life of highly stressed blades. Such models for turbopump blades are operational and are currently being validated. Advanced single-crystal blade materials and improved design concepts show that approximately 80 percent higher strength may be attainable using these new techniques as compared to current materials.

Experimental data for high-pressure combustion stability and heat transfer has been obtained for liquid oxygen (LOX)/methane and LOX/propane in both subscale main combustor hardware and in turbine-drive gas generators and is being used to update analytical models developed for low-pressure operating conditions. Studies of the incompatibility of hydrocarbon fuels with copper alloys (combustor materials) have been initiated.

Optical diagnostic sensors for measuring bearing wear, turbine blade temperature, and shaft speeds have been successfully demonstrated in the laboratory and are scheduled for verification testing on the technology testbed engine. Nonintrusive cryogenic flow meters and hot gas temperature sensors are currently being evaluated in laboratory tests.

Auxiliary, or low-thrust propulsion technology, is aimed at improving our capabilities in electrothermal thrusters; arcjets; ion thrusters; small gaseous oxygen/gaseous hydrogen motors; and long-life efficient, storable propellant motors. Successful firings of three 25- to 50-pound thrust hydrogen/oxygen motors were accomplished for a total burning time of approximately 32 hours. Successful firings of a thin-walled rhenium chamber with storable bipropellants in which the chamber temperature stabilized at over 4300 degrees Fahrenheit occurred. More efficient combustion resulted, giving a 10-percent increase in performance, a significant amount for planetary spacecraft which may be over 50-percent propellant by weight. In electric propulsion, a platinum-alloy resistojet was successfully operated using the anticipated waste gases from the Space Station. On the basis of these tests, the resistojet has been selected for the Space Station drag make-up, and this will utilize waste that otherwise would have to be returned to earth. Small arcjets are now starting and operating smoothly, and specific impulses of over 700 seconds have been delivered with storable propellants. This is more than double the performance of current systems for controlling satellites. Ion thruster progress includes the tripling of the thrust levels at a given size and the successful computer operation of a two-thruster system to investigate component interactions.

Advanced propulsion studies continue to investigate promising concepts beyond today's capabilities. The potential of such advanced concepts as antimatter and fusion plasma is being considered, as well as nearer term concepts, such as on-site production and use of propellants on the moon and planets. Magnetoplasmadynamic (MPD) testing has been advanced by the development of a capability to operate thrusters for extended durations at relatively low power. Forty-minute tests were performed with thrusters at 20-kilowatt levels, giving the first extended operational experience with MPD units. Performance was promising, and higher power testing is planned.

In FY 1988, some of the propulsion research program on LOX/hydrogen and LOX/hydrocarbon research concerning analysis methods and components experiments formerly in the research and technology base program will become part of the CSTI program in earth-to-orbit propulsion. Fundamental efforts in reusable engine research and technology, which are aimed at establishing the technology base for component life extension and prediction, will continue in the research and technology base program. Bearing model verification testing (utilizing an advanced cryogenic-fluid lubricated bearing tester) will be nearing completion, and previously developed analytical techniques will be used to initiate the design and fabrication of advanced, longer life, rolling-element bearing concepts. Computational fluid dynamic analyses will continue to be used to define and improve internal engine hot gas flows and resulting aerothermodynamic loads. The full-scale testbed facility, appropriately instrumented, will be used to validate the probabilistic structural analyses theories that have been developed in this program. Diagnostic sensors will be developed, with emphasis on sensors that will be able to detect fatigue life degradation of component parts and on the remote sensing of leak detection. Both types will be used in the SSME testbed. An optical bearing deflectometer will be used to detect bearing failures, and an optical pyrometer will be used to measure blade temperatures and temperature profiles across a blade. Isotope wear detectors will be used to measure radiation loss in bearings which can be correlated to the amount of wear in the bearing.

The orbit transfer propulsion technology program will provide the design and analysis tools for the future design and development of a reusable, space-based, high-performance, throttleable, oxygen/hydrogen expander cycle engine. Ribs will be provided on hot gas side walls and fins will be included in coolant channels thus providing more surface area and a resultant increase in heat transfer rates. High-efficiency, variable-flow turbomachinery enhancements will be achieved through the investigation of losses in the pump, diffusing losses in the crossover passages, and seal technology to reduce recirculation losses. An understanding of flow processes in high-expansion-ratio nozzles will be developed so that the contributions of viscous and kinetic losses in the boundary layer can be accounted for. Such losses will be measured using both probes and schieleren photography methods. To promote life expectancy in very small high-speed rotating machinery, hydrostatically-supported bearing systems and the rotor dynamics of such bearings will be investigated, as will hydrodynamic lift seals to promote increased life with less contact. High-strength combustor liner materials capable of transferring very high ratios of heat transfer will be developed using rapid solidification rate powder metallurgy technology. Such materials have the potential for unique properties in strength and conductivity with improved, low-cycle fatigue life. Diagnostic sensors will be developed to provide the basis for integrated condition monitoring/engine control systems leading to automated, fault-tolerant flight operations and between-flight head-off inspection, servicing, and checkout. One potential sensor could consist of a spectrometer used to analyze exhaust gas plumes to search for the existence of microscopic materials and other component material which will provide information about possible malfunctioning of the turbomachinery and/or allow for appropriate conditioning of engine operating parameters as required. Other sensors will be developed which can determine the condition of the thrust chamber materials and detect cracks prior to the development of catastrophic failure modes. Advanced eddy-current probes will be investigated to allow for monitoring wear and misalignment in turbomachinery system.

For auxiliary and low-thrust propulsion, the design of a high-temperature storable bipropellant thruster will be established and life tests performed to verify its candidacy for planetary missions. Small hydrogen/oxygen thruster designs to increase performance versatility over a wider fuel/oxidizer range will be evaluated. Resistojet and arcjet efforts will be aimed at improving materials and developing understanding of the complex internal flow conditions to improve lifetime and specific impulse. Ion propulsion work will be directed at simplifying the design while increasing the thrust-per-unit area, characterizing inert gas propellants, and studying component interactions through system tests. Advanced concept work with MPD thrusters will be at power levels up to 100 kilowatts for extended periods to understand, model, and minimize cathode erosion. Advanced concept studies will continue with the objective of identifying promising areas and establishing experiments necessary to prove their potential.

Materials and Structures Research and Technology

The objective of the Materials and Structures Research and Technology program is to provide technology that will allow the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, efficiency, durai lity, and economy. Major technical areas of emphasis in materials include fundamental understanding of the properties and behavior of advanced space materials; characterization of long-duration space environmental effects on materials; development of computational chemistry for predicting the fundamental properties of materials and their interaction with the space environment; and the development of ceramic, metallic, and advance carbon-carbon thermal protection systems. Structures technology focuses on the development of erectable and deployable structural concepts; efficient and reliable methods for erection/deployment, monitoring, maintenance, and repair of space structures; new structural and cryogenic tank concepts for advanced earth-to-orbit rockets, hypersonic vehicles, and orbital transfer vehicles; and efficient analysis methods for design and evaluation of advanced space structures, including integrated structure/controls analysis and design optimization.

Materials research concentrates on fundamental materials science and the development of space durable materials. Emphasis is placed on the basic understanding of the nature and behavior of advanced polymeric, metallic and ceramic composites; nondestructive evaluation and testing methods; effect of the space environment, such as thermal cycling, atomic oxygen, radiation, and high energy particles on materials; the development of dimensionally stable materials resistant to the space environment and debris impact. Examples of recent major accomplishments include the achievment of an equivalent 30 years' damage accumulation of electron exposure on graphite-epoxy composites using accelerated test methods, performance verification of aluminum-coated graphite-epoxy tubes under thermal cycling loads, prediction of surface-gas interaction effects and spontaneous ignition temperature for hydrogen on nickel, an enhanced understanding of the effect on processing and crystallinity of high-temperature thermoplastics.

The structures program continues to focus on the development of advanced space structural concepts and dynamics of flexible structures. Research in the advanced space structural concepts area includes the development of erectable and deployable concepts and design technology for large-area space structures, validated multidisciplinary analysis and optimization methodology for large-area space structures, and design and analysis methods for advanced space mechanisms. Recent major advances in the structural concepts program include an integrated interdisciplinary optimization procedure successfully applied to a 55-meter generic antenna design; space construction methods for erectable large space structure, successfully demonstrated by the assembly concept for construction of an erectable structure (ACCESS) flight experiment performed on shuttle mission 61-B; an integrated multidisciplinary study for the Space Station structured design, which resulted in the selection of the 5-meter bay size; and a comprehensive Space Shuttle solid rocket motor joint analysis and the development of an alternate joint design for the solid rocket motor case.

Research on the dynamics of flexible structures emphasizes the development of advanced system identification technology, analytical methodology for predicting coupled dynamics of large flexible space structures, validated active and passive vibration damping of large space structures, and efficient and reliable techniques for ground testing of large space structures. Major recent accomplishments in this area include active damping of flexible structures using piezoelectric devices, prediction of vibration frequencies for large flexible structures with nonlinear joint behavior, demonstrated methodology for assessing on-orbit structural damage, and completion of comprehensive study which defined the ground-based test facility requirements for large space structures.

Work in the aerothermal materials and structures technology area continues to focus on the development of advanced, efficient, thermostructural and thermal management concepts for future space transportation systems and hypersonic vehicles; an integrated fluid-thermal-structural analysis methodology and aerothermal loads data base; and new reusable thermal protection systems using metallic, ceramic and advanced carbon-carbon materials. Recent progress includes the development of new "hard hat" thermal protection tiles, a demonstrated three-dimensional woven silicon-carbide reusable thermal insulation blanket concept suitable for aeroassist orbit transfer vehicle applications, and verified prediction of the combined fluid-thermal-structural analysis code using benchmark high-temperature wind tunnel data.

The hypersonics program proceeds with the development of efficient, durable, and lightweight materials and structural concepts for applications at both high and cryogenic temperatures; materials and thermal structural concepts for airbreathing launch and sustained hypersonic cruise vehicles; and analysis and testing methods for advanced structural concepts evaluation and validation. An advanced, efficient, lightweight, and reusable cryogenic tank concept has been developed which incorporated a recently developed high-temperature foam insulation system.

In FY 1988, the materials program will continue to focus on the effect of the space environment on structural materials for spacecraft, large-area space structures, advanced space transportation systems, and orbital transfer vehicles; development of lightweight, impact-resistant, environmentally durable, and thermally and dimensionally stable composite materials and protective coatings; and test methods for nondestructive evaluation of ceramic flaw detection and strength characterization. Strong emphasis will continue in computational chemistry. Research will be focused on the prediction of atomic oxygen and radiation effects on space materials through a fundamental understanding of physical properties of atomic clusters and gas/atom interactions, such as between atomic oxygen and hydrocarbon molecules. This focused effort will be coordinated with the ongoing activity in computational chemistry described under aerothermodynamics research and technology where the focus is on the dynamics of rarefied gas flows.

In FY 1988, research to develop and verify lightweight erectable and deployable structural concepts, including modification and repair technology for large-area space structures and for large high-precision antennas and reflectors with high-dimensional stability, will continue as a major thrust. Development of mobile manipulator systems for efficient construction will be evaluated by ground test. Three-dimensional modeling and simulation of a multijointed, flexible, 20-meter beam will be performed to establish the technology base for the control of dynamic response predictions. The activity will concentrate on analytical methods to predict model characteristics, transient response, and deflection behavior.

Active and passive damping methodology will be developed to reduce unwanted structural vibration during space operation. Particular emphasis this year will be on innovative active structural damping methodology. Novel piezoelectric devices will be developed and embedded into structural components to obtain the needed damping forces. The associated control law algorithms will be generated and experimentally verified using simulated large space structures.

In support of advanced space transportation systems, research to develop an advanced integrated fluid-thermal-structural analysis capability will continue in FY 1988 with focus on generic configurations to allow for the development of highly efficient, reliable hot structures for hypervelocity flight. Concurrent with this activity, innovative concepts for extremely lightweight structures utilizing advanced foil gage joining techniques will be explored. Development of advanced processing, including weaving techniques and coating procedures for carbon-carbon composites for stable long-life structures, will be investigated.

In FY 1988, the dynamics of large space structures effort will be conducted under the large structures and control of the CSTI program.

Space Data and Communications Research and Technology

The Space Data and Communications Research and Technology program is directed toward developing the advanced ability to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

The objective of the data systems research is to provide the onboard computing technology needed for new classes of data systems that will enable and make affordable future NASA missions with challenging computing requirements. The work is concentrating on system-level development. These systems are largely based upon existing or newly emerging components and integrated circuits. A multiple processor computer using very high speed integrated circuits has been assembled and is now being combined with NASA high-reliability and fault-tolerant architectures and software. This unit is being evaluated as a candidate for space applications. Other work, with longer term objectives, is underway to produce a complete computer using gallium arsenide technology for the first time. Gallium arsenide components have the potential of replacing the existing silicon technology devices because of the increased speed and improved radiation tolerance. New architectures are being developed with the objective of providing dramatic increases in performance and reliability. Increased emphasis is being placed on enhancing software reliability while also reducing the cost.

The communications technology effort is directed toward maintaining and ensuring the U.S. preeminence in satellite communications and providing the necessary technology to enable future reliable data communication links for ultra-high data generation rate dependent missions, such as the earth observation satellite, the large deployable reflector, and the Mars rover. Fundamental materials research has led to high-emission current long-life reservoir cathodes. These cathodes will have applications in high-frequency/high-power tubes for space communications and high-frequency submillimeter backward oscillators for remote sensing. Other materials research has led to a technique to apply a pyrolitic graphite coating to a copper electrode in a multistage depressed collector. This technique has extended the efficiency of traveling wave tubes by producing a surface with extremely low secondary electron emission properties. A digital filter processor, integrated on a silicon chip, has been developed which replaces the cumbersome and unreliable series-parallel tracking loop capacitors found in past transponders. It will provide numerical control of the voltage controlled oscillator frequency by command, is radiation hard, and is a generic technology which can provide other functions such as automatic signal acquisition and ranging. The mathematics have been developed to yield the necessary information for correcting a phased-array antenna feed for distortion in the reflector given a random distribution of measurements of the far-field antenna pattern. An Intelsat 24-phased array horn feed has been obtained for experiments on the 15-meter hoop column antenna to investigate the correction of the far-field pattern of a distorted reflector by reconfiguring the phase and amplitude of the feed. This technology will allow for less active control of the large structure antennas. A 30-gigahertz integrated gallium arsenide receiver module, which provides the basic receiver functions such as low noise amplification, phase shifting, down conversion, intermediate frequency amplification, and output power control, has been fabricated. The next generation of communications will employ laser optics. Efforts under way have indicated that it may be possible to have a two-dimensional surface emitting semiconductor diode laser array. Each individual laser beam may be individually controlled in both amplitude and phase, making it theoretically possible to electronically steer the laser beam like that of a microwave phased-array antenna. Research is continuing on an artificially layered solid-state device with a built-in staircase electric potential which may enable a solid-state device with the equivalent properties of a photomultiplier tube, but without the associated reliability problems. The device will find immediate application as a receiver for optical communication links.

Prior to FY 1988, the Space Data and Communications Research and Technology program had the broad focus of addressing the technology needs of all advanced applications. In FY 1988, a systems program in information technology will be established as part of the new CSTI program. Technologies needed to meet the high-rate/capacity data requirements for the earth observing system, large deployable reflector, evolutionary space station, and future missions will be developed in that program. The remaining space data research and technology program will emphasize general purpose, fault-tolerant computing. All space communications research and technology will remain in this research and technology base program.

In FY 1988, work will continue toward development of onboard processors that provide the combinations of performance, weight, power, and very high reliability needed for future NASA missions. The developmental computer, using very-high-speed integrated circuits, will continue to be used to evaluate the performance of those circuits in combination with new architectural and software concepts. Elements of this work could benefit upcoming missions, such as the Space Station and earth observing system. The development of gallium arsenide-based computers will continue to be aimed at more advanced computers for missions and payloads further in the future. The evaluation of data flow architectures will move from the study and design phases into testing. Work using simulation to design and evaluate alternative intercomputer communications approaches will continue. Work to provide high-capacity onboard data links using very fast and multichannel fiber optic approaches will continue. Chip level development will be conducted in very specific areas, such as communications channel coding, data compression and radiation tolerant microprocessors where NASA's needs are not being met by products from industry. Work initiated in FY 1987 to develop an erasable associative memory will be continued. Work will be initiated on theoretical exploration of the use of optical processing technology in conjunction with the ongoing research. The 14-inch space-qualifiable optical disk recorder, together with parallel real-time optical processing technology, will be included in the CSTI program.

In FY 1988, because of advances in photolithography, the possibility of micro-fabricating slow wave circuits with application to field emission cathodes will be tested. Advantages include low-beam voltage and low-power consumption with one-watt output. Part of the monolithic microwave integrated circuit effort will be focused on Ka-band integrated gallium arsenide transmitters for eventual upgrade of the deep space communications network. Also, experiments will be done to enable the development of an efficient 32-gigahertz traveling wave tube. The Intelsat 24-reconfigurable horn feed and a 20-gigahertz integrated microwave feed will be tested on the 15-meter Langley Research Center hoop-column antenna in an appropriate near-field antenna pattern measurement facility. The mathematical concept of reconfiguring the phase and amplitude of the feed to compensate for distortions in the reflector surface will be experimentally tested. Also, the mathematical concept of nonuniform sampling of the far-field will be experimentally tested. Research will begin to develop a monolithic gallium arsenide module which will provide an interface for an optical-fiber carrying control network with performance goals of one gigabit of information, 16 parallel outputs, and 50 milliwatts power consumption for receiver and control logic.

Research will continue on laser summing techniques to sum the power from multiple individual devices to increase the total transmitted power, flexibility, and reliability of semiconductor diode lasers for deep space and planetary optical communications applications. This will enable the laser sources, beam diagnostics, tracking, and imaging and steering optics to be tested singly or in a system environment. For deep communications, power is important. Experimental work will begin on a semiconductor laser diode end pumped neodymium yttrium iron garnet laser as a possible source. For low earth applications, the semiconductor laser diode phased array will be demonstrated with a single-lobed far-field pattern while remaining at high power and high modulation rates.

Information Sciences Research and Technology

The objectives of the Information Sciences Research and Technology program are to discover advanced concepts, techniques, and system algorithms and to invent architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In computer science, the selection of Ada as the chosen programming language for Space Station has provided a focal point for the development of improved techniques to develop and manage large-scale software projects. A new set of software management tools, called software automation, generation and administration (SAGA), have been developed to theorize and produce requirements and assist managers in the control of software projects. Findings from software management research are now the topic of a NASA-sponsored annual workshop. Algorithms for concurrent processors have been developed to efficiently deal with the general problem of efficient allocation of tasks to the individual processors in multiprocessor systems. Research in data base logic has resulted in improved tools to allow scientific investigators to access space-derived data that is stored in various forms at various locations in the country. The Center for Aeronautics and Space Information Sciences at Stanford University continues to identify telescience as a focal point for the fundamental work in computing.

In the sensor technology program, major advances have been made through NASA-sponsored research at industrial, academic, and NASA laboratories in titanium-doped sapphire as a viable candidate laser material for active remote sensing. In particular, the anomalous self-absorption losses seen in these crystals have been discovered to be caused by impurities in the material. Subsequent crystal growth has been successfully tailored to rectify this problem.

In the detector device area, a direct read-out 58x62-pixel antimony-doped silicon array has been successfully tested in the important scientific wavelength region of 24 to 31 micrometers.

In the area of devices for heterodyne detection in the far infrared portion of the spectrum, a mercury-cadmium-telluride alloy frequency mixer has been successfully built at 28 micrometers in wavelength with possibilities for extension out to 118 micrometers. In addition, preliminary experiments on a superconducting-insulating-superconducting junction employing a new material, niobium nitride, show promise as a mixer at 500 gigahertz and above in frequency.

In the area of sensor materials research, a new artificial material, an indium arsenide/indium-gallium arsenide strained layer superlattice, which shows promise as a new candidate material for sensing, has been grown for the first time in the world by molecular beam epitaxy at the Jet Propulsion Laboratory.

Prior to FY 1988, the Information Sciences Research and Technology program had the broad focus of addressing the technology needs of all advanced space applications. In FY 1988, a systems program in information technology will be established as part of the new CSTI program. Technologies needed to meet the science sensor requirements of the earth observing system and large deployable refector will be developed in this program.

A reduction in the FY 1988 budget from that of FY 1987 reflects the fact that portions of the submillimeter passive sensing program, together with portions of the active sensing program, have been incorporated in the information section of the CSTI program. All computer science research will remain in this program.

In computer science, major emphasis is being placed on software engineering research leading toward improved techniques and tools to produce, document, and manage large and complex tasks for development of highly reliable software. NASA software development will continue to be coordinated with comparable Department of Defense (DOD) work via the DOD software technology for adaptable reliable systems program and the DOD Software Engineering Institute. The pioneering use of the Ada programming language on Space Station will include improvements in the language and its associated support environment. Research to provide a common tool to access a variety of scientific data bases will move from demonstrations with homogeneous data bases to demonstrations with heterogeneous data bases. Work will continue in the development of algorithms to use the unique capabilities of the NASA-developed massively parallel processor to solve space-related problems, such as defection of stars and galaxies in images, ocean dynamics modeling, and space plasma simulation. The Center for Aeronautics and Space Information Sciences at Stanford University will continue as a center of excellence in aerospace computing, conducting fundamental research and educating students in concurrent processing, networking, information managment, and large-scale system architecture.

In the sensors technology area, work will continue in active remote sensing on the problems associated with making lasers space qualifiable. This includes increasing the number of shots over the total lifetime of the laser to at least 100 million, tuning the laser to the frequencies of scientific importance, getting enough energy in the laser pulse, and assuring the frequency purity of the pulse. Associated technologies, such as semiconductor diode laser arrays for pumping laser amplifiers and materials research, will continue. Solid-state technology for pumping lasers with semiconductor laser diode arrays will be included in the CSTI program.

In passive remote sensing, heterodyne detection is the method of choice for spectroscopic measurement applications in the submillimeter portion of the electromagnetic spectrum. Devices research in frequency sources and mixers in the submillimeter region will be pursued. The advanced coherent detector concepts, including revolutionary heterodyne arrays, which will enable both spatial and spectral instrument resolution, will be included in the CSTI program together with advanced tube oscillator concepts. The area of the growth of artificial layered structures by means of molecular beam epitaxy shows great promise for providing materials for detectors and mixers in the near- and far-infrared portion of the electromagnetic spectrum. Methods will be investigated for growing electro-optic materials on silicon in order to integrate the detecting and electronic on one chip, thereby reducing unwanted electronic noise. New materials will be investigated for extending the response of detectors out into the far infrared and upper portions of the submillimeter region for space-based background-limited astronomical observations.

Controls and Guidance Research and Technology

The Controls and Guidance Research and Technology program goals are to generate the practical design methods and techniques required to enable precise pointing and stabilization for future NASA spacecraft and payloads; to maintain precise structural shape control for highly flexible large space systems; and to guide, navigate, and control advanced space transportation vehicles. Emphasis is being placed in two areas: (1) advancing the methodology of combining both ground-based testing and future space-based testing with modern control theory to validate advanced flexible-body modeling techniques and control laws; and (2) providing advanced guidance, navigation, and control algorithms combined with real-time fault-tolerant distributed control architectures and validation and reliability tools.

Recent program accomplishments include the successful performance of distributed active control algorithms in the spacecraft control laboratory experiment program. These results are important in defining the active controls experiments for the 60-meter control of flexible structures experiment and the three-dimensional antenna flight experiment currently under definition. These successful ground tests and subsequent flight validation experiments will also be important to implementing the NASA-planned pinhole occulter and mobile communications satellite ventures and will supply valuable control algorithms for large flexible astrophysical reflector telescopes. Refined system identification techniques have been developed which can accurately determine, on orbit, the vibration modes in large space systems, such as growth space station. A precision position measurement sensor useful in determining the shape of large antennas and other large space systems has successfully demonstrated millimeter accuracy in a multitarget ranging test. Advanced guidance and navigation concepts and flight experiments were generated supporting a wide range of aeromaneuvering orbital transfer vehicles. Also, in the transportation system vehicle controls area, the initial advanced information processing system architecture was demonstration. It provides reliable, long-life, low-cost controls capability for a wide spectrum of transportation vehicles, including the aerobraking orbital transfer vehicle, Shuttle II, and the heavy lift launch vehicle.

In FY 1988, all controls research that directly supports the control of flexible structures experiment has been transferred to the large structures and controls section of the CSTI program.

FY 1988 controls and guidance research and technology activities will continue theoretical exploration of modern control theory methods associated with both system identification and distributed and adaptive control. The goal is to identify and develop promising advanced control concepts for future large space systems. The unique piezoelectric payload mounting and isolation device, useful for eliminating Space Station induced instrument motions, will be carried to the breadboard stage. A three-dimensional millimeter accuracy shape and motion sensor will demonstrate combined range and lateral displacement functions.

For advanced transportation systems, theoretical research will be carried out to provide guidance and navigation algorithms for aeromaneuvering vehicles undergoing skip trajectories, synergistic plane changes, and precise landings involving large down-range and cross-range capability. Theoretical approaches for adaptive guidance, navigation, and control algorithms and software will be developed for next generation earth-to-orbit transportation vehicles to enable lower cost and higher efficiency launch operations. Integrated function solid-state optical processing chips will be tested in the fiber-optic rotation sensor testbed, to provide transportation vehicles and interplanetary spacecraft with long life and highly reliable navigation devices. To meet extremely demanding future transportation vehicle mission requirements, the advanced information processing system control architecture will be developed and experimentally validated in the avionics integration research laboratory. Prevalidation performance and reliability tools and methodology will be developed. Guidance, navigation, and control flight experiments will be defined and analyzed for the proposed aeromaneuvering vehicle flight experiments.

Human Factors Research and Technology

The objective of the space Human Factors Research and Technology program is to provide the technology base for productivity, efficiency, and safety in increasingly complex manned space operations, including the Space Station and a potential National Aero-Space Plane. The research is focused on crewstation design and productivity enhancements for extravehicular activity (EVA). The objective of the crewstation design effort is to determine the requirements for effective interfaces between human operators and advanced automation. This issue has become very challenging due to the increasing levels of machine intelligence and autonomy sought by system designers. Instead of performing low-level sensor integration and determining actuator positions, the human operator is becoming a supervisor of intelligent systems. Thus, a major goal of the crewstation research and technology program is to ensure effective information transfer between the system and the operator, which is fundamental to the operation of highly automated systems. Increased EVA capability can be achieved by developing high-pressure suits and gloves which are comfortable, durable, and maintainable on orbit and by introducing EVA electronic information displays which provide flexibility and rapid information access.

Research in FY 1987 emphasized crew workstation design and a focused effort in EVA suits and displays. A comprehensive set of human factors guidelines that are specific to NASA's missions were developed and will be distributed to Space Station contractors in FY 1987. Prototype workstation mockups have been fabricated, and more detailed and functional ones are being built. These facilities are supporting rapid prototyping, in which advanced research concepts are brought in for integrated evaluation, operational simulations, and comment by users.

Research on the wide field-of-view stereo display, called the virtual visual environment display (VIVED), last year formed the basis of the virtual workstation project in FY 1987. This workstation is a major leap beyond current human-computer interfaces, since it allows computer-generated graphics and text to be displayed anywhere in the user's workspace. This greatly improves information transfer in applications, requiring the user to be spatially oriented relative to the displayed information, such as in telerobotics monitoring and control. Currently, higher resolution, liquid crystal displays and cathode ray tubes are being integrated into the design. Improved support electronics have been fabricated which will allow replications and improve reliability. Application-specific spatial data bases and under development.

Expert system interfaces is a key area of study since the level of interaction is far higher than in traditional systems. In these more intelligent systems, communication is in terms of goals, intentions, and problem-solving, rather than in terms of knobs, dials, and a few numerical parameters. Several teams of leading designers in NASA, industry, and universities are cooperating to develop the paradigms on which this kind of system should be built. The payoff will be rapid and accurate decision-making in highly complex automated systems, even as the total number of operators is reduced. Expert system interfaces, which incorporate graphical information, improved explanation capability, and enhanced reasoning, are being built for experimental evaluation.

Since EVA is physically demanding, it is important to understand the strength and motion capabilities of humans in zero-gravity conditions. This informaiton is essential to guide the design of EVA tools, suits, and gloves. Progress in FY 1987 includes the development of quantitative models of strength and motion, and these are being combined with powerful computer graphics tools for use by designers. Software improvements are enabling scientists to combine graphical and physical data. Preliminary strength experiments in zero gravity have been accomplished in aircraft flying parabolic arcs. Strength measurement equipment for later shuttle flights is being developed.

Display hardware has been developed for demonstration and evaluation of helmet-mounted information displays in EVA space suits. This display will greatly add to flexibility in presenting mission-critical information to EVA astronauts. The current alternative is a book of information mounted on the astronaut's arm, whose content must be finalized well before the mission. A helmet display would not only add real-time update capability but would also enable substantial improvement in the display of system status of the suit, life support, and manned maneuvering unit. Two prototypes have been completed. One uses state-of-the-art helmet-mounted display technology and is designed for intergration with current space helmets. The second uses advanced wide-angle optics and is used for more far-term studies of formats and operational uses.

Two high-pressure hard space suits have been constructed and pressure tested. As a result of this accomplishment, considerable interest has been shown by Space Station designers. Further work on the gloves is in progress, since it is critical that gloves be flexible at high pressure and not interfere with astronaut manual performance. On-orbit experiments indicated severe problems with manual work and, because of this, among other reasons, the Space Station has been redesigned to reduce EVA requirements. Improved EVA systems are being studied so that later space systems are not similarly constrained.

Workstations for proximity operations will be evaluated. The virtual workstation will undergo hardware integration and display upgrade. A demonstration of the virtual workstation in telerobotic applications is planned for FY 1988. Expert systems studies will focus on specific subsystems and users. Subsystem specialists, software designers, and cognitive psychologists will work together to analyze the key features of an expert system interface needed to support the user. Graphical strength and motion models of EVA astronauts will be refined to include mass, inertia, and other physical properties. The models will also be used to evaluate such intravehicular activities as the change-out of modular racks in Space Station. Testing of the hard EVA space suit will be conducted in weightless environment test facilities (neutral buoyancy water tanks). Glove design will receive particular attention in the area of materials and manufacturing processes. EVA helmet displays will be evaluated for use, and a summary report on the status of this effort and further technology needs will be written. Format research based on head-up display studies by aeronautical human factors researchers will be conducted.

The productivity of humans in space is critically important to the success of NASA's missions, and an increase of the space human factors research and technology base is planned in FY 1988. As part of the planning for this augmentation, NASA and the National Research Council (NRC) of the National Academy of Sciences will conduct a space human factors symposium in FY 1987 which will bring together leaders of industry, government, and academia in order to survey human factors research which would most likely benefit NASA's manned space goals. The Space Human Factors Research and Technology program will integrate the NRC guidance with NASA's strategic plan to determine the additional FY 1988 research activities which will enable NASA's visionary missions. Key elements will include: (1) supervisory control of autonomous space systems (e.g., rovers, orbital transfer vehicles, and life support subsystems); (2) teamwork and interaction between automation/robots and humans; and (3) automation-augumented human physical and intellectual capability.

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 and operation of future space systems. This objective is accomplished through the utilization of current and future space facilities such as in-space research laboratories. 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.

The cryogenic fluid management flight experiment will provide the basic understanding of the storage, acquisition, and transfer of cryogenic fluids in zero gravity. This technology is critical to design of future cryogenically fueled orbital transfer vehicles (OTV) and for the on-orbit supply and resupply of cryogens to both spacecraft and platforms. In FY 1987, procurements were initiated for component development of liquid hyrogen flowmeters and valves and gaseous hydrogen/gaseous helium flowmeters and pressure regulators. In addition, analytical models were developed and/or refined to provide the design data base for the heat and mass transfer during nonvented fluid transfer and understanding of low-gravity fluid behavior.

Under the orbiter experiments program, first flight was completed for three key aerodynamic and aerothermodynamic experiments. Significant contributions were made to the aero/aerothermodynamic data base, although anomalies occurred during experiment operations which reduced the planned data return. Subsequently, the causes of these anomalies have been determined and modifications or repairs have been or are in the process of being made in preparation for an additional five flights upon resumption of the orbiter flight schedule. The orbital acceleration research experiment, which will provide a better understanding of vehicle aerodynamics and aerothermodynamics in both the molecular and continuum flow regimes, as well as expand the data base for orbital drag predictions, has completed critical design review and is in process of hardware fabrication. Fabrication of flight test panels for the advance thermal protection system experiments was completed, and certification of test materials initiated. This experiment will provide actual flight data on durable, high-performance material concepts which could become candidates for future aerospace vehicles.

The outreach program, to provide leadership and funding support to the aerospace industry and university communities to better utilize the potential of space for technology development, was initiated in FY 1986. The solicitation and selection of experiments will be completed during FY 1987, followed by the initiation of experiment definition/development activities.

The development of a space technology experiments platform (STEP) initiated in FY 1985 was continued in FY 1986 with the fabrication of mission peculiar hardware and the completion of the preliminary design of the required avionics element. STEP is configured to accommodate a wide variety of space experiments in the microgravity and low disturbance environment of space over broad thermal excursions. Functionally, STEP, as a reusable payload support system and standard shuttle interface, will provide a cost-effective means for routinely conducting a variety of shuttle unique in-space experiments. In FY 1987, a critical design review was conducted on the avionics elements for STEP; fabrication and testing of a quarter platform was completed; and a pyrotechnic separation system was developed.

The capillary pump loop experiment, successfully flown in January 1986, provided systems and component research data for future development of two-phase heat-pipe systems. The results of this experiment lend confidence to the potential for the early application of two-phase technology to Space Station and future spacecraft. The long-duration exposure facility awaits retrieval by the shuttle and subsequent data analysis. The LIDAR in-space technology experiment, to evaluate the capability of making measurements of aerosols and other atmospheric parameters from a spaceborne platform, has completed preliminary design review. 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. In FY 1987, efforts focused on the identification and definition of new space experiments required for the enhancement or enablement of future space endeavors was initiated. These experiments are being defined for the Shuttle or the future Space Station.

In FY 1988, under the orbiter experiments program, key aerodynamic, aerothermodynamic, and thermal protection system experiments will resume flights for completion of the previously planned six-flight series for these experiments. Early fiscal year activities will be in preparation for these flights, including completion of material sample fabrication flight certification and instrument installation into the orbiter.

In FY 1988, preliminary design activities will be initiated with concept design planned for completion in mid-year and a design review scheduled for FY 1989. Ground-based tests to support component development and analytical models development will continue.

The outreach program, initiated in FY 1987 to expand flight opportunities to the industry and the university communities, will continue with experiment definition/development activities.

The LIDAR in-space technology experiment effort will include the critical design review of the instrument, followed by the initiation of hardware development in preparation for a planned 1991 flight.

Systems Analysis

The objectives of the Systems Analysis program are to: (1) conduct systems analyses to identify technology requirements for spacecraft systems, space transportation systems, and large space systems for the national space program; (2) integrate these requirements into a comprehensive technology plan; and (3) provide data to establish the ability to develop these technologies in a timely manner. Close coordination with NASA flight program offices and other users is maintained to ensure proper prioritization of enabling and high-leverage technologies.

Spacecraft systems analysis is concentrated in four science and application areas: astrophysics, earth science, communications, and solar system exploration. In FY 1987, the critical technology trade-offs for the large deployable reflector and the earth observing system have been completed, and the results will be transitioned into the discipline technology programs. In earth science, a series of studies will be initiated to understand the critical technologies associated with geosynchronous earth science observations. A comprehensive series of studies on the technologies required for a Mars surface sample return mission will be continued. Emphasis will be on the detailed technologies required for robotic sample collection, including the robotic mobility system and the alternatives for electrical power. A Mars rover workshop was held to stimulate detailed analysis of rover requirements with respect to the current state of the art and future directions of the automation and robotics program. Working through the spacecraft 2000 government/industry steering group, a joint strategic plan was developed for future spacecraft technology development and transition into specific missions and applications.

The space transportation systems analyses are focused in three areas: advanced earth-to-orbit (ETO) vehicles, aeroassist orbit transfer vehicles (AOTV), and advanced space transportation systems conceptual design and analysis methods. More specifically, the FY 1987 studies/analyses focus on the generic architecture from the ongoing space transportation architecture studies (STAS). The earth-to-orbit (ETO) studies include the technology to support a second generation fully reusable manned vehicle (Shuttle II), an 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. Shuttle II efforts will identify and prioritize enabling and high-leverage technologies required for a transportation vehicle that operates between earth and the Space Station for logistics, crew change-out, up and down payloads, and, in some cases, platform and satellite servicing. Liquid oxygen/hydrocarbon (LOX/HC) engines/vehicle integration and design studies include the impact on reusable transportation vehicle performance and cost. The use of LOX/HC engines, which require very high density propellants and thus significantly smaller propellant tanks, has the potential for large reductions in dry weight and in cost per pound of payload to orbit. AOTV technology and environment studies are continuing in FY 1987 but are concentrated on cislunar transportation systems—in particular, on the identification of the class or classes of AOTV's that will be required to operate between lunar orbit and low earth orbit (LEO). The analyses emphasize performance, reusability, and space basing. These studies are consistent with the renewed interest in lunar and planetary colonization and mining. Finally, conceptual design and analysis methods are being developed to conduct required trade studies in a most efficient and cost-effective manner. This involves the update and development of the necessary analytical and numerical tools including the computer-aided engineering software and the technology and cost data base.

In the area of large space systems, both manned and unmanned, the focus of the analysis program is on technology for evolutionary space stations and the space infrastructure that they will support. Analysis activities will 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 will be completed.

In FY 1987, three specific activity study areas will be continued in the large space Systems Analysis program: (1) systems analysis methods; (2) future space systems, including the evolutionary space station/infrastructure, large unmanned platforms, and a manned lunar base; and (3) in-space research, technology, and engineering planning. The objective of the systems analysis methods is 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. The objective of the second activity area, future space systems, is to address mission and system requirements and to identify their associated technology needs and trends. Specifically, efforts will continue for developing generic space system models to permit the conduct of sensitivity trade studies incorporating advanced technology concepts and options. Additional tasks will investigate 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. The activities in the third area are associated with developing a sound technical basis for conducting in-space research and technology experiments using the Space Station as a laboratory facility. This FY 1987 activity includes the preliminary definition of experiment support equipment for an aggressive in-space experiments program across the spectrum of such technical areas as fluids, power, environmental effects, and structures and control.

In FY 1988, the Mars rover studies will be completed, and emphasis will be redirected toward an outer planet science station study. Within the astrophysics focus, activities will center on the technology requirements for interferometric observatories across a range of wavelengths. The definition study of a space flight testbed for validating government 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 capability.

The transportation systems analysis effort in FY 1988 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 technology 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 evolutionary space stations, lunar bases, and long duration manned space trips, will be effected. 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 future. Additionally, the FY 1988 program will continue to include planning for the use of the Space Station as a facility to support research and technology.

SYSTEMS AND TECHNOLOGY BASE

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Chemical propulsion systems technology	$8,100,000	0
Space flight systems technology	11,300,000	0
Automation and robotics	18,000,000	0
Total	37,400,000	0

Chemical Propulsion System Technology

The objective of the advanced earth-to-orbit systems component of the Chemical Propulsion Systems Technology program is to verify life, performance, and operations technologies that have been developed under the space propulsion research and technology program by utilizing a testbed engine which has been assembled from existing Space Shuttle main engine components. This will provide experimental data with which to verify advanced design concepts in true internal engine environments and to validate analytical models created to simulate these internal environments. Initial testing will be conducted with an engine instrumented with research-quality instrumentation to accurately measure both transient and steady-state pressures, temperatures, flow rates, stresses, and strains. Experimental data from this testing will be used to anchor simulation codes. Advanced subcomponent hardware items, including advanced single-crystal hollow turbine blades, advanced longer life bearing designs, and improved rotordynamic damping seals, are currently being fabricated for installation into engine component hardware for later hot-fire testing. Diagnostic sensors, including a bearing wear deflectometer, a fiber optic pyrometer blade temperature sensor, an optical hot-gas temperature sensor, a nonintrusive shaft speed sensor, a plume anomaly detector, and a brushless torquemeter, are all being similary fabricated for later installation and testing.

The testbed engine program will generate the experimental data needed to provide final verification of advanced design and analysis tools that will lay the foundation for advanced high-performance, reusable earth-to-orbit engines. These engines are essential for future national space transportation needs. The Office of Aeronautics and Space Technology funds the analyses, design, and fabrication of advanced technology instrumentation, subcomponent hardware, new diagnostic sensors, and the analysis of the test results. The Office of Space Flight provides engine component hardware, installs advanced technology items, assembles the testbed, and conducts test operations. Testing of the instrumented engine is scheduled to begin in FY 1988, followed by initial technology evaluation testing beginning in FY 1989.

In FY 1988, this program will be absorbed into and become an integral part of the propulsion program under the CSTI program.

Space Flight Systems Technology

The objective of the control of flexible structures (COFS) program is to provide experimental validation of analytical methods for predicting coupled structural dynamics and controls response for complex multibody space structures with flexible components, interfaces, and dissipative mechanisms.

In order to meet the requirements of the program, a comprehensive research activity which includes analytical methods development, ground-based testing, and in-space experiments was initiated in 1985 to provide a focus for control structures interactive technology. An in-space experiment program is planned, building progressively from modeling and dynamic characterization of large space structures to more complex flexible-body interactive controls/structure issues. The approach provides for structural dynamic functional complexity in a baseline configuration that has fundamental frequencies below one hertz, complex nonlinear joint effects, structural dynamic/control sytems interactions, and inherent low structural damping effects. This test article will be tailored to validate discipline research objectives addressing the major concerns of large space system spacecraft, independent of any specific configurations ultimately chosen for new missions. The first flight article, COFS I, a large 60-meter deployable/stowable structure (termed Mast) will be dynamically tested in space cantilevered from the shuttle. The second flight article, COFS II, is a Mast with a three-dimensional appendage to study the structural dynamics and controls of large, flexible, spacecraft configurations.

This program is incorporated in the CSTI program in FY 1988.

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. In FY 1987, the preliminary design and development of the telerobot demonstration facility with a two-arm manipulator was completed, and a sequence of demonstrations for FY 1988 defined. The facility has a suspended spacecraft (Solar Max) which the robot will acquire, despin, and service, with two cooperating robot manipulator arms mounted on tracks to accomplish these tasks, and a third arm with a mounted television camera which supplies the vision for the robot system. In systems autonomy, a comprehensive plan was developed and the management structure put into place. A prototype knowledge base for a thermal control system (TCS) was demonstrated on a symbolic 3640 computer, using the artificial intelligence (AI) development tools KEE and Simkit. Demonstrator targets include the TCS; prelaunch ECS, power, and pneumatics; the Space Station power system; and the shuttle communication system.

In the associated core research area, several outstanding achievements were attained. In sensing and perception, an intermediate-level computer vision system called PIFEX (programmable image feature extractor) has been developed which can detect hardware edges and vertices. In the operator interface area, a six degree-of-freedom force-reflecting controller has been developed. In task planning, an artificial intelligence planner has been developed which, given a set of goals and a knowledge base of relevant actions, can generate a sequence of actions in a satellite's payload to implement those goals. Other accomplishments include rudimentary learning by the expert system planner deviser, telerobotic operation of fuel transfer/strut node coupling, verification of the smart hand and force reflecting controller, and the development of a computer graphics display for that controller.

In FY 1988, the automation and robotics program has been incorporated into the CSTI program.

CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Propulsion	0	$39,200,000
Vehicle	0	15,000,000
Information	0	17,400,000
Large structures and control	0	22,800,000
Power	0	14,000,000
Automation and robotics	0	25,700,000
Total	0	134,100,000

CSTI—Propulsion

The objective of the CSTI Propulsion program is to develop and demonstrate, in full-scale component and system tests, main engine and booster propulsion technology which will enable the development of the next generation of earth-to-orbit vehicle.

The earth-to-orbit propulsion technology program will verify the design and analysis tools developed with laboratory scale and subscale test hardware in the research and technology base program and demonstrate their performance under large-scale hot-fire engine environment. These validated analytical techniques will become the basis for the design and development of advanced, reusable, high-performance earth-to-orbit propulsion systems. These design and analysis tools will be generalized to accommodate both hydrogen and high-density propellant engine systems for broad application and operating conditions. Candidate propellant combination include oxygen/hydrogen (at Space Shuttle main engine (SSME) and oxygen rich mixture ratios) oxygen/propane, oxygen/RP-1, and oxygen/methane. The program initially includes the SSME testbed engine which will provide comprehensive operating data for the SSME and a large-scale liquid oxygen/hydrocarbon (LOX/HC) main chamber to explore stability limits associated with high-pressure operation. The testbed will also be used to verify the performance of advanced technology components in a system-level environment, incuding advanced bearings, hollow and single-crystal turbine blades, and diagnostic instrumentation. A LOX/HC research engine will be assembled for subsequent system-level testing of the gas-generator turbomachinery.

The booster technology program will develop technologies for alternate propulsion concepts for the Space Shuttle booster. Two types of systems are to be considered, solid-liquid hybrid boosters and pressure-fed bipropellant liquid boosters. Performance models will be generated and verified with data from a number of increasing size static firings. Thrust levels of up to a million pounds will be considered. A single system will be selected for large-scale demonstration of performance and the safe abort capability.

In FY 1988, the CSTI propulsion program will include earth-to-orbit technology for both LOX/hydrogen and LOX/hydrocarbon propulsion systems. CSTI will also include LOX/hydrocarbon specific technology tasks to verify high pressure ignition, combustion performance and stability, and heat transfer and cooling. The CSTI propulsion program incorporates some of the effort formerly in the research and technology base and the Chemical Propulsion Systems Technology program.

The LOX/HC effort will be focused on the design and fabrication of large-scale (750,000-pound-thrust class) oxygen/hydrocarbon combustor hardware in preparation for conducting hot-fire tests to accumulate experimental data to upgrade and finalize analytical models for combustion performance, stability, heat transfer, and cooling. 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 overall objective of the program is to develop a set of generalized design and analytical tools that can be used for the design of advanced high-density propellant engine systems of any thrust class functioning under any desired set of operating conditions.

The SSME testbed effort will include the final assembly of the testbed engine and the initial hotfire operations utilizing the newly activated SIC test stand at the Marshall Space Flight Center. The research-quality diagnostic instrumentation, including selected advanced technology sensors, will be installed and calibrated. Advanced technology components (turbine blades, dampers) will be prepared for installation for the second hot-fire test sequence.

For the hybrid booster system, tasks include evaluating candidate fuels, establishing burning characteristics and a propellant configuration, 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 structual design and material evaluation.

CSTI—Vehicle

The aeroassist flight experiment (AFE) will investigate the critical vehicle design and environmental technologies applicable to the design of an aeroassisted orbital transfer vehicle (AOTV). The technology areas 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.

In FY 1987, preliminary advanced development activities were completed under the Space Flight Research and Technology program in preparation for initiation of the final design and long-lead hardware procurements in FY 1988. Also a ground-based testing program was conducted in support of the definition and design efforts to establish the aerodynamic and aerothermodynamic data base for the vehicle systems and mission design. Both arc-jet and wind-tunnel tests were performed in support of the instrumentation layout for the aeroshell. Supported by the above tests, the development of analytical codes for the design of the AFE has been initiated.

Development of the AFE will be initiated in FY 1988. Final systems design and instrument design efforts will be initiated. Ground-based activities will be continued to support these design activities. Long-lead procurements will be initiated where required to meet the scheduled 1992 planned launch date and will include major hardware items, such as the propulsion system and the thermal protection tile for the aeroshell. Integration activities will be initiated to support the definition of shuttle interface requirements, system and component certification requirements, and a preliminary assessment of flight operational requirements.

CSTI—Information

The objective of the information systems technology program is to discover and develop new materials, devices, and components in order to enable viable and productive detection, imaging, and storage systems for future space and planetary mission in the next century.

The high rate/capacity data efforts are directed toward maintaining U.S. preeminence in collection and productive utilization of space-derived data. The work will enable a new generation of smart on board information systems that will increase the return of scientific information from space. The science sensor efforts concentrate on visual and infared scanning and imaging instruments and radar and optical surface mapping instruments. The utilization of both classes of instruments can be greatly improved by using onboard artificial intelligence to manage the instrument operation. Smart instruments could be taught to look for particular features or events and transmit only data of interest.

The next revolutionary impact on instrumentation will be submillimeter detectors utilizing a heterodyne array for missions such as the large deployable reflector. This particular instrument concept will be able to accomplish both spectral and spatial imaging. Parts of the ongoing sensor technology base have been focused onto this problem, namely materials which can incorporate mixing arrays. In addition, a heterodyne frequency source with enough power to illuminate the entire array is needed. Ongoing work in novel backward oscillator tubes at the submillimeter frequency and with promise of ample power will continue to be focused from the ongoing base to this systems technology thrust area. Millimeter and submillimeter wave heterodyne radiometer front-ends employing planar antenna structure and quasi-optical coupling have been investigated.

Research to enable active laser sensors is being conducted. Solid-state materials and pump device advances have contributed toward extending laser operational lifetimes. One approach transferred from the research and technology base is pumping the laser material with laser diode arrays. The objective is to develop two-dimensional semiconductor laser diode arrays with ample output power density. Materials studies into problems such as heat dissipation, frequency stability, and efficiency are in progress. In addition, a research effort is being initiated to develop sub-Kelvin cooler technology to improve and extend infrared sensor performance and life.

Onboard computing and optical disk memory technology elements of the space data and communications program have been incorporated into the CSTI program in FY 1988 to focus on the high-rate/capacity data requirements of future NASA missions. Submillimeter and laser sensor technology elements of the information science research and technology program have been incorporated into the CSTI program in FY 1988 to focus on science technology for earth observing system and large deployable reflector.

Future onboard imaging instruments operating in the visual and infared regions that create images of much higher spatial and spectral resolution than those now in use are being developed. These instruments enable an exciting new scientific exploration capability. However, the volume of raw data from these instruments will be enormous. Onboard processing work is targeted at reducing the data by a factor of 1,000 with equivalent science return. Improvements in the useful information from surface mapping instruments, such as synthetic aperture radars and light-detecting and ranging devices. will be obtained by using onboard processing. Remote sensing of surface features could be automatically configured for the scene (ocean, mountains, ice fields, etc.) which would both increase information return and reduce the operations support staff needed on the ground.

In the high-rate data area, work concentrates on the development of onboard processing techniques for surface mapping measurements and visual and infared scanning instruments. These instruments share the common characteristic of being voluminous producers of data. Early work in the area of surface mapping will concentrate on elimination of data with no information content from the communications channel. Adaptive processes will be developed so that data is collected only at times and places of interest. In a like manner, onboard processing of focal plane image data will delete unneeded information before transmission. This processing will be done in coordination with the scientific users of the data. There is work underway to demonstrate onboard processing techniques to automate the identification of surface minerals.

The development of a 14-inch optical disk recorder that is space qualifiable continues. This provides the very large onboard storage needed to do onboard calculations that are based on historical comparisons. The applications of the optical disk storage also extend into spacecraft automation where trend data must be stored. There are also expected to be applications for the optical recorder in the area of pattern recognition for vision systems.

New devices will be developed to enable scientific observations in the submillimeter region of the electromagnetic spectrum. Techniques for making square (NxN) mixing arrays using superconducting-insulating-superconducting junctions will be investigated together with quasi-optical methods for illuminating the device. In addition, the backward oscillator tube will be tested to determine whether it oscillates in band and to measure output power. The NxN mixing array will necessitate inventing devices for doing an NxN signal analysis. Promising candidates such as a two-dimensional acousto-optic receiver will be investigated.

In laser remote sensing, research will be focused on developing critical technology to enable space-based light detection and ranging (LIDAR) capability to meet the science requirements of the earth observing system. Research into promising two- and three-dimensional semiconductor laser diode arrays for maximum pumping efficiency will continue. In addition, methods for tuning the solid-state laser amplifiers into the science frequency regions of interest will continue. Technologies for a 10-Joule per pulse with a 10-pulse per second duty cycle and a 100-million-pulse lifetime carbon dioxide laser to enable a doppler planetary and tropospheric wind field measurement instrument will be initiated. Studies include preionization electrode and cavity optics degradation, gas recycling, and isotopic operation. Active cooler technology to enable the earth observational and astronomical missions requiring low instrument temperatures will be initated. Non-contact Stirling cycle mechanical refrigerators will be developed to provide cooling down to 45°K and adsorption coolers will be developed to provide sensor cooling to less than 1°K.

CSTI—Large Structures and Control

The objective of the Large Structures and Control program is to provide experimental validation of analytical methods for predicting coupled structural dynamics and controls response for complex multibody space structures with flexible components, interfaces, and dissipative mechanisms. As the agency initiates planning and implementation for large space systems (Space Station/platforms/antennas), there are basic unknowns in the areas of structural dynamics, controls, structural interaction, structural performances, and deployment dynamics which must be resolved in order to develop this new class of spacecraft with the assurance of meeting safety, performance, and cost goals. The size and flexibility of these systems require development of analysis and test methods and a space-based experiment activity addressing the key technology unknowns through graduated testing of flexible elements. The research data base will allow the design and development of integrated complex control systems and structural configurations for future generation large spacecraft.

The control of flexible structures (COFS) program, a comprehensive research activity which includes analytical methods development, ground-based testing, and in-space experiments, was initiated in FY 1985 to provide a focus for large structures and control technology. The first flight article, COFS I, a large 60-meter deployable/stowable structure (termed Mast) will be dynamically tested in space cantilevered from the shuttle. In 1986, fabrication of the subsystems of COFS I was initiated, and a conceptual design review was completed. In FY 1987, the preliminary and critical design reviews were completed, and development testing has been initiated on actuators and instrumentation required for the excitation, measurement, and control of the low-frequency modes of the Mast. The structural design characteristics, representative of large space structures, have been carefully integrated into a beam design for safe experimentation. An experiment requirements document has been completed which initiates the rigorous integration activities required to place an experiment onboard the shuttle. Also, in FY 1987, the avionics subsystems were defined for a fault-tolerant flight control system and a high-volume data acquisition system. A guest investigator program was developed, and participants from several universities and industrial firms were selected for the COFS I in-space experiments.

The second flight article, COFS II, is a Mast with a three-dimensional appendage to study the structural dynamics and controls of large, flexible spacecraft configurations. Key technology elements include maneuver control, articulation, pointing, shape control, alignment, system identification, deployment dynamics and adaptive controls. In FY 1987, a project plan for COFS II was developed with rigorous involvement of industry, universities, and other government agencies, and a competitive procurement process was started for the test hardware. A guest investigator program to leverage the technology impact of the COFS II program was also initiated.

Further technology advancement required for the COFS program is included in the COFS III activity. The focus of COFS III is on the validation of control-structure interactive analysis and design methodology for multibody, flexible spacecraft, a step beyond space station. For COFS III, a project plan was defined for analytical development for multibody dynamics and controls, ground test methods and capabilities, and flight test to validate in space the analytical methodology and ground-based experiments.

The precision segmented reflectors (PSR) program will develop a large-size segmented reflector structure that is lightweight, low cost, thermally stable, and structurally stiff in order to meet stringent optical precision requirements and to develop an accurate system necessary for pointing, vibration, and wavefront figure control. The overall system requirements for large precision segmented reflectors include large aperture for very faint astronomical signals, narrow field of view to focus on single targets, minimal slow rate and structural dynamical response, and low radiation temperature environment. The required technology does not currently exist and must be developed systematically.

Optical design, reflector materials, fabrication, and controls are essential technologies for precision segmented reflectors to be used in NASA's space science missions. The stringent pointing and low jitter required for such systems, together with its optical figure precision requirement, impose very challenging demands on sensing and control technology. Graphite-epoxy composites and metal-core structures need to be evaluated and developed as candidate materials. Precision replication of segments is essential. The primary reflector structure is a driver in the overall systems design. Its mass, surface accuracy, and thermal behavior affect most of the other subsystems. Long-term dimensional stability, which includes moisture effects, microcracking, ultraviolet degradation, and active oxygen erosion, will also be investigated.

Prior to FY 1988, the COFS program was included in the space flight systems technology program, and the supporting structural dynamics and controls technologies were included in the research and technology base, materials and structures, and controls and guidance programs, respectively. Since the principal focus of the COFS program is to develop new design options for future generations of large, flexible spacecraft, this program is included in the large structures and control area of the CSTI program.

Ground-based elements initiated earlier will be continued in FY 1988 for the COFS I and II structures. Analysis and ground-based experiments will focus on qualifying these in-space experiments for flight on the shuttle. Additional analysis and ground-based experiments will focus on expanding the newly developed technology for application to more complex multibody and three-dimensional structures. The delivery of the COFS I flight test article is scheduled for 1989. The characteristics of the Mast truss-beam flight test article will be defined with an analytical model to be validated in the ground-based experiments and finally in the COFS I in-space experiments manifested for 1991–1992.

In FY 1988, plans for a phased competitive procurement for the development of COFS II experimental configurations will be completed. A related ground test program will be developed. Guest investigators from universities and industry will be invited to participate in the development of this technology.

In FY 1988, the COFS III scaled-model analytical and ground-based studies will be focused on the Space Station initial operating configuration (IOC). The Space Station offers an inexpensive means of obtaining flight data as the components of the station IOC are assembled. Precise location and definition of required instrumentation for the Space Station will be determined in COFS III scaled-model experiments, and a systematic mission plan to acquire structural dynamics and control data on the assembly configurations of the Space Station IOC will be established.

During FY 1988, research in the precision segmented reflectors program will focus on developing new concepts for very lightweight and dimensionally stable panels. Both erectable and deployable concepts will be considered along with mechanisms and control systems for maintaining very accurate alignment and stability. Tests on advanced materials and fabrication methods will be conducted to support the selection of initial concepts and to define specific areas for advanced materials development to be performed under this program. Prototype mechanisms for erecting/deploying/aligning the panels will be designed, and fundamental control laws for controlling these processes will be developed and tested. This activity will directly support a seven-panel reflector ground demonstration test program planned for FY 1992.

CSTI—Power

The objective of this program is to develop the technology needed to meet the high-capacity power systems requirements for evoluntary space station, lunar and planetary bases, and for high-power-demand electric propulsion systems.

For high-capacity power systems, power levels of interest are greater than tens of kilowatts to multimegawatts. An advance technology program was initiated in FY 1986, as part of the space energy conversion research and technology program, with emphasis on significantly improving the SP-100 power conversion efficiency to take advantage of the reactor's estimated thermal output capability of eight megawatts. In the thermoelectric converter area, identification and the laboratory characterization of the physical, thermal and electrical properties of potentially stable, higher efficiency, rare earth chalocogenide junction material candidates, e.g., lanthanum telluride, has resulted in good progress toward achieving the desired higher level figure of merit. Recent experimentation and microstructural analyses of the silicon germanium junction materials have shown that favorable phase precipitation changes can occur at particular annealing temperatures during material processing. The net positive effect of this newly discovered interrelationship would be an improved electrical activity characteristic without detrimentally affecting desired thermal conductivity characteristics for the material. Couple efficiency could then be improved threefold or more for the baseline silicon germanium material. For a dynamic conversion system alternative, the development of the free-piston Stirling engine technology for use with advanced nuclear reactor power systems is continuing. Testing of the initial 25-kilowatt space power demonstration engine was concluded with near achievement (91 percent) of the design power goal. Preliminary engineering design of the next generation developmental engine with a higher hot-side temperature capability has been completed. Advanced radiator configuration concept studies are in progress with supporting research and technology in heat pipe modeling and analyses, testing of improved high-temperature radiator materials, and advanced surface emissivity treatments. Tests of a new family of semiconductors have substantiated the materials tolerance capability for resisting without failure extremely high levels of radiation exposure. These signficant improvements in radiation tolerance of dielectric electrical insulating materials have been measured in repeated laboratory tests. The broad-based SP-100 advanced technology program has been highly successful in identifying potential component/subsystem improvements and in developing solutions for those nonnuclear technology areas critical to successful development and application of high-capacity space nuclear power systems.

Prior to FY 1988, funding for high-capacity space power systems was contained within the space energy conversion research and technology program. The principal focus of the high-capacity space power program was support of the SP-100 nuclear reactor power technology development program primarily in the advanced conversion component technology developments area and in the directed support of the SP-100 ground engineering systems program in selected nonnuclear technology areas. In FY 1988, an aggressive dynamic conversion systems technology development and verification program will be initiated. The fabrication and assembly of a space prototypical free-piston Stirling engine capable of 1050°K hot-side temperature operation will be well underway. Advanced heat pipe configurations for heat transport, as well as advanced regenerator/heat exchanger concepts, will be incorporated into this design. Test plans for the performance mapping and endurance testing of this advanced Stirling engine will be developed. The reactor being developed in the SP-100 program would provide the heat source for the Stirling dynamic converter in a flight power system. In the Stirling engine development ground tests, however, a simulated heat source will be used. Thermoelectric materials research for the N-leg and the P-leg will continue for the alternative static converter system, seeking experimental substantiation of a 3- to-5-fold increase in cycle efficiency with stable, repeatable, single cell and multicell couple performance. In parallel with these efforts, other key power system technology elements will be pursued, both analytically and experimentally. Advanced waste heat radiator concepts incorporating lighter weight heat pipes and innovative surface conditioning techniques for greatly improving the emissivity of the candidate surface materials will continue to be investigated. Component testing will be initiated to confirm performance predictions. The waste heat radiator is a critical item, not only from a thermal performance standpoint, but also from a weight standpoint, for the space nuclear reactor power system. Supporting research and technology activities (i.e., analysis, fabrication, testing) will be conducted in the area of high-temperature, high-strength, long-life materials and thermal management modeling and analyses. Laboratory-scale tests of candidate advanced power conditioning and control components will proceed into FY 1988. A diagnostics/fault-tolerant system technology assessment and advancement effort for the high-capacity power system will be initiated.

CSTI—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. Specifically, the objectives of the robotics element are to evolve the level of autonomy of remote operations from teleoperation to robotics and to increase the operational capability of remote manipulation from its current state as a crane on the shuttle orbiter to the capability for on-orbit assembly, servicing and repair, and for planetary exploration. The objectives of the autonomous systems element are to reduce the size of the ground control and operations crew and to automate control of appropriate subsystems aboard the Space Station, spacecraft, or transportation vehicles. Goals of the program are to replace 50 percent of extravehicular activity (EVA) with telerobotics, decrease mission operations manpower by 60 percent, and reduce the manpower required to do routine housekeeping functions aboard the spacecraft by 50 percent.

A series of evoluntary ground demonstrations is planned for both robotics and autonomous systems elements. Underlying the sequence of demonstrations in both programs are five core technology areas: sensing and perception, control execution, task planning and reasoning, operator interface, and system architecture and integration. Integrated plans have been developed for the demonstration sequences, and research is underway in the five core technology areas. Coordination with the Defense Advanced Research Projects Agency (DARPA) assures leverage of relevant technologies being developed under their strategic computing initiative. Intercenter memoranda of agreement have been signed to facilitate the transfer of technology from the technology development centers to the user centers.

In FY 1987, the preliminary design and development of the telerobot demonstration facility with a two-arm manipulator was completed, and a sequence of demonstrations for FY 1988 defined. The facility has a suspended spacecraft (Solar Max) which the robot will acquire, despin, and service, with two cooperating robot manipulator arms mounted on tracks to accomplish these tasks, and a third arm with a mounted television camera which supplies the vision for the robot system. A notable accomplishment was the establishment of the hierarchical computer architecture which will allow artificial intelligence planners to control this robot.

In FY 1987, in the system autonomy area, a comprehensive plan was developed and the management structure put into place. A prototype knowledge base for a thermal control systems (TCS) was demonstrated on a symbolic 3640 computer, using the artificial intelligence (AI) development tools KEE and Simkit. Demonstrator targets include the TCS; prelaunch ECS, power, and prenumatics; the Space Station power system; and the shuttle communication system.

In the associated core research area, several outstanding achievements were attained. In sensing and perception, an intermediate-level computer vision system called PIFEX (programmable image feature extractor) has been developed which can detect hardware edges and vertices. Such a visual system will be necessary to enable autonomous recognition of objects from a well defined data base, as well as autonomous capture and despin of tumbling satellites. A prototype of PIFEX, which provides the realtime acquisition, feature tracking, motion stereo, stereo matching, and processing of the visual system for the robot, was demonstrated. This system is capable of performing 100 billion arithmetic operations per second. Two stand-alone expert systems including an error diagnostician and an execution monitor, which monitors and predicts the behavior of the system, were integrated using a communications blackboard. This is the first time two separate expert systems have been made to cooperate using a common or shared knowledge base. In control execution, computer vision and force/torque feedback have been used to automatically guide a pin to a close tolerance hole and insert it. This is necessary for autonomous module insertion when the telerobot is operating under conditions of communications time delay. In operator interface, a six degree-of-freedom force-reflecting controller has been developed. Using this technology, the same controller can be used with a number of different space arms. In task planning, an artificial intelligence planner has been developed which, given a set of goals and a knowledge base of relevant actions, can generate a sequence of actions in a satellite's payload to implement those goals. Other notable accomplishments include rudimentary learning by the expert system planner deviser, telerobotic operation of fuel transfer/strut node coupling, verification of the smart hand and force reflecting controller, and the development of a computer graphics display for that controller.

The automation and robotics program in its entirety has been incorporated into the CSTI program in FY 1988. In addition, the program has been augmented to include pre-launch and post-launch operations, including pneumatics and power pre-launch subsystems and the shuttle communications subsystem.

Development and advancing technologies in telerobotics are described by a sequence of evolutionary ground demonstrations scheduled from 1987 to 1996. The initial demonstration will be of a two-armed remote manipulator for satellite module replacement and fluid transfer tasks. Automony will be implemented in terms of preplanned sequences of task primitives, e.g., open, close, screw in, etc. The second demonstration (1990) will include automatic acquisition and despin of a spacecraft and servicing it using dexterous cooperative arms, automatic sequence planning, and autonomy at the task element level, e.g., remove panel. The 1993 demonstration will comprise task level (e.g., replace module) commands, automated replanning for error conditions, and automated planning using a computer-assisted design (CAD) data base. The 1996 demonstration will extend to repair tasks involving cutting and fabrication.

The FY 1988 telerobot demonstration will incorporate dual arm control, AI-based planning, smart end effectors, force reflecting controllers, and vision-based robotic control for simple servicing tasks.

Research and development in each of the five core technology areas associated with telerobotics will continue. In sensing and perception, research on multiple-class three-dimensional object recognition and tactile/proximity sensing will be conducted in order to reduce reliance on the human operator's vision system. In task planning, experiments will be conducted on spatial planning of manipulator trajectories and on reasoning about nonstandard procedures in order to reduce reliance on the human operator's cognitive capabilities in task planning. In control execution, telerobot control of flexible manipulators and control of multiple-arm degrees of freedom will be developed to enable telerobot servicing of a wider class of spacecraft and payloads. In operator interface, predictive displays and simulation aids for anticipated failures will be developed to permit the operator to take over when the autonomous system encounter difficulty. In systems architecture and integration, the focus will be on developing techniques for expert systems to control an entire system by coordinating the needs and tasks of a number of subsystems.

Integration of advancing technologies in systems autonomy is described by a sequence of evolutionary ground demonstrations scheduled from 1988 to 1996. The initial demonstration (1988) is of a rule-based expert system for control of a single-mission operations subsystem in which reasoning is limited to standard procedures and knowledge of the task world is complete and unambiguous. The second demonstration (1990) will be a model-based expert system for coordinated control of multiple subsystems, and it will be capable of reasoning about nonstandard procedures and diagnosis of anticipated failures. The third demonstration (1993) will be of hierarchical control of multiple subsystems and will be capable of reasoning about emergency procedures, planning under uncertainty, and recovery from unanticipated failures. The 1996 demonstration will consist of distributed control of multiple subsystems and will have this capability for fault prediction, real-time replanning, and learning.

The initial systems autonomy demonstrations will take place early in FY 1988. The initial demonstration will comprise automated control (i.e., an intelligent aide) for the Space Station thermal control subsystem. Demonstrations using expert system control will be developed and demonstrated for pre-launch and post-launch ground system operations. The consoles and programs for demonstrating the expert system using real-time shuttle date in an off-line (parallel) mode to actual subsystem control by human controllers will be developed.

Research and development in each of the five core technology areas associated with systems autonomy will continue. Anticipated research achievements include the development of an expert system with the capability of learning by example and a prototype spaceborne symbolic processor with two 32-bit numeric processors and two 40-bit symbolic processors, using VLSI/VHSIC technology. This combined processor uses a reconfigurable, fault-tolerant multiprocessor architecture and is capable of 10-mega instructions per second execution rate. It will support the LISP, Ada, PROLOG, and C software environments.

12. SAFETY, RELIABILITY AND QUALITY ASSURANCE

NASA REQUEST, $16,200,000

AUTHORIZATION, $16,200,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Safety, Reliability and Quality Assurance:	
Estimates fiscal year 1987	$9,200,000
Authorization fiscal year 1988	16,200,000

The objective of the Safety, Reliability and Quality Assurance (SR&QA) program, formerly the Standards and Practices program, is to support NASA's goals through activities in safety, productivity, reliability and quality assurance, maintainability, software assurance, systems engineering, and program practices which reduce program risk; to improve product confidence; and to encourage good program procedures in the technical execution of NASA programs.

During FY 1986, efforts to improve NASA's software management, assurance and productivity continued. Emphasis was placed on developing validated procedures to ensure the integrity of the systems to be put into service. Exploration of non-destructive evaluation techniques continued, with emphasis on composites and advanced metals problems using probing energries, such as sonic and thermal, and electromagnetic techniques to examine material properties. The results of this effort will ensure that material and fabrication specifications can be non-destructively verified and quantitatively documented.

In FY 1987, work continues in concert with the NASA Centers and industry 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. In the near-term, the Non-Destructive Evaluation (NDE) Program will place special emphasis on NDE techniques for Solid Rocket Motors. The program will be expanded to include electronics, and will explore and develop qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors. The Software Management and Assurance Program will develop standards, specialized training, distributed software, corporate memory data bases, and guidebooks to facilitate improved software business practices and resources sharing by NASA projects. In response to the findings and recommendations contained in the Report of the Presidential Commission on the Space Shuttle Challenger Accident (Rogers Commission), an effort is underway to develop a system to address the reporting and documentation of problems, problem resolution, and trends. The initial effort will define the goals that the systems must achieve, the criteria by which success will be judged, and a plan for system support of the next Shuttle flight. Efforts to inventory available data sources, determine information flow incompatibilities and constraints, and obtain other data necessary to develop a detailed system architecture are currently underway.

In FY 1988, the SR&QA program will continue to conduct activities in support of the objectives of the agency. The increase in funding from the FY 1987 level reflects an increase in safety related activities and the creation of a Technical Assessment Program. The Technical Assessment Program will develop systems that monitor the status of equipment; validate technical designs; report and analyze problems; analyze trends; and judge system acceptability in agencywide programs.

The Technical Assessment Program will address the reporting and documentation of problems, problem resolution and trends, and other safety systems as required. One component of the assessment program is a computerized, real-time, agencywide problem reporting and corrective action system which will allow an assessment of SR&QA problems. As currently planned, the system will contain data on failures, nonconformance anomalies, and unsatisfactory conditions for problem analysis and resolution, remedial and preventive actions, and trend analysis for flight and critical ground hardware, as well as certain generic program hardware. The information resulting from the system will be used for design, flight, and test reviews. It will be specifically designed to provide a broad data base which will be accessible by NASA and its contractors on an iterative basis. It will provide a means whereby effective trend analysis can be accomplished, thus providing early and more complete illumination of problems to management.

Efforts are being planned that will revitalize the basic NASA safety program. Major activities will be focused on increasing the safety of high hazard operations, better understanding the failure modes of highly stressed wind tunnel components and pressure systems, and quantifying the hazard potential of new, exotic propellants, existing cryogenic propellants, and new composite materials.

The existing effort to automate mishap reporting will be expanded to include the capability for trend analysis and generation of multi-media, generic lessons-learned from the central data base. Critical policies, procedures, practices, regulations, guidelines, and directives will be reviewed and revised, or developed, as appropriate. Risk assessments of hazards indentified in NASA activities will be conducted to determine the implied risks to people and property.

13. TRACKING AND DATA ADVANCED SYSTEMS

NASA REQUEST, $18,100,000

AUTHORIZATION, $13,100,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Advanced system:	
Estimated fiscal year 1987	$17,100,000
Authorization fiscal year 1988	13,100,000

The objective of the Advanced System program is to perform studies and provide for the development of tracking and data systems and techniques required to: (1) obtain new and improved tracking and data handling capabilities that will meet the needs of approved new missions and near term new starts; and (2) improve the cost effectiveness 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 which continues 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 tradeoffs for the lowest life cycle costs to support future space missions.

Activities planned for FY 1988 include efforts to obtain location accuracies within the one meter 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 to be analyzed for particular application include the Department of Defense's Global Positioning System and 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.

Efforts to improve communications between the ground and spacecraft will continue in such areas as development of a K-band terminal for TDRSS user spacecraft; use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; and, antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by reducing spacecraft weight and power requirements and 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 increase 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. 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; advanced technology for on-board recording; digital 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 centers and users.

Investigations will continue on achieving 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 areas of expert 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

NASA REQUEST, $4,064,300,000

AUTHORIZATION, $4,034,300,000

SUMMARY

		Estimated fiscal year 1987	Authorization fiscal year 1988	Page No.
1	Shuttle production and operational capability.	$3,105,100,000	$1,174,600,000	193
2	Space transportation operations	1,847,000,000	1,945,800,000	201
3	Space and ground networks, communication and data systems.	862,900,000	913,900,000	206
	Total	5,815,000,000	4,034,300,000	

1. SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

NASA REQUEST, $1,229,600,000

AUTHORIZATION, $1,174,600,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Orbiter operational capability	$373,000,000	$348,200,000
Orbiter replacement	2,100,000,000	0
Launch and mission support	148,200,000	249,300,000
Propulsion systems	463,900,000	552,100,000
Changes and system upgrading	20,000,000	25,000,000
Total	3,105,100,000	1,174,600,000

The Committee reduced the NASA request by $55,000,000 to reduce the purchase of structural spares. The intent of the Committee is to fund those structural elements (such as the OMS pod, payload bay doors, vertical tail, and body flap) that could reasonably be required for use as spare or repair parts. The Committee believes that funding should be delayed for other structural elements (such as the crew cabin) that are more accurately "long lead" procurements toward the production of an additional Orbiter rather than true spare parts.

The objectives of this program are to provide for the completion of the modifications required to return the Space Transportation System (STS) to a safe flight status and 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; preparation of launch site capabilities; and, the potential changes and upgrading the STS.

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 existing post-Challenger accident 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 on-going activity to support the requirements for the initial lay-in of spares to support the flight rate buildup.

Launch and Mission Support provides for the requirement investment in Launch Operations and Flight Operations capability to meet STS program objectives which include returning safely to flight and supporting the operational 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, the Mission Support budget provides collateral hardware, principally the extra-vehicular maneuvering units (EMU) while the Mission Operations Capability budget provides for improvements in the flight support systems. 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, software production facility and the mission control center.

Propulsion Systems provide for the production of the Space Shuttle Main Engine (SSME) and the development of the capability to support operational requirements established for the SSME, Solid Rocket Booster (SRB), and External Tank (ET) The SSME program includes: production of the main engines necessary to outfit and provide spares for the orbiter fleet, ground testing in support of engine development, anomaly resolution, and an advanced development effort. The SRB production and capability development activities include: the redesign and recertification efforts necessary as a result of the Challenger accident and the procurement of tooling and equipment to support the revised flight rate; selected studies to continue investigative, analytical and problem-solving activities; and, the completion of the filament wound case structural testing. In the ET program, the objectives are to support the recovery activities and return to safe flight efficiently.

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 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Orbiter	$201,300,000	$241,200,000
Systems integration	12,100,000	4,100,000

	Estimated fiscal year 1987	Authorization fiscal year 1988
Orbiter spares	159,600,000	102,900,000
Total	373,000,000	348,200,000

With the recent loss of Challenger (OV-099), the primary objective is to return the three orbiter fleet to safe flight 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) and auxiliary propulsion units (APU). 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.

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 1988. 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 study is underway to determine logistics depot and maintenance requirements. An interim depot system is being implemented utilizing NASA and contractor facilities while the study is being completed and a long-term configuration identified.

Orbiter funds provide for the procurement of a logistics capability including establishing 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, completing the existing set of structural spares to support the production of a replacement orbiter, initiating manufacture of a replacement set of structural spares, and the engineering analysis and integration support for the increasing flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, the on-board flight software, and potential implementation of a crew escape system during orbiter controlled gliding flight.

The orbiter logistics capability program in FY 1988 is continuing the lay-in of line replaceable units, shop replaceable units, 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 intermediate, depot level 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 be completed in 1988. 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 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 maintainable system. In addition, funds are included to continue necessary safety modifications such as a new carbon brake system and to conduct studies on a crew escape 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.

Orbiter Replacement

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Orbiter Replacement:	
Estimated fiscal year 1987	$2,100,000,000
Authorization fiscal year 1988	0

In order to provide safe access to space and to maintain United States preeminence 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 nearing completion and will be utilized in the production of OV-105. A proposal is being prepared by Rockwell International for the production of this orbiter with a planned full start in August 1987 and planned delivery in 1991. Funding includes a full set of new main engines and the necessary ancillary government furnished equipment such as the remote manipulator arm, space suits, galley, etc. Procurement of this equipment is planned for an August 1987 start leading to delivery of the orbiter in FY 1991.

Launch and Mission Support

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Launch site equipment	$61,800,000	$57,700,000
Mission support capability	42,900,000	120,900,000
Mission operations capability	43,500,000	70,700,000
Total	148,200,000	249,300,000

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 on 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 has been delayed from an originally scheduled completion of September 1986 until early 1989 due to the program standdown. An orbiter maintenance and refurbishment facility is under construction to provide a minimal maintenance and storage capability. In FY 1987, this budget also contains funding required to conduct the necessary modifications to the KSC ground support equipment to return to flight status, such as improving the external tank hydrogen vent system on the launch pad, installation of debris traps in the main propulsion system propellant lines and new support equipment for the redesignated solid rocket boosters.

Funding has been included for additional landing aids and runway end barriers for the current, and one additional, contigency/abort landing site. Capability improvements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. A shift in priority in the ground systems replacement/refurbishment program, consistent with the Rogers Commission recommendations, has delayed improvements to the Mission Control Center and accelerated improvements in the simulation training facility including new host computers and associated interface controllers. 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. A "kit" will be manufactured that will allow the modification of a Boeing 747 into a (second) Shuttle Carrier Aircraft (SCA), thus reducing the potential downtime impact of this major single point of failure. Projects that have been ongoing but which have been rephased or otherwise restructured include the overhaul/uprating of the SCA engines, the life extension of the T-38 aircraft, and procurement of sufficient extravehicular mobility units (EMU's) and other crew-related equipment.

In FY 1988, the launch site equipment activity includes finalizing the return-to-flight status modifications in the KSC ground support equipment associated with the vehicle and launch processing facilities. Activities are also underway to improve the capability to support the flight rate requirements at KSC. These include a digital intercommunications system with associated fiber optics cabling, equipment for installation into the orbiter maintenance 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 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 processing equipment is also continued.

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 the STS achievement of program-wide requirements including flight safety, mission success, and rate capability.

Mission operations capability funding in FY 1988 provides for completion of replacement of the host computers and selected critical items for the Shuttle training simulators. FY 1988 is the initial year in the efforts to procure a fourth Shuttle Training Aircraft (STA), to re-engine the Shuttle Carrier Aircraft (SCA) and to replace ADP and other hardware in the Software Production facility. Continuing projects include the procurement of the Shuttle Carrier Aircraft (SCA) mod kit and improvements to weather prediction, information handling, and mission control systems.

Propulsion Systems

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Main engine	$299,800,000	$366,800,000
Solid rocket booster	115,500,000	140,700,000
External tank	46,800,000	42,200,000
Systems support	1,800,000	2,400,000
Total	463,900,000	552,100,000

Propulsion Systems provide 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 spares, ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes a major redesign, development and qualification effort for the solid rocket motors to improve safety margin and correct the deficiencies that led to the Challenger accident. The SRB program also includes a thorough reevaluation of the booster hardware, redesign of the hardware for reusability and operational cost reductions, and procurement of manufacturing tooling and equipment to support the projected flight rate. In the ET program, the objectives are to support recovery activities and the return to safe flight. Systems support primarily provides for the testing of the SSME in the main propulsion test article configuration.

The total SSME ground test experience now exceeds 1,300 tests, totaling approximately 270,000 seconds of test time. This experience includes 250 tests, exceeding 55,000 seconds of operation, at the full power level (FPL).

During the course of FPL testing over the past several years, it became apparent that design margins were inadequate for routine FPL flight operation and that the current SSME configuration required an unacceptable amount of maintenance at that power level. Consequently, 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 flight engine activity includes the production of new engines, retrofit of improved hardware into the fleet, and anomaly resolution activity. One additional engine is being procured to replace engines lost during ground testing during the past year.

The development engine activity provides for the development, certification, and flight certification extension of improvement hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as improved blades and bearings. The conversion of the NSTL B-1 test stand to single engine test capability has been added to the program to meet ground test requirements.

The advanced development element includes the alternate turbopump and the technology test bed. An alternate source for high pressure turbopumps was elected 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 alternative pump effort, and the OAST technology program.

The solid rocket booster (SRB) funding requirements support the redesign and requalification efforts necessary as a result of the Challenger accident. Based upon the investigation results of the failure and the actions recommended by the Rogers Commission, a complete reassessment of the certification program on all hardware and a redesign of the solid rocket motor joint configurations are underway. In-depth reviews of the systems failure mode and effects analysis (FMEA), operational procedures and the design of critical hardware on the critical items list (CIL) is being conducted and changes will be implemented as necessary. Extensive testing will be conducted of all design alternatives under conditions that accurately simulate the launch environment to insure that the final design meets the program safety and performance requirements. A second SRM static firing test stand is being provided to assure the capability to initiate the flight program in FY 1988. All necessary hardware replacement on refurbishments will be procured to support resumption of flight activities and the planned build-up in flight rate. Funding is also included for alternative source procurement studies for the SRM. The filament wound case program is being deferred a a result of the extensive changes being considered in the basic SRB program and the Air Force's decision to defer activation of the Vandenberg launch site. FWC funding is provided through completion of the structural test program.

In systems support, capability is being maintained for the full power level test of three clustered engines in the NSTL main propulsion test stand in early 1989. 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.

Funding for the FY 1988 budget is based upon resumption of the flight program in February, 1988 and the design, test, and certification of the propulsion hardware for flight. A complete reassessment of the program is included. It consists of a thorough review of the FMEA/CIL's 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 program will complete the redesign of the solid rocket motors and be re-certified prior to the first flight. The external tank program will complete the FMEA/CIL reviews and continue the efforts to develop processing improvements to reduce the cost of manufacturing tanks, the continued installation of rate tooling to support the future flight rates and overhaul of the barges used to transport finished tanks from Michoud to the launch sites.

Changes and Systems Upgrading

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

Changes and systems upgrading:	
Estimated fiscal year 1987	$20,000,000
Authorization fiscal year 1988	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 modifications which inevitably are required in a large, complex, and technically demanding space system.

The Changes and Systems Upgrading budget represents the estimated requirement for potential changes and systems modifications and unanticipated developments which are not included in the program element budget estimates. Such funds are necessary to provide for programmatic and technical changes, such as modifications to the flight hardware to improve system reliability, safety and performance; changes and upgrading of ground systems to reduce turnaround time between missions, and replacement/modification of hardware elements to achieve increased operating economies.

As the changes and upgrading requirements are identified and aproved, the remaining FY 1987 funds will be allocated to the appropriate budget activity.

The funding requested for FY 1988 will provide for those changes which are considered to have the highest priority. The objectives are to improve reliability, increase operating safety margins and efficiency, and reduce costs. Changes and upgrading areas of interest include modifications to flight and ground systems; design and development of hardware/software systems which meet requirements for improved safety, reliability, performance and cost-effectiveness; and changes which will reduce operational costs by extending operational life, by facilitating improved mission-to-mission turnaround time, and by improving mission performance margins.

2. SPACE TRANSPORTATION OPERATIONS

NASA REQUEST, $1,885,800,000

AUTHORIZATION, $1,945,800,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Flight operations	$557,700,000	$561,100,000
Flight hardware	936,000,000	923,100,000
Launch and landing operations	353,300,000	401,600,000
Expendable launch vehicle operations	0	60,000,000
Total	1,847,000,000	1,945,800,000

Funding for Shuttle Operations is combined with the reimbursements for Shuttle launch services received from other U.S. Government, commercial, and international users to support the launch and flight operations requirements of the Space Shuttle. Previous Shuttle missions demonstrated many of the Shuttle's capabilities including deployments of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Spacelab systems, extravehicular activity operations, a night landing, and a widening of the Shuttle's performance envelope.

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 base operational support at JSC and systems support activity at JSC, Headquarters, and the Goddard Space Flight Center.

The Flight Hardware program element provides for: the procurement of external tanks (ET), solid rocket motors, booster hardware, and propellants; spare components 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, and subsystems necessary to sustain the production of elements in a manner consistent with the flight rate.

Launch and Landing Operations provides for the pre-launch preparation, launch, and landing operations of the Shuttle and its cargo. Also, liquid propellants used in launch operations are provided for in this budget.

There are currently no planned reimbursable funds for Shuttle Operations in either FY 1987 or FY 1988. The FY 1987 Amended Budget had projected a net reimbursement availability in FY 1987 of $352.0 million reflecting the net of planned receipts from DOD and planned re-payments to foreign and commercial customers. Congressional action on the amended budget appropriated the funding that had been planned for DOD reimbursements. It is anticipated that reimbursable funding will resume in the future as the Shuttle flight rate builds up.

The Expendable Launch Vehicle (ELV) program provides for the procurement of expendable launch vehicles and launch support services. The Department of Defense and the National Oceanic and Atmospheric Administration are continuing to utilize the Delta, Scout, Atlas and Atlas Centaur expendable launch vehicles on a fully reimbursable basis. The only planned NASA launch is for the COBE spacecraft which will utilize a Delta launch vehicle made available by using reimbursements for residual vehicle hardware made available to other users.

The Committee added a new budget line item, expendable launch vehicle operations, which for fiscal year 1988 is authorized at no less than $60,000,000. The Committee has provided the authorization for the purposes of establishing a program for launching payloads by means of expendable launch vehicles, and if available, by commercial launch services. The Administrator is directed, pursuant to section 107, to obtain ELV's or commercial launch services to launch the following payloads: Roentgen Satellite (ROSAT), for launch in 1990; Tracking and Data Relay Satellite (TDRS)-F or a planetary mission, for launch in 1991; Extreme Ultraviolet Explorer (EUVE), for launch in 1991; and Mars Observer, for launch in 1992.

FLIGHT OPERATIONS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Mission support	$158,200,000	$167,000,000
Integration	195,400,000	196,200,000
Support	204,100,000	197,900,000
Total	557,700,000	561,100,000

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of planning activities ranging 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. 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 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 at JSC and systems level support at JSC, Headquarters, and Goddard. Currently, the resources for Flight Operations are focused upon 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. Those changes, as well as the long lead time in certain areas of flight preparation (e.g. payload analytical integration) require that work be underway now for the early Shuttle flights. Flight preparation, training of ground and flight crews (including systemwide integrated simulations), and other functions are being carried out. These efforts are being held to the minimum level required to prepare for the planned resumption of Shuttle flights.

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 the on-orbit portion of STS missions from launch to landing. The functions are essentially the same as in the past: maintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; maintenance and operation of proficiency, training and orbiter ferry aircraft and to perform analyses and operation of the mission planning necessary to conduct and control each mission. It also includes the sustaining engineering required to intergrate 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 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Orbiter	$366,100,000	$278,300,000
Solid rocket booster	251,600,000	317,800,000
External tank	318,300,000	327,000,000
Total	936,000,000	923,100,000

The Flight Hardware program element provides for the procurement of external tank (ET), the manufacturing and refurbishment of solid rocket booster (SRB) hardware and motors, spare components for the main engine (SSME); orbiter spares including ET disconnects, sustaining engineering and logistics support for ET/SRB/main engine flight hardware elements; and maintenance and operation of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time 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 production capability. In the ET, production continues at a minimum level of activity 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 are provision for the fixed level of annual support for the liquid hydrogen plant and 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 the 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. The majority of the crew equipment tasks transitioned into the consolidated Flight Equipment Processing Contract (FEPC) during FY 1986 from 16 earlier contracts.

Requirements for orbiter flight spares, crew equipment spares, and logistics are based on estimates that consider projected flight rates, maintenance schedules, operational hours, turnaround 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 1988, as well as the support of the production of units which will be flown thereafter.

LAUNCH AND LANDING OPERATIONS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Launch operations	$315,100,000	$352,400,000
Payload and launch support	38,200,000	49,200,000
Total	353,300,000	401,600,000

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 ground 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 include 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 manpower is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation and inventory management.

Base support to the Shuttle program is provided by the Base Operations Contract (BOC) which will complete its fourth full year of operation in January 1987. The BOC is responsible for operations support functions such as printing and graphics, calibration of instrumentation, and evaluation, test and modification to launch support equipment.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports both 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 related to the Shuttle Processing Contractor.

The Payload and Ground Operations Control (PGOC) is the third and final consolidation contract for KSC operations and will be the major contract for the payload processing activities. McDonnell Douglas was selected as the PGOC as the result of a competitive procurement and it is anticipated that the contractor will begin tansition in January 1987. 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 1988 provides for manpower and support services necessary for processing launches from KSC. This includes manpower to process the build-up of 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/modifications of all other Shuttle related ground support equipment and facilities.

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.

3. SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEM

NASA REQUEST, $948,900,000

AUTHORIZATION, $913,900,000

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Space networks	$407,300,000	$446,500,000
Ground networks	250,100,000	257,100,000
Communications and data systems	205,500,000	210,300,000
Total	862,900,000	913,900,000

The Committee reduced the NASA request by $35,000,000 to slow the completion of the TDRS replacement. In adopting the reduction from the request level for the replacement TDRS spacecraft, the Committee fully recognizes that this will result in about a one-year delay in delivery date for TDRS-7 and a potential increase in total cost. The Committee's action is predicated on the assumption that successful deployment of TDRS-3, 4, and 5 will allow storage of TDRS-6 and a phased replacement requirement for TDRS-7 that can accommodate this delay. However, unforeseen events that may affect the successful launch of TDRS-3, 4, or 5 may result in an earlier than planned requirement for TDRS-7. Thus, the Committee's action implies an increased risk of a reduced capability for the TDRS constellation.

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 television transmission 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 spaceflight projects is presently accomplished through the use of 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. Ground facilities are interconnected by terrestrial and communications satellite circuits which tie together the spacecraft and control centers for control 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, highly elliptical, and planetary and solar system exploration missions, 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 are collected from flight projects. In addition, instrumentation facilities are provided for support of 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 funds for: (a) the cost of TDRSS service; (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 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Tracking and data relay satellite system (TDRSS)	$301,500,000	$325,000,000
Space network operations	43,700,000	44,400,000
Systems engineering and support	28,100,000	27,000,000
TDRS Replacement spacecraft	33,000,000	41,000,000
Second TDRSS ground terminal	1,000,000	9,100,000
Total	407,300,000	446,500,000

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 itself, 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 1988 request includes funding for: repayment of the loans extended by the Federal Financing Bank of 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 procurement of an additional TDRS spacecraft to replace the one lost in the Challenger accident; and the implementation of a second ground terminal at White Sands.

Tracking and Data Relay Satellite System

The Tracking and Data Relay Satellite System (TDRSS) objective is to provide communications service between the user spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from the 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 missions such as the Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesopheric Explorer (SME). The TDRS-2 was destroyed in 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. Launch of the next TDRS is scheduled for the first quarter of 1988 on the first Shuttle mission when flights resume. The third TDRS is scheduled for launch in the last half of 1988. Once these two spacecraft have been successfully launched and the system achieves 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 completion of satellite construction and other support provided during the year. Funding is also included for studies to define the next generation of relay statellites and the required technology.

Of the amount requested in FY 1988, 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 objectives 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 communnications services to user spacecraft in low Earth orbit. Each of these NASA network elements performs 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 inferface between White Sands and all other facilities. The Network Control Center (NCC) 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 mission supported by the ground networks. The Bilateration Ranging Transponder System (BRTS) provides precision location and orbit determination information for the TDRSS. The Simulations Operations Center (SOC) and the Compatibility Test Vans (CTV) provide necessary per-launch testing, simulations, and interface verification for both user spacecraft and the various network elements to assure the operational readiness of the network to support a given mission.

The individual network elements are designed to function as an integrated operational system. The overall system has provided service to a variety of missions, including Shuttle and Spacelab, since TDRS-1 became operational. Effort is continuing to achieve an operational configuration that will be capable of supporting an expanded workload in the late 1980's.

The funding request provides for services to operate the network 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 through the operations and maintenance contract and a number of small engineering service contracts which provide highly specialized support.

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. In the Network Control Center (NCC), equipment modifications and replacements are being made and software development continues to improve TDRSS user access and operational reliability.

Funds are requested to provide systems engineering, performance and operations analysis, minor facility modifications, network readiness testing and interface verification, sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Design and analytical studies will be conducted on a wide variety of items, ranging from subsystem modification to meet new mission requirements or to correct operations deficiencies to the analysis of radio frequency environment for potential impact to network systems. Funds are also requested for continued software development for the NCC and ongoing hardware implementation, replacement, and modification.

TDRS Replacement Spacecraft

A contract has been awarded to TRW, the sub-contractor for the TDRS space segment, to provide a repacement spacecraft and long/lead parts for an optional additional spacecraft. During the program definition phase preliminary design studies will identify parts and components no longer available and recommend design changes to increase spacecraft safety and reliability. The design objective is to provide a functionally identical satellite with minimal change from the current spacecraft and which is fully compatible with the existing system.

The requested funding will provide for continuing the development phase of the program which is scheduled for initiation in mid-1987. This will include the acquisition of parts, materials, and subsystems as well as detailed system design.

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 the 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 the two satellite operations capability in the mid-1990's.

A competitive award for two preliminary design contracts will be made in late FY 1987. The FY 1988 request includes funds for completing these design efforts and for development of system specifications for the implementation phase. A competitive award to a single contractor for implementation is planned for late FY 1988. Initial funding for the implementation phase is also included in the request.

GROUND NETWORKS

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorization fiscal year 1988
Spaceflight tracking and data network systems implementation	$3,900,000	$3,300,000
Spaceflight tracking and data network operations	81,400,000	85,500,000
Deep space network systems implementation	44,000,000	49,000,000
Deep space network operations	93,300,000	94,100,000
Aeronautics, balloons, and sounding rocket support systems implementation	11,200,000	8,500,000
Aeronautics, balloons, and sounding rocket support operations	16,300,000	16,700,000
Total	250,100,000	257,100,000

The Ground Networks program provides support to the 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 supportable by 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. The workload in FY 1988 will include support to the Space Shuttle and support to ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM). Preparation will be underway for the upcoming 1989 Voyager-Neptune encounter and future planetary missions including Galileo, Ulysses, Magellan, and Mars Observer. 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 1988 request includes funds for replacement of obsolete and difficult-to-maintain equipment at the eight 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 which provides orbital tracking support.

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 provides 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 state when the Space Network achieves operational status. At that time five STDN stations will cease operations and either close or be transferred to other organizations. These stations are Ascension Island, Guam, Hawaii, Santiago, and Yarragadee. Dakar will close when the Space Network is capable of supporting the ascent phase of STS missions. The two remaining stations at Merritt Island and Bermuda will provide prelaunch, launch, and Shuttle landing support as well as limited orbital support.

The FY 1988 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 GSFC.

Deep Space Network (DSN)

The role of the Deep Space Network (DSN) is to provide the communication link between each of NASA's planetary 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 ranging in distance from earth orbit to over 6.0 billion kilometers from earth. The DSN also has support responsibility for several 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.

With the first deep space mission using the X-band frequency spectrum planned for launch in 1989, the ground network is being equipped to transmit commands in this frequency range. Initially, the 34-meter antennas at Goldstone, 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 will also utilize X-band, it is planned to implement this capability on most of the remaining antennas in the DSN by 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 spacecraft requirements; (3) to provide support for a new set of spacecraft which will include non TDRSS compatible highly eliptical 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 late 1989. This encounter will occur some 4.5 billion kilometers from earth. At the time, Voyager 2 is expected to transmit the first high resolution images ever received from a spacecraft at such a distance. To meet the challenge, an expansion of the 64-meter antennas to 70 meters is currently underway. This expansion along with multiple antenna arraying (signal combining) of radiotelescopes in New Mexico and Australia, will provide the increased signal capturing capability for our first look at Neptune.

Future deep space missions which will be supported by the DSN include Galileo, Ulysses, Magellan and Mars Observer.

Funding in the FY 1988 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 1988 budget to implement the new capabilities required for the planned 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.

The X-band transmission capability being implemented at the new 34-meter sites require modifications to the antenna feed systems and the addition of a transmitter to the antennas which are currrently in a "listen only" configuration. Extensive improvements to the ground tracking systems are required in 1988 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 1988 in preparation for the Voyager 2 spacecraft encounter with Neptune in late 1989. This activity consists of implementation of an X-band receive capability for the Very Large Array radiotelescope at Socorro, New Mexico (which will be arrayed with the Goldstone, California antennas) and the 64-meter radiotelescope antenna at Parkes, Australia (which will be arrayed with the Goldstone, California antennas) and the 64-meter radiotelescope antenna at Parkes, Australia (which will be arrayed with the DSN antennas at Canberra, Australia).

This program also includes funds for sustaining type activity in the DSN such as reliability modifications, operational improvements, and replacement of obsolete equipment at the signal processing centers, the three DSN complexes 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 and solar system spacecraft. After completion of the project in 1988 to expand the diameter of the 64-meter antenna dishes to 70 meters, each complex will have four antennas: one 70-meter, two 34-meter and one 26-meter. A centralized control center for the network 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 over 4 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 just under ten 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 3.4 billion kilometers from earth, continues to be tracked. The Pioneer-6 through 8 spacecraft are provided support during solar conjunctions and gravity wave experiments.

The DNS facilities are also used on a non-interference basis 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 1988 consists of support for the two Voyager spacecraft, the six ongoing Pioneer spacecraft (Pioneer 6, 7, 8, 10, 11 and Pioneer Venus), Active Magnetosphere Particle Tracer Explorer, International Sun Earth Explorer-1 and -2, Nimbus-7, Dynamics Explorer, and International Comet Explorer. Provision has also been made in the DSN to provide emergency backup support for 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 low 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 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 WFF to provide tracking and data acquisition support to certain low 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, Fairbanks, Alaska; and the National Scientific Balloon Facility, 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), under the management of ARC, are configured to support aeronautics research. The DFRF also 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. FY 1987 is the last year of a phased equipment replacement and refurbishment program which will insure reliable real-time data collection and handling support in the future.

The aeronautical research efforts and scientific experiments using sounding rockets and balloons are programs of a continuing nature which generally require a constant level of support. Support for these programs requires fixed and mobile instrumentation systems; namely, radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, 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 and the Goddard Space Flight Center. These facilities support NASA aeronautics, sub-orbital and a limited number of low-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 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 1986, about 1300 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 managed activities supported aeronautics programs as well as sounding rocket, balloon and low earth orbiting satellite programs. During 1986, approximately 290 aeronautics missions were supported at the Wallops Flight Facility covering such programs as Advanced Transport Operating Systems, AV-8B full scale development tests, runway friction testing, microwave landing system operations testing, storm hazards research and general aviation light aircraft stall/spin research. The sounding rocket program conducted approximately 140 launches in FY 1986 which included 37 of the larger rockets with major scientific payloads. The remainder were the smaller meteorological and special purpose rockets supporting a variety of research programs. The balloon program had 122 launches during FY 1986. Low earth orbiting satellites supported included IUE, IMP-8 and Nimbus.

The funding estimate for FY 1988 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, orbiting satellite and aeronautical research programs.

Communications and Data Systems

FISCAL YEARS 1987 AND 1988 FUNDING LEVELS

	Estimated fiscal year 1987	Authorized fiscal year 1988
Communications systems implementation	$7,400,000	$6,400,000
Communications operations	91,700,000	97,200,000
Mission facilities	12,200,000	7,400,000
Mission operations	23,700,000	28,000,000
Data processing systems implementation	28,400,000	22,300,000
Data processing operations	42,100,000	49,000,000
Total	205,500,000	210,300,000

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 determining the condition of the spacecraft and payloads for the generation of commands for spacecraft and payload control. Data received from the various spacecraft must be processed into a usable form before transfer to control centers and experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects and international cooperative efforts.

Major activities underway include the implementation of: (1) a mission control and data capture system for the Hubble Space Telescope and (2) mission control and data processing capabilities for support of upcoming missions such as Spacelabs, Gamma Ray Observatory (GRO) and Upper Atmosphere Research Satellite (UARS). In addition, studies have been initiated to evaluate Space Station support requirements.

Communications 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 TDRS ground terminal at White Sands with the second TDRS ground terminal. This requires an integrated communications capability for the control and transfer of data between the two facilities.

The FY 1988 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and continue replacement of the voice and data message switching system at GSFC. Effort will continue on the implementation of a new voice intercom system for all the Project Operations Control Centers at GSFC. Additional funding will be provided to continue modifications to the fiber optic system at GSFC to handle high speed data, digital voice, and increased security requirements.

Communications 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 key domestic and overseas locations. 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 by means of leased voice, data, and wideband circuits the NASA Centers, Headquarters, and major contractor locations for the transfer of programmatic and administrative information. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

The FY 1988 funding requirements for Communications 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.

In addition, funds are included for PSCN which provide for the circuits and facilities for programmatic and day-to-day operations such as facsimile, teleconferencing, data transmission, and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1988, funds are required to operate and maintain the PSC network 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 management information system. In addition, the network will support office automation and institutional information systems.

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 late calendar year 1988. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning System to plan and schedule spacecraft support.

The FY 1988 funding requirements will provide for Hubble Space Telescope prelaunch systems testing and software to control the accurate pointing of the telescope and the on-orbit power consumption of the spacecraft subsystem and scientific instruments.

In addition, FY 1988 funds are included for modifications to the existing Multisatellite Operations Control Center (MSOCC) for control of the Gamma Ray Observatory (GRO), Cosmic Background Explorer (COBE), Upper Atmosphere Research Satellite (UARS), and various Shuttle attached payloads. In FY 1988 control center modifications to permit spacecraft payload operations from user facilities will be underway. 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 1988 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 prelaunch preparations for four 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 per week in mission support. For Shuttle launches with attached payloads, for which GSFC has 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 1988 budget request includes funds to operate the POCC's and supporting facilities for control of on-orbit missions and control center software development for supporting upcoming missions. In FY 1988, the new Hubble Space Telescope POCC will be in the final stages of spacecraft and ground systems testing. 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 1988, software development activities will continue to increase for the GRO and UARS missions. Software to enable the POCC to control the COBE will continue along with SPIF software development.

Also included in the FY 1988 budget request are funds for software and related support services which include maintenance of a software library, computer-generation of command sequences, equipment maintenance, engineering, logistics and documentation services.

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) which support both the operational and payload requirements of space 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 Command Management System which provides memory management for on-board computers. In addition, there are four major systems for processing 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 supported the Spacelab 1, 2, 3, and D1 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 include is the development of a test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced Systems programs. 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 1988 budget request will provide continued funding for phased replacement of the existing computation systems at GSFC which provide real-time support to NASA spacecraft. Funding is also included for completing replacement of display equipment and for large application software programs for the Trajectory Computation Orbit Products System (TCOPS). In addition, the request provides for the improvement/upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation.

Funds are required in FY 1988 to continue that implementation of an institutional packet telemetry processing system with the GRO as its first user. This facility will capture, error check, and ship real-time, quick-look and production data to various users. The "packet" telemetry concept allows the scientific data of an experiment to be handled with minimum involvement by the ground system, thus reducing ground data processing time as well as ensuring faster delivery of data to the experimenters.

The FY 1988 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 of which the 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 tradeoffs 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. This upgrading will also expedite the shipment of science data to users.

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.

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 control centers and 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 prelaunch orbit analysis including spacecraft position and attitude predictions. Analyses are also required to develop operational sequences and procedures to be used 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), 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 pre-process different types of raw experimental data.

The IPF, initially established to handle image data from the Landsat-1, has supported Landsat-2 and Landsat-3 and presently is processing data from the Nimbus mission. The Nimbus spacecraft is being supported with an all-digital system using high density recorders and computer compatible tapes. This system is being used to process data, required for climatic and meteorological studies, into film and digital tape products. The digital data can be manipulated in the scientist's computer with specific algorithms to enhance the interpretation of the data and related phenomena.

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, and mission simulations.

The FY 1988 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. Requirements definition and analysis have been initiated in support of uncoming space science and applications missions such as Cosmic Background Explorer, Gamma Ray

Observatory, Shuttle attached payloads, and the Upper Atmosphere Research Satellite. For on-orbit spacecraft, software development and maintenance is required on a continuing basis in order to perform flight control manuever operations and for the data processing activities.

CONSTRUCTION OF FACILITIES

SUMMARY

NASA REQUEST, $195,500,000

AUTHORIZATION, $185,500,000

The Construction of Facilities (CofF) authorization of appropriations provides 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 1988 provide for: The continuation of prior year endeavors in meeting the facilities requirements for Space Flight and the Space Programs; modification of 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; and facility planning and design activities. In addition, and as a separate Program under the Facilities Engineering Division, funds are also requested for environmental compliance and restoration.

The projects and amounts in the budget estimate reflect Space Flight requirements that are time sensitive to meet specific milestones. Other program requirements for 1988 include the construction of a spacecraft systems development and integration facility as well as modifications for utility reliability at the Goddard Space Flight Center; construction of an integrated test facility at Dryden Flight Research Facility; modifications to the Hypersonic Propulsion Facility for Vacuum Systems at the Langley Research Center; construction of an addition to the Research Analysis Center and modifications for Fan/Compressor Research to the Engine Research Building at the Lewis Research Center; and the Construction of a Communications Development Antenna at Goldstone, California.

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 original design 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 assure that statutory environmental requirements will be met and any necessary remedial action promptly taken.

Funds requested for facility planning and design cover requirements for potential future projects, master planning, facilities studies, engineering reports and studies and the preparation of facility project design drawings and bid specifications.

The budget authority requested for FY 1988 is $195,500,000. Including the Environmental Compliance and Restoration Program with estimated outlays of $151,749,000.

	Project	Authorization fiscal year 1988	Page No.
1.	Construction of LC 39 Operations Support Bldg., Kennedy Space Center	$22,800,000	225
2.	Construction of Spacecraft Systems Development & Integration Facility, Goddard Space Flight Center	8,600,000	226
3.	Modifications for Utility Reliability, Goddard Space Flight Center	2,900,000	226
4.	Construction of Integrated Test Facility, Dryden Flight Research Facility	10,500,000	227
5.	Modifications to Hypersonic Propulsion Facility for Vacuum Systems, Langley Research Center	3,100,000	228
6.	Construction of Addition to the Research Analysis Center, Lewis Research Center	9,800,000	229
7.	Modifications for Fan/Compressor Research, Engine Research Building, Lewis Research Center	6,500,000	229
8.	Construction of Communications Development Antenna, Goldstone, CA	6,400,000	230
9.	Repair of Facilities at Various Locations, Not in Excess of $750,000 Per Project	25,000,000	231
10.	Rehabilitation and Modification of Facilities at Various Locations, Not In Excess of $750,000 Per Project	32,000,000	232
11.	Minor Construction of New Facilities and Additions to Existing Facilities at Various Locations, Not in Excess of $500,000 Per Project	8,000,000	232
12.	Facility Planning and Design	16,000,000	233
13.	Environmental Compliance and Restoration Program at Various Locations	23,900,000	234
14.	Rehabilitation of Aeronautical Test Facilities	10,000,000	235

1. CONSTRUCTION OF LC 39 OPERATIONS SUPPORT BUILDING—JOHN F. KENNEDY SPACE CENTER, $22,800,000

For the construction of the Launch Complex 39 operations support building at the Kennedy Space Center, the committee added $5.8 million to provide for a minimum of 60,000 square feet of additional space over the current design. The building proposed by NASA will not accommodate the number of people at the Center who need adequate facilities near the Vehicular Assembly Building. Approximately 400 people will not be accommodated.

The temporary accommodations are not safe or efficient. Access to central services such as computation, reproduction, and conference centers is remote. Quarters are cramped and some desks are shared by more than one person.

This project will provide permanent office facilities for Shuttle support personnel currently in temporary relocatable housing in the Vehicle Assembly Building (VAB) area. The building will provide office space for approximately 1,550 civil service and contractor personnel, and improve morale, efficiency, and save considerable maintenance and replacement costs associated with the temporary housing.

Another important benefit of the permanent facility is the significantly lower operation and maintenance cost as compared to the existing temporary housing. The savings in FY 1990 is estimated to be in excess of $800,000 per year and will escalate thereafter. Because trailers have a short life cycle, additional savings will be realized by avoiding future temporary housing replacement costs.

This project provides for the construction of an approximately 188,000-square-foot, five-story, concrete and steel building. The building is to be located in the VAB area adjacent to the recently constructed Multi-function Facility (K6–1145). The project site development will provide utilities and parking for the new building and also include the demolition/relocation of the existing small buildings on the site including the Security Patrol Headquarters (k6-1148), Electrical Shop (K6-1195), and Temporary TPS Building (K6-1095); and the construction of a replacement 12,000-square-foot security facility at a nearby site.

2. CONSTRUCTION OF SPACECRAFT SYSTEMS DEVELOPMENT AND INTEGRATION FACILITY—GODDARD SPACE FLIGHT CENTER, $8,600,000

This project provides the second and final increment of funding for an addition to the Building 7/10/15 complex to provide a Spacecraft Systems Development and Integration Facility. This facility is essential to meet impending programmatic needs such as satellite servicing, continuing Explorer series spacecraft integration, and meeting new Space Station commitments. The existing facilities represent a 20-year-old, obsolete capability, which is fully utilized and not adequate for current program requirements. The first increment (FY 1987) provides the site preparation and a basic building structure. This final increment is required to provide a complete and useable facility.

This facility will significantly enhance GSFC's ability to retain and maintain the necessary in-house expertise in research, development, integration, and test activities and keep GSFC viable as an institution at the forefront of space programs.

The facility addition includes a 12,500-square-foot high-bay laminar flow clean room with 90,000 cubic feet per minute of class 100 filtered air entering the room at the north side through a state-of-the-art floor-to-ceiling, wall-to-wall, high-efficiency particulate air (HEPA) filter bank. This filtering system will produce a cleanliness level of at least class 10,000 within all work stations in a room capable of accommodating the development and integration of two full shuttle bay payloads. Other features of the addition include a 35-ton crane in the staging, shipping and receiving area; a passenger/freight elevator; a dual type electrical power system to provide redundancy; and a fire protection and utility control system which will be connected to the center wide utility control system.

3. MODIFICATION FOR UTILITY RELIABILITY—GODDARD SPACE FLIGHT CENTER, $2,900,000

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 space science and applications satellites and DOD missions. The present system provides emergency backup electrical power for critical data acquisition and communications 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 electrical power is still available. This project will provide short-term backup for the cooling systems to allow the safeing of satellites and the orderly shutdown of control and communication equipment.

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. 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 backup power capability to fully operate the existing cooling system during electrical power shortage is not adequate. While commercial power is normally reliable, the present air-conditioning system is essentially disabled by short power interruption. 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. The spacecraft must be placed 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 the 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. A 500KW diesel, now excess to the Ground Tracking System will be located near Building 24 and a battery backup system will be located at the 3/13/14 complex to provide electrical power for operation of the chilled water system for a least 15 minutes. Automatic valves also will be installed in the chilled water distribution system for isolation of critical areas. Controls for this system will be located in the power house. A 100,000-gallon chilled water reservoir will be constructed to provide 15-minute (minimum) cooling.

4. CONSTRUCTION OF INTEGRATED TEST FACILITY—DRYDEN FLIGHT RESEARCH FACILITY, $10,500,000

This project will complete the construction of the Integrated Test Facility (ITF) to provide an adequate ground testing facility to help NASA maintain its pre-eminence in aeronautical research. The facility will provide aircraft test areas and computer laboratory space to test complex and highly interactive/integrated systems of both present and future aircraft. This increment provides the exterior cladding, mechanical and electrical systems, and interior architectural finishes.

Existing facilities are only able to support a limited number of system driven aircraft. This has the effect of forcing each new program to purchase specialized test equipment to meet the needs of new requirements.

The construction provided by this project will complete the deferred portion of the originally authorized FY 1987 increment. Deferring part of the project into the FY 1988 program was considered prudent based on construction schedules, long lead deliveries, and budget constraints. The FY 1987 increment provided for site preparation, utilities, and the building's structural steel framing. This increment will complete the facility.

The project provides for contruction of a 112,000-square foot Integrated Test Facility composed of six aircraft hangar-type test bays totaling 53,000 square feet and an adjoining 59,000-square foot two-story masonry structure housing computer, laboratory, office, and technical support areas. Each of the six test bays will be large enough to house conventional and/or experimental type fighter or research aircraft, or three bays can be opened to accommodate large aircraft. Each test bay will be provided with data bus and discrete interface control and logic points, power (115VAC, 208VAC, 28VDC, 270VDC at 400 H_z and $60H_z$), cooling air for aircraft systems, hydraulic support systems, ambient heating systems, industrial waste collection systems, fire suppression, shop air, overhead cranes, and shielding. At least one bay will be provided with EMI shielding to protect sensitive electronic systems from externally generated electromagnetic radiation. The laboratories and shop areas will be provided with power, HVAC, plumbing, fire detection and suppression, a central 4,000 psig hydraulic system manifolded throughout the complex, compressed air, lighting, and emergency power. Also to be provided is a building grounding system including separate aircraft test system grounds, lightning protection, and landscaping. The site preparation, utilities, and the building's structural steel framing was provided by the FY 1987 increment.

5. MODIFICATIONS TO HYPERSONIC PROPULSION FACILITY TO ADD NEW VACUUM SYSTEM—LANGLEY RESEARCH CENTER, $3,100,000

This project will modify the existing hypersonic propulsion facilities to provide scramjet research capability by installing a new vacuum system.

Hypersonic Propulsion Test Cells 1 and 2, and the Scramjet Test Facility at the Langley Research Center are the only facilities in NASA for small-scale, high-run-frequency scramjet (supersonic combustion ramjet) combustor and inlet-combuster component integration engine testing. Together they provide a general purpose capability for supporting research in scramjet combustor design, fuel injector configurations, ignition, flameholding, hypersonic inlet performance, and complete subscale engine performance.

The Langley facilities represent a substantial national asset for the extension of scramjet technology. NASA Langley has the only broad-based, comprehensive technology program in the country related to sustained hypersonic flight in the atmosphere. These facilities have been utilized extensively over the last several years in research related to highly airframe-integrated, hydrogen-fueled engine concepts. In addition, the U.S. Navy has conducted studies over several years that show the scramjet to be the preferred propulsion option for several defense requirements.

This project provides for the following: (1) a 70-foot vacuum sphere; (2) approximately 200 feet of 4-foot vacuum lines, three remote-operation isolation valves, cooling system, and blowout diaphragm; and (3) a four-stage steam ejector and lines and controls to provide steam for the ejector (approximately 26,000 pounds per hour of steam).

The sphere will be located adjacent to the rear of the Building 1221 in an area previously occupied by air dryers. Piping from the test cells to the sphere will be run from the downstream end of the test cells, out the roof (similar to current exhaust system), and across to the sphere.

6. CONSTRUCTION OF ADDITION TO THE RESEARCH ANALYSIS CENTER—LEWIS RESEARCH CENTER, $9,800,000

This project will prohibit an addition to the Research Analysis Center of approximately 46,000 square feet to accommodate the additional ADP equipment along with the support services and personnel required to satisfy accelerated computational requirements at LeRC. The demand for additional equipment and services has greatly increased since the RAC was completed in 1980 because of that theoretical, scientific, and engineering changes at LeRC which required increased computational support.

The increased workload has resulted in accelerating the augmentation of the IBM 370/3033AP system which was to be implemented over a period of 6 years, but instead had to be accomplished in less than 3 years in order to keep up with demands.

In addition, the recent acquisitions of both the Cray IS/2200 and the two Amdahl 5840 computer systems were also a result of increased workloads.

The proposed expansion of the Research Analysis Center will be a two-story brick and metal panel addition, located on the north side of the existing Building No. 142. The expansion will have a gross floor area of approximately 46,000 square feet.

Modifications will also be performed in the existing building to accommodate the expansion. In addition, a chiller building of 3,200 square feet will be built just west of the project. Existing HVAC, water supply, and plumbing systems will be extended to the addition. Electrical work includes power for equipment, interior and exterior lighting, and communications systems. Transformer and distribution equipment will be provided along with modification to the existing switchgear equipment. Fire protection includes installation of a preaction sprinkler system in the operations area along with smoke detectors throughout the Computer Operations and Support Areas. Existing security systems will be extended to the addition.

The existing north service drive and the north parking lot will be reworked and expanded to accommodate the addition. An additional parking lot will be build east of the building across Walcott Road. The south parking lot will also be reworked and expanded. A total of 78 new parking spaces will be added. The site development will include landscaping, and installation and repair of lawn areas.

7. MODIFICATIONS FOR FAN/COMPRESSOR RESEARCH, ENGINE RESEARCH BUILDING— LEWIS RESEARCH CENTER, $6,500,000

This project provides for modifications to Buildings 5 and 23 of the Engine Research Building Complex and of the Refrigeration Building 9 at the Lewis Research Center, to extend the range of high-pressure ratio compressor research by precisely controlling speed and air temperature. This capability is necessary to test a new generation of fans and compressors that are a part of the advanced gas turbine propulsion system. The project will replace and upgrade the controls and instrumentation components of the variable frequency system and will extend the refrigerated air system to the ERB complex.

To achieve the needed research data it is necessary to obtain a much greater accuracy of flow property measurements at higher fan/compressor pressure ratios than has been possible in the past. This greater accuracy can be accomplished by using the laser velocimeter for flow property measurements, but the speed of the research package must remain stable over longer periods of time than is now possible with the existing regulators and control system. Additionally, the air temperature must be maintained low enough to ensure flourescence of the dye seed used to measure the flow. This project will provide a fivefold improvement in the regulation capability of the speed control system. A new regulation system will also be more reliable and easier to maintain. The present system was installed in 1940 and is controlled by outdated components which are no longer manufactured.

The modification to the variable frequency system will provide for replacement of the 40-year-old mechanical and electrical components (motor generator sets, switchgear, contactors and relays) with present-day technology equipment. The modifications also include replacement of the existing vacuum tube variable frequency control system with a solid-state control system. A programmable controller which will provide master control for the regulators and control switching for parallel operation of the 1,500 kVA frequency converters is also included. Sensors for interfacing converter selection to the master control will also be added, and monitoring and control devices on existing test cell operator's panel will be replaced.

Also provided is a refrigerated air system with a flow capacity of 60 pounds per second at 10 psig pressure and minus 70 °F temperature. The work includes the installation of a turbo expander with air compressor brake; an intercooler; regulated refrigeration equipment; controls and instrumentation; and refrigerated air piping between ERB and Building 9. The equipment for this refrigeration system will be located in a 1,200-square foot addition to Building 9.

8. CONSTRUCTION OF COMMUNICATIONS DEVELOPMENT, GOLDSTONE, CALIFORNIA, $6,400,000

This project provides for the construction of a high-efficiency 34-meter Deep Space Network development antenna at the Coldstone Deep Space Communications Complex, and will replace the existing obsolete 26-meter development antenna. The 34-meter antenna will allow development of high-efficiency transmitting and receiving capabilities at Ka-band and improvement in antenna pointing. These improvements will significantly increase spacecraft tracking data rates and navigation precision as well as enhance radio science measurement capabilities.

The construction of a new configuration high-performance 34-meter wheel and track type, azimuth-elevation antenna will be located at Goldstone immediately adjacent to the site of the existing DSS-13 26-meter development antenna, and will be site-adapted to use existing facilities and utilities.

The project includes the installation of the antenna structure, mechanical drives and controls, and beam waveguide as well as the construction of the foundation and antenna-mounted equipment enclosures. Also included in this project is the construction of a 2,000-square foot concrete block building to provide engineering offices, laboratories, shops, and storage which are now located in six badly deteriorated trailers.

9. REPAIR OF FACILITIES, NOT IN EXCESS OF $750,000 PER PROJECT, AT VARIOUS LOCATIONS, $25,000,000

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 for FY 1988 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 provide a means 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 substantially 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.

The major thrust of this repair program, as well as the rehabilitation and modification programs, is to preserve the Agency's $4.0 billion (as of September 30, 1986) physical plant.

This repair program has been distilled from requests for FY 1988 exceeding $50,000,000, and thus represents a modest request in relation to the continuing backlog of this type of work. Based on relative urgency and expected return on investment, the projects which comprise this request are of the highest priority. Deferral of this mission-essential work would adversely affect the availiabilty of critical facilities and program schedules.

During the course of the year, it is recognized that some rearrangement of priority may be necessary. This may force a change in some of the items to be accomplished. Any such change, however, will be accomplished within total available repair resources.

Summary of project amounts by location:	Amount
Ames Research Center	$1,960,000
Dryden Flight Research Facility	240,000
Goddard Space Flight Center	2,300,000
Jet Propulsion Laboratory	1,380,000
Johnson Space Center	2,060,000
Kennedy Space Center	2,845,000
Langley Research Center	3,150,000
Lewis Resesarch Center	2,850,000
Marshall Space Flight Center	2,290,000
Michoud Assembly Facility	1,030,000
National Space Techology Laboratories	2,220,000
Wallops Flight Facility	1,570,000
Varaious Locations	210,000
Miscellaneous projects less than $150,000 each	895,000
Total	25,000,000

10. REHABILITATION AND MODIFICATION OF FACILITIES AT VARIOUS LOCATIONS, NOT IN EXCESS OF $750,000 PER PROJECT, $32,000,000

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 1988 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:

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 facilties and thereby mitigate the effects of obsolescence.

d. Provide a better and safer environment for all personnel.

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 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 $1,685,000.

Summary of projects amounts by location:	Amount
Ames Research Center	$1,345,000
Dryden Flight Research Center	1,235,000
Goddard Space Flight Center	3,100,000
Jet Propulsion Laboratory	1,270,000
Johnson Space Center	3,040,000
Kennedy Space Center	3,820,000
Langley Research Center	3,000,000
Lewis Research Center	3,060,000
Marshall Space Flight Center	3,500,000
Michoud Assembly Facility	1,970,000
National Space Technology Laboratories	2,220,000
Wallops Flight Facility	1,610,000
Various Locations	1,145,000
Miscellaneous projects not exceeding $150,000 each	1,685,000
Total	32,000,000

11. MINOR CONSTRUCTION OF NEW FACILITIES AND ADDITIONS TO EXISTING FACILITIES, NOT IN EXCESS OF $500,000 PER PROJECT, AT VARIOUS LOCATIONS, $8,000,000

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 more additions to facilities. The FY 1988 request of $8,000,000 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.

Projects were selected on the basis of the relative urgency of each item and the expected return on the investment. During the course of the year, rearrangement of priorities may require changes in some of the items to be accomplished. Such changes will be accommodate within the resources allocated.

Summary of project amounts by location:	Amount
Dryden Flight Research Facility	$490,000
Goddard Space Flight Center	980,000
Jet Propulsion Laboratory	910,000
Johnson Space Center	400,000
Kennedy Space Center	1,270,000
Langley Research Center	940,000
Lewis Research Center	480,000
Marshall Space Flight Center	200,000
Michoud Assembly Facillity	180,000
National Space Technology Laboratories	820,000
Wallops Flight Facility	550,000
Various Locations	780,000
Total	8,000,000

12. FACILITY PLANNING AND DESIGN, $16,000,000

The funds requested in this estimate are required to provide for the following advance planning and design activities related to facilities activitie 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.

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.

	Amounts
Regular requirements	$9,900,000
Master planning	315,000
Sustaining engineering support	1,535,000
Preliminary engineering reports and related space engineeing support	2,650,000
Final design	5,400,000
Other requirements	6,100,000
Total	16,000,000

13. ENVIRONMENTAL COMPLIANCE AND RESTORATION PROGRAM, AT VARIOUS LOCATIONS, $23,900,000

The Committee recognizes the necessity for a comprehensive environmental program for the purpose of rectifying previous activities resulting in the accumulation of waste products in cerain areas at NASA sites. In addition the Committee also recognizes that more recent environmental standards and regulations have required changes in processes and equipment which are essential to maintaining a clear environment. For this reason, the Committee takes this action to identify a separate and distinct program entitled, "Environmental Compliance and Restoration Program" within the Facilities Engineering Division. NASA shall organize staff and conduct studies, assessments, design, and carry out remedial projects for environmental compliance and restoration measures at NASA field installations and government-owned industrial plants supporting NASA's activities. The purpose of the program is to enable compliance with 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, clean up of enclosures, and removal of unsafe buildings and debris. In establishing this program the Committee recognizes the need for flexibility in carrying out these tasks expeditiously. For these purposes the Committee authorizes twenty-three million nine hundred thousand dollars for FY 1988. In accordance with this authorization, the Committee requests a semi-annual report identifying total commitments and expenditures by category such as studies, assessments, and designs as well as by projects which are in excess of two million dollars each. The reports will be due by April 15th and October 15th of each year and will cover the sixth month period preceding the report.

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.

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.

The following broad categories of work will be accomplished in Fiscal Year 1988. As studies, assessments, and designs progress, it is expected that priorities may change and reordering of activities, including studies, assessments, and design may be necessary.

(a) Air Pollution Abatement and Asbestos Management	$4,000,000
(b) Rehabilitation/Replacement of PCB Transformers	2,900,000
(c) Hazardous Waste Monitoring and Control	17,000,000

Project Cost Estimates at Various Locations:	Amount
Ames Research	$800,000
Dryden Flight Research Facility	650,000
Goddard Space Flight Center	600,000
Jet Propulsion Laboratory	1,610,000
Johnson Space Center	850,000
Kennedy Space Center	190,000
Lewis Research Center	650,000
Marshall Space Flight Center	2,000,000
Michoud Assembly Facility	5,720,000
National Space Technology Laboratories	180,000
Wallops Flight Facility	530,000
White Sands Test Facility	4,060,000
Various Locations	2,660,000
Miscellaneous Projects, less than $150,000 each, studies, assessments, and design	3,400,000

An estimated $25,000,000 per year for the next several years will be required for continuing Environmental Restoration and Compliance.

14. REHABILITATION OF AERONAUTICAL TEST FACILITIES, $10,000,000

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 pressure tunnel at Ames, which has been decertified because of numerous cracks in the pressure shell. The Committee believes annual investments of $60-100 million are needed to properly maintain these critical national facilities. As a first step toward reaching this goal, the Committee recommends an augmentation of $9.75 million to begin rehabilitation of the most seriously threatened wind tunnels.

The Committee further recommends a $.25 million augmentation to perform the preliminary engineering report for the acoustic treatment of the 4X7 meter tunnel at Langley. This modification is needed to permit noise testing of rotorcraft and turboprop aircraft, an activity that can only be performed in the Netherlands currently.

RESEARCH AND PROGRAM MANAGEMENT

NASA REQUEST, $1,598,000,000

AUTHORIZATION, $1,605,000,000

SUMMARY

	Estimated fiscal year 1987	Authorization fiscal year 1988
Personnel and related costs	$1,023,015,000	$1,111,631,000
Travel	37,200,000	43,312,000
Operation of installations	406,269,000	443,057,000
General increase for 175 permanent aeronautical researchers		7,000,000
Total	1,466,484,000	1,605,000,000

The Research and Program Management appropriation provides funds for 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 adminisrative support for the research and development programs.

The Research and Program Management appropriation provides funding for the 22,600 permanent and temporary civil service workyears (FTE) an 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. About seventy percent of the Research and Program Management appropriation provides for the salaries and related costs of this civil service workforce. Three percent of this appropriation is used 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 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, opertional procedures and flight control; and management of the selected Space Station hardware and subsystems development 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 selected Space Station hardware and subsystems.

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 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, 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 trans-atmospheric 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 1988 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, follows.

PERSONNEL AND RELATED COSTS

NASA REQUEST, $1,111,631,000

AUTHORIZATION, $1,111,631,000

COMPENSATION AND BENEFITS

1. Compensation

a. *Permanent Positions.*—This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest part of this functional category.

b. *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.

c. *Reimbursable Detailees.*—In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

d. *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.

2. 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.

TRAVEL

NASA REQUEST, $43,312,000

AUTHORIZATION, $43,312,000

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 technical advances which arise outside NASA, as well as allowing personnel to persent 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).

Operation of Installation

NASA REQUEST, $443,057,000

AUTHORIZATION, $443,057,000

	Estimated fiscal year 1987	Authorization fiscal year 1988
Facilities services	$214,079,000	$232,548,000
Technical services	83,355,000	89,980,000
Management and operations	108,835,000	120,529,000
Total	406,269,000	443,057,000

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 data 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). 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 Installation. 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

Maintenance and related activities include the recurring day-today 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 operation 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 education 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. *Shop and Support Services.*—Shop and support services include general fabrication shops, reliability and quality assurance activities, safety, photographic services, graphics, and audio-visual material.

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

Transporation services include the operation and maintenace of all general purpose motor vehicles used by both civil service and support contractor personnel. 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.

GENERAL INCREASE

AUTHORIZATION, $7,000,000

The general increase of $7,000,000 is to provide for the hiring of an additional 175 permanent Civil Service work years. These are needed to restore the 25 aeronautical positions cut from FY 1987 to 1988, to provide approximately 100 additional research personnel to carry out the recommended increased level of basic aeronautical research, and to add approximately 50 personnel to increase the rate of flight testing and the analyses and publication of results.

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—NASA AUTHORIZATION

Section 101—Authorization of Appropriations

Subsections 101 (a), (b), (c), and (d) would authorize funds in the total aggregated amount of $9,522,000,000, to be appropriated to the National Aeronautics and Space Administration to become available no sooner than October 1, 1987. The total authorized funding would consist of the following: (a) for Research and Development," a total of 13 program line items aggregating the sum of $3,697,200,000; (b) for "Space Flight Control and Data Communications," a total of 4 line items aggregating the sum of $4,034,300,000; and such sums as may be necessary to return the Space Shuttle to flight status; (c) for "Construction of Facilities," a total of 14 line items aggregating the sum of $185,500,000; and (d) for "Research and Program Management," $1,605,000,000.

Subsection 101(e) would authorize the transfer and utilization of $35,000,000 of prior year, unobligated funds (except for aeronautical and transatmospheric research and technology and related construction of facilities and research and program management of funds) for the preparation of the Advanced Communications Technology Satellite for launch prior to 1992.

Subsection 101(f) 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 maintenance and operation of facilities or support services, under the research and program management, may be entered into at any time during the fiscal year for periods no longer than 12 months.

Subsection 101(g) 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 shall be final and conclusive.

Section 102—Tranfer of Funds

Section 102 would authorize the Administrator to propose transfers to or from line items (1) through (12) and (14) in the "Construction of Facilities" appropriation (subsection 101(c)), to any other line item in those paragraphs, a single amount of not more than 10 percent of the amount authorized for that line item. Cumulative transfers may not exceed 10 percent of the total authorized for those paragraphs. The transfer would be effected only after 30 days on which the Congress is in session after a written notification and explanation to Congress.

Section 103—Limitation on Use of Funds

Section 103 would provide that, notwithstanding any other provision of this Act, no amount appropriated:

(1) pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House or Senate Authorizing Committees.

(2) pursuant to subsection 101(a), (b), or (c) may be used for any program in excess of the amount actually authorized for such program by that subsection.

(3) pursuant to this Act may be used for any program which has not be presented to either the House of Senate Authorizing Committees unless 30 days on which either the House or the Senate is in session have passed after the Speaker of the House or the President of the Senate and the Committees have been given a complete explanation of the proposed action.

(4) pursuant to this Act may be obligated for any purpose unless 20 days on which either the House or the Senate is in session have passed after the Administrator submits a detailed agency-wide operating plan to the House and Senate Authorizing Committees.

Section 104—Geographical Distribution of Funds

Section 104 would require that the National Aeronautics and Space Administration should explore ways and means to geographically distributing its research and development fund whenever feasible. The Administrator shall report to the Congress by January 15, 1988 on the extent to which such consideration had been given and such ways and means explored during the fiscal years 1982 through 1987.

Section 105—Reimbursements from the Department of Defense

Section 105 would require the Administrator, in cooperation with the Secretary of Defense, to submit a five-year plan to Congress before July 1, 1988, setting forth a schedule for planned reimbursements from the Department of Defense for Space Shuttle services, and a schedule for the provision of such services. The bill would require an updated plan to be submitted annually along with the President's annual budget request.

Section 106—Award of Contracts to Domestic and Foreign Firms

Section 106(a) would require the Administrator to award to a domestic firm a contract which, 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 5 percent.

Subsection 106(b) would require that this section not apply if the Administrator determines that:

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

(2) compelling national security considerations require otherwise.

Subsection 106(c) defines the terms "domestic firm" and "foreign firm."

Subsection 106(d) would limit the applicability of the section only to contracts for which (1) amounts are made available by this Act, and (2) solicitations for bids are issued after the date of enactment.

Subsection 106(e) would require the Administrator to report to the House and Senate on contracts entered into with foreign entities, by fiscal year, for the fiscal year 1982 through 1987 by January 15, 1988.

Section 107—Use of Space Shuttle and Expendable Launch Vehicles

Section 107 would require the Administrator to establish a program for launching payloads by means of expendable launch vehicles, and, if available, by commercial launch services and would recognize the Space Shuttle to be a critical national resource. It would state that the sense of Congress that the Space Shuttle should be preserved for those missions that require manned presence and that a diversified family of expendable launch vehicles should be used in the nation's civilian space flight program. The Administrator would also be required to ensure that expendable launch vehicles, or, if available, commercial launch services, are made available for 4 specified payloads in the period 1990-1992. The Administrator would be required to report to Congress no later than October 1, 1987 on compliance with this section.

Section 108—Satellite Servicing System

Section 108 would express the sense of Congress that the establishment of a system for servicing, rehabilitation, and repair of satellites in orbit should enhance and protect the capital investment in space satellites and vehicles. The Administrator would be required to conduct a study of satelite servicing with a view toward establishing national goals and ojectives for utilizing such capabilities and report to Congress by January 15, 1988.

Section 109—National Commission on Space Report

Section 109 would require the Administrator to review the findings, recommendations and space agency in the report of the National Commisison on Space and submit a long-range implementation plan to Congress.

Section 110—Competition in Solid Rocket Motor Project

Section 110 would direct the Administrator to institute comptition in the Solid Rocket Motor project by undertaking the competitive design and development of an Advanced Solid Rocket Motor. In the event NASA does not proceed with an Advanced SRM, the Administrator is directed either to conduct a competition to select a qualified second source of supply for flight sets of the redesigned SRM currently under development, or to recompete the current source of supply for flight sets of the redesigned SRM. The Administrator is directed to consult with the Comptroller General concerning the competition. The Committee intends that NASA carry out this section in accordance with general procurement law.

Section 111—Amendment to 1958 National Aeronautics and Space Act

Section 111 would amend the NASA Act to require that the positions of Administrator and Deputy Administrator not be simultaneously occupied by retired commissioned officers of the armed forces unless a period of ten years have passed since active duty.

Section 112—Congress to be Kept Fully and Currently Informed

Section 112 would require the Administrator to keep Congress fully and currently informed with respect to all of the Administration's activities.

TITLE II—SPACE STATION

Section 201—Construction of Space Station—Declaration of Policy

Section 201 would establish general policy and guidelines for the construction and use of a permanently manned Space Station. Priorities would be established for the use of the Station. The Space Station would be used so as not to infringe on other science and space activities. The Administrator would also be required to (1) develop advanced technologies to enhance the ground and in-orbit operations of the Space Station; (2) seek to have appropriate portions of the Space Station constructed and operated by the private sector; (3) promote international cooperation in the Space Station program by undertaking cooperative projects with foreign Governments; and (4) design, develop and operate the Station in a manner that enables evolutionary enhancement.

Section 202—Capital Development Program

Section 202 would authorize a capital development program for the Space Station with certain restrictions. With each annual budget request between 1989 and 1996 (inclusive), the Administrator would be required to include budget estimates for the two succeeding fiscal years capital development of the Station would be completed by or during fiscal year 1997. After fiscal year 1988, the President's Space Station development budget submission to Congress shall not exceed 25 percent of the total NASA budget request for any given year. The term "Capital Development" would be defined to include all direct "Research and Development," Space Flight Control and Data Communications," "Construction of Facilities," and "Research and Program Management" activities associated with the construction of the Space Station and its supporting elements and services. Each year, along with the President's annual budget submission to Congress, the Administrator would be required to submit a report certifying compliance with the provisions of this Section.

Section 203—Operation and Enhancement

Section 203 would determine funding parameters for the operation and enhancement of the Space Station after development is completed. The President's budget request to Congress would be required to contain an amount for Space Station operation and enhancement which should in no case exceed 10 percent of the total

NASA budget submission for that year. The Administrator would be authorized to make a separate request for additional funds may be necessary for the utilization of the Space Station pursuant to the policies set forth in section 201. The terms "Operation" and "Enhancement" are defined as all direct research and development, space flight, control and data communications, constuction of facilities and research and program management funds that are associated with the operation of the Space Station and the acquisition of additional Space Station elements or ground facilities.

Section 204—Launch of Space Station Elements

Section 204 would express the sense of the Congress that the launching and servicing of the Space Station should be accomplished by the most cost-effective use of the space transportation systems for the launch and operation of the Space Station. The report would take into consideration the (1) potential use of future advanced or heavy lift expendable launch vehicles, (2) use of existing expendable launch vehicles, (3) requirements for Space Shuttle launches, and (4) risk of capital losses.

Section 205—Capacity Charges to Other Federal Agencies Desiring to Enhance the Space Station

Section 205 would require the Administration to assess appropriate charges on other Federal agencies desiring to enhance portions of the capacity of the Space Station for their own purposes. The Administrator would be authorized to construct the enhanced capacity, provided that (1) the proceeds of such charges cover the full cost of the construction, and (2) 30 days on which either the House or the Senate is in session have passed after the submission by the Administrator to the House and Senate Authorizing Committees of an explanation of the proposed construction, including a certification that the proposed enhancement is consistent with this Act and does not interfere with other uses of the Space Station.

Section 206—Non-NASA User Fees

Section 206 would require the Administrator to set and collect reasonable user fees for the use and maintenance of the Space Station and would provide policy guidance as to how the fees are set. The Administrator would be authorized to waive or modify user fees under certain circumstances as specified.

Section 207—Submission of Plan

Section 207 would require the Administrator to submit to the President and the Congress on or after January 15, 1988, (1) a plan that outlines the total cost of development and operation of the Space Station in conformance with the provisions of this Act, and on or before September 30, 1988, (2) a detailed plan of the Space Station as required by this Act, and the utilization of the Space Station as required by this Act, and the Administrator is authorized to obligate no more than $250,000,000 appropriated in this Act for the development of the Space Station until 15 calendar days have passed after the submission of the report to Congress.

Section 208—Agreements with Foreign Entities

Section 208 would require any agreement concerning the detailed design, development, construction and operations of the Space Station between the United States Government and any foreign entity to be submitted to the House and Senate. The agreement would not take effect until 30 days during which the House or Senate is in session after receipt of such agreements by the House and Senate.

TITLE III—OFFICE OF COMMERCIAL SPACE TRANSPORTATION

Section 301—Authorization of Appropriations

Section 301 would amend section 24 of the Commercial Space Launch Act (49 U.S.C. App. 2623) to authorize funding in the amount of $4,548,000 for fiscal year 1988 to the Secretary of Transportation to carry out the provisions of this Act.

Section 302—Requirement for Reports to the Congress

Section 302 would amend section 15 of the Commercial Space Launch Act to require that any agreement between a government agency and a commercial user involving terms and conditions under which the government will furnish goods and services to the user in support of production and/or launch of a launch vehicle shall be presented by the Secretary to the Congress for review. The agreement would not be effective until a period of 30 days had passed after the receipt of the agreement by the House and Senate.

EFFECTS OF LEGISLATION ON INFLATION

In accordance with Rule XI, clause 2(l)(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 1988, NASA will employ about 22,425 civil servants and support about 157 thousand 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 450,000 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, 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 is shown in roman):

SECTION 202 OF THE NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEC. 202. (a) * * *

* * * * * * *

(d) At no time may the two positions of Administrator and Deputy Administrator be occupied simultaneously by retired commissioned officers of a regular component of the Armed Forces who have been on active duty with a regular component of the Armed Forces within the last 10 years.

COMMERCIAL SPACE LAUNCH ACT

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USE OF GOVERNMENT PROPERTY

SEC. 15. (a) * * *

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(d) Any agreement between a government agency and a commercial user involving terms and conditions under which the government will furnish goods and services to the user in support of production and/or launch of a launch vehicle shall be presented on behalf of such agency by the Secretary to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives for their review. No such agreement shall be effective until 30 days on which either House is in session have passed after the receipt by such committees of such agreement.

* * * * * * *

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.*

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OVERSIGHT FINDINGS AND RECOMMENDATIONS

Pursuant to Rule XI, clause 2(l)(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 and in the Committee's recent report entitled "Investigation of the Challenger Accident," Union Report 99-1016, House of Representatives.

CONGRESSIONAL BUDGET OFFICE COST ESTIMATE

U.S. CONGRESS,
CONGRESSIONAL BUDGET OFFICE,
Washington, DC, July 1, 1987.

Hon. ROBERT A. ROE,
Chairman, Committee on Science, Space, and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: The Congressional Budget Office has prepared the attached cost estimate for H.R. 2782, the National Aeronautics and Space Administration Authorization Act of 1988.

If you wish further details on this estimate, we will be pleased to provide them.

With best wishes,

Sincerely,

ROBERT F. HALE
(For Edward M. Gramlich, Acting Director).

CONGRESSIONAL BUDGET OFFICE COST ESTIMATE

1. Bill number: H.R. 2782.
2. Bill title: National Aeronautics and Space Administration Authorization Act of 1988.
3. Bill status: As amended and ordered reported by the House Committee on Science, Space, and Technology on June 26, 1987.
4. Bill purpose: This bill authorizes the appropriation of an estimated $9,876 million in fiscal year 1988 for the ongoing activities of the National Aeronautics and Space Administration (NASA). The specified fiscal year 1988 NASA authorizations total $9,462 million. The bill also authorizes the appropriation in fiscal year 1988 of such sums as may be necessary to return the space shuttle fleet to flight status, requires the NASA Administrator to provide or procure expendable launch vehicle (ELV) services to launch four satellites in the early 1990s, and requires the Administrator to request funding for the construction, operation and enhancement of the space station.

Of the specified NASA authorization, $3,697 million is for research and development, $3,974 million is for space flight, control, and data communications, $186 million is for construction of facilities, and $1,605 million is for research and program management.

In addition to the NASA authorizations, the bill authorizes the appropriation of about $4.5 million for the Office of Commercialization in the Department of Transportation.

5. Estimated Cost to the Federal Government: The following table shows funding amounts specifically authorized by H.R. 2782 and estimated outlays based upon those amounts.

[By fiscal year, in millions of dollars]

	1988	1989	1990	1991	1992
Specified authorization level:					
Function 250:					
Civilian space	8,702.9				
Function 400:					
Aeronautics	759.1				
Commercial space	4.5				
Total specified authorizations	9,466.5				
Estimated outlays	6,176.8	2,625.0	631.6	27.9	5.2

In addition, the bill authorizes the appropriation of such sums as may be necessary in fiscal year 1988 to return the shuttle system to operational flight status. The bill also requires the NASA Administrator to provide or procure ELVs for launching four satellites. Based upon preliminary information, the estimated authorization level and estimated outlays associated with this requirement would be as shown in the table below.

[By fiscal year, in millions of dollars]

	1988	1989	1990	1991	1992
Estimated authorization level					
Space Shuttle	350.0				
ELVs	64.0	107.0	146.0	77.0	61.0
Estimated outlays	291.9	172.3	153.2	95.0	69.9

The table below shows the total authorization and outlay levels for H.R. 2782.

[By fiscal year, in millions of dollars]

	1988	1989	1990	1991	1992
Total authorization levels (specified and estimated)	9,880.5	107.0	146.0	77.0	61.0
Total estimated outlays	6,468.6	2,797.3	784.8	122.8	75.2

In addition to a fiscal year 1988 authorization of $767 million, this bill requires the Administrator to seek funding for fiscal year 1989 and beyond for the capital development, operation, and enhancement of the space station. The annual funding requirements for the space station depend upon its configuration, launch mode, operational target date and other considerations that have yet to be determined. Consequently, annual requirements cannot yet be estimated with any precision. Total funding requirements, however, could be as high as $30 billion throughout the year 2000.

Including outlays from previous years' appropriations, total NASA outlays for fiscal year 1988 are estimated to be $9,708 million, assuming appropriation of the amounts authorized in this bill.

The costs of this bill fall within budget functions 250 and 400.

Basis of estimate: The authorization levels in the first table are those specified in the bill. The outlay estimates assume that all funds authorized are appropriated prior to the beginning of fiscal year 1988 and that spending will reflect historical patterns.

The fiscal year 1988 authorization required to return the shuttle system to flight status and the subsequent authorizations required to provide for the four satellite launches are CBO estimates based upon preliminary information. It is assumed that the estimated amounts will be appropriated. Estimated outlays are assumed to follow historical patterns for the shuttle system and ELV operations.

6. Estimated cost to State and local governments: None.

7. Estimate comparison: None.

8. Previous CBO estimate: On July 1, 1987, CBO provided a revised cost estimate for S. 1164, the National Aeronautics and Space Administration Act of 1988, as amended and ordered reported by the Senate Committee on Commerce, Science, and Transportation. Outlay differences between S. 1164 and H.R. 2782 reflect different authorization levels.

9. Estimate prepared by: Paul M. DiNardo.

10. Estimate approved by: 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. 2782 by voice vote, and recommends its enactment.

NASA REQUEST

MARCH 16, 1987.

Hon. BILL NELSON,
Chairman, Subcommittee on Space and Application, 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 enclosed 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 1988. For that fiscal year, the bill would authorize appropriations totaling $9,481,000,000, to be made to the National Aeronautics and Space Administration as follows:

(1) for "Research and development," amounts totaling $3,623,200,000;

(2) for "Space flight, control and data communications," amounts totaling $4,064,300,000;

(3) for "Construction of facilities," amounts totaling $195,500,000; and

(4) for "Research and program management," $1,598,000,000.

In addition, the bill would authorize such sums as may be necessary for fiscal year 1989, i.e., to be available October 1, 1988.

The enclosed bill follows generally the format of the National Aeronautics and Space Administration Authorization Act for FY 1987 as proposed by the Administration. However, the bill differs in substance from the prior Act in several respects.

First, subsections 1(a), 1(b), 1(c), and 1(d), the authorizations for the four NASA appropriation accounts, differ in the dollar amounts and in some of the line items for which authorization to appropriate is requested. There is a new budget line item under "Research and development" entitled "Safety, reliability and quality assurance.

Second, there is a new section 5 which gives the Administrator transfer authority, after notification to the Congress, when a percentage reduction is applied to the FY 1988 appropriation. This will enable the Administrator to balance the effects of such a cut.

Third, there is a new section 6 which would amend the National Aeronautics and Space Act to provide NASA the authority to withhold from public disclosure certain technical data that are subject to control under the export control laws. This amendment is similar to authority which the Department of Defense was given in 1983.

Fourth, there is a new section 7 which would allow the Administrator to appoint up to 15 retired military or civilian Federal employees without reducing their retirement pay or regular pay. This will enable NASA to employ some key experienced personnel in executive positions to assist in the recovery from the Challenger accident and to staff up the Space Station reorganization.

Fifth, in addition to providing authorization of appropriations in the amounts recommended by the President in his Budget for fiscal year 1988, the bill also would provide authorization for sums as may be necessary for fiscal year 1989. It is specified that all of the limitations and other provisions of the bill applicable to amounts appropriated pursuant to section 1 shall apply in the same manner to amounts appropriated pursuant to section 9.

Finally, the last section of the draft bill, section 10, has been changed to provide that the bill, upon enactment, may be cited as the "National Aeronautics and Space Administration Authorization Act, 1988," rather than "1987."

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 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.*

SUPPLEMENTAL VIEWS H.R. 2782, NASA FY88 AUTHORIZATION SOLID ROCKET MOTOR COMPETITION

The Committee has taken an important first step in directing NASA to introduce some competition into the solid rocket motor program. The investigation following the Challenger accident reaffirmed an inherent weakness in relying on a single source for important hardware elements. Although the O-ring anomalies were discovered early in the Shuttle program, and several attempts were made by engineering personnel within the company producing the motors to correct the problem, there was little incentive to do so. The cost of the failure to correct the problem has been incalculable.

We strongly support plans to develop an advanced solid rocket motor. The state-of-the-art in solid rocket technology has advanced significantly since the design of the existing motors, and in as much as the Shuttle program is planned to continue for another two decades or more, it is prudent to begin replacing this outdated technology. We believe the enhanced quality and safety in addition to the long term cost savings in utilizing more modern production methods justify the investment in the advanced solid rocket motor program.

We are concerned that in spite of the good intentions of the agency in fulfilling the Committee's direction to pursue the advanced solid rocket motor program, factors beyond NASA's control could very likely prevent the realization of this objective. We do not believe this bill adequately addresses this possibility and raise the following specific concerns:

1. Although the bill refers to the "determination for any reason not to conduct the design and development . . .", it is not specified when that determination should be made. Given the fiscal constraints on future NASA budgets, it is a very real possibility that the necessary funds will not be made available, yet the Administrator may continue to propose the program and be unwilling to determine that the program will not be conducted. This could lead to an unacceptable continuation of the status quo with regard to the production of the solid rocket motors.

2. If the determination is finally made, it is not clear what specific action is directed to follow and when it should take place. We are concerned that in NASA's anxiety to build up the Shuttle flight rate, it may find it more expedient to continue with the existing contract. It could be a very long time before NASA deems that "sufficient technical and programmatic data are available" to take action.

3. Although the bill directs NASA to consult with the Comptroller General and give primary consideration to cost and safety, we are concerned that NASA's predisposition to working with a single contractor will prejudice the outcome. We believe it is important that an independent assessment be made of the total cost-benefit over the life of the program, taking into account the effect of continued competition in future negotiations and the benefits of two independent sources for future product improvements. Moreover, we believe that the recommendation of the Comptroller General and/or other independent consultants should be accepted unless NASA can clearly show why to do so would not be in the best interests of the government.

Robert G. Torricelli.
Dan Glickman.
Rick Boucher.
Norman Mineta.
Sherry Boehlert.
Constance A. Morella.
Harold L. Volkmer.
Terry L. Bruce.
Doug Walgren.
James H. Scheuer.
Ernie Konnyu.
Manuel Lujan, Jr.

MINORITY VIEWS FOR H.R. 2782, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION

NASA's role as an independent civil space agency was firmly established in the National Aeronautics and Space Act of 1958. Sec. 102 clearly states that the aeronautics and space activities defined in the Act shall be the responsibility of, and be directed by, a civilian agency. However, the Act also makes clear that Congress never intended that the military had no role to play in the Agency or that military interests should not be considered in the formulation of NASA's program.

In drafting this legislation, Congress recognized a legitimate relationship between NASA and DOD; Sec. 102 addresses the importance of cooperation, sharing discoveries of mutual interest, and avoiding unnecessary duplication of effort, facilities, and equipment. Moreover, Sec. 203(b), paragraph 12 of the Space Act authorizes NASA to enter into cooperative agreements with DOD, under which members of the Armed Services may be detailed to NASA.

Sec. 202 of the Act calls for the Administrator and Deputy Administrator to be appointed from civilian life by the President with the advice and consent of the Senate, thus assuring that the Agency would not be directed by the military. Sec. 202 also prohibits the Administrator and Deputy Administrator from engaging in any other business, vocation or employment, thus further assuring the independence of the Agency and avoiding other conflicts of interest. However, Congress certainly did not intend that NASA be denied the expertise of the military, and they wisely refrained from putting further restrictions on the qualifications of the Administrator or Deputy Administrator.

It is becoming increasingly difficult to attract qualified people to positions of responsibility in the government. The pool of qualified people willing to take the position of NASA Administrator is especially limited in that a high degree of specialized technical competence is needed in addition to the administrative qualifications. To arbitrarily limit the field further by eliminating from consideration categories of potentially qualified people based on the presumption of their biases is, it seems to us, extremely short-sighted, not to mention an insult to the many fine men and women who have served in the Armed Forces.

The restriction set forth in Sec. 111 of H.R. 2782 is especially curious in as much as the position of Administrator has never been filled by a retired military officer. The Senate confirmation process provides ample safeguards against the Committee's concerns that the NASA leadership could become unduly influenced by DOD, and therefore we believe this restrictive section is unwarranted and should be deleted from the bill.

Manuel Lujan, Jr.
Harris W. Fawell.
Jack Buechner.
Bob Walker.
D. French Slaughter, Jr.
Ernie Konnyu.
F. James Sensenbrenner, Jr.
Ron Packard.
Lamar Smith.
Sherry Boehlert.
Robert C. Smith.
Tom Lewis.
Constance A. Morella.

ADDITIONAL VIEWS OF NORMAN Y. MINETA, GEORGE E. BROWN, DOUG WALGREN, DAN GLICKMAN, HAROLD VOLKMER, ROBERT C. TORRICELLI, TERRY L. BRUCE, JAMES A. TRAFICANT, JR., CARL C. PERKINS, DAVID R. NAGLE AND DAVID SKAGGS ON THE NATIONAL SECURITY USE OF THE SPACE STATION

We are concerned that the Committee position on national security uses of the space station would not adequately ensure that the Space Station is preserved for the essentially peaceful purposes for which that Station has been conceived, designed, and authorized. Specifically, we are concerned that Section 201(b) of this bill, as amended, fails to restrict military or national security uses of the Space Station beyond the vague prohibitions found in current United States laws or treaty obligations. As it is now written, Section 201(b) simply affirms current policy, and does nothing to promote the use of the Space Station for peaceful purposes.

When NASA was established in 1958, President Eisenhower determined that the civilian space agency should be free from military dominance. In the thirty years since that time, NASA has enjoyed broad support from the American people as a civil endeavor dedicated to peaceful exploration and the pursuit of science. This support has, to a remarkable degree, remained strong even throughout those periods when there were deep divisions within our society over this country's political or military policies.

We now find ourselves at the beginning of a new space age, an age of infinitely expanded opportunity and challenge. The coming years will see our scientists stationed permanently in space, developing new technologies and new products that will undoubtedly change our lives. We will move from simply exploring space to actually living and working there.

At the same time, we are certain to see an increase in military activities in space, as technological advances make it both possible and necessary to extend ground, air, and naval operations beyond the atmosphere. This militarization of space is already well along. In 1982, a GAO study found that 25% of NASA's research and development budget was devoted to military projects. Almost half of the shuttle flights carry military payloads. Since the Challenger incident, high priority military payloads have crowded out many commercial and scientific missions from the space shuttle. Additionally, the Department of Defense budget for space activities is now nearly double that of NASA.

It is important to return to our original intent for NASA prior to NASA's next major initiative, the space station.

The space station was conceived as a vital component in the country's effort to renew our tradition leadership role in space. Scientists believe that the space station will serve as the base for experiments that could lead to dramatic advances in medicine, computers, materials science and communications technology.

The station, too, is believed to be the logical step from the moon landings and the shuttle to human exploration of Mars and beyond.

This picture of a civilian space station as a floating research laboratory is inconsistent with military use of the space station for weapons development and testing irrespective of existing United States laws and treaty obligations.

In order to protect the essentially peaceful nature of the Space Station, it is important to go beyond existing laws and treaty obligations which are clearly not sufficient to assure the peaceful exploration and exploitation of space. There are three treaties which govern our role in space: the 1963 Limited Test Ban Treaty, the 1967 Outer Space Treaty, and the 1972 Anti-Ballistic Missile (ABM) Treaty.

The Limited Test Ban Treaty prohibits nuclear devices in space that cause or are powered by a nuclear explosion. This treaty is not much of a limiting factor at present, since there are many other military uses of space that are not related to nuclear devices. The ABM Treaty bans the development, testing and deployment of any anti-ballistic missile system which is land, sea, or space based. It remains to be seen whether this treaty is a limiting factor on the national security use of space. The administration is fighting to expand its interpretation to allow for SDI research and testing. The House reaffirmed its commitment to the traditional interpretation of the ABM Treaty; however, the battle is far from over.

The Outer Space Treaty is the main treaty governing space. It is a treaty ratified for foreign nations through a United Nations process and about 100 countries are signatories. The treaty rests on the principle that space exploration should be for the benefit of "all peoples irrespective of the degree of their economic or scientific development." It mandates that the "exploration and use of outer space (be) for peaceful purposes." Article IV bans nuclear weapons or "weapons of mass destruction." It goes on to say, "the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden."

We believe that this treaty is insufficient to restrain DOD's use of the space station for weapons development and testing. It is clear that the intent of the treaty was to assure that space exploration and use be consistent with "peaceful purposes." However, "peaceful purposes" can be defined in a variety of ways. Almost all research and development can be construed to be for peaceful purposes, including SDI related research, such as lasers and kinetic energy weapons. The space community believes that "peaceful purposes" refers to an undefined "non-aggressive" military activity such as reconnaissance satellites or navigational satellites. Given the administration's penchant for interpreting treaties in the broadest possible terms, we believe that we must provide specific guidance concerning the allowable activities for the space station.

We believe that national security use of the space station should be limited to basic research and exploratory development, directed towards solving specific military problems, but short of major development projects. Exploratory development would not result in the development of prototypes in field configuration for technical or operational testing. We believe that weapons testing, and testing of the command, control, and communications associated with a weapon or a weapons system should be prohibited on the space station.

We believe that only by explicitly restricting the national security use of the space station can we assuage our foreign partners' concerns regarding the military on the space station. Some of these partners feel that excessive military involvement would jeopardize their participation. We believe that we must provide assurance to our partners that national security needs will not compromise the original objective of the space station, to further basic research and promote scientific projects which will result in commercial applications, and further our exploration and development of space.

GEORGE BROWN.
CARL PERKINS.
JAMES TRAFICANT, Jr.
DAVE NAGLE.
HAROLD L. VOLKMER.
DAN GLICKMAN.
NORMAN MINETA.
TERRY L. BRUCE.
DAVID SKAGGS.
ROBERT G. TORICELLI.
DOUG WALGREN.

ADDITIONAL VIEWS OF HON. MANUEL LUJAN, JR. (R-NM), NEW DIRECTIONS FOR U.S.-LATIN AMERICAN COOPERATION IN SCIENCE AND TECHNOLOGY

During the decade of the sixties and the early seventies, many important programs for scientific and technological cooperation between U.S. and Latin American scientists were initiated. Some were under the mandate of the Alliance for Progress, others were funded by USAID, National Science Foundation, the Fulbright program, the Organization of American States, and other agencies both within and outside the U.S. Government. The impact on U.S.-Latin American Scientific relations was significant, and many important scientific institutions in Latin America were created or strengthened through this effort. During the 1970's these programs declined, and most of the Latin American countries which had participated were pronounced "AID graduates," and became ineligible for AID funds. At the same time, political unrest caused many scientists to leave their countries, thereby affecting some of the best Latin American institutions as well as the economic stability and vitality of these countries.

The weakening of links in Science and Technology cooperation between these countries and the U.S. is believed to be adversely affecting the spirit of inter-American cooperation. However, in visits from senior Latin American scientists, particularly at the National Research Council, the situation in Latin American universities and other scientific institutions appears significantly changed. Many believe that the decline in joint research programs, graduate and postgraduate training opportunities, and networking relationships are detrimental to the scientific advancement in the hemisphere.

The time is ripe to consider new approaches to science and technology collaboration, more appropriate to the changed climate, to the problems and technologies of the eighties, and to the new capability in some scientific fields of some of the Latin American countries which coincide with U.S. scientific interests.

For this reason, I offered language to the Committee's reports on the NASA and NSF FY88 Authorization bills calling for an independent, interagency study of mechanisms for present and future cooperations in science and technology. I see NSF as having the lead coordinating role for the Federal agencies participating in this study.

Furthermore, among the reasons commending a study of Science and Technology (S&T) cooperation in the Americas are:

Several countries have recently elected democratic governments, and scientists who were working abroad for many years have returned to their home countries. Thus, both the opportunity for increased S&T collaboration and the trained personnel to engage in programs is greater than at any time since the mid 1960s when cooperation reached its peak.

Latin American scientists have expressed interest in strengthened S&T cooperation with the United States, although using different modes than were prevalent in the 1960s and 70s.

A number of countries are reorganizing their S&T systems and infrastructure, creating new counterpart organizations for planning, funding priority programs, and mechanisms for international cooperation. One of the frustrations of Latin American scientists in dealing with the United States is that there is no central source of information on possible U.S. opportunities nor is there a single policy-making body in the U.S. government empowered to address the problem of scientific interaction.

There are important areas of S&T which can produce mutual benefits to the cooperating parties. Examples are seismic studies and prediction of earthquakes, tropical ecosystems, tropical diseases, the influence of El Nino on weather patterns in both the Northern and Southern Hemispheres, and technoeconomics of alcohol fuels.

The forthcoming 500th anniversary of the Columbus voyages may provide an opportunity for new initiatives.

Currently, there are independent efforts pursuing mechanisms for U.S.-Latin American S&T cooperation. For example, a report entitled "Inter-American Cooperation in Space, Science and Technology" was prepared in response to an amendment I offered to the FY86-87 Foreign Relations Authorization Act (P.L. 99-93). This Department of State study surveyed past programs, but stopped short of recommending new actions for scientific interaction, though the provision asked for such recommendations.

In September 1986, President Jose Sarney and Ronald Reagan agreed to undertake a special initiative for implementation of the existing U.S.-Brazil Agreement of Cooperation in S&T. Establishment of a high-level panel was agreed to, composed of eminent scientists, engineers, and governmental authorities from each country to present recommendations and suggestions of topics for bilateral cooperation, focusing on selected priority areas of mutual strength and benefit. The bi-national panel will suggest procedures to encourage and facilitate engagement of the private sectors of their countries. Cooperative projects would be financed jointly through resources to be allocated for this purpose by both countries.

The U.S.-Brazil agreement follows the pattern of the U.S.-India bilateral program in S&T, managed by NSF, which began with an initiative between the Indian Prime Minister and the U.S. President.

Finally, NASA's role in the international scientific community is of premier importance to the Committee. I believe that NASA should be at the forefront of any recommendations coming from the scientific community.

MANUEL LUJAN, Jr.

100th Congress
1st Session

SENATE

Report
100-87

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, 1988

June 24, 1987.—Ordered to be printed

Mr. Hollings, from the Committee on Commerce, Science, and Transportation, submitted the following

REPORT

together with

ADDITIONAL VIEWS

[To accompany S. 1164]

The Committee on Commerce, Science, and Transportation, to which was referred the bill (S. 1164) 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 this bill is to authorize appropriations to the National Aeronautics and Space Administration (NASA) totaling $9,621 million for fiscal year 1988, as follows:

	Budget request	Committee authorization
Fiscal year 1988:		
Research and development	$3,623,200,000	$3,721,000,000
Space flight, control, and data communications	4,064,300,000	4,081,300,000
Construction of facilities	195,500,000	210,700,000
Research and program management	1,598,000,000	[1] 1,608,000,000

[1] Includes $10 million authorized in title II for Space Grant College and Fellowship Program.

Legislative History

In January, 1987, the Administration submitted its fiscal year 1988 budget request for NASA. The Committee considered budget and related policy matters in hearings on January 22, February 3, February 19, February 26, March 5, and April 29. The Committee received testimony from the NASA Administrator and NASA officials associated with major agency programs, the Secretary of the Air Force, the Director of the Office of Commercial Space Transportation, and the space science and aerospace communities.

On May 7, 1987, Senators Riegle and Pressler introduced S. 1164, a bill to authorize appropriations for the National Aeronautics and Space Administration. On May 8, Senator Riegle introduced S. 1173, a bill to authorize appropriations for the Office of Commercial Space Transportation. Both of these measures were introduced at the request of the Administration. On May 14, the Committee met in executive session and unanimously ordered reported S. 1164 with an amendment in the nature of a substitute. The amendment reported by the Committee also incorporated the language of S. 1173 (the Office of Commercial Space Transportation FY 1988 Authorization), S. 502 (Technical Amendments to the Land Remote-Sensing Commercialization Act of 1984), S. 503 (the Shuttle Gifts and Donations Bill), S. 504 (Reestablishment of the National Aeronautics and Space Council), and S. 752 (the Space Grant College and Fellowship Program).

NASA AUTHORIZATION SUMMARY

[In millions of dollars]

	Fiscal year—		Proposed fiscal year 1988 Senate authorization
	1987 operating plan	1988 request	
I. Research and development	(3,120.7)	(3,623.2)	(3,721.0)
1. Space station	420.0	767.0	767.0
2. Space transportation capability development	491.1	568.6	592.6
Spacelab	(73.9)	(73.5)	
Upper stages	(156.1)	(159.7)	(181.7)
Engineering and technology base	(133.4)	139.8)	
Payload operations and support equipment	(44.5)	(83.4)	(85.4)
Advanced programs	(27.6)	(24.9)	
Tethered satellite system	(10.6)	(7.3)	
Orbital maneuvering vehicle	(45.0)	(80.0)	
3. Space science	983.4	949.0	973.7
A. Physics and astronomy	(552.8)	(567.1)	(591.8)
Hubble space telescope development	101.3	98.4	
Gamma ray observatory development	50.5	49.1	
Shuttle/Spacelab payload development	90.1	95.4	
Explorer development	56.7	60.3	80.3
Mission operator and data analysis	125.7	128.1	
Research and analysis	53.4	60.1	
Suborbital program	75.1	75.7	80.4
B. Life sciences	(72.2)	(74.6)	(74.6)
C. Planetary exploration	(358.4)	(307.3)	(307.3)
Galileo development	71.2	55.3	
Magellan	97.3	59.6	
Ulysses	10.3	10.8	
Mars observer	35.8	29.3	

NASA AUTHORIZATION SUMMARY—Continued

[In millions of dollars]

	Fiscal year— 1987 operating plan	Fiscal year— 1988 request	Proposed fiscal year 1988 Senate authorization
Mission operations and data analysis	75.8	77.0	
Research and analysis	68.0	75.3	
4. Space applications	569.2	559.3	651.4
A. Solid Earth observations	(75.6)	(76.8)	(80.8)
Shuttle/Spacelab payloads	21.6	21.1	
Geodynamics	32.1	33.1	
Research and analysis	21.9	22.6	26.6
B. Enviornmental observations	(320.9)	(393.8)	(393.8)
Applied research, data analysis and related activities	142.8	141.3	
Shuttle/Spacelab payload development	12.0	19.4	
Scatterometer	32.9	22.7	
Upper atmosphere research satellite [UARS]	114.2	95.4	
Ocean topography experiment [TOPEX]	19.0	90.0	
Global geospace science	0	25.0	
C. Materials processing in space	(47.9)	(45.9)	(50.0)
D. Communications	(103.5)	(20.5)	(104.5)
E. Information systems	(21.3)	(22.3)	(22.3)
5. Commercial programs	40.9	54.0	49.0
Technology utilization	(15.7)	(18.3)	(18.3)
Commercial use of space	(25.2)	(35.7)	(30.7)
6. Aeronautical research and technology	374.0	375.0	375.0
Research and technology base		(285.2)	
Systems technology programs		(89.8)	
Rotocraft systems technology		5.0	
High-performance aircraft systems technology		14.6	
Advanced propulsion systems technology		30.5	
Numerical aerodynamic simulation		39.7	
7. Transatmospheric research and technology	45.0	66.0	66.0
8. Space research and technology	168.0	250.0	212.0
9. Safety reliability and quality assurance	12.0	16.2	16.2
10. Tracking and data advanced systems	17.1	18.1	18.1
II. Space flight control and data communications	(5,799.5)	(4,064.3)	(4,081.3)
1. Space shuttle productions/operations capability	1,005.1	1,229.6	1,150.6
Orbiter operational capability		(403.2)	(324.2)
Launch and mission support		(249.3)	
Propulsion systems		(552.1)	
Changes and systems upgrading		(25.0)	
2. Replacement orbiter	2,100.0		
3. Space transportation operations	1,847.0	1,885.8	1885.8
Flight operations	(557.7)	(561.1)	
Flight hardware	(936.0)	(923.1)	
Launch and landing operations	(353.3)	(401.6)	
4. Space tracking and data acquisition	845.4	948.9	944.9
Space network		(481.5)	
Ground network		(257.1)	
Communications and data systems		(210.3)	
5. Expendable launch vehicle operations	2.0	0	100.0
III. Construction of facilities	(166.3)	(195.5)	(210.7)
IV. Research and program management	(1,460.5)	(1,598.0)	[1] (1,608.0)
Total NASA	10,547.0	9,481.0	9,621.0

[1] Includes $10 million authorized in title II for Space Grant College and Fellowship Program.

SUMMARY OF MAJOR PROVISIONS

For fiscal year 1988, the Committee would authorize $9,621,000,000 for NASA, and $4,550,000 for the Office of Commercial Space Transportation. Of this, $3,721,000,000 is authorized for research and development, $4,081,300,000 for Space Flight Control and Data Communications. In addition, $210,700,000 is authorized for Construction of Facilities, and $1,608,000,000 for Research and Program Management, including the $10 million authorized in title II of the National Space Grant College and Fellowship Program.

The Committee provides $767,000,000 to initiate Phase C/D activities with the intent that actual hardware development activities will begin in this fiscal year. This represents no change from the fiscal year 1988 budget request of the Administration.

The Space Transportation Capability Development budget of $592,600,000 represents a $24,000,000 increase over the fiscal year 1988 NASA budget request. This increase will provide for the development of the upper stage and payload operations necessary to accommodate the Advanced Communications Technology Satellite (ACTS), which is scheduled for launch in November 1990.

The Committee authorizes $973,700,000 for Space Science activities, which is $24,700,000 above the Administration's budget request. $20,000,000 of this increase will provide additional funds for the Explorer Development program. The additional $4,700,000 of the increase will be directed at the suborbital programs to increase flight opportunities in this productive area. The Planetary Exploration and Life Sciences programs are funded at the level of the President's budget request for fiscal year 1988, $307,300,000 and $74,600,000 respectively.

The Committee authorizes $651,400,000 for Space Applications programs compared with the President's budget request of $559,300,000. The Committee increases funding for Materials Processing in Space by $4,100,000 to increase the development of flight hardware. The Committee augments the Solid Earth Observations budget to establish capabilities for receiving directly from foreign remote sensing satellites data collected over the United States. The Committee also provides $84,000,000 for the Advanced Communications Technology Satellite (ACTS) program, for which no funding was requested by the Administration. Other programs, such as the Upper Atmosphere Research Satellite (UARS), the Ocean Topography Experiment (TOPEX), and the Global Geospace Science program (the only new start included in the budget request) are authorized at the levels of the President's budget request.

The Committee has authorized $49,000,000 for NASA's commercial programs, a $5,000,000 reduction from the requested level.

In the Aeronautical Research and Technology programs, the Committee authorizes $375,000,000 which is identical to the Administration's request.

Transatmospheric Research and Technology is also authorized at the requested level of $66,000,000.

NASA requested $250,000,000 for Space Research and Technology in fiscal year 1988, including $134,100,000 for the Civilian Space Technology Initiative (CSTI). The Committee authorizes $212,000,000 for these programs. The $38,000,000 reduction anticipates that in fiscal year 1988 the Department of Defense will fund duplicative propulsion technology activities to be undertaken by NASA as part of the Advanced Launch System program. This reduction is without prejudice since the Committee strongly endorsed the CSTI initiative.

The Committee authorizes $16,200,000 for Safety, Reliability and Quality Assurance, and $18,100,000 for Tracking, and Data Advanced Systems. Both of these programs are funded at the requested funding level.

The total Research and Development budget for fiscal year 1988 is $3,721,000,000, compared with a budget request of $3,623,200,000, and a fiscal year 1987 operating plan of $3,120,700,000.

The Committee authorizes $4,081,300,000 for Space Flight, Control and Data Communications for fiscal year 1988 compared to the President's budget request of $4,064,300,000. Of this amount $1,150,600,000 is for Space Shuttle Productions and Operations Capability, $1,885,800,000 for Space Transportation Operations, $944,900,000 is for Space Tracking and Data Acquisition, and $100,000,000 is for Expendable Launch Vehicle Operations.

The Administration requested $1,229,600,000 for fiscal year 1988 for Space Shuttle Production/Operations Capability. The Committee authorizes $1,150,600,000 for these activities. The Committee deleted funding for Space Shuttle structural spares, which totals $79,000,000, until such time as NASA's use of expendable launch vehicles is resolved and the Nation's space transportation requirements are thoroughly identified.

The Committee authorizes $1,885,800,000 for Space Transportation Operations, the President's request. However, the Space Tracking and Data Acquisition request is reduced by $4 million to $948,900,000. This is a general reduction to be made at the discretion of the Administrator of NASA.

In addition, the Committee authorizes $100,000,000 to initiate the procurement of Expendable Launch Vehicles despite the fact these funds were not requested.

In fiscal year 1988, the Committee authorizes $210,700,000 for Construction of Facilities, compared to the requested level of $195,500,000. The Committee, without prejudice, defers initiation of Space Station Construction of Facilities activities until 1989, resulting in a reduction of $25,800,000, and authorizes Phase I of the repair and rehabilitation of the Ames Research Center 12 foot pressure wind tunnel which results in an increase of $41,000,000. The deferral of space station facilities projects adjusts this schedule to the most recent Administration proposal.

The Research and Program Management account would be increased $10,000,000 over the NASA request of $1,598,000,000. This increase would accommodate initiation of the Space Grant Fellowship program contained in Title II. The total authorization for Research and Program Management would be $1,608,000,000 in fiscal year 1988.

The total authorization for NASA in fiscal year 1988 is $9,621,000,000, compared with the President's budget request of $9,481,000,000 and the fiscal year 1987 operating plan of $10,547,000,000.

The Committee also has included $4,550,000 in S. 1164 for the activities of the Office of Commercial Space Transportation. This meets fully the request submitted by the Administration and compares with $1,245,000 in fiscal year 1987.

I.—RESEARCH AND DEVELOPMENT—$3,721,000,000

The Committee authorizes $3,721,000,000 for research and development activities in fiscal year 1988. This is $97.8 million greater than the President's fiscal year 1988 request.

The objectives of the National Aeronautics and Space Administration 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 development U.S./Italy 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 intersellar 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 achieved in NASA's research, technology, and development programs.

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 United States 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 improve tracking and data program capabilities.

Research and development budget summary

[In millions of dollars]

	Proposed fiscal year 1988 Senate authorization
I. Research and development	(3,721.0)
1. Space station	767.0
2. Space transportation capability development	592.6
3. Space science	973.7
A. Physics and astronomy	(591.8)
B. Life sciences	(74.6)
C. Planetary exploration	(307.3)
4. Space applications	651.4
A. Solid Earth observations	(80.8)
B. Environmental observations	(393.8)
C. Materials processing in space	(50.0)
D. Communications	(104.5)
E. Information systems	(22.3)
5. Commercial programs	49.0
6. Aeronautical research and technology	375.0
7. Transatmospheric research and technology	66.0
8. Space research and technology	212.0
9. Safety reliability and quality assurance	16.2
10. Tracking and data advanced systems	18.1

A. Space Station—$767,000,000

The Committee authorizes $767,000,000 for fiscal year 1988 for the Space Station program. This is the same as the President's fiscal year 1988 budget request.

Summary of fiscal year 1988 funding levels

Development	$733,000,000
Pressurized modules	(196,500,000)
Assembly hardware/subsystems	(204,000,000)
Platforms and servicing	(59,000,000)
Power system	(88,000,000)
Operations capability/utilization	(52,000,000)
Management and integration	(133,500,000)
Flight telerobotic system	22,00,000
Operations	7,000,000
Transition definition	5,00,000
Total space station	$767,000,000

The Space Station will provide a unique capability to enhance the Nation's space science and applications program and to further the commercial utilization of space while stimulating advanced technologies. Development of the U.S. permanently manned Space Station, as directed by President Reagan, will follow a deliberately paced program plan which will permit us to maintain the preeminence in space our Nation has attained through various manned and unmanned programs.

The U.S. Space Station will be a multi-purpose, national facility, providing a permanent human presence in space to conduct essential scientific and technical research, to support unique commercial activities, and to perform operational tasks more efficiently in space. International participation with the U.S. Space Station program has been encouraged by the President. Canada, member states of the European Space Agency (ESA), and Japan have responded enthusiastically. Memoranda of Understanding (MOU) for the definition and preliminary design phase were executed with Canada, ESA, and Japan in the Spring of 1985 concurrent with the initiation of the NASA definition contracts. These international partners have undertaken parallel definition and preliminary design studies to identify Space Station elements that each of them may consider for development. Negotiations for the development phase of the program are currently under way with our current international partners.

The Space Station will be designed to permit the system to evolve, as warranted, over time to provide greater user utility and operational capabilities. Its manned and unmanned elements will be designed to facilitate on-orbit maintainability/restorability, operational autonomy, human productivity, and simplified user interfaces. Implicit in these objectives is the recognized need to optimize man/machine systems in space via automation, robotics, and artificial intelligence technologies.

Based on President Reagan's announcement of April 3, 1987, the final decision on the cost configuration and schedule of the space station program will not be determined until after the NASA proposal is thoroughly reviewed by the National Research Council's (NRC) Committee on the Space Station, which is chaired by Robert Seamans. The Council's report is due on September 1, 1987, and the final proposal should be included in the fiscal year 1989 NASA budget request. The most recent NASA space station proposal would implement the program in two phases—Block I and Block II. Block I would commence in fiscal year 1988, and cost an estimated $12.2 billion (1984 constant dollars). Block II would commence in fiscal year 1991, and cost an estimated $3.8 billion (1984 constant dollars). The first space station hardware would be launched in March 1994, and the proposed U.S. space station would become permanently manned in the 1996 time frame.

The Station and its platforms will be placed and maintained in low-Earth orbit by the Space Transportation System, thereby building upon the previous national investment in space. However, the use of a heavy lift launch vehicle or advanced launch system for the space station is also under review by NASA.

The definition and preliminary design phase will continue through fiscal year 1987 and will provide the technical and programmatic plan for the Space Station development program, including the completion of the detailed definition and preliminary design, the analysis and integration of national and international user community requirements, and the advanced development of technology options. A continuing emphasis on user requirements and operations will be maintained as the engineering design evolves through subsystem advanced development and testing in dedicated test beds.

The fiscal year 1988 budget provides for the buildup of Space Station development activities initiated with funding approved in the fiscal year 1987 appropriation. The rate at which the buildup of these activities will occur will be somewhat reduced from last year's projection as a result of the configuration review and changes and the resulting delay of the request for proposals release. In addition to this effort, an in-depth assessment of the Space Station's management structure has been completed, and implementation of the recommendations is well under way. The key elements of the program are now baselined and ready to proceed.

The development phase will not be initiated until fiscal year 1988, although funds were provided to initiate these activities in fiscal year 1987. The development phase includes the prime contractor effort on the work packages, which will provide the major hardware components. Pending the outcome of on-going negotiations, supporting development activities such as the systems engineering and integration (SE&I), the program's Technical and Management Information System (TMIS) and Software Support Environment (SSE), and the evolvement of operational planning including user accommodations and interfaces could still be initiated in fiscal year 1987. Based on the current NASA Space Station Office schedule, the contract awards for the major hardware components should be awarded by November 1987. The TMIS, SE&I, and SSE contract awards are scheduled for the May-July 1987 time frame.

Space Station—Committee Comments

As an indication of the Committee's strong support of the development of a permanently manned space station, the Committee authorizes $767 million for the space station program, which is identical to the President's budget request. The Committee anticipates that by this Fall a final space station configuration will have been approved and these monies will be used to aggressively initiate Phase C/D of the program—the hardware/development phase.

Despite the Committee's strong support of the space station program, the Committee is concerned about the degree of confusion and lack of commitment that has become apparent within the Administration to develop a permanently manned space station. Recent events have unnecessarily caused a great deal of consternation and unacceptable delays in the U.S. space station program. At the same time key White House officials are debating whether or not to build a space station and the proposed cost, schedule, and configuration, the Soviets have a permanently manned space station that circles the globe every ninety minutes. The Committee believes that 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.

The Committee is optimistic that the National Research Council's review of the cost, schedule and configuration of the space station program will resolve the outstanding issues with only marginal changes to the NASA proposal and will help the Administration commit to a single, clearly defined concept. Once the concept has been agreed upon, the Committee hopes the Administration will manifest its commitment to the program with a commensurate request for resources in the fiscal year 1989 budget submission. The Committee is concerned that currently the only budgetary commitment the Administration has made to the space station program is for fiscal year 1988-90. This creates some uncertainty as to the degree of commitment to and scope of the program beyond fiscal year 1990.

This Committee has long supported a balanced space program and continues to see the space station as a critical element of that program. However, the Committee does not see the space station as an end in and of itself. Rather, it is a means to accomplish basic scientific goals and space research. The Committee, therefore, expects to see a sustained commitment to NASA's other research and development activities, especially space science and applications and aeronautics.

The Committee is strongly committed to the belief that the space station project should advance the state of technology—specifically, technologies that can be spun-off for ground-based applications or that improve the performance and economics of space-based activities. For this reason, the Committee has been most supportive of the space station advanced technology initiatives, in particular automation and robotics and the solar dynamic power system. Concerning the latter, the Committee instructs NASA to continue within available fiscal year 1988 funding the preliminary design activities for the development of solar dynamic power. In parallel with these activities, NASA is instructed to initiate the development of solar dynamic hardware that will permit this advanced technology to be incorporated into the space station program if the "full up" or "phased program" is agreed to in fiscal year 1989.

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 fiscal year 1988 bill which reaffirms this position. The same language was included in the fiscal years' 1985, 1986, and 1987 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 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.

The Committee recognizes that an important element of the international negotiations over the use of the space station is the issue of national security related activities. The Committee understands that the current negotiating record in this regard has been clearly established and that all utilization will be for peaceful purposes consistent with international law, including utilization for national security purposes.

The Committee is deeply concerned about the extent and degree of preceived interagency differences of opinion as to the character and role of the proposed space station. Final resolution of this issue is critical to the successful completion of international negotiations and to final Congressional approval of the space station program. The fact that the current space policymaking apparatus does not appear to have been able to resolve these interagency differences is cause for serious concern.

Finally, the Committee is concerned that nearly $150 million of fiscal year 1987 space station funding remains frozen pursuant to report language contained in the fiscal year 1987 HUD-Independent Agencies Appropriations Bill (H.R. 99-731). The Committee feels it is absolutely essential that NASA and the Appropriations Committees resolve this issue in a timely manner. These monies are required to initiate critical support, non-prime contracts in fiscal year 1987, including the Technical Management Information System (TMIS), the Software Support Environment (SSE), and the Program Support Contractor (PSC) that could substantially enhance the implementation of the space station program in fiscal year 1988. The Committee expects to the kept well informed of any development in this area and in any other area pertaining to the space station program.

B. SPACE TRANSPORTATION CAPABILITY DEVELOPMENT—$592,600,000

The Committee authorizes $592,600,000 for fiscal year 1988 for space transportation capability development. This is $24 million greater than the President's budget request in order to accommodate the launch of the Advanced Communications Technology Satellite (ACTS) in 1990. The President requested no funds in fiscal year 1988 for ACTS.

Summary of fiscal year 1988 funding levels

Spacelab	$73,500,000
Upper stages	181,700,000
Engineering and technical base	139,800,000
Payloads operations and support equipment	85,400,000
Advanced programs	24,900,000
Tethered satellite systems	7,300,000
Orbiting maneuvering vehicle	80,000,000
Total space transportation capability development	592,600,000

The principal areas of activity in Space Tranportation 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 of the Orbital Maneuvering Vehicle.

Spacelab is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The development program which has been carried out jointly by NASA and the European Space Agency (ESA) continues with the procurement of hardware for the Hitchhiker System, the Spacelab Pallet System, the Space Technology Experiment Platform and the lay-in of spares to support the flight program.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle 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 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.

The Payloads 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 the program area are the STS support service for NASA payloads, satellite servicing tools and techniques development, flight demonstrations and multi-mission payloads support equipment.

The Advanced Programs effort identifies potential future space initiatives and provides technical as well as programmatic data for their definition and evaluation. Activity is focused on six major areas: advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Advanced development activities are conducted to provide a basis for obtaining significant performance and reliability improvements and reducing future program risks and development costs through the effective use of new technology. Extensive studies are being conducted jointly with DOD on future launch vehicle requirements.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reusable capability for conducting space experiements 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 (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. The first scheduled operational use of OMV is the reboost of the Hubble Space Telescope scheduled for November 1991.

Spacelab

The fiscal year 1988 Spacelab development funds are required to complete the Hitchhiker and Space Technology Experiments Platform (STEP) programs, to complete the lay-in of both U.S. and European source spares, and to make the necessary hardware and GSE modifications and upgrades for return-to-flight recertifications as recommended by the Rogers Commission in preparation for reflight in 1989.

The fiscal year 1988 operations program reflects significant restructuring and rescheduling of Spacelab missions resulting from the *Challenger* accident. 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 the Materials Science Laboratory (MSL-3 and MSL-4) and two to three Hitchhiker systems in fiscal year 1989 and the first Spacelab Life Science Laboratory (SLS-1), the International Microgravity Laboratory (IML-1), MSL-5, and four Hitchhiker systems in fiscal year 1990. The support for these missions includes analytical integration, configuration management, hardware integration and software development and integration. Funding is also included to operate and maintain the SMFC and JSC Payload Operations Control Centers (POCC) required to support the Spacelab manifest. Spacelab operations also provide 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 fiscal year 1988 request also reflects significant program restructuring and rescheduling of Spacelab missions resulting from the standdown of the Shuttle. The current program provides for launching one to two major Spacelab missions per year beginning in 1989 as compared to three to four missions planned previously.

In addition to these NASA missions, Spacelab reimbursable missions are scheduled to support DOD, Germany (D-2) and Japan (J).

Upper stages

The STS upper stages are required to deploy Shuttle-launched payloads to orbits not attainable by the Shuttle 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 on the STS. Several other upper stages now being commercially developed, including the Transfer Orbit Stage (TOS), will become available for use with the STS.

Production and operations funds in fiscal year 1988 are required to continue production of three IUS's and one PAM-S vehicle to support the Galileo, Ulysses and Magellan missions, and upper stages for the Mars Observer, ACTS, TDRSS-E and TDRSS-F missions. Monitoring of the PAM-D, PAM-DII and TOS programs will continue. Funds are also required to support continuation of the solid rocket motor integrity program. Funding starts in fiscal year 1988 on four upper stages, three PAM-D class and one Apogee and Maneuvering Stage class, for the Global Geospace Science missions.

Engineering and Technical Base

The Engineering and Technical Base (ETB) provides the core capability required to sustain an engineering and development base for various NASA programs at the manned space flight centers. Additional center program support requirements above the core level are funded by the benefitting programs, such as Shuttle 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. The funding for center operations base support is split between the ETB and Shuttle Operations budget elements in accordance with the principle that ETB will provide the core level, and the benefitting program is responsible for funding additional support requirements. At KSC, due to its operational character, the core level provides for future studies and ground systems research and development. 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, including security.

Payload Operations and Support Equipment

The Payload Operations and Support Equipment objectives are to centralize the provisioning of payload services, both unique and common, which are required beyond the basic standard services for NASA missions, and to provide multi-mission support equipment in support of payload operations.

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. As a result of the *Challenger* accident and the decision to cancel the Centaur program for planetary launches, there have been major changes in payload integration requirements. Major NASA payloads receiving support during this year include Hubble Space Telescope, Galileo, Ulysses, Magellan, Astro, the Advanced Communications Technology Satellite, and Tracking and Data Relay Satellite (TDRS). The change to IUS upper stages for the planetary launches of Galileo, Ulysses and Magellan requires substantial new integration. The significant change in launch dates for all NASA payloads will require a thorough reassessment of the payload integration into the Shuttle. 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. These demonstrations will provide the experience necessary for realization of the Shuttle's potential for satellite servicing missions and on-orbit assembly functions.

Advanced Programs

Advanced Program's principal objectives are to conduct mission requirements analyses, conceptual system definition, detailed system definition, and advanced and supporting developments to acquire the technical and programmatic data for the evaluation of new space flight initiatives. Future space program and systems requirements, configurations, costs, and capabilities are identified to provide the basis for development decisions on new space flight systems.

The objective of efforts to be initiated in the advanced manned mission area will be the planning and analysis of potential follow-on programs to exploit the STS and the Space Station. Integrated program options involving low Earth orbit, geostationary orbit, lunar and planetary missions will be investigated, with the multi-year purpose to develop goals, planning information, and infrastructure requirements.

In fiscal year 1988, major emphasis will be placed on system concept definition and key advanced technology in crew systems, geostationary Earth orbital unmanned platforms, reusable orbital transfer vehicles (OTVs), new capability mission kits for orbital maneuvering vehicles, future tethered systems applications, satellite servicing systems near and remote from the orbiter, and second generation shuttles. A major goal continues to be the conceptual definition of the systems architecture and space elements needed for space operations over the next twenty years.

Tethered Satellite System

The development of a Tethered Satellite System (TSS) will provide a new reusable 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.

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.

Orbital Maneuvering Vehicle

The Orbital Maneuvering Vehicle (OMV) will provide a new STS reusable 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 spacebaseable reusable OMV, operating as far as 1,200 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 of satellite to original operational altitudes or higher; delivery of 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 OMB. The planned first flight for the OMV is late 1991.

Space Transportation Capability Development—Committee Comments

The Committee's authorization of $592.6 million for Space Transportation Capability Development is $24 million more than the President's budget request. This additional authorization represents an increase of $22 million for Upper Stages and $2 million for Payloads Operations and Support Equipment to procure and integrate a TOS upper stage for the Advanced Communications Technology Satellite which is scheduled to be launched in November 1990.

The Committee maintains its concern about the significant reduction in the space shuttle manifest of Spacelab missions—from twenty-eight missions through 1990 in the pre-*Challenger* manifest to eleven in the October 1986 manifest through 1994. Spacelab missions offer a unique laboratory environment for research and development activities and are important precursors to the space station. The Committee expects to be kept well-informed of any developments in this area and be apprised of any options that may be considered to compensate for any reductions in Spacelab capabilities.

Along this same line of concern, the Committee is intrigued by two concepts that could significantly enhance our Nation's short-term space capabilities and improve the prospects for our mid- and long-term policy goals. These two concepts are the Extended Duration Orbiter and the Industrial Space Facility (ISF); both of which are currently being analyzed for development by commercial entities.

The Committee wants to be sure that the United States is well prepared to take advantage of the unique opportunities which our Space Station will provide. Accordingly, the Committee favors interim measures to maintain a vigorous space science program and to obtain important flight experience that can contribute to the eventual success of the Space Station. For example, the Committee notes the recommendation from the Task Force on Scientific Uses of Space Station that "the use of free-flying, man-tended modules such as the Industrial Space Facility proposed for development by Space Industries, Inc. can provide an important, interim solution to having significant space research capabilities prior to Space Station operations."

The Committee also believes that the availability of a facility like the ISF could provide valuable flight experience prior to the construction and operation of the Space Station. The Committee urges NASA to consider and submit by November 1, 1987 a report on the ways in which such a facility could enhance U.S. space science and space station programs.

The Committee also would like NASA to reconsider the feasibility of extending the flight duration and capabilities of the orbiter. The Committee realizes the Extended Duration Orbiter (EDO) concept is not new; it has been intermittently studied by NASA since 1977. However, the events of January 1986 have significantly changed the results of prior evaluations that assumed robust shuttle flight rates (24 flights per year). The current reduction of the space shuttle flight rate has seriously reduced space science flight opportunities, and perhaps the time has come to shift the emphasis of the space shuttle program from flight rate to stay time. At the same time, the EDO, once perceived as a threat to the requirement for a permanently manned space station, now is seen as a potential aid in space station assembly and in reducing space shuttle support requirements.

The Committee, therefore, directs NASA to reassess the concept of an Extended Duration Orbiter and to report back by November 1, 1987 as to the feasibility, value, and cost of such a project. The Committee also directs NASA to assess and report back as to the feasibility of a commercial EDO venture along the lines of the proposal submitted by EFFORT, Inc.

Finally, the Committee requests that it be kept well-informed of the progress being made in (1) the Orbital Maneuvering Vehicle program and its availability to reboost the Hubble Space Telescope in 1991 and (2) the procurement and integration of upper stages for the three planetary programs—Galileo, Ulysses, and Magellan.

In the aftermath of the *Challenger* tragedy, there is renewed interest in the value and importance of the activities in the Space Transportation Capability Development Account. The Committee strongly supports these activities and believes they can greatly enhance the overall performance and capability of the civil space program.

C. SPACE SCIENCES—$973,700,000

The Committee authorizes $973,700,000 for Space Sciences—Physics and Astronomy, Life Sciences and Planetary Exploration—for fiscal year 1988. This is $24.7 million greater than the President's fiscal year 1988 budget request in order to accommodate more robust Explorer and suborbital programs. Of this amount, $591,800,000 is for Physics and Astronomy, $74,600,000 is for Life Sciences, and $307,300,000 is for Planetary Exploration.

1. PHYSICS AND ASTRONOMY—$591,800,000

Summary of fiscal year 1988 funding for physics and astronomy

Hubble Space Telescope	$98,400,000
Gamma Ray Observatory	49,100,000
Spacelab/Space Station payload development	95,400,000
Explorer development	80,300,000
Mission operation and data analysis	128,100,000
Research and analysis	60,100,00
Suborbital program	80,400,000
Total for physics and astronomy	591,800,000

The objectives of the Physics and Astronomy program are to increase understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. The objects under study include the most distant clusters and galaxies, stars and structures in nearby galaxies, and the interstellar medium in our galaxy. The most unusual and exotic phenomena exhibited as quasars, black holes, neutron stars, and pulsars are of particular interest. We also include our own Sun, with its multitude of time varying phenomena at all scales of special resolution. Spece research allows observations in wavelength regions, such as the infrared, ultraviolet, or x-rays and gamma-rays, which are absorbed by the Earth's atmosphere, or in the visible region, where ground based work is limited by atmospheric distorting effects. We also couple these observations to those of cosmic ray particles, which have their origin in energetic acceleration processes occurring in sites such as solar flares and supernovae.

The objectives of the program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights, retrievable Spartans, and suborbital opportunities. The latter include balloons, aircraft, and sounding rocket flights. In the future, the Space Station will provide an opportunity for both attached payloads and major free-flying observatories requiring assembly, maintenance, and refurbishment on-orbit. 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 will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the board 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. 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. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The Hubble Space Telescope design will permit on-orbit maintenance and repair, and/or retrieval by the Space Shuttle for return to Earth for required refurbishment and then relaunch by the Space Shuttle.

The FY 1988 funding level is required to maintain the irreplaceable skilled experts who have hands-on experience with the spacecraft. During fiscal year 1988, the HST Program will be performing additional safety and spacecraft review work as a consequence of the shuttle accident, as well as returning to the program manning levels needed to support pre-ship functional testing of the HST system, transporting the spacecraft to Kennedy Space Center, and conducting launch preparations and operations at KSC.

Gamma Ray Observatory development

The Gamm Ray Observatory (GRO) has as its objective the measurement of 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.

In fiscal year 1987, instrument calibration and testing will continue. Assembly of the spacecraft structure will be completed, electronic manufacturing will continue, and all government furnished property subsystems for GRO will be delivered.

Fiscal year 1988 funding is required for completion of the spacecraft modal survey and static load testing. In addition, the fabrication and testing of the spacecraft attitude control and power system electronics will be completed. The development of the GRO mission operations and data systems will be continued, 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.

Spacelab/Space Station Payload Development and Mission Management

A primary objective of the Spacelab Payload Development and Mission Management program is to develop instruments used for Shuttle/space flight investigations in the disciplines of physics and astronomy on board the Space Shuttle or Spacelab carriers. These science payloads include sounding rocket class experiments for flight on the Space Shuttle.

A second objective 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 new focus includes the study definition of integration and operational requirements of potential Space Station payloads and missions, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Another major objective is to manage the mission planning, integration, and execution of all NASA Spacelab and attached 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; data dissemination to experimenters; and initial analysis of flight data from physics and astronomy science payloads. Similar mission management activities will be carried out for Space Station payloads as they enter the development phase and interface requirements become well defined.

Mission management of ongoing Spacelab missions will continue in fiscal year 1988. For non-physics and astronomy missions, such as the Spacelab Life Sciences missions (SLS) and the International Microgravity Lab (IML), this includes all Spacelab efforts except instrument development and data analysis. Development of instruments will continue for the Space Plasma Lab as well as for the Shuttle High Energy Astrophysics Lab. For the Astro-l mission, final integration and test activities will resume in preparation for a planned flight in early 1989. Fiscal year 1988 funding will support the continued development of low-cost sounding rocket class payloads which will be flown on the Space Shuttle to provide more flight opportunities for the science community.

In addition, fiscal year 1988 funding is required to continue ongoing Space Station payload development and planning activities. Fiscal year 1988 funding will support continued early definition, design and development activities for payloads selected for early Space Station flights. Other planning activities will address concerns or issues that typically cut across OSSA disciplines and will include continued science operations concept development, information systems concept and architecture studies, servicing studies, platform utilization studies as well as other special systems engineering and integration support studies.

Explorer development

Investigations selected for Explorers are usually of an exploratory or survey nature, or have focused 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 Giacobinni-Zinner, and completed the first high sensitivity, all sky survey in the infrared, discovering over 300,000 sources.

Solar terrestrial and atmospheric Explorers provide a means for conducting studies of the Earth's near space environment. The International Sun Earth Explorer (ISEE-1977), International Cometary Explorer (ICE-1978), Dynamics Explorer (DE-1981), and Advanced Magnetic Particle Trace Experiment (AMPTE-1984), have provided data on plasmas and fields, near the Earth and throughout the interplanetary medium.

Astrophysics Explorers have been the principal means for conducting the first sky surveys in the gamma ray, x-ray, ultraviolet, infrared, and low frequency radio regions of the electromagnetic spectrum. The IUE (1978) is still operating and has shown that our galaxy has an extended hot halo, that the local interstellar medium is much more transparent and less homogeneous than expected, and determined the spectra of hundreds of hot stars which are losing mass. The IRAS (1983), in nearly a year of operation, performed a complete sky survey over the 10–100 micron region, locating over 300,000 sources.

In fiscal year 1986, a new cooperative mission called Solar-A (formerly High Energy Solar Mission, HESP) 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 be the first simultaneous observations of these phenomena from space.

In fiscal year 1987, 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. Funding in fiscal year 1987 will be used to continue development and testing of the three COBE instruments and to redesign the COBE spacecraft to fit on the Delta vehicle.

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 in-depth studies on selected objects. The United States will provide one of the ROSAT instruments and the launch services; Germany will provide the spacecraft, telescope, and other instruments. Although ROSAT is currently manifested for a 1994 Shuttle launch, a possible launch on an expendable launch vehicle in late 1989 or early 1990 is also under consideration.

Definition and design will continue in fiscal year 1987 on the X-ray Timing Explorer. This mission, the last currently planned major effort in the Explorer line, can be ready for launch as early as 1993. During fiscal year 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over 43 were received, and these will be evaluated in fiscal year 1987, but selection for further study will depend on the availability of future launch opportunities for the Explorer program.

During fiscal year 1988, the reconstruction, integration and test of the COBE spacecraft structure and its instruments will be completed, and the spacecraft will begin pre-launch preparations. The major activity will be on the EUVE development. Activities on ROSAT and the development of the U.S. instrument for the Japanese Solar-A will also continue.

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 solar terrestrial operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering supported activities, are typically carried out under a variety of mission support or center support contracts.

The fiscal year 1988 funding level is required to maintain critical skills for the operation and maintenance of the Hubble Space Telescope and to prepare for launch activities currently scheduled for the first quarter of fiscal year 1989.

Mission operations, data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM) and the International Ultraviolet Explorer (IUE). Funding will also continue for the High Energy Astronomical Observatories (HEAO 1-3), and the Infrared Astronomy Satellite (IRAS) data analysis. These programs have produced valuable data sets which are used by a wide segment of the astronomy community.

Research and analysis

This 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 supporting research and technology (SR&T) funding will provide for continuation of definition work on Gravity Probe-B. 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.

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.

Candidate missions for the 1980s and early 1990s that require advanced technology development activities include the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). The AXAF mission, which is the first priority new mission recommendation in astronomy by the National Academy of Sciences, will study stellar structure and evolution, active galaxies, clusters of galaxies and cosmology.

During fiscal year 1988, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for a viable physics and astronomy program. Fiscal year 1988 funding will also support continued studies on potential candidate missions such as the Advanced X-Ray Astrophysics Facility and the Space Infrared Telescope Facility. In the data analysis activities to be carried out at university and government research centers in fiscal year 1988, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). The Gravity Probe-B activities in fiscal year 1988 are designed to verify the entire GP-B design, leading to confidence in the information necessary to decide the feasibility of progressing into the next phase of design and development activities.

Suborbital programs

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 on an international cooperative basis.

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.

Forty-four sounding rockets are currently scheduled for launch in fiscal year 1987. Included in this number are eight NASA launches in Greenland as a follow-up to the fiscal year 1985 effort. Of significant interest in fiscal year 1986 were two rocket launches to observe Halley's Comet which were recovered, field refurbished, and reflown for a total of four flights. These flights produced some of the data originally planned to be obtained from the Astro-1 Shuttle flight which was postponed as a result of the 51-L accident. An equivalent number of flights is scheduled for fiscal year 1988.

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 Airborne Science and Applications program also operates an ER-2, two U-2Cs, and a C-130. In addition, an aircraft has been acquired to replace the CV-990 research facility, "Galileo II," which was destroyed in 1985. The replacement, A DC-8, is undergoing modifications and is expected to be ready for science operations in late 1987. Acquisition of a second ER-2, to replace the aging U-2Cs is under way. These aircraft support other major segments of the Space Science and Applications programs dealing with the Earth, the oceans, and the atmosphere.

The Balloon Program 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.

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.

The Spartan missions involve low-cost Shuttle payloads flown as autonomous sub-satellites which are deployed and retrieved by the Space Shuttle. Six Spartan missions are currently under development, each with a different scientific instrument.

Fiscal year 1988 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 for potential long-duration balloon flights. In fiscal year 1988, the Airborne Science and Applications funding will be used to continue flights of the Kuiper Airborne Observatory. Requested fiscal year 1988 funding will allow operation of the DC-8, the ER-2s, and the C-130. Operation of these aircraft will allow continuation af airborne infrared astronomy exploration, collection and analysis of stratospheric air samples, testing of newly developed instrumentation, and the demonstration of new sensor concepts.

Physics and Astronomy—Committee Comments

The Committee authorizes $591.8 million for Physics and Astronomy in fiscal year 1988. This increase of $24.7 million, compared to the President's budget request, is to augment Explorer Development (+$20 million) and the Suborbital Program (+$4.7 million).

The events of the last year have not done much to improve the status of NASA's Physics and Astronomy Programs. The Hubble Space Telescope (HST) and the Gamma Ray Observatory (GRO) are still grounded and based on the October 1986 Shuttle manifest, are not scheduled for launch until November 1988 and January 1990, respectively, and the Spartan program is being redesignated and rescoped. Meanwhile, the next great observatory scheduled to attain new start status, the Advanced X-Ray Astrophysics Facility (AXAF), was not included in the President's fiscal year 1988 budget request nor was the High Resolution Solar Optical Telescope, which is the only new start space science program directly associated with the space station program.

As can be seen in the following table, the space shuttle *Challenger* tragedy has adversely affected the Physics and Astronomy payload launch schedule.

PHYSICS AND ASTRONOMY PAYLOAD LAUNCH DELAYS [1]

Payload	Preaccident launch date	Current launch date	Delay (in months)
Astro-1	Mar. 6, 1986	Jan. 19, 1989	34
Hubble Space Telescope	October 1986	Nov. 17, 1988	25
Environmental observation mission	Oct. 27, 1986	Unscheduled	
Astro-2	Jan. 12, 1987	do	
Shuttle High Energy Astro Physics Laboratory	do	4th quarter 1993	82
Spartan-2	Jan. 27, 1987	2d quarter 1991	52
Space Life Sciences Laboratory	Mar. 16, 1987	Dec. 7, 1988	33
Spartan-3	Aug. 4, 1987	2d quarter 1992	57
Astro-3	Aug. 18, 1987	Unscheduled	
Rosat	Sept. 28, 1987	1st quarter 1994	77
Spartan-205	Nov. 9, 1987	Unscheduled	

PHYSICS AND ASTRONOMY PAYLOAD LAUNCH DELAYS [1]—Continued

Payload	Preaccident launch date	Current launch date	Delay (in months)
Gamma Ray Observatory	June 8, 1988	Jan. 18, 1990	19
Spartan-211	June 14, 1988	Unscheduled	
Cosmic background explorer	July 15, 1988	do	

[1] Astronomy and physics payloads were also to have flown on some of the 10 materials science labs listed on the November 1985 manifest.

Source: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986

In light of these serious problems, the Committee has taken three steps that it hopes will correct some of these deficiencies in a cost effective manner.

First, it has augmented the Explorer Program by $20 million to promote additional low cost, high return space science missions. These funds should permit NASA to initiate evaluation of the 43 pending proposals and to start development of additional space science missions.

Second, the Committee has increased funding for the Suborbital program by $4.7 million to provide additional flight opportunities for space scientists and graduate researchers. The Committee is deeply committed to our university space science programs and is hopeful these augmentations will assist these programs during the space shuttle hiatus.

Finally, the Committee has initiated a new line item in the NASA Space Flight, Control and Data Communications appropriations account entitled "Expendable Launch Vehicle (ELV) Operations." This new entry is to initiate procurement of ELVs, pursuant to a NASA/DOD quid pro quo or launch services agreements with commercial vendors, to launch NASA payloads. The Committee feels this initiative should greatly assist the Physics and Astonomy Program which has several candidates for ELVs.

Despite these actions, the Committee remains concerned about the overall health and well-being of the space science community. The number of prestigious institutions and advisory committees issuing reports about the crisis in space science is troublesome to the Committee. The Committee, therefore, intends to hold hearings this Summer and Fall on the long-term policy goals and budgetary requirements of NASA and the ability of NASA to balance its research and development mission with its operational programs.

Meanwhile, the Committee expects to be kept well informed of any technical concerns, schedule changes, or additional cost requirements for the Hubble Space Telescope or Gamma Ray Observatory Programs and to be well advised by the Physics and Astronomy Program Office of developments in the space station program that impact this area of space science.

The Committee also expects NASA to down-select to one contractor for the Advanced X-Ray Astrophysics Facility in fiscal year 1988 in order to better position the program for Phase C/D development activities and to take advantage of any potential economies.

In recognition of the severe strain the current "standdown" period has inflicted on the space science community, the Committee has fully authorized NASA's fiscal year 1988 Physics and Astronomy research and analysis and mission operations and data analysis budget requests. The Committee notes the importance of the university space research programs to our national space infrastructure and believes that these university space research programs should continue to perform productive and meaningful research during this period.

2. LIFE SCIENCES—$74,600,000

The Committee authorizes $74,600,000 for Life Sciences in fiscal year 1988. This is the same as the President's budget request.

Summary of fiscal year 1988 funding for life sciences

Life sciences flight experiments	$32,900,000
Research and analysis	41,700,000
Total for life sciences	74,600,000

The goals of the Life Sciences program are to provide a sound scientific, medical, and technical basis for safe and effective manned space flight and to advance the understanding of the basic mechanisms of biological process by using the unique capabilities of the space program. Results from the research program are applied to: the immediate needs in the maintenance and health of the astronauts; understanding biological mechanism and the response of biological systems to weightlessness; the design of the advanced life support systems for use on future missions; and understanding the biosphere of the planet Earth, as well as the origin, evolution, and distribution of life in the universe.

The Life Sciences program is the key to developing a capability to sustain a permanent manned presence in space and to utilize the space environment to study living systems. These activities include both ground-based and space research efforts which are mutually supportive and integrated, and use a composite of disciplines and techniques in both biology and medicine to address space-related medical problems and fundamental biological processes.

The Life Sciences research and analysis program includes five major elements; (1) space medicine; (2) advanced life support systems; (3) gravitational biology; (4) exobiology research; and (5) biospheric research.

The goals of the Space Medicine program are to assure space crew members' health and ability to function effectively in the space environment.

The Advanced Life Support System program seeks ways to develop technologies for more efficient life support systems for the space program.

The goals of the Gravitational Biology program are to further our understanding of basic physiological mechanisms and the effects of microgravity on plants and animals through the use of the space environment.

The Exobiology efforts are concentrated on studies of life's origin, with particular emphasis on developing sounds hypotheses which could lead to discovering the relationships which may link the formation of the solar system and the origin of life.

The Biospherics Research Program seeks to utilize NASA technology in remote sensing, combined with ground-based research and mathematical modeling, to study the biosphere (the thin layer around the planet that contains all of terrestrial life).

Life Sciences Flight Experiments

The objective of the life Sciences Flight Experiments program is to assimilate information and scientific questions from the various life sciences disciplines and translate them into payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation to weightlessness. The program includes selection, defintion, inflight execution, data analysis, and reporting on medical and biological investigations involving humans, animals and plants. Past experience indicates that humans clearly undergo physiological changes in weightlessness. Thus far these changes appear to be reversible upon return to Earth; however, many of the observed changes are physiologically significant and are not well understood. With weightless exposure beyond several months, these chagnes may prove irreversible. Shuttle/Spacelab missions are suitable for gaining a greater understanding of the early response to weightlessness, which will improve the management of several existing problems (e.g., space adaptation syndrome) and will enhance the confidence of estimating the physiological consequences of more sustained weightless exposure (e.g. Space Station).

Fiscal year 1988 funding is required for the final preparation and flight of approved experiments and the continued definition and development of new experiments and hardware that will be flown on future Spacelab/Shuttle missions—i.e., Shuttle middecks, Japanese-J mission, the second dedicated life sciences mission (SLS-2), German D-2 mission, IML-2, and SLS-3. The selection of new experiments through the Announcement of Opportunity (AO) process is continuing. In addition, increasing activities are planned to support the development of Space Station Life Sciences experiments.

Research and analysis

The research and analysis activity of the Life Sciences program is concerned with ground-base and pre-flight research in basic biology and in those medical problem areas that affect manned spaceflight.

In fiscal year 1988, the Space Medicine program will collect information on occupational exposure in zero-gravity on each Shuttle flight and conduct inflight clinical testing of countermeasures, especially in the areas of cardiovascular deconditioning, vestibular problems and muscle atrophy. The program will also develop health care procedures, equipment, and facilities compatible with the space environment. At the same time, problems associated with the initial adaptation to weightlessness, such as vestibular dysfunction and fluid shifts, will continue to be vigorously investigated. Furthermore, increased emphasis will be placed on radiation biology so that it will be possible to precisely measure dosages and effects of cosmic and solar radiation. This information will be required to determine the proper radiation shielding of humans in space. The performance and efficiency of flight crews will be emphasized by research in psychology and human factors.

Life Sciences—Committee Comments

The Committee authorizes $74.6 million, the President's budget request, for Life Sciences for fiscal year 1988.

The Committee continues to maintain its belief that the level of support for the NASA Life Sciences Programs is not commensurate with our Nation's desire to establish a permanent presence in space and to pursue long duration missions to other planetary bodies.

As the space station program progresses and leadership initiatives are evaluated, it is essential that the Life Sciences program assume a higher priority. The Committee, therefore, expects to see increased support of these activities in future budget submissions.

3. PLANETARY EXPLORATION—$307,300,000

The Committee authorizes $307,300,000 for planetary Exploration in fiscal year 1988. This is the same as the President's budget request.

Summary of fiscal year 1988 funding for planetary exploration

Galileo development	$55,300,000
Magellan	59,600,000
Ulysses	10,800,000
Mars observer	29,300,000
Mission operations and data analysis	77,000,000
Research and analysis	75,300,000
Total planetary exploration	307,300,000

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteriods, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means of 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 been adopted calls for a balanced emphasis of 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 charcterization of the bodies and then proceed to levels of more detailed study.

Both the Galileo orbiter/probe mission to Jupiter and the Ulysses mission to the Sun had been ready for launch in May 1986 on the Space Shuttle/Centaur Upper Stage. The *Challenger* accident in January 1986 forced a postponement of these launches, and subsequent cancellation of the Centaur launch stage resulted in further re-evaluations of these missions. The Magellan mission was also adjusted to accommodate a one-year launch delay caused by the *Challenger* accident and cancellation of the original Centaur upper stage.

According to a plan recently agreed to by NASA and ESA, Galileo will be launched in October 1989, and Ulysses will be launched in October 1990. Despite the fact Ulysses will be launched one year after Galileo, it will arrive at its destined location in 1984, one year before Galileo enters the Jovian system.

Magellan, formerly the Venus Radar Mapper mission, will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Magellan now is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer will follow up on earlier discoveries of Mariner 9, and Viking and will be launched on the Shuttle in 1992.

Beginning in later 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.

The Planetary Exploration program is also founded on a coordinated 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.

Galileo development

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.

Current plans call for the orbiter and probe to be launched together in the time frame 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. When the orbiter arrives at Jupiter in 1995, it will provide remote sensing of the proble 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 surface and the dynamic magnetosphere will be comprehensively mapped. During this time, ten close flybys of Jupiter's major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG) 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.

Fiscal year 1988 funds will provide for completion of the reassembly, integration and initial testing of the reintegrated spacecraft system. Modification of the flight software and mission operations system will be continued.

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 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 of about 150 meters.

In fiscal year 1988, the flight model of the radar instrument will be delivered for integration with the spacecraft and environmental testing will be initiated for the entire system. Integration of the mission operations system will be completed to be followed by initiation of operations testing and training preparatory for launch.

Ulysses

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.

Because of the *Challenger* accident and subsequent cancellation of the Centaur upper stage, the Ulysses launch is currently planned for October 1990.

Fiscal year 1988 funding will provide for completion of the documentation of the new spacecraft/launch vehicle interface, launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments.

Mars Observer missions

The Mars Observer mission is the first in a series of planetary missions utilizing a new low-cost approach to inner solar system mission exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well-defined and focused science objective and makes use of high-inheritance, modified production-line Earth-orbital spacecraft. The objective of the Mars Observer mission is 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 characterize their interaction with the Martian environment.

The limitation on the number of launch opportunities through 1990 and the further restrictions placed on scheduling by the 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 using the Space Shuttle 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.

The fiscal year 1988 funding required to initiate instrument hardware fabrication and assembly and to maintain a minimum level of support in spacecraft and ground operations subsystem developments.

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, telemetery, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now traveling through the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continued 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. The observatory phase of this encounter, which began in November 1985, included 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 will continue to explore the outmost 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 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.

Fiscal year funding is required for the continued operation and data analysis activities in support of the Voyager and Pioneer missions. Development activities will also be continued in fiscal year 1988 on the Space Flight Operations Center (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 rational 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 to Halley's Comet.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, and instrument definition.

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 explorations has been developed by the Solar System Exploration Committee (SSEC), and advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system.

The Mars Data Analysis activity continues to ensure that we capitalize on the wealth of data provided by Viking and earlier missions and that we are scientifically prepared for the next phase of Mars exploration. While continuing to support a variety of scientific investigations, the major emphasis of this program will address the origin and evolution of Martian volatiles.

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 1985-86 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.

The fiscal year 1988 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 fiscal year 1988 funding is also required to continue operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

Planetary Exploration—Committee Comments

The Committee authorizes $307.3 million for Planetary Exploration for fiscal year 1988, the President's budget request, but the Committee is concerned that there will be additional requirements in fiscal year 1988 as a result of the significant launch delays in the Planetary Exploration Program. The Committee feels that the currently manifested planetary missions are of the highest priority and should be treated accordingly in order to minimize the degree of post-*Challenger* stress in the science community.

As noted in "The Crisis in Space and Earth Science",

> Even before the *Challenger* accident, and the resulting hiatus in the space program, it was becoming clear that the nature of the Space and Earth Science Program was changing and that major stresses were developing as a result of those changes. Within the scientific community there was growing sense of unease and frustration over the program's diminishing pace. As the result of a number of trends, it appeared that a major transition as taking place in the nature of the Space and Earth Science Program, but it seemed that this transition was occurring more by accident than as a matter of conscious policy. Decisions were being made that had long-term consequences on ways the program would be conducted, but the consequences of those decisions were largely unexamined. More and more missions were being identified as candidates for "New Starts" at a time when prospects for New Starts were becoming uncertain. . . .

In the post-*Challenger* environment, the situation has worsened. As highlighted by the following table included in the recent Congressional Budget Office report entitled, "The 1988 Budget and the Future of NASA," major space science payloads manifested to fly on the space shuttle have been significantly delayed, and these delays also have significantly added to the projected costs of these missions.

PLANETARY MISSION LAUNCH DELAYS

Mission	Preaccident launch date	Current launch date	Delay (in months)
Ulysses	May 15, 1986	Oct 5, 1990	53
Galileo	May 20, 1986	Nov. 1, 1989	41
Magellan (Venus radar mapper)	Apr. 6, 1988	Apr 25, 1989	13
Mars observer	August 1990	4th quarter 1992	27

Source: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986

Besides further squeezing out any potential "new starts," these delays have adversely affected the scientific teams and the scientific community. Worse yet, 33 space science missions on the pre-*Challenger* space shuttle manifest have been completely off-loaded with no designation of an alternative launch vehicle.

It is in this predicament that the Committee discovers NASA's space science programs, and it is this predicament that the Committee must attempt to ameliorate. Therefore, the Committee has exempted the entire space science and space applications portion of the budget from any reductions and in some cases has been able to add funds.

Despite these setbacks, the Committee's commitment to a robust space science program, including planetary exploration, is as strong as ever, as is its resolve to provide expendable launch vehicles to help fly these critical space science missions.

The Committee is pleased that after months of negotiations, the U.S. and the European Space Agency (ESA) have finally agreed on the launch of Galileo Mission in October 1989, and the launch of Ulysses Mission in October 1990. These two planetary missions, originally scheduled to be launched in May 1986, are critical elements of the restoration of the U.S. planetary program.

The Committee also is hopeful the Magellan Mission, formerly the Venus Radar Mapper Program, will remain on schedule and be launched on the space shuttle in April 1989 (Magellan will be the first U.S. planetary mission since the Voyager was launched in 1978). The Committee is concerned that there will be additional fiscal year 1988 budget requirements for the Magellan Mission. The Committee expects to be notified immediately if such requirements surface so that they can be addressed expeditiously and effectively.

As for the Mars Observer Mission, the Committee has thoroughly reviewed the 1990 and 1992 launch options and has decided to budget for a 1992 launch date. While there are many factors in favor of a 1990 date, the Committee is reluctant to try and force a 1990 launch and feels that a 1992 mission presents fewer risks and fewer schedule pressures.

In recognition of the severe strain the current "standdown" period has inflicted on the space science community, the Committee has fully authorized NASA's fiscal year 1988 Planetary Exploration research and analysis and mission operations and data analysis budget requests. The Committee notes the importance of the university space research programs to our national space infrastructure and believes that these university space research programs should continue to perform productive and meaningful research during this period.

D. Space Applications—$651,400,000

The Committee authorizes $651,400,000 for Space Applications—Solid Earth Observations, Environmental Observations, Materials Processing in Space, Communications and Information Systems—in fiscal year 1988. This is $92.1 million greater than the President's budget request. This increase is required to accommodate the launch of the Advanced Communications Technology Satellite in 1990.

Of this amount, $80.8 million is for Solid Earth Observations, $393.8 million is for Environmental Observations, $50 million is for Materials Processing, $104.5 million is for Communications, and $22.3 million is for Information Systems.

1. SOLID EARTH OBSERVATIONS—$80,800,000

The Committee authorizes $80,800,000 for Solid Earth Observations in fiscal year 1988. This represents a $4.0 million augmentation to the President's budget request, to establish a national capability for receiving directly from foreign remote sensing satellites data collected over the United States.

Summary of fiscal year 1988 funding levels

Shuttle/Spacelab payloads	$21,100,000
Geodynamics	33,100,000
Research and analysis	26,600,000
Total solid Earth observations	$80,800,000

The objectives of the Solid Earth Observation 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.

Specific land surface objectives include determination of the terrestrial landscape including the biosphere and the hydrosphere and understanding the changes and change mechanisms that are occurring within that landscape. Studies of the cycling of key biogèochemical elements, interactions between the biosphere and the climatic system, and the composition and evolution of crustal rock systems 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 required precise measurements of crustsal movements and Earth orientation over an extended period along with accurate knowledge of the variability of the Earth's geopotential fields.

The objective of the Shuttle/Spacelab payload development project is to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data for solid Earth Observations research.

Fiscal year 1988 funding for Shuttle/Spacelab payload development is required for continued development of SIR-C technology and for advanced spectrometer activities including the development of the Shuttle Imaging Spectrometer Experiment.

In fiscal year 1988, measurements of plate motion between North America and Europe will be continued in cooperation with NOAA and several European countries. Measurements of the motions of the Pacific Plate will also be continued in cooperation with DOD and Japan and will be extended to include China. In addition, regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. Similar measurements will be initiated in Europe in cooperation with a consortium of 10 European, North African, and Mid-East countries. The Caribbean studies will be continued in fiscal year 1987 and are expected to involve some eight countries in 1988.

Finally, in fiscal year 1988 emphasis will continue on investigations of the Earth's systems which are undergoing stress in order to better understand the processes which control such systems.

Activities will also emphasize studies to determine continental rock type and erosion processes in semi-arid regions in sedimentary basins. Sensor systems such as the Advanced Visible-Infrared Imaging Spectrometer, quad-polarization L- & C-Band imaging radar and the Thermal Visible-Infrared Imaging Spectrometer will be used in these investigations and will serve as prototypes for Shuttle instruments now under development and for future Space Station polar platform instruments. The Thematic Mapper or the operational Landsat will continue to serve as the focal instrument for multidisciplinary investigations, with particular emphasis on the tectonic structure of continental highlands.

Solid Earth Observations—Committee Comments

The Committee authorizes $80.8 million for Solid Earth Observations for fiscal year 1988. This is $4 million more than the President's budget request.

The Committee believes that there is compelling scientific need to increase U.S. access to and utilization of multiple sources of satellite remotely sensed data. For this reason, the Committee has augmented NASA's authorization level for its Solid Earth Observations, Research and Analysis program by $4 million. This reflects the Committee's desire to ensure that the United States develops a capability for the reception of data from current and future operating remote sensing satellites from multiple sources, the reduction of these data for research and development purposes, and the archiving of these data. NASA, in cooperation with the U.S. Geological Survey, the National Oceanographic and Atmospheric Administration and other appropriate federal agencies, should endeavor to establish capabilities for receiving directly from foreign remote sensing satellites data collected over the United States.

During the past 15 years, the United States has developed and implemented unparalleled capabilities in civil satellite land remote sensing through experimental and operational programs that have led to the recognition of the United States as the world's technological leader in space remote sensing. As the science and technology of satellite remote sensing have evolved, and as important interdisciplinary scientific applications of the data have been developed and implemented, a growing recognition has begun to evolve that this country's capabilities in satellite land remote sensing represent an important national asset.

In the decades ahead, civil satellite land remote sensing will take on even greater importance as a unique source of basic, world-wide information critical to the ultimate success of many of the currently emerging programs on global change. This increased importance of satellite remotely sensed land data and related technology comes at a time when uncertainties surround the future of the United States' Landsat program and place in jeopardy this country's ability to independently meet our own scientific requirements for global satellite remotely sensed data.

However, opportunities exist to minimize the effects of a possible gap in U.S. capabilities through important and beneficial programs of international cooperation with countries such as France, Japan, India, Indonesia, Canada, Brazil, the European Space Agency and others that have launched or soon will launch earth remote sensing satellites. They will acquire global data sets capable of meeting many of our future requirements for scientific information needed to conduct studies and programs of global change and global monitoring.

NASA, working in cooperation with other appropriate federal agencies, is directed to study and initiate implementation of a global land processes information system to include capabilities and facilities to receive (or otherwise obtain), process, and make available data from foreign land remote sensing satellite systems and other appropriate data required for land processes and earth science research and global monitoring programs by federal agencies with responsibility in those areas.

Further, NASA should implement complementary cooperative programs of remote sensing research and development aimed at fully extracting and exploiting the information contained in the data acquired by these various satellite systems, particularly for the purpose of advancing capabilities important to emerging and growing requirements to study and monitor global change.

2. ENVIRONMENTAL OBSERVATIONS—$393,800,000

The Committee authorizes $393,800,000 for Environmental Observations in fiscal year 1988. This is the same as the President's budget request.

Summary of fiscal year 1988 funding for environmental observations

Upper atmosphere research and analysis	$34,400,000
Atmospheric dynamics and radiation research and analysis	32,900,000
Oceanic processes research and analysis	21,500,000
Space physics/research and analysis	21,500,000
Payload and instrument development	19,400,000
Extended mission operations	26,800,000
Interdisciplinary research and analysis	1,100,000
Tethered satellite payloads	3,100,000
Scatterometer	22,700,000
Upper atmosphere research satellite mission	95,400,000
Ocean topography experiment	90,000,000
Global geospace science	25,000,000
Total Environmental Observations	393,800,000

The objectives of the Environmental Observations program are to improve our understanding of the processes in the magnetosphere, 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, plasma acceleration, and dynamic processes occurring in the magnetosphere, 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; improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction; and enabling a comprehensive understanding of solar terrestrial processes and a detailed determination of the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

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.

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.

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.

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 have been 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 model. In fiscal year 1988, 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 fiscal year 1988 to aid in the understanding of large-scale atmospheric processes.

The comparison of ballon, aircraft, and ground-based measurements will be continued in fiscal year 1988 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 fiscal year 1988 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 dynamical processes that are causing this phenomenon, the Upper Atmospheric Research Program is planning a major aircraft mission in late fiscal year 1987—early fiscal year 1988 using the NASA ER-s and DC-8. Analysis and interpretation of the results of this mission will be a critical effort in fiscal year 1988.

Atmospheric dynamics and radiation research and analysis

The research and analysis activities within the Atmospheric Dynamics and Radiation program comprise a core effort which is fundamental to using space technology to solve problems in atmospheric science. The program's three main thrusts are in the areas of global scale tropospheric processes research, mesocale processes research 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 meteorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively.

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 over local to regional size scales (severe weather, such as tornadoes and hurricanes).

The Climate Research Program seeks to develop a space capability for global observations of climate parameters which will contribute to our understanding of the processes that influence climate and its predictability. Research is focused in accordance with the National Climate Program priorities wherein NASA has the role of lead agency for solar and Earth radiation research.

A significant research effort on developing the capability to observe rainfall from space has been initiated. This includes studies of instrumentation, sampling requirements, algorithm development and modeling to determine the feasibility of remotely sensing rainfall from space.

Fiscal year 1988 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in 3-dimensions. Analysis of the data collected in interagency field experiments during fiscal years 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.

Oceanic Processes Research and Analysis

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and applications 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. As such, the program operates in concert with a variety of federal agencies (e.g., Navy, NOAA, NSF) and foreign countries (e.g., Canada, Europe, Japan).

The Oceanic Processes R&A program is actively pursuing scientific research with other federal agencies and foreign countries 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 Flux Experiment (GFE), and a Program for International Polar Oceans Research (PIPOR).

In fiscal year 1988, the physical oceanography research activities will include implementation planning for WOCE and TOGA, as well as the development of numerical models and associated data assimilation techniques for use in determining the general circulation of the oceans. In biological oceanography, the analysis of data from Nimbus-7 will be continued in order to estimate global ocean productivity, as well as to help with the conceptual design of the Global Flux Experiment. 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 in Alaska of SAR data from the European Space Agency's ERS-1 and from the Japanese JERS-1 spacecraft due for launch in the 1989-91 time frame.

Advanced technology development activities also will be continued on prospective future sensors for flight aboard both the Shuttle and free-flying spacecraft.

Space physics research and analysis

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.

During fiscal year 1988, the space physics research and analysis activities will be continued with particular emphasis on the analysis of data obtained from the 1986 Polar Region and Outer Magnetosphere International Study (PROMIS) campaign and from the International Cometary Explorer (ICE) which collected unique data in the Earth's distant magnetotail before going on to an encounter with the comet Giacobini-Zinner in September 1985. Definition studies will be conducted during fiscal year 1988 for advanced missions such as the follow-on for the United States-Italian Tethered Satellite System, which will investigate atmospheric and electrodynamics effects, a solar proble mission to study the unexplored region between four and sixty radii from the Sun, and Space Station Payloads including the Solar Terrestrial Observatory.

The solar terrestrial theory program will be continued during fiscal year 1988. In addition, a comprehensive and quantitative aggregate model of solar-terrestrial interactions will continue to be developed.

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.

Fiscal year 1988 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 initial flight of the Atmosphere Trace Molecules Observed by Specstroscopy (ATMOS) instrument was completed in 1985, with greater than expected science results. The fiscal year 1988 funding is required to support the ground observation program of ATMOS as well as continued science team activities, data processing and analysis, and limited refurbishments.

Fiscal year 1988 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.

Development activities will continue on the international (U.S. and French) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of conceptual definition, breadboard laboratory activities, and preliminary design reviews for this multi-phase user program.

In fiscal year 1988, the Collaborative Solar Terrestrial Research Program (COSTR) will continue development of U.S.-provided instruments for the ISAS/NASA GEOTAIL Mission. NASA also will begin development of U.S.-provided instruments and mission support equipment for the ESA/NASA joint CLUSTER and SOHO missions.

Extended mission operations

The objectives 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.

The Solar Mesosphere Explorer (SME,) launched in October 1981, is providing major input to our overall atmospheric parameter data base. SME is producing simultaneous measurements needed to understand the complex chemical processes taking place in the mesosphere, including data measurements of ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties. A ground truth program to aid in the validation of the SME data is also being undertaken. SME is providing excellent data on the effect of volcanoes on the Earth's atmosphere.

Solar terrestrial research activities rely on data received from the International Sun-Earth Explorers, (ISEE-1 & 2), the Interplanetary Monitoring Platform (IMP), the Active Magnetospheric Particle Trace Explorer (AMPTE), and the Dynamics Explorers (DE) which are still operational. 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 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).

Fiscal year 1988 funding is required to support continuing mission operations and data analysis activities for the International Sun-Earth Explorers, the Interplanetary Monitoring Platform, the Dynamics Explorer, International Cometary Explorer, and the Active Magnetospheric Particle Trace Explorer. 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.

In addition, fiscal year 1988 funding is required for operating the Earth Radiation Budget Satellite (ERBS) spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE-II instrument on ERBS.

Interdisciplinary research

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.

In fiscal year 1988, 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.

Tethered Satellite Payloads

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 TSS will allow unique science to be undertaken such as observations of atmospheric processes occurring within the lower thermosphere (below 180 km altitude), observations of crustal geomagnetic phenomena, and direct observation of magnetospheric-ionospheric-atmospheric coupling processes in the 125-180 kilometer region.

The TSS is an international cooperative project with the Italian government. The United States is developing the tether deployment and retrieval system and is responsible for overall project management and system integration, development and integration of the 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. An Announcement of Opportunity for investigations was issued in April 1984. Selection of investigators was completed in late 1985, and instrument design initiated in 1986.

The fiscal year 1988 funding is required to continue development of U.S.-provided instruments on TSS-1 and core equipment development and integration.

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 1990-91 will provide an overlap of data gathering with the World Ocean Circulation Experiment, Tropical Ocean-Global Atmosphere Experiment planned by the international oceanographic community; and additionally, concurrent flight with the Ocean Topography Experiment (TOPEX) would result in unique measurements of the oceans' driving force (winds) and the resulting ocean response (topography).

Pursuant to a recent decision by the Secretary of the Navy, the Scatterometer will be flown on the Navy Remote Ocean Sensing System (N-ROSS) satellite in late 1990. This is a reversal of the position taken in the fiscal year 1988 DOD budget request that would have terminated the N-ROSS program and forced the Scatterometer to fly on an alternative spacecraft.

Planned fiscal year 1988 activities will include the continuation of hardware development leading to testing and integration of the Scatterometer Flight Model, delivery of the second computer system and beginning of its testing, and continued refinement of post-launch research and verification plans.

Upper Atmosphere Research Satellite Program

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.

The fiscal year 1988 funds are required for continuation of the development of the ten UARS instruments including flight hardware fabrication, instrument assembly and environmental testing leading to instrument delivery to the spacecraft in 1989. In addition, the spacecraft development and hardware fabrication activities will continue.

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 hardward 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, fiscal year 1988 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. 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.

On March 23, 1987, NASA and the French Space Agency (CNES) signed a Memorandum of Understanding (MOU) to collaborate on TOPEX in order to more fully exploit the scientific value of the data. Under the terms of the MOU, NASA will provide a spacecraft bus and several instruments including a radar altimeter, a microwave radiometer, and tracking systems whereas the French will provide a French altimeter and tracking system and will launch TOPEX in late 1991 usiong 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 within 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.

In fiscal year 1988, preliminary design of the satellite and ground data systems will be well under way. Sensor development will continue through the Critical Design Review phase leading to the initiation of fabrication by late fiscal year 1988. At the same time, the science team will be refining their research plans and will assist in design options as they relate to achieving scientific success with TOPEX.

Global Geospace Science

The Global Geospace Science (GGS) is proposed as a fiscal year 1988 new initiative and 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.

The GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program initiated in fiscal year 1987 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 would be greatly enhanced by the addition of the two spacecraft proposed in the GGS program. The combined program would include five spacecraft missions: two U.S. spacecraft, WIND and POLAR; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, GEOTAIL. NASA will launch and provide upper stages for all spacecraft except SOHO. ESA will provide for launch and associated costs for SOHO. Initiation of GGS in fiscal year 1988 will move the U.S. from a supporting to a leadership role in this international cooperative program.

The Global Geospace Science (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.

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

Fiscal year 1988 funds are required to initiate development of GGS spacecraft instruments and ground system. Fiscal year 1988 funding will allow initiation of these effects in time to take advantage of simultaneous measurements provided by the Collaborative Solar Terrestrial Research (COSTR) program and other solar-terrestrial research efforts.

Environmental Observations—Committee Comments

The Committee authorizes $393.8 million for Environmental Observations for fiscal year 1988. This is the same as the President's budget request.

The Committee was pleased to be informed that on March 23, 1987, NASA and the French Space Agency (CNES) signed a Memorandum of Understanding to collaborate on the Ocean Topography Experiment (TOPEX). This cooperative venture should enhance the standing of the United States in the international community and assist our understanding of global ocean dynamics. TOPEX is scheduled to be launched in late 1991 on a French Ariane vehicle.

The Committee also was pleased to see the Upper Atmosphere Research Satellite (UARS) on the October 1986 space shuttle manifest for the 4th quarter of 1991. Although this mission has been delayed two years by the *Challenger* disaster, there is still a great deal of support on the Committee for the UARS mission since it will provide the first integrated global measurements of ozone concentration and chemical species that affect ozone.

The recent reinstatement of the Navy Remote Ocean Sensing System (N-ROSS) by the Secretary of the Navy has been well received by the Committee. NASA has been developing the scatterometer to fly on N-ROSS. The flight of both the N-ROSS Mission and the TOPEX Mission simultaneously will significantly enhance the scientific return from these missions.

Finally, the Committee has fully authorized the fiscal year 1988 NASA budget request for the Global Geospace Science (GGS) proposal—the only "new start" included in the President's budget request. The GGS proposal is an international, multi-spacecraft mission designed to improve the understanding of the interaction between the Sun and the Earth. Approval of this proposal by the Committee should permit the United States to maintain its leadership in solar terrestrial physics.

3. MATERIALS PROCESSING IN SPACE—$50,000,000

The Committee authorizes $50,000,000 for Materials Processing in Space in fiscal year 1988. This is $4.1 million greater than the President's budget request.

The Materials Processing in Space program emphasizes the science and technology of processing materials to understand constraints imposed by gravitational forces and unique capabilities made possible by controlling these processes in the space environment. Ground-based research, technology development, and payload definition activities in fiscal year 1988 are being concentrated on six major processing areas: metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. These activities will provide the scientific basis for future space applications of materials processing technology as well as provide a better understanding of how these processes occur on the ground. Definition studies will be performed for Shuttle and Space Station experiment candidates in areas such as containerless experiments, combustion science, solidification and crystal growth, and blood storage.

The Microgravity Shuttle/Space Station payloads budget supports a consolidation of ongoing activities which provide a range of experimental capabilities for all scientific and commercial participants in the Microgravity Science and Applications program. These include Shuttle mid-deck experiments, the Materials Experiment Assembly and the Materials Science Laboratory, which is carried in the orbiter bay.

In fiscal year 1988, 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.

Fiscal year 1988 funding also is required to continue basic and applied research activities using mid-deck and cargo bay experiments leading to several flights over the next few years. Investigations will be planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will begin on a number of Physics and Chemistry Experiments (PACE) as well as continued development of several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metallic casting, and levitation.

Funding will also support definition activity for Space Station hardware development.

MATERIALS PROCESSING IN SPACE—COMMITTEE COMMENTS

The Committee authorizes $50 million for Materials Processing in Space in fiscal year 1988. The increase of $4.1 million above the President's budget request is to accommodate additional hardware/instrumentation development activities that will better position the program when space shuttle flights resume.

The Committee is most supportive of NASA's materials processing activities and believes that the long-term returns from this program will be substantial. The Committee is concerned, therefore, with the Findings and Consequences of the Interim Dunbar Report that point to possible erosion of the microgravity science community, inadequate preparedness for space station, and the loss of international competitive advantage. The Committee expects NASA to seriously review this report and its recommendations and to initiate corrective actions as soon as possible.

The Committee also expects to be kept well informed of any developments in the Centers of Excellence Program. The Committee is sensitive to the effect of the loss of flight opportunities on the Centers' activities. However, these Centers of Excellence are expected to yield significant breakthroughs and establish foundations for more sophisticated research in space, and, therefore, NASA is expected to maintain the highest standards for this program.

4. COMMUNICATONS—$104,500,000

The Committee authorizes $104,500,000 for Communications for fiscal year 1988. This is $84 million greater than the President's budget request to accommodate the launch of the Advanced Communications Technology Satellite in 1990.

Summary of Funding for Fiscal Year 1988

Advanced commications technology satellite (ACTS)	$84,000,000
Research and analysis	14,400,000
Search and rescue	1,300,000
Technical consultation and support studies	3,400,000
Experiment coordination and operations support	1,400,000
Total Communications	104,500,000

The Communications Research and Analysis program 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 utilization, satellite switching, and intersatellite link technologies, 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 at the end of the decade.

Advanced Communications Technology Satellite

The objective of NASA's Advanced Communications Technology Satellite (ACTS) Program is to prove the feasibility of certain advanced communications technologies through a flight test program.

The specific technologies to be validated include: (a) the use of multiple fixed and scanning spot antenna beams; (b) frequency reuse; (c) beam interconnectivity at both intermediate frequencies and at baseband; (d) advanced system network concepts; and (e) dynamic rain-compensation techniques. These technologies will apply to a wide range of communications systems in the 1990s. A contract was signed in August 1984 to develop the flight and ground hardware.

The ACTS spacecraft is scheduled to be launched in 1990 from the shuttle into geostationary orbit. The spacecraft will consist of a commercial communications package, including a multibeam antenna, baseband processor, RF matrix switch, traveling wave tube amplifier, and low noise receiver. The ground segment will consist of a NASA ground station and a master control station. Following launch and checkout, a 2-year program of user-funded experiments will be initiated during which time ACTS system technologies will be tested, evaluated, and validated. To date, over 80 organizations, including DOD, have requested consideration for over 118 experiment opportunities on ACTS.

Research and analysis

The Communications Research and Analysis 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 on-board switching, intersatellite links, and antennas, as well as advanced radio frequency (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.

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.

During fiscal year 1988, advanced studies and selected technology development will continue in the high risk areas of microwave and optical technology, satellite switching, RF systems, and intersatellite links. Work in these technology areas will support U.S. industry, NASA, and other government agencies and address national economic and security interests.

In fiscal year 1988 all prototype components for the mobile communications technology experiment will be completed, and field testing of the full mobile terminal will begin.

Search and Rescue

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 Search and Rescue satellite system has met all specifications and was declared operational in July 1985. The system has received world-wide acclaim and has been credited with saving over 675 lives to date. In addition, the system is demonstrating the potential to save millions of dollars annually in search logistics costs.

In fiscal year 1988, an experiment using geostationary satellites for instant alert will be completed and the results analyzed. Work to improve cost and performance of emergency beacons will continue.

Technical consultation and support studies

Technical consultation and support 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.

In fiscal year 1988, work will be completed on the geostationary orbit arc allotment planning method, and support will continue for the second session of the Space World Adminstrative Radio Conference. Studies will continue for the purpose of identifying techniques to increase the efficient use of the limited orbit/spectrum resources and to understand and alleviate the adverse effects of propagation phenomena on space communications.

Experiment coordination and operations support

The objectives of this program 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-3, continues to support the National Science Foundation, the National Oceanic and Atmospheric 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.

In fiscal year 1988, operational support for ATS-3 will continue. NASA will maintain approval and policy control of the ATS program. NASA will continue planning support for educational, scientific, and public service communications experiments for organizations within the Western Hemisphere, and will support similar experimental activities of Pacific basin organizations within the footprint of the ATS-3 coverage.

COMMUNICATIONS—COMMITTEE COMMENTS

The Committee authorizes $104.5 million for Communications for fiscal year 1988 including $84 million for the Advanced Communications Technology Satellite (ACTS) that is scheduled for launch in November, 1990.

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 for NASA.

The Committee finds that the Office of Management and Budget justification for the exclusion of any funding request for ACTS in fiscal year 1988 is without merit. The Committee expects funding for the ACTS program to be included in the fiscal year 1989 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 and to have the satellite ready for launch in 1990—which is one to two years prior to the expected launch of competing foreign experimental satellites.

5. INFORMATION SYSTEMS—$22,300,000

The Committee authorizes $22,300,000 for Information Systems for fiscal year 1988. This is the same as the President's budget request.

The objectives of the Information Systems program are to: develop and demonstrate advanced capabilities of managing; distributing, and processing data and information; implement information system standards and provide common software in order to lower data system costs; and develop the basis for data services to provide improved access to, and rapid delivery of, space data and advanced data systems in support of the nation's satellite programs and space science and applications projects.

The fiscal year 1988 Information Systems funding is required to provide support for space science and applications programs. Funds are required: to continue development of planetary, Earth resources, and astrophysics data systems projects which are being implemented at the Jet Propulsion Laboratory, the Goddard Space Flight Center, and participating academic institutions; to continue implementation of on-line data directories and catalogs; to operate the large-scale computers in the Space and Earth Sciences Computing Center (SESCC) and the archives at the National Space Science Data Center (NSSDC) (both facilities located at the Goddard Space Flight Center); to develop common software to support ongoing research in the space and Earth sciences; and to continue development of data management and data archiving to support flight projects, discipline program offices, and other NASA program offices. The FY 1988 funding levels will also provide the university/research community with improved access to NASA computational facilities and data archives by expanding network communications links, by increasing online data storage capacities, and by developing standards for data and protocols.

Information Systems—Committee Comments

The Committee authorizes $22.3 million for Information Systems in fiscal year 1988. 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.

E. COMMERCIAL PROGRAMS—$49,000,000

The Committee authorizes $49,000,000 for Commercial Programs in fiscal year 1988. This is a reduction of $5 million from the President's budget request.

Summary of funding for fiscal year 1988

Technology utilization	$18,300,000
Commercial use of space	30,700,000
Total commercial programs	49,000,000

Technology Utilization

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 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 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 non-aerospace 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 to *NASA Tech Briefs* which now exceeds 130,000 readers. This 60 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 20 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 fiscal year 1987 and on into fiscal year 1988.

An additional milestone was reached in late 1986 when the Federal Laboratory Consortium (FLC) for Technology Transfer (formerly established under P.L. 99-502) and NASA elected to enter into an agreement which establishes formal linkages between the NASA IAC network and the various Federal laboratories. Based on the successful completion of an experimental program between the NASA 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 paralled commercial interest. This effort should spur and accelerate the process for the transfer and application of federally sponsored technologies into the mainstream of the U.S. economy.

Commercial Use of Space

The goal of the Commercial Use of Space Program is to provide a national focus in support of the expansion of U.S. private sector investment and involvement in civil space activities, while emphasizing new high technology commercial space ventures and promoting the development of new markets for civil space services. 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, and radiation for commercial purposes.

Facilitate private sector space activities through improved access to available NASA capabilities.

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.

In order to maintain momentum in commercial use of space activities, NASA will continue to establish Centers for the Commercial Development of Space (CCDS). Institutions with strong research capabilities in sciences and engineering, in collaboration with industy and/or industrial associations, will be encouraged to participate. The Centers are joint undertakings involving, to the extent practicable, teams of industrial corporations and/or government agencies (other than NASA) and/or non-profit institutions. Resources support and technical assistance will be partially furnished by NASA with the remainder furnished by the Center members.

In fiscal year 1985, NASA provided partial funding to establish five Centers for the Commercial Development of Space. In fiscal year 1986, NASA funded four additional Centers for a total of nine CCDS in operation. Awards are planned for fiscal year 1987 and fiscal year 1988 for an eventual total of up to 18 Centers simultaneously operating. NASA's individual CCDS funding is planned for five years in order to stimulate and stabilize the Center's activities. Nevertheless, NASA's support, on a year-to-year basis, will depend on a favorable annual review of the Centers' progress in stimulating commercial use of space. There is a mandatory requirement for industry participation in each Center, including the expenditure of corporate resources. NASA support will be reduced and finally discontinued at the end of five years as the successful Centers achieve self-sufficiency.

NASA's goal of expending 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, 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 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. Emphasis is placed on building the required technical infrastucture. The main thrust of the effort will be directed by the private sector in coordination with NASA. Resources will also be made available to obtain flight support experimentation hardware required by industrial researchers.

Commercial Programs—Committee Comments

The Committee authorizes $49.0 million for Commercial Programs for fiscal year 1988. This includes $18.3 million for Technology Utilization and $30.7 million for the Commercial Use of Space. This is $5 million less than the President's budget request which represents a general reduction to Commercial Use of Space to be made at the discretion of the Administrator.

The NASA Technology Utilization Program was created to ensure that technology developed for NASA aerospace research could be transferred to other areas. One of the areas in which technology transfers has been successful is in adapting aerospace technology to meet the unique needs of individuals with physical disabilities. This has resulted in advancement in voice controlled wheelchairs, communication aids, and prosthestic devices, etc., which have allowed individuals with physical disabilities to have greater access to education, employment, housing and recreation resulting in greater independence and productivity for these individuals.

The Committee, therefore, directs NASA's Technology Utilization Program to place additional emphasis on its projects and activities in applying technology to meet the needs of individuals with disabilities in the areas of employment, education, housing and recreation, as well as the dissemination of information on such technology transfers to persons and organizations involved with disabilities. In addition, the Committee directs NASA's Technology Utilization Program to report back to Congress within 180 days on what they are currently doing nationally in applied technologies with regard to employment, education, and housing, as well as how they are disseminating information on such technology transfers.

The Committee continues to support the Commercial Use of Space Programs and the establishment of Centers for the Commercial Development of Space. Yet, the Committee is concerned about the effect that the grounding of the space shuttle and the current unavailability of flight opportunities could have on the program/project plans of the Centers. Consequently, it might even be necessary to extend the original financial commitment that NASA made to those Centers beyond three years.

In light of these developments, the Committee recommends that NASA perform a mid-course reassessment of the program's goals, objectives, funding requirements, and flight opportunities prior to the solicitation for additional Centers in fiscal year 1988.

The Committee is most supportive of the Office of Commercial Programs' efforts to build multi-use, multi-user government hardware that will reduce individual entrepreneur experiment costs to a level that can be afforded. The Committee supports full funding of these activities in fiscal year 1988 and believes the availability of this hardware will substantially increase interest in the program and broaden the base of participation to entrepreneurs and small non-aerospace firms.

F. Aeronautics and Space Technology—$375,000,000

The Committee authorizes $375,000,000 in fiscal year 1988 for Aeronautics and Space Technology. This is the same as the President's budget request.

Summary of fiscal year 1988 funding levels

Research and technology base	$285,200,000
Systems technology programs	89,800,000
Total Aeronautics and Space Technology	375,000,000

The goal of the NASA aeronautical research and technology program is to conduct effective and productive aeronautical research and to develop technology which contributes materially to the enduring preeminence of U.S. civil and military aviation. This goal is supported by five comprehensive program objectives: (1) identify and concentrate on those emerging technologies with potential for order-of-magnitude advances in aircraft capability and performance that will enhance U.S. industrial competitiveness; (2) sustain the excellence of NASA's research centers by modernizing and enhancing the efficiency of national facilities, advancing scientific and engineering computational capabilities, and enhancing staff technical excellence by selecting highly qualified personnel and providing them with challenging career opportunities; (3) ensure timely and efficient transition of research results to the U.S. aerospace community through reports, conferences, workshops, and active participation of industry in contractual and cooperative 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 DOD, other government agencies, and U.S. industry for major aeronautical programs.

1. Research and Technology Base—$285,200,000

The Committee has authorized $285,200,000 for fiscal year 1988 for Research and Technology Base. This is the same as the President's budget request.

Summary of fiscal year 1988 funding levels

Fluid and thermal physics research and technology	$29,000,000
Applied aerodynamics research and technology	61,000,000
Propulsion and power research and technology	41,000,000
Materials and structures research and technology	42,000,000
Information sciences research and technology	26,000,000
Controls and guidance research and technology	27,600,000
Human factors research and technology	26,000,000
Flight systems research and technology	26,100,000
Systems analysis	6,500,000
Total research and technology base	285,200,000

Fluid and thermal physics research and technology

The fluid and thermal physics research and technology program is a combined analytical and experimental research effort directed at external aerodynamics.

A principal objective is the development of computational methods to enhance the ability to predict and simulate aerodynamics flow fields for complete aircraft or missile configurations in any flight condition.

In fiscal year 1988, the fluid and thermal physics program will focus upon 3-D configuration analysis and design. Particular focus will be given to validating Navier-Stokes prediction codes.

Applied aerodynamics research and technology

The objective of applied aerodynamics research is to generate advanced technology to improve the performance and flight dynamics of future aircraft and missiles through analytical and experimental programs.

This effort is directed at specific technology goals in all classes of aircraft: subsonic, rotorcraft, short takeoff and vertical landing (STOL), supersonic and hypersonic.

In fiscal year 1988, activites will focus upon subsonic and rotocraft technologies including reduced drag, laminar flow wings and uncoventional configurations. Additional work will be performed in the supersonic and hypersonic areas.

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 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 performed on a wide variety of subsystems with applications ranging from the general aviation class through hypersonic/aerospace planes.

Major emphasis will be in the hypersonic/supersonic cruise areas and in further development of fuel-efficient propulsion systems.

In 1988, activities will focus upon the development of the analytical and experimental data base for supersonic combustion and Mach 3-6 high speed cruise systems, as well as all other propulsion-related areas.

Materials and structures research and technology

The objectives of the materials and structures research and techonololgy program are to: (1) investigate 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, and economy in aircraft.

The development of high temperature, higher reliability ceramic materials for use in engines has produced significant results. Other research into composites, aeroelasticity and hypersonics has also been fruitful.

In fiscal year 1988, research on materials will concentrate on advancing the understanding of material behavior, properties, microstructures, and processing paramenters for advanced metallic, ceramic, polymer, and composite materials. In the structures area, emphasis will be placed on development of innovative structural concepts for composites using advanced filament winding and pultrusion, as well as design concepts using high-temperature brittle materials.

Information sciences research and technology

The objectives of the information sciences research and technology program are to increase NASA's capabilities in advanced aerospace computing and to exploit key computer science disciplines to meet the agency's unique computing requirements. Support for computational fluid dynamics (CFD) and other aerospace research disciplines is provided by developing a fundamental understanding of the relationships between essential algorithms and advanced architectures and exploting the potential of concurrent processing to singificantly increase computing power.

In fiscal year 1988, research in matching computer architectures and algorithms will continue to serve NASA's needs for efficient processing of aerospace algorithms. Investigations of the most advanced supercoputers, such as the Cray 2, and their use for computational fluid dynamics research and similar problems will continue.

Controls and guidance research and technology

The objectives of the controls and guidance research and technology program are to: (1) investigate emerging controls, guidance, artificial intelligence, and display technologies which offer automation/system integration for aviation effectiveness and efficiency; (2) develop architectures for flight-crucial systems for future aircraft and devise analytical methods and techniques for assessing their reliability and performance; (3) develop methods to alleviate the threat of wind shear and heavy rain though airborne detection and avoidance; (4) develop advanced controls and guidance theories and analysis methods for extending the performance envelope and reliability of highly augmented future aircraft; and (5) explore new concepts for achieving integration of multidisciplinary technologies.

In fiscal year 1988, a key goal is to develop robust control algorithms which are resistant to vehicle or environment uncertainties. Additionally, nonlinear modeling and system identification methods are being developed to support high angle-of-attack controls requirements. In the flight-crucial systems area, research will stress validation techniques, assessment technology, software reliability, lightning effects, and advanced architectures.

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. This is necessary for safety, efficiency, and increased capability in transcentury rotorcraft and transports and, ultimately, in the National Aerospace Plane.

In fiscal year 1988, research will continue in the areas of pilot error in operational aviation environments, as well as in cockpit design and automation.

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.

Major thrusts of this program are flight safety, flight instrumentation, and flight support.

In fiscal year 1988, the aviation safety program will emphasize coordinated wind tunnel and analytical investigations of ice accretion and its effects on fixed- and rotary-wing aircraft performance and handling qualities. Research to establish a flight-validated severe storms and lightning effects data base will be completed and the results reported to the FAA and industry. Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft.

Systems analysis

The objective of the systems analysis effort is 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, and provide potential economic benefits. Systems analysis studies of subsonic aircraft, which include general aviation, commuter, and transport aircraft, concentrate on the impact of very advanced materials and structures for propulsion systems on a 150-passenger class of transports powered by advanced turboprops and on a 500-passenger class of transports powered by turbofans.

In fiscal year 1988, rotorcraft efforts will assess the impact of advanced technologies on high-speed tilt rotor configurations and X-wing concepts. The high-speed civil transportation studies will also continue through fiscal year 1988. Systems studies for advanced high-performance aircraft will focus on new capabilities enabled by key technology developments in high thrust-to-weight ratio propulsion, propulsive control, and systems integration.

2. SYSTEMS TECHNOLOGY PROGRAM—$89,800,000

The Committee has authorized $89,800,000 for fiscal year 1988 for Systems Technology Programs. This is the same as the President's budget request.

Summary of Fiscal Year 1988 funding levels

Rotocraft systems technology	$5,000,000
High-performance aircraft systems technology	14,600,000
Advanced propulsion systems technology	30,500,000
Numerical aerodynamic simulation	39,700,000
Total Systems Technology Program	89,800,000

Rotocraft systems technology

The rotorcraft systems technology program consists of research conducted on two fronts. The first element focuses on advanced technology applicable to the broad class of rotorcraft, with a present focus on reducing noise and vibration and increasing the performance of helicopters. The second element consists of research leading to new, enabling rotorcarft concepts with vastly greater capabilities, such as triple the speed, range, and altitude of current generation helicopters.

In fiscal year 1988, the NASA/American Helicopter Society (AHS) cooperative industry noise research program will conclude with the release of the operational version of the comprehensive noise prediction code called ROTONET. A task of this program will be a design exercise for a low noise rotor with practical operational limitations with a view toward validating improvements in the technology. An effort will also be accelerated to gather a modern data base on rotor airloads with comprehensive measurement of pressures, structural shears, pilot control activity, and acoustics.

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.

A particular focus of the program has been the turbine engine hot section technology (HOST) program.

In fiscal year 1988, the flight research activity will involve a variety of high-performance aircraft to investigate advanced concepts. Several projects will continue their flight phases during this period. The turbine engine hot section technology element and the ceramics for turbine engines element have been combined and augmented to form the advanced high-temperature engine materials program in the Advanced Propulsion Systems Technology program. The programs were combined to focus the efforts on developing fundamental technology for revolutionary advances in high-temperature materials for advanced propulsion systems and will be reported under advanced propulsion systems technology.

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 the general aviation and commuter engine technology program, will the objective of raising the performance level of small turbine engines to more nearly match that of large engines, the work continues to be focused on providing fundamental experimental data to obtain a detailed understanding of the design parameters that affect component performance as size is reduced.

In fiscal year 1988, advanced turboprop systems research will emphasize source noise, cabin environment, turboprop installation aerodynamics, and the development of advanced aerodynamic and structural analysis techniques for both single- and counter-rotation propellers. Advanced high-temperature engine materials research will develop fundamental technology to enable very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life hot section components.

Numerical Aerodynamic Simulation

The Numerical Aerodynamic Simulation (NAS) program objective is to significantly augment the native's capabilities in computational fluid dynamics and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. This program will provide the computational capabilities required to obtain solutions to problems which are currently intractable. Ongoing research and technology base efforts in computational aerodynamics will benefit significantly from the advanced computational capabilities to be provided by the NAS program.

Fiscal year 1988 will be an important year in the development of the NAS system. The second high-speed processor (HSP-2), which will be four to six times more powerful than HSP-1, will be installed and integrated into the NAS system. NAS operations support funding has been consolidated in the NAS program from the Research and Technology Base. This consolidation of funding simplifies management and reporting of NAS progress.

Aeronautics Research and Technology—Committee Comments

The Committee authorizes $375 million for Aeronautics Research and Technology in fiscal year 1988. This is the same as the President's budget request.

In 1987, the Aeronautical Policy Review Committee issued its second report entitled "National Aeronautical R&D Goals, Agenda for Achievement." This report recognized the considerable importance the aeronautics sector has to the balance of trade and to the overall competitive position of the United States in world markets, a position that is strongly endorsed by this Committee. The aerospace trade surplus in 1986 was almost $12 billion, but there are signs that this sector of the economy is facing serious and sustained threats from other nations, such as Japan, the European Economic Community (EEC),Brazil, Indonesia, and others. The report states, for example, that in 1986, for the first time in our history, high technology imports exceeded exports.

The Committee has long recognized the relationship between NASA's aeronautics research and development program and our national economic and defense security. The United States has long been the world leader in aeronautical technology development, and we must maintain this lead. To do so, we must continue the successful government-industry partnership that has successfully identified the opportunities, provided the advanced technologies, and made possible the industry we enjoy today. In that same tradition, it is expected that the studies on long-distance, high-speed transports, recently initiated by NASA with the aeronautics industry, may confirm this area as one of the most important unexploited opportunities for leadership in world civil aviation markets at the turn of the century and beyond. These studies should be applauded and supported because they could lay a foundation upon which the United States establishes new technological and market leadership.

The recent history of funding for the aeronautics R&D program has not reflected the full importance of the program. Overall, funding for aeronautics research and development has declined 25 percent in the last decade. This trend is disturbing, since this program offers a tremendous economic benefit to this country. The two major categories of funding within the area, the Research and Technology Base and the Systems Technology program reveal an even more unsettling narrowing of emphasis in aeronautics. The R&T Base, which funds the research and innovations that produce new concepts and designs is at an adequate level—the important basic seed work is being done. The Systems Technology programs, however, have been reduced 70 percent in the same time period. It is this category of programs which identify the concepts from the R&T programs and, in cooperation with industry, take the first step along the path to transform these concepts into commerically viable applications. These programs, which are generally high risk in nature and the most costly part of the R&T chain because they often require large-scale hardware, ensure that the products of the basic R&T programs at NASA don't simply end up on the shelf somewhere, but are introduced into the commerical markets to help keep our industry a world leader.

In preparation of its fiscal year 1989 budget request, the Committee requests that NASA review these perceived trends in the Systems Technology programs and initiate corrective measures. At the same time, NASA is directed to prepare a multi-year technology development validation plan that will help the United States retain its leadership in aeronautics research and technology and compete in the international marketplace for future civil aircraft. This plan shall be prepared in cooperation with private industry and shall be designed to assure continued U.S. leadership in future civil aircraft markets. This Plan should be submitted to the committee by March 1, 1988.

G. Transatmospheric Research and Technology—$66,000,000

The Committee authorizes $66,000,000 for Transatmospheric Research and Technology for fiscal year 1988. This is the same as the President's budget request.

The National Aerospace Plane (NASP) program is a joint effort between NASA and the Department of Defense to accelerate the development of critical enabling techologies for this 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 low-cost access to space.

For fiscal year 1988, ongoing activities in the National Aerospace Plane program include technology development in subsonic, supersonic, and hypersonic hydrogen-fueled propulsion technology; advanced high-temperature materials and lightweight, high-strength, thermal structural concepts; and computational fluid dynamics, which remain the three critical technologies for all transatmospheric vehicle applications. The engine and airframe contracted efforts will be supported by an extensive focused technology effort at NASA centers (Ames, Langley and Lewis) and other government laboratories. Work will continue on development of, and manufacturing technology for, lightweight, high-temperature advanced materials. For example, processing techniques for fabricating ceramic matrix composite panels will be demonstrated. Tests will be conducted on subscale component integration models of scramjet concepts over the speed range of Mach 3.5 to Mach 8.

Transatmospheric Research and Technology—Committee Comments

The National Aerospace Plane 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 program—airbreathing 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/DOD 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.

Recognizing the value of this fundamental research and development program, the Committee authorizes the Administration's full request of $66 million in fiscal year 1988 for the NASA portion of the program.

H. Space Research and Technology—$212,000,000

The Committee authorizes $212,000,000 for fiscal year 1988 for Space Research and Technology. This is $38,000,000 less than the President's budget request. However, pursuant to the approach taken in H.R. 1827 (S. Report 100-48), the fiscal year 1987 Supplemental Appropriations Bill, for the development of an Advanced Launch System, the Committee assumes that NASA will be reimbursed by DOD to carry out the propulsion technologies activities associated with the Committee reduction.

Summary of funding for fiscal year 1988

Research and technology base	$115,900,000
Systems technology programs	0
Civil Space Technology Initiative (CSTI) Program	96,100,000
Total Space Research and Technology	212,000,000

The goal of the space research and technology program is to retain national preeminence in space by advancing the technology base that supports the civil space program. The specific objectives are to provide a broad base of advanced technology for vehicle and subsystem concepts, components, devices and software; to develop the underlying analyses methods, materials behavior, and discipline technologies; and to perform ground and in-space experiments to provide basic data and verify concepts so that new technology can be utilized with confidence.

1. Research and Technology Base—$115,900,000

The Committee authorizes $115,900,000 for fiscal year 1988 for Research and Technology Base. This is the same as the President's budget request.

Summary of funding for fiscal year 1988

Aerothermodynamics research and technology	$11,100,000
Space energy conversion research and technology	14,600,000
Propulsion research and technology	14,500,000
Materials and structures research and technology	17,900,000
Space data and communications research and technology	8,900,000
Information sciences research and technology	8,000,000
Controls and guidance research and technology	6,300,000
Human factors research and technology	4,900,000
Space flight research and technology	23,200,000
Systems analysis	6,500,000
Total Research and Technology Base	115,900,000

Aerothermodynamics research and technology

Future aerospace vehicles, such as aeroassisted orbital transfer vehicles (AOTV), aerospace planes, and hypersonic cruise and maneuver vehicles, must be capable of hypervelocity flight in the atmosphere—ranging from the rarefied to the continuum flow regimes.

In fiscal year 1988 continued emphasis will be placed on developing computer codes capable of simulating external flows relevant to aerospace transportation systems and on providing analysis and design capability to predict aerodynamic and aerothermodynamic loads.

Space energy conversion research and technology

The objectives of this program are to explore concepts and components to improve the performance, lifetime, and cost effectiveness and to reduce the size and weight of power and life support systems for large manned space systems, small earth-orbiting and planetary exploration spacecraft, and other ambitious future space missions.

In fiscal year 1988, a system program in high-capacity nuclear power will be established as part of the new CSTI program. Nuclear technologies needed to meet the high-capacity power systems requirements for evolutionary space station(s), lunar and planetary bases, and for high-power demand electric propulsion systems will be developed in this program.

Propulsion research and technology

The objective of the propulsion research and technology program is to establish a base of design concepts and analytical tools that will allow the design and development of advanced propulsion systems with the known performance, life, and operational characteristics essential for next generation space transportation systems.

In fiscal year 1988, fundamental efforts in reusable engine research and technology, which are aimed at establishing the technology base for component life extension and prediction, will continue in the research and technology base program.

Materials and structures research and technology

The objective of the materials and structures program is to provide technology that will allow the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, efficiency, durability, and economy.

In fiscal year 1988, the materials program will continue to focus on the effect of the space environment on structural materials for spacecraft, large-area space structures, advanced space transportation systems, and orbital transfer vehicles.

Space data and communications research and technology

The space data and communications research and technology program is directed toward developing the advanced ability to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

In fiscal year 1988, the space data research and technology program will emphasize general purpose, fault-tolerant computing. All space communications research and technology will remain in this research and technology base program.

Information sciences research and technology

The objectives of the information sciences research and technology program are to discover advanced concepts, techniques, and system algorithms and to invent system architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In fiscal year 1988, technologies needed to meet the science sensor requirements of the Earth Observing System and Large Deployable Refractor will be developed in this program.

Controls and guidance research and technology

The controls and guidance research and technology program goals are to generate the practical design methods and techniques requried to enable precise pointing and stabilization for future NASA spacecraft and payloads.

In fiscal year 1988, this activity will continue theoretical exploration of modern control theory methods associated with both system identification and distributed and adaptive control.

Human factors research and technology

The objective of the space human factors research and technology program is to provide the technology base for productivity, efficiency, and safety in increasingly complex manned space operations, including the space station and a potential National Aerospace Plane.

In fiscal year 1988, work stations for proximity operations will be evaluated. The virtual work station will undergo hardware integration and display upgrade.

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 and operation of future space systems. This objective is accomplished through the utilization of current and future space facilities such as in-space research laboratories.

In fiscal year 1988, under the orbiter experiments program, key aerodynamic, aerothermodynamic, and thermal protection system experiments may resume flights for completion of the previously planned six-flight series for these experiments.

System analysis

One of the primary objectives of the systems analysis program is to conduct systems analyses to identify technology requirements for spacecraft systems, space transportation systems, and large space systems for the national space program and integrate these requirements into a comprehensive technology plan.

In fiscal year 1988, the Mars rover studies will be completed; emphasis will be redirected toward an outer planet science station study; and astrophysics activities will center on the technology requirements for interferometric observatories across a range of wavelengths.

2. CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM—$96,100,000

The Committee authorizes $96,100,000 for fiscal year 1988 for Civil Space Technology Initiative (CSTI) program. This is $38,000,000 less than the President's budget request. The reduction results from the assumption that NASA will be reimbursed for propulsion technology activities by DOD.

Summary of funding for fiscal year 1988

Propulsion	$1,200,000
Vehicle	15,000,000
Information	17,400,000
Large structures and control	22,800,000
Power	14,000,000
Automation and robotics	25,700,000
Total CSTI	96,100,000

Many of these activities have been transferred from previous Space Research and Technology Activities and augmented in the CSTI program.

Propulsion

The objective of the CSTI propulsion program is to develop and demonstrate main engine and booster propulsion technology which will enable the development of the next generation of earth-to-orbit vehicle.

In fiscal year 1988, the CSTI propulsion program will include earth-to-orbit technology for both LOX/hydrogen and LOX/hydrocarbon propulsion systems.

Vehicle

The aeroassist flight experiment (AFE) will investigate the critical vehicle design and environmental technologies applicable to the design of an aeroassisted orbital transfer vehicle (AOTV).

In fiscal year 1988, development of the AFE will be initiated.

Information

The objective of the information systems technology program is to discover and develop new materials, devices, and components in order to enable viable and productive detection, imaging, and storage systems for future space and planetary missions in the next century.

In fiscal year 1988, onboard computing and optical disk memory technology elements of the space data and communications program have been incorporated into the CSTI program to focus on the high-rate/capacity data requirements of future NASA missions.

Large structures and control

The objective of the large structures and control program is to provide experimental validation of analytical methods for predicting coupled structural dynamics and controls response for multibody space structures with special emphasis on the control of flexible structures (COFS) program.

In fiscal year 1988, ground-based elements initiated earlier will be continued for the COFS I and II structures.

Power

The objective of this program is to develop the technology needed to meet the high-capacity power systems requirements for evolutionary space station, lunar and planetary bases.

In fiscal year 1988, an aggressive dynamic conversion systems technology development and verification program will be initiated.

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.

In fiscal year 1988, the initial demonstration will be of a two-armed remote manipulator for satellite module replacement and fluid transfer tasks.

Space Research and Technology—Committee Comments

The Committee authorizes $212 million for Space Research and Technology for fiscal year 1988. This is $38 million less than the President's budget request. The Committee's reduction is made without prejudice to the Civilian Space Technology Initiative (CSTI), an initiative strongly endorsed and prescribed by the Committee.

The Committee strongly supports an enhanced level of activity in the NASA Space Research and Technology Program as evidenced in the fiscal year 1987 NASA authorization bill that earmarked an additional $20 million for advanced technology development toward next generation launch systems that would provide low-cost, reliable access to low-earth and geosynchronous orbits.

Despite the Committee's strong support for Space Research and Technology, the initiation of the Advanced Launch System (ALS) in conjuction with the submission of the President's fiscal year 1988 budget request has raised the possibility that duplication may exist between the ALS and CSTI propulsion proposals, both of which emerged from the ongoing National Space Transportation Architecture Study. In light of this situation, the Committee has reduced the fiscal year 1988 level of activity in accordance with the assumed reimbursement of NASA by DOD for these particular propulsion activities (H.R. 1827, S. Report 100-48).

The Committee assumes that this duplication will not appear in the fiscal year 1989 budget request and that any future DOD reimbursements to NASA will be in addition to the base CSTI program. The Committee also anticipates that NASA will initiate additional civilian space technology initiatives in the fiscal year 1989 budget submission, including propulsion technologies for space systems other than the ALS.

The Committee feels strongly that the National Commission on Space identified a serious deficiency in the Nation's space program when it recommeneded that the United States substantially increase its investment in the space technology base—the Commission recommended a threefold growth in NASA/s base technology budget. The Committee is committed to correcting this deficiency and continues to strongly support space research and technology activities, in particular the Civilian Space Technology Initiative.

I. Safety, Reliability and Quality Assurance—$16,200,000

The Committee authorizes $16,200,000 for fiscal year 1988 for safety, reliability and quality assurance. This is the same as the President's budget request.

The objective of the Safety, Reliability and Quality Assurance (SR&QA) program, formerly the Standards and Practices Program, is to support NASA's goals through activities in safety, productivity, reliability and quality assurance, maintainability, software assurance, systems engineering, and program practices which reduce program risk; to improve product confidence; and to encourage good program procedures in the technical execution of NASA programs.

In fiscal year 1988, the SR&QA program will continue to conduct activities in support of the objectives of the agency. The increase in funding from the fiscal year 1987 level reflects an increase in safety related activities and the creation of a Technical Assessment Program. The Technical Assessment Program will develop systems that monitor the status of equipment; validate technical designs; report and analyze problems; analyze trends; and judge system acceptability in agency-wide programs.

The Technical Assessment Program will address the reporting and documentation of problems, problem resolution and trends, and other safety systems as required. One component of the assessment program is a computerized, real-time, agency-wide problem reporting and corrective action system which will allow an assessment of SR&QA problems. As currently planned, the system will contain data on failures, nonconformance anomalies, and unsatisfactory conditions for problems analysis and resolution, remedial and preventive actions, and trend analysis for flight and critical ground hardware, as well as certain generic program hardware. The information resulting from the system will be used to design, flight, and test reviews. It will be specifically designed to provide a board data base which will be accessible by NASA and its contractors on an iterative basis. It will provide a means whereby effective trend analysis can be accomplished, thus providing early and more complete illumination of problems to management.

Efforts are being planned that will revitalize the basic NASA safety program. Major activities will be focused on increasing the safety of high hazard operations, better understanding the failure modes of highly stressed wind tunnel components and pressure systems, and quantifying the hazard potential of new, exotic propellants, existing cryogenic propellants, and new composite materials. The existing effort to automate mishap reporting will be expanded to include the capability for trend analysis and generation of multimedia, generic lessons learned from the central data base. Critical policies, procedures, practices, regulations, guidelines, and directives will be reviewed and revised, or developed, as appropriate. Risk assessment of hazards identified in NASA activities will be conducted to determine the implied risks to people and property.

Safety, Reliability and Quality Assurance—Committee Comments

The Committee authorizes $16.2 million for Safety, Reliability and Quality Assurance for fiscal year 1988. This is the same as the President's budget request.

The Committee remains strongly committed to the restoration of NASA's Safety, Reliability and Quality Assurance (SR&QA) programs as the hallmarks of the agency. The inclusion of a separate line item in the fiscal year 1988 NASA Research and Development budget request for SR&QA helps to identify the level of effort, but the budget justification does not provide adequate supporting documentation. The Committee is hopeful that this situation will be corrected in the fiscal year 1989 NASA budget submission.

As an indication of the Committee's support of the SR&QA program, the Committee has approved 99 additional slots for these activities in the Research and Program Management account. Thirty-three of these slots will be located at NASA Headquarters, and sixty-six of the slots will be at the NASA field centers. These additional persons should greatly increase NASA's internal capabilities and reduce the need to contract out for SR&QA services.

The Committee must note its dissatisfaction with the "process" and the "personnel" involved in the Atlas/Centaur Fltsatcom launch which failed on March 26, 1987. Regrettably, this launch failed to meet all existing launch commit criteria and, in some regards, a reasonable standard of care. The Committee sees the failure of NASA and the SR&QA Office to reassess the expendable launch vehicle launch commit criteria and the associated launch process as a grievous error of judgment. There was no excuse for the Atlas-Centaur failure, and the failure of NASA to realize that the lessons learned from the *Challenger* tragedy were also applicable to other NASA programs is incomprehensible.

The Committee, therefore, instructs the Office of Safety, Reliability and Quality Assurance to include as part of its fiscal year 1989 budget justification, a detailed accounting of the systems and processes currently under review or proposed for review by the Office. The Committee expects SR&QA to be the hallmark of NASA's manned and unmanned space activities, and it will continue to work with the Office of SR&QA to ensure the reestablishment of this standard.

J. Tracking and Data Advanced Systems—$18,100,000

The Committee authorizes $18,100,000 for Tracking and Data Advanced Systems fiscal year 1988. This is the same as the President's budget request.

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: (1) obtain new and improved tracking and data handling capabilities that will meet the needs of approved new missions and near-term new starts; and (2) improve the cost effectiveness and reliability needed for overall support of the total mix of spaceflight missions.

Activities planned for fiscal year 1988 include efforts to obtain location accuracies within the one meter 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; studies on ground based navigation strategies, analyses and demonstrations for Galileo, Uylsses, and Mars Observer; efforts to improve communications between the ground and spacecraft; and investigations on achieving more efficient operation of the mission control facilities and providing for the necessary real time interaction between the spacecraft experimenters and their experiments.

Tracking and Data Advanced Systems—Committee Comments

The Committee authorizes $18.1 million for Tracking and Data Systems for fiscal year 1988, which is the same as the President's budget request.

The Committee continues to strongly support these activities that will improve the cost effectiveness and reliability of the total mix of spaceflight missions.

II.—SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS—$4,081,300,000

The Committee authorizes $4,081,300,000 for fiscal year 1988 for Space Flight, Control and Data Communications. This is $17 million more than the President's budget 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 and tracking and communication system support to all NASA flight projects. This objective is achieved through the following elements:

Shuttle Production and Operational Capability.—A program 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.—A program 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.—A program 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 fiscal year 1988 funding levels

Shuttle production and operational capability	$1,150,600,000
Space transportation operations	1,885,800,000
Space and ground networks, communication and data systems	944,900,000
Expendable launch vehicle operations	100,000,000
Total space flight, control, and data communications	4,081,300,000

The primary program objective of current activity in the Space Transportation System is to complete the safe return to Space Shuttle flight activities. The Space Shuttle is the key element of a versatile Space Transportation System (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)—to retrieve payloads from orbit for reuse; to service and repair satellites in space; to transport to orbit, operate, and return space laboratories; and to perform rescue missions.

Shuttle Production and Operational Capability provides for the national fleet of Shuttle orbiters including the replacement orbiter which is fully funded in fiscal year 1987. Funding also provides for the launch site facilities, initial spares, production tooling, and related supporting activities. This line item also includes 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 return to flight.

Shuttle Operations provides the standard operational support services for the Space Shuttle. 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 3 flights in 88 (the first launch after the *Challenger* accident is scheduled for June 1988), and 7 flights in 1989. However, pending NASA decisions and the results of the solid rocket motor test program, this schedule could change.

The ELV program is currently totally funded through reimbursements from users. Privatization of these systems continues to be actively pursued. The only planned NASA launch at this time is for the Cosmic Background Explorer spacecraft which will utilize a Delta launch vehicle acquired with reimbursements for replacement of residual assets.

The purpose of the Space Ground Networks, Communications, and Data Systems 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 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.

Tracking and acquisition of data for the spaceflight projects presently accomplished through the use of a worldwide network of NASA ground stations and by the first of a system of three tracking and data relay satellites in geosynchromous orbit working with a single highly specialized ground station. Ground facilities are interconnected by terrestrial and communications satellite circuits which tie together the spacecraft and control centers for control 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.

A. Shuttle Production and Operational Capability—
$1,150,600,000

The Committee authorizes $1,150,600,000 for fiscal year 1988 for Shuttle Production and operational Capability. This is $79 million less than the President's budget request.

Summary of fiscal year 1988 funding levels

Orbiter operational capability	$324,200,000
Launch and mission support	249,300,000
Propulsion systems	552,100,000
Changes and systems upgrading	25,000,000
Total shuttle upgrading and operational capability	1,150,600,000

Orbiter operational capability

With the recent loss of *Challenger* (OV-099), our primary objective is to return the three orbiter fleet to safe flight in fiscal year 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.

The structural spares program initiated in fiscal year 1983 provided the foundation for a production of a replacement orbiter with a delivery date planned for mid-1991. A new set of structural spares was proposed by the Administration in fiscal year 1988 in order to sustain the capability to *produce another vehicle,* in addition to providing additional spares for inventory. Pending further review of the Nation's space transportation requirements and the role expendable launch vehicles will play in that system, the Committee has deferred initiation of this program in fiscal year 1988.

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 study is under way to determine logistics depot and maintenance requirements.

In fiscal year 1988, orbiter funds provide for the procurement of a logistics capability including establishing 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, completing the existing set of structural spares to support the production of a replacement orbiter, and the engineering analysis and integration support for the increasing flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, the on-board flight software, and potential implementation of a crew escape system during orbiter controlled gliding flight.

Launch mission support

This activity supports the development of launch and mission support capabilities, principally at the Johnson Space Center (JSC) and Kennedy Space Center (KSC). This budget contains funding required to conduct the necessary modifications to the KSC ground support equipment to return to flight status, such as improving the external tank hydrogen vent system on the launch pad, installation of debris traps in the main propulsion system propellant lines and new support equipment for the redesigned solid rocket boosters.

Funding has been included for additional landing aids and runway end barriers for the current, and one additional, contingency/abort landing site. Capability improvements have been added for weather prediction and information handling to improving system monitoring, notably for anomaly tracking. A shift in priority in the ground systems replacement/refurbishment program, consistent with the Rogers Commission recommendations, has delayed improvements to the Mission Control Center and accelerated improvements in the simulation training facility including new host computers and associated interface controllers. Funding also is included for a "kit" to allow the modification of a Boeing 747 into a (second) Shuttle Carrier Aircraft (SCA), thus reducing the potential downtime impact of this major single point of failure.

In fiscal year 1988, the launch site equipment activity includes finalizing the return-to-flight status modifications in the KSC ground support equipment associated with the vehicle and launch processing facilities. Activities are also under way to improve the capability to support the flight rate requirements at KSC.

Mission operations capability funding in fiscal year 1988 provides for completion of replacement of the host computers and selected critical items for the Shuttle training simulators. Fiscal year 1988 is the initial year in the efforts to procure a fourth Shuttle Training Aircraft (STA), to re-engine the Shuttle Carrier Aircraft (SCA) and to replace ADP and other hardware in the Software Production facility. Continuing projects include the procurement of the Shuttle Carrier Aircraft (SCA) mod kit and improvements to weather prediction, information handling, and mission control systems.

Propulsion Systems

Propulsion Systems provide 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 spares, ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes a major redesign, development and qualification effort for the solid rocket motors to improve safety margin and correct the deficiencies that led to the *Challenger* accident. The SRB program also includes a thorough reevaluation of the booster hardware, redesign of the hardware for reusability and operational cost reductions, and procurement of manufacturing tooling and equipment to support the projected flight rate. In the ET program, the objectives are to support recovery activities and the return to safe flight. Systems support primarily provides for the testing of the SSME in the main propulsion test article configuration.

The solid rocket booster (SRB) funding requirements support the redesign and requalification efforts necessary as a result of the Challenger accident. Based upon the investigation results of the failure and the actions recommended by the Rogers Commission, a complete reassessment of the certification program on all hardware and a redesign of the solid rocket motor joint configurations are under way. In-depth reviews of the systems failure mode and effects analysis (FMEA), operational procedures and the design of critical hardware on the critical items list (CIL) is being conducted and changes will be implemented as necessary. Extensive testing will be conducted of all design alternatives under conditions that accurately simulate the launch environment to insure that the final design meets the program safety and performance requirements. A second SRM static firing test stand is being provided to assure the capability to initiate the flight program in fiscal year 1988. All necessary hardware replacement on refurbishments will be procured to support resumption of flight activities and the planned build-up in flight rate. Funding is also included for alternative source procurement studies for the advanced solid rocket motor (ASRM). The filament wound case (FWC) program is being deferred as a result of the extensive changes being considered in the basic SRB program and the Air Force's decision to defer activation of the Vandenberg launch site. FWC funding is provided through completion of the structural test program.

In systems support, capability is being maintained for the full power level test of three clustered engines in the National Space Technology Laboratory (NSTL) main propulsion test stand in early 1989. 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 funding request for the fiscal year 1988 budget is based upon resumption of the flight program in February 1988—a date that was recently slipped to June 1988—and the design, test, and certification of the propulsion hardware for flight. A complete reassessment of the program is included. It consists of a thorough review of the FMEA/CILs 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 program will complete the redesign of the solid rocket motors and be re-certified prior to the first flight. The external tank program will complete the FMEA/CIL reviews and continue the efforts to develop processing improvements to reduce the cost of manufacturing tanks, the continued installation of rate tooling to support the future flight rates and overhaul of the barges used to transport finished tanks from Michoud to the launch sites.

Changes and Systems Upgrading

The Changes and Systems Upgrading budget represents the estimated requirement for potential changes and systems modifications and unanticipated developments which are not included in the program element budget estimates. Such funds are necessary to provide for programmatic and technical changes, such as modifications to the flight hardware to improve systems reliability, safety and performance; changes and upgrading of ground systems to reduce turnaround time between missions, and replacement/modification of hardware elements to achieve increased operating economies.

The funding requested for fiscal year 1988 will provide for those changes which are considered to have the highest priority. The objectives are to improve reliability, increase operating safety margins and efficiency, and reduce costs.

Space Shuttle Production and Operational Capability—Committee Comments

Restoring the Space Transportation system to flight readiness is the highest priority for NASA in fiscal year 1988. Therefore, the Committee has authorized $1,150.6 million for Space Shuttle Production and Operational Capability for fiscal year 1988. In addition, in Section 111, the Committee has authorized "such sums as may be necessary" for the Administrator to take the necessary steps to return safely the space shuttle fleet to flight status. These monies are authorized in anticipation of a fiscal year 1988 NASA Budget Amendment for additional anomaly resolution activities and Rogers Commission recommendations.

The only change made to the Space Shuttle Production and Operational Capability budget request by the Committee was the deletion of $79 million of funding for the structural spares program. This decision was based on the fact that until there is a final determination as to how and what mix of expendable launch vehicles, including an Advanced Launch System, will be used to meet the Nation's space transportation requirements, funding of structural spares would be premature. The Committee is well aware of the original intent of the structural spares program and recognizes the value of the existing structural spares to the construction of a new orbiter. However, at this time, the Committee does not feel that funding for this initiative is warranted in fiscal year 1988.

The most immediate concern to the Committee is the restoration of the space shuttle fleet to flight status. Successful implementation and verification of the proposed anomaly resolution activities and Rogers Commission recommendations are the critical elements of this area of the program.

In general, the Committee is pleased with NASA's effort in this regard. However, the Committee agrees with the National Research Council Panel for the Technical Evaluation of the Redesign of the Space Shuttle Solid Rocket Booster that the real barometer of the success of the anomaly resolution program will be the outcome of the proposed test program. Since the first full-scale test is not scheduled until August 1987, it is still premature for the Committee to comment on these activities.

The Committee remains convinced that NASA should fully involve the solid rocket motor industry in the solid rocket motor redesign and test activities. However, the Committee is still uncertain that NASA is pursuing this matter as virogously as the Committee desired. Restoration of the space shuttle fleet to flight status is a national priority, and no available resource should be overlooked or underutilized in this effort. The Committee expects that NASA fully understands the Committee's position on this matter.

Meanwhile, the Committee intends to closely review anomaly resolution activities and implementation of the Rogers Commission's recommendations. An oversight hearing to look at these and other related issues will be conducted during this summer. The Committee also intends to review closely the fiscal year 1988 budget amendment for anomaly resolution activities and to provide funds for critical activities related to the safe return of the shuttle to flight status.

Despite the fact the Committee is anxious to see the space shuttle return to flight, the Committee recognizes the need for the Administrator's recent decision to slip the flight date from February until June 1988. The conduct of a "wet" countdown test and a Flight Readiness Firing Test is a prudent decision that should help hone the skills of the launch team.

The Committee looks forward to the receipt of a new manifest as soon as possible and hopes the proposed delay wil not have an adverse impact on major space science payloads. The Committee also supports the more by NASA toward more realistic flight rates for 1988 and 1989.

For the mid-term, the critical issue is the successful implementation of an Advanced Solid Rocket Motor (ASRM) program. The Committee is pleased that NASA submitted an ASRM program to the Committee on March 31, 1987 and that a Request for Proposals for Phase B studies was released on May 29. However, the Committee will reserve its final judgment on the proposal until after it has conducted an oversight hearing. In general, the Committee feels that an ASRM program that provides added reliability and performance, with the emphasis on the former and not the latter, is a step in the right direction. The Committee also feels strongly that NASA cannot depend upon the redesigned solid rocket motor, a technical fix to a design flaw, for the long-run. However, the Committee does have concerns about the proposed extension of the current contract and the proposal for a government-owned, contractor-operated facility to manufacture the ASRM.

Based on the Committee's review of the available data, it does not believe the Second Sourcing of the redesigned motor is now warranted. The emphasis should be directed to an Advanced Solid Rocket Motor as has been properly done by NASA.

For the long-term, the Nation must begin to make some decisions about the space transportation network of the future. The space shuttle fleet has a limited life expectancy and will need to be replaced. New generations of expendabie launch vehicles wiii need to be developed that dramatically reduce the cost of transportation. The dilemma confronted by the Committee is that it is trying to restore the existing space transportation infrastructure, while simultaneously trying to lay the foundation for the future. Unfortunately, a clear set of requirements has not yet been made available to the Committee in terms of the future space transportation requirements. The Committee requests that NASA and DOD provide such a set of requirements to assist in its determination and strongly suggests that the final National Space Transportation Architecture Study be released to the appropriate Congressional Committees.

B. Space Transportation Operations—$1,885,800,000

The Committee authorizes $1,885,800,000 for fiscal year 1988 for Space Transportation Operations.

Summary of fiscal year 1988 funding

Flight Operations	$561,100,000
Flight Hardware	923,100,000
Launch and Landing Operations	401,600,000
Total Space Transportation Operations	1,885,800,000

Funding for Shuttle Operations is normally combined with the reimbursements for Shuttle launch services received from other U.S. government, commercial, and international users to support the launch and flight operations requirements of the Space Shuttle. However, in fiscal year 1988 there are no anticipated reimbursables due to policy changes and the grounding of the space shuttle fleet.

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 base operational support at JSC and systems support activity at JSC, Headquarters, and the Goddard Space Flight Center.

The Flight Hardware program element provides for: the procurement of external tanks (ET), solid rocket motors, booster hardware, and propellants; spare components 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.

Launch and Landing Operations provides for the pre-launch preparation, launch, and landing operations of the Shuttle and its cargo. Also, liquid propellants used in launch operations are provided for in this budget.

There are currently no planned reimbursable funds for Shuttle Operations in either fiscal year 1987 or 1988. It is anticipated that reimbursable funding will resume in the future as the shuttle flight rate builds up.

The Expandable Launch Vehicle (ELV) program provides for the procurement of expendable launch vehicles and launch support services. The only planned NASA launch is for the COBE spacecraft which will utilize a Delta launch vehicle made available by using reimbursements for residual vehicle hardware made available to other users.

Flight Operations

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 the on-orbit portion of STS missions from launch to landing. The functions are essentially the same as in the past: maintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; maintenance and operation of proficiency, training and orbiter ferry aircraft and to perform analyses and operation of the mission planning necessary to conduct and control 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

The Flight Hardware program element provides for the procurement of external tank (ET), the manufacturing and refurbishment of solid rocket booster (SRB) hardware and motors, spare components for the main engine (SSME); orbiter spares including ET disconnects, sustaining engineering and logistics support for ET/SRB/main engine flight hardware elements; and maintenance and operation of flight crew equipment.

In fiscal year 1988 requirements for orbiter flight spares, crew equipment spares, and logistics are based on estimates that consider projected flight rates, maintenance schedules, operational hours, turnaround 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 fiscal year 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 fiscal year 1988, as well as the support of the production of units which will be flown thereafter.

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 ground processing facilities at KSC. These services are primarily provided by means of three separate operations contracts.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). Base support to the Shuttle program is provided by the Base Operations Contract (BOC) which is responsible for operations support functions such as printing and graphics, calibration of instrumentation, and evaluation, test and modification to launch support equipment, and other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports both 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 related to the Shuttle Processing Contractor.

The Payload and Ground Operations Control (PGOC) is the major contract for the payload processing activities including Spacelab and Space Station payload processing at KSC.

Launch operations funding in fiscal year 1988 provides for manpower and support services necessary for processing launches from KSC. This includes manpower to process the build-up of 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/modifications of all other Shuttle-related ground support equipment and facilities.

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.

Space Transportation Operations—Committee Comments

The Committee authorizes $1,885.8 million for Space Transportation Operations. This is the same as the President's budget request and reflects the Committee's strong support of activities critical to the restoration of the space shuttle fleet to flight status.

The Committee is very supportive of and most interested in the changes that are being made in the space shuttle launch and landing operations programs. Many of these changes stem from the recommendations of the Rogers Commission and the NASA Management Study Group and are designed to increase flight safety and to improve the launch decisionmaking process.

The Committee notes with concern the events surrounding the recent Atlas Centaur failure and hopes that NASA fully understands the importance of its personnel to any launch process. The Committee also expects to see a significant improvement in the weather forecasting capabilities and in the communications between Air Force and NASA personnel, along with a clarification of launch commit criteria for the Kennedy Space Center prior to the launch of any orbiter or expendable launch vehicle.

As noted in the prior section, the Committee anticipates additional fiscal year 1988 budgetary requirements for anomaly resolution activities, including Space Transportation Operations. The Committee, therefore, has provided "such sums as may be necessary" for these additional activities. It is the Committee's intent to include a specific amount for these activities before final action is completed on the fiscal year 1988 NASA Authorization Bill.

C. Space and Ground Networks, Communications and Data Systems—$944,900,000

The Committee authorizes $944,900,000 for fiscal year 1988 for ground networks, communications and data systems. This is $4 million less than the President's budget request.

Summary of fiscal year 1988 funding levels

Space Network	$481,500,000
Ground Networks	257,100,000
Communications and Data Systems	210,300,000
Total Space and Ground Networks, Communications and Data Systems	[1] $948,900,000

[1] The Administrator of NASA is given discretion to apply a general reduction of $4 million to this total amount of funding.

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 DOD, other Government agencies, commercial firms, and other countries and international organizations engaged in space research.

The Space Tracking and Data Network (STDN) will provide Earth orbital support until the Tracking and Data Relay Satellite System (TDRSS) becomes operational. At that time the STDN phase down will continue with the closure of several ground stations. The Deep Space Network (DSN) under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Space Network

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 itself, 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 TDRSS can provide a nearly six-fold increase in the orbital coverage compared to the eight existing ground stations.

The fiscal year 1988 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 procurement of an additional TDRS spacecraft and long-lead parts from TRW to replace the spacecraft lost in the *Challenger* accident and provide the option for an additional spacecraft; and the implementation of a second ground terminal at White Sands.

The TDRS-1 was launched in April 1983, and since that time it has supported Shuttle missions. The TDRS-2 was destroyed in 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. Launch of the next TDRS is expected to occur in June 1988 on the first Shuttle mission when flights resume. The launch date of the third TDRS is currently under review. Once these two spacecraft have been successfully launched and the system achieves operational status, TDRS-1 will become the on-orbit spare.

Due to the aging of the equipment and the necessary replacement of major subsystems and components in the existing TDRSS ground terminal, a second TDRSS ground 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.

At the same time, 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, NASA and DOD mission requirements exceed the two satellite operations capability in the mid-1990's.

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. 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 supportable by TDRSS. Aeronautics, balloons and sounding rocket research is supported by especially 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. The workload in fiscal year 1988 will include support to the Space Shuttle and support to ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM). Preparations will be underway for the upcoming 1989 Voyage-Neptune encounter and future planetary missions including Galileo, Ulysses, Magellan, and Mars Observer. Aircraft test programs will also be supported.

The fiscal year 1988 request includes funds to operate all eight STDN stations and 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 which provides orbital tracking support.

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 and solar system spacecraft. After completion of the project in 1988 to expand the diameter of the 64-meter antenna dishes to 70 meters, each complex will have four antennas: one 70-meter, two 34-meter and one 26-meter. A centralized control center for the network is located at the Jet Propulsion Laboratory (JPL) In Pasadena, California.

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.

Major activities underway include the implementation of: (1) a mission control and data capture system for the Hubble Space Telescope and (2) mission control and data processing capabilities for support of upcoming missions such as Spacelabs, Gamma Ray Observatory (GRO) and Upper Atmosphere Research Satellite (UARS) In addition, studies have been initiated to evaluate Space Station support requirements.

Space Tracking and Data Acquisition—Committee Comments

The Committee authorizes $944.9 million for Space Tracking and Data Acquisition for fiscal year 1988. This is $4 million less than the President's budget request. This reduction is a general reduction to be applied at the discretion of the Administrator.

The Committee is most supportive of NASA's Space Tracking and Data Acquisition program and is well-aware of the critical value of this program to the success of the nation's space program.

The Committee has fully authorized the fiscal year 1988 budget request for the replacement of the Tracking and Data Relay Satellite (TRDS) lost in the *Challenger* tragedy and feels that the deployment of this system is a high priority.

The Committe expects to be kept fully informed of any developments in this area and of any changes to the current program. Meanwhile, the Committee anxiously awaits the launch of a TDRS satellite on the first flight of the space shuttle in June 1988.

D. Expendable Launch Vehicle Operations—$100,000,000

The Committee authorizes $100,000,000 for fiscal year 1988 for expendable launch vehicle operations. No monies were requested for this activity by the President in his budget request. The Committee recognizes this initiative as a high priority and feels that NASA must have a mixed fleet capability.

Expendable Launch Vehicle Operations—Committee Comments

The Committee authorizes $100 million for Expendable Launch Vehicle Operations for fiscal year 1988 to initiate the procurement of expendable launch vehicles (ELVs). This line item is a "new start" initiated by the Committee in recognition of the need to expand the national launch capability and to preserve the space shuttle fleet for these critical missions that require its unique capabilities. The Administration requested no fiscal year 1988 funds for ELVs for NASA. However, NASA is currently preparing a fiscal year 1988 budget amendment for submission to the Office of Management and Budget for the procurement of expendable launch vehicle services. The Committee assumes the Administration will endorse this amendment since it provides funding for a critical national requirement.

Prior to 1984, the national policy was phase-out the government's use of ELVs and to rely upon the space shuttle for the launch of government payloads. At the end of 1985, this policy underwent a major revision when DOD expressed grave concerns about the lack of an alternative launcher to serve national security requirements. DOD then initiated the procurement of ten Complementary Expendable Launch Vehicles, now referred to as Titan IVs.

In the aftermath of the *Challenger* disaster, the fabric of the ELV policy has totally dissolved. The Air Force has doubled the procurement of Titan IVs, increased the refurbishment of Titan IIs, and entered into an agreement for an initial buy of 12 Delta IIs. DOD Also has submitted a fiscal year 1987 supplemental appropriations request for a Heavy Lift Vehicle or Advanced Launch System. Meanwhile, the only ELV procured by NASA in this same period has been a single Delta for the Cosmic Background Explorer Mission. Several comprehensive studies were conducted within and and outside of NASA highlighting the requirements for ELVs for civil payloads, and NASA's May 15 announcement of a plan to acquire ELV services for NASA missions is responsive to the conclusions of these studies.

In light of the convincing empirical evidence which reveals the need for NASA to maintain a Mixed Fleet capability, the Committee has initiated an Expendable Launch Vehicle Operations program in fiscal year 1988. The Committee also strongly endorses the proposed change to the fiscal year 1987 Operating Plan that would establish the framework for this initiative.

The Committee drew strongly upon the NASA Advisory Council "Report of the Task Force on Issues of a Mixed Fleet" and the Office of Space Flight "Report of the NASA Mixed Fleet Study Team" in proposing this new ELV initiative. In general, the Committee supports the recommendations and findings of both of these reports and feels that they formulate a very pragmatic space transportation policy and recovery program for NASA.

The Committee feels strongly that in implementing its initiative, NASA should incorporate a diversified family of launchers into the NASA space flight program. The Committee also advises NASA that its budgeting and planning should be more realistic and not always based upon a best-case scenario. Some level of problem generation and stand-downs (whether post-accident or merely precautionary) should be assumed at the flight rate anticipated by NASA during the next decade.

The Committee was most pleased with NASA's May 15th announcement of a plan to acquire ELV services for NASA missions. The major objective of the NASA plan is to accelerate the deployment of the Nation's backlog of space science missions—an initiative whole heartedly endorsed by the Members of this Committee.

Despite the fact that a formal request has yet to be submitted to the Committee, the Committee agrees in principal with the recently announced NASA plan and is pleased that NASA may augment existing DOD ELV contracts as well as secure separate launch services agreements. While the Committee generally requires NASA to utilize a competitive procurement process for the acquisition of hardware or services, it would endorse a limited noncompetitive procurement of ELVs in the near-term to best match available ELVs and already designed payloads and mission requirements.

The Committee feels that its ELV initiative is a critical element of the Nation's space transportation restoration program and an important first step toward the creation of a robust Mixed Fleet.

III.—CONSTRUCTION OF FACILITIES—$210,700,000

The Committee authorizes $210,700,000 in fiscal year 1988 for the Construction of Facilities. This is $15.2 million more than the President's budget request.

The Construction of Facilities (CoF) appropriation provides 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 1988 provide for: the continuation of prior year endeavors in meeting the facilities requirements for Space Flight and the Space Station Programs; modification of aeronautical research and develop 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 estimate reflect Space Flight requirements that are time sensitive to meet specific milestones. Other program requirements for 1988 include the construction of a spacecraft systems development and integration facility as well as modifications for utility reliability at the Goddard Space Flight Center; construction of an integrated test facility at Dryden Flight Research Facility; modifications to the Hypersonic Propulsion Facility for Vacuum Systems at the Langley Research Center; construction of an addition to the Research Analysis Center and modifications for Fan/Compressor Research to the Engine Research Building at the Lewis Research Center; and the construction of a Communications Development Antenna at Goldstone, California.

The fiscal year 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 assure 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.

The $210,700,000 authorized for Construction of Facilities projects in fiscal year 1988 is for the following activities:

(1) Construction of LC 39 Operations Support Building, Kennedy Space Center, $17,000,000;

(2) Construction of Spacecraft Systems Development and Integration Facility, Goddard Space Flight Center, $8,600,000;

(3) Modifications for utility reliability, Goddard Space Flight Center, $2,900,000;

(4) Construction of Integrated Test Facility, Dryden Flight Research Facility, $10,500,000;

(5) Modifications to Hypersonic Propulsion Facility for Vacuum Systems, Langley Research Center, $3,100,000;

(6) Construction of addition to the Research Analysis Center, Lewis Research Center, $9,800,000;

(7) Modifications for Fan/Compressor Research, Engine Research Building, Lewis Research Center, $6,500,000;

(8) Construction of Communications Development Antenna, Goldstone, California, Jet Propulsion Laboratories, $6,400,000;

(9) Repair of facilities at various locations, not in excess of $750,000 per project, $25,000,000;

(10) Rehabilitation and modification of facilities at various locations, not in excess of $750,000 per project, $32,000,000;

(11) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project, $8,000,000;

(12) Environmental compliance and restoration, $23,900,000;

(13) Repair and modernization of the 12-foot pressure wind tunnel at the Ames Research Center, $41,000,000; and

(14) Facility planning and design not otherwise provided for, $16,000,000.

Construction of Facilities—Committee Comments

The Committee authorizes $210.7 million for Construction of Facilities activities in fiscal year 1988. This increase of $15.2 million to the President's budget requet is the result of two specific actions by the Committee.

First, without prejudice, the Committee has decided to delay the initiation of space station facilities activities until fiscal year 1989. This one year delay is consistent with the revised schedule that NASA has formulated and with the Space Station Program Office's facilities requirements. The proposed delay affects four projects and results in a fiscal year 1988 savings of $25.8 million.

Second, the Committee has provide an additional $41 million in fiscal year 1988 to initiate Phase I of the repair and modernization of the 12 foot pressure wind tunnel at the NASA Ames Research Center.

The 12 foot pressure wind tunnel, constructed in 1944, has been one of the world's premier subsonic wind tunnels and has played a major role in the development of every U.S. commercial and military aircraft design since 1960. During a recent inspection of the pressure shell, major cracks were discovered, and the wind tunnel's use was greatly restricted to prevent a catastrophic failure. At present, the tunnel is of no real value to industry or the development of aircraft such as the Boeing 767, the McDonnell Douglas MD-11, and DOD's Advanced Tactical Fighter.

The Committee strongly supports the repair and modernization of this facility in a timely manner and feels it is a national priority. The Committee instructs NASA to initiate Phase I activities in fiscal year 1988 with an anticipated completion date of March 1991. The design monies for these activities should be provided in fiscal year 1988 pursuant to a provision contained in the pending fiscal year 1987 Supplemental Appropriations bill.

Meanwhile, review of these two changes being prescribed by the Committee has surfaced another issue—the overall health and well-being of the infrastructure of our civil aeronautical and space program. While a great deal of time and energy has been focused on R&D programs and transportation systems, the Committee fears that the rehabilitation and modernization of the facilities critical to the success of these programs have not kept pace with the R&D programs and transportation systems. It is with great anticipation, therefore, that the Committee awaits submission of NASA's Five Year Plan for Construction of Facilities, and is hopeful that NASA will recognize the importance of rehabilitation and modernization of these facilities.

IV.—RESEARCH AND PROGRAM MANAGEMENT—$1,608,000,000

The Committee authorizes $1,608,000,000 for fiscal year 1988 for Research and Program Management, including the $10 million authorized in Title II for the National Space Grant College and Fellowship Program. This is $10 million more than the President's budget request which reflects the inclusion of the Space Grant College and Fellowship Program initiative.

The Research and Program Management appropriation provides funds for 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 .

The Research and Program Management appropriation provides funding for the 22,425 permanent and temporary civil service workyears (FTE) at eight major installations and Headquarters—an increase of 625 FTE from 1987. This civil service workforce is NASA's most important resource and is vital to future space and aeronautics research activities. About seventy percent of the Research and Program Management appropriation provides for the salaries and related costs of this civil service workforce. Three percent of this appropriation is used 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 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 selected Space Station hardware and subsystems development and operations planning and definitions.

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 selected Space Station hardware and subsystems.

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 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, 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, and 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 fiscal year 1988 budget request for Research and Program Management provides for (1) personnel and related costs, including the full year cost of January 1987 pay raise and the estimated cost to implement the new Federal Employees Retirement System (FERS); (2) travel; and (3) the operations of NASA installations including facilities services, technical services and management and operations.

Research and Program Management—Committee Comments

The Committee authorizes $1,598.0 million for Research and Program Management in fiscal year 1988. In addition, the Committee has authorized $10 million additional in Title II to accommodate the initiation of the National Space Grant College and Fellowship Program in fiscal year 1988. The total amount of funding available to NASA, therefore, is $1,608.0 million.

The Committee has long felt that NASA's key asset has been its talented and dedicated managers, scientists, and engineers. However, the Committee fears that not enough emphasis has been placed by NASA or the Congress on developing the next generation of qualified scientists and engineers, as more than 56 percent of NASA's current technical base are civil servents over age 45.

To address this deficiency, the Committee has included the provisions of the National Space Grant College and Fellowship Program Bill, S. 752, as Title II of S. 1164, the fiscal year 1988 NASA Authorization Bill. The principal purposes of this act are to:

(1) increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques;

(2) utilize the capabilities and talents of the universities of the Nation to support and contribute to the exploration and development of the resources and opportunities afforded by the space environment;

(3) encourage and support the existence of interdisciplinary and multidisciplinary programs of space research within the university community of the Nation, to engage in integrated activities of training, research and public service, to have cooperative programs with industry, and to be coordinated with the overall program of the National Aeronautics and Space Administration;

(4) encourage and support the existence of consortia, made up of university and industry members, to advance the exploration and development of space resources in cases in which national objectives can be better fulfilled than through the programs of single universities;

(5) encourage and support Federal funding for graduate fellowships in fields related to space; and

(6) support activities in colleges and universities generally for the purpose of creating and operating a network of institutional programs that will enhance achievements resulting from efforts under this act.

To accomplish these objectives, the Administrator of NASA is provided an additional $10 million authorization in fiscal year 1988, to be equally divided between the (1) space grant college program and (2) the new space fellowship program.

As provided for in the amendment offered by Senator Danforth to S. 1164, the "Administrator shall not under this title designate any space grant college or space grant regional consortium or award any fellowship, grant, or contract unless such designation or award is made in accordance with the competitive, merit-based review process employed by the Administration, i.e., National Aeronautics and Space Administration, on the date of enactment of this Act."

In implementing the Danforth Amendment, the Committee expects NASA to apply Section 107 of the bill to the Space Grant College and Fellowship Program (Section 107 of the bill instructs NASA to consider distributing its research and development funds on a geographical basis, where feasible).

The Committee recognizes that a conflict may exist between the Danforth amendment and any desire to distribute grants, awards, and fellowships on a geographical basis. The intent of the Danforth amendment is to ensure that Federal tax dollars are spent in the most efficient and productive manner possible. Furthermore, this amendment recognizes the government's responsibility to the taxpayer to ensure that the award of grants, contracts, and fellowships are made to the most competent and qualified individuals and universities possible. Yet, the Committee recognizes the benefits of developing a broader university space research infrastructure. Therefore, the Committee expects to be kept informed as to the award of contracts, grants, and fellowships under the Space Grant College and Fellowship Program and the manner in which they are awarded.

The Committee also instructs NASA to utilize the Space Grant College and Fellowship Program to broaden, where practical and desirable, the range of universities involved in space related research and development activities and to distribute these fellowships across a broad range of disciplines. The intent of the Space Grant College and Fellowship Program is not to concentrate activities among a few centers of higher education and their graduate students. The purpose of the program is to utilize the capabilities and talents of the universities of the entire Nation and to increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base.

Title II of S. 1164 is not specific as to whether the Space Grant College and Fellowship Program should be funded from within NASA's existing research and education program funds or as an augmentation to NASA's budget. While S. 1164 accommodates the College and Fellowship Program as an augmentation to NASA's existing research and education program funds, it is the Committee's intent that in future years the College and Fellowship Program should, likewise, not be funded from within NASA's existing research and education program funds.

The Committee is pleased to see the augmentation of critical skills in the NASA workforce with the addition of 625 new civil service job slots in the fiscal year 1988 budget request. These additional slots should greatly increase the safety, reliability, and quality assurance capabilities and engineering skills of the agency.

For fiscal year 1988, the Committee earmarks $250,000 of the funds authorized for Research and Program Management 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.

Office of Commercial Space Transportation—Section 108

The Committee has authorized $4,550,000 for the operation of the Office of Commercial Space Transportation within the Department of Transportation in Section 108 of S. 1164. This is the same as the President's budget request and is consistent with the provisions of S. 1173, the Administration's fiscal year 1988 budget request that was included in the NASA Authorization bill.

The Office of Commercial Space Transportation was established pursuant to Public Law 98-575, with the specific purpose of initiating the regulatory activities necessary for commercial space transportation operations. These activities include safety research and planning, licensing procedures, inspection operations and risk management.

In light of the advent of the marketing of commercial launch services by U.S. firms, this Office should face increased requirements in fiscal year 1988 in order to accommodate the approval of these launches. For this reason, the Committee provides the Administration's request. However, the Committee expects to see an increase in technical proficiency of this Office as a result of the significant increase over the fiscal year 1987 operating plan.

The Committee is also concerned about the delay in the final approval of the range use agreement with the U.S. Air Force. This agreement is essential to the success of any commercial launch effort. The Committee, therefore, expects to be informed of any impediments which may exist to prevent the formal completion of this agreement. The Committee is sensitive to the complexity of the issues surfaced by such an agreement and feels strongly that the final agreement must both protect U.S. interests and assist this nascent industry. Once again, it is clear that government/industry cooperation is required if a commercial launch industry is to emerge.

National Aeronautics and Space Council—Section 109

Section 109 of the bill authorizes the reestablishment of a National Space Council within the Executive Office of the President. The Council would be composed of the Vice President as Chairman, the NASA Administrator, and the Secretaries of State, Defense, Commerce, and Transportation. The functions of the Council would be to advise the President on all space policy matters and to coordinate civilian space activities with national security space activities.

In addition, a nine member User Advisory Group would be created and would provide advice on space policy from the perspective of the users. The Group would be composed of nine non-federal representatives from aerospace, science and other related fields and shall from time to time meet with the Chairman.

The Council also would be assisted in performing its duties and functions by a professional staff of not more than seven members.

A provision identical to Section 109 of the fiscal year 1988 NASA Authorization was included in the fiscal year 1987 NASA Authorization bill that was agreed to by the House of Representatives but vetoed by the President in the 99th Congress. One of the bases for the veto was the inclusion of the National Space Council in the Authorization bill and a belief on the part of the President that the language impinged on his authority over the composition of the Executive Office of the President. This language was reintroduced in the 100th Congress as S. 504, by Senators Riegle, Hollings, Gore, Kerry, Rockefeller, Adams, Pressler, and Bentsen.

The Committee has included this language as a reflection of its deep concern about the lack of effective space policymaking in the government. The National Security Council has nominal control over interagency space policy but has failed on several occasions to provide adequate direction, focus or coordination. Our national space program is a resource and endeavor that warrants and deserves the highest priority within the Administration. Moreover, decisions and policies affecting our space program must be made in a timely and responsible manner. The Committee's concern is related to the difficulty, over the past two to three years, of our space policymaking process to resolve effectively and in a timely manner particular issues that have been crucial to the conduct of our civilian space program.

At the time this provision was originally included in the fiscal year 1987 NASA Authorization bill, the Committee was deeply concerned about a space policymaking apparatus that placed the respective agency interests above the national interests. The events surrounding the shuttle pricing policy decision, the commercialization of expendable launch vehicles, and the determination to procure a replacement orbiter for the space shuttle *Challenger*, pointed to an unacceptable deficiency that had to be corrected. The Presidential veto of the fiscal year 1987 NASA Authorization bill, however, precluded a legislative remedy to this problem.

Since the time of the Presidential veto, November 14, 1986, the situation has not improved. The confusion associated with the cost, schedule and configuration of the space station program and the fiscal year 1987 supplemental request for a heavy lift launch vehicle (HLLV), now referred to as an Advanced Launch System, manifests the same symptoms that were of concern to the 99th Congress. The existing space policymaking apparatus seems incapable of resolving conflicts in a timely manner. The existing space policymaking process either has to be altered dramatically or a new process, with greater visibility and a dedicated staff, needs to be established. This Committee supports the latter option and feels the appropriate starting point is the exact same language that was vetoed by the President.

The Committee believes that actions must be taken now to create more coherence and consistency to the civilian space program. It is impossible for several different agencies within the government to maintain independent space programs. The costs in terms of inefficiency and budget are simply too great. In the Committee's opinion, a National Space Council, under the direction of the Vice President, could produce a more rational and balanced space policy. The Council performed a function similar to this during the early days of the space program with great success. In addition, the Council may elevate space and issues to a much higher level of interest and visibility than in recent years and thereby cast these issues in terms of a national priority.

The Committee recognizes that the establishment of the Council will not, in and of itself, remedy all of the existing problems within the space program. It could, however, provide the necessary focus, motivation and policymaking framework to resolve the current difficulties, allocate resources in a sensible fashion, and provide the impetus to move the space program toward future successes.

Amendment to the National Aeronautics and Space Act of 1958 to Authorize the Acceptance of Gifts and Donations—Section 110

S. 503 would permit NASA to accept conditional gifts and donations from private citizens and corporations. This bill was introduced on February 5, 1987, by Senators Riegle, Hollings, Gore, Kerry, Rockefeller, Nickles, Danforth, Pressler, and Bentsen.

The bill would permit citizens to contribute to a specific activity within NASA, such as the construction of the new space shuttle. Currently, such donations cannot be accepted and dedicated strictly to one purpose. The need for this legislation emerged in the aftermath of the *Challenger* disaster when NASA was receiving contributions from various groups, organizations and individuals to buy a new orbiter. Presently, there are roughly $29,000 in this category, primarily the result of the Nickels for NASA program.

In addition, the bill would require that the new name for the orbiter be selected from names submitted by school children who spearheaded them fund raising effort with the Nickels for NASA program.

To facilitate consideration of this amendment in a timely fashion, S. 503 has been incorporated into S. 1164, the fiscal year 1988 NASA Authorization bill, as Section 110.

International Space Year—Committee Comments

The International Space Year (ISY), which will extend from 1992 through 1994, is an initiative of the United States Congress that has gained support from NASA, the President, foreign nations, and International scientific organizations. For the past two years, Congress has urged NASA to intensify its efforts on behalf of them ISY; and NASA, in association with the National Academy of Sciences and other relevant agencies, has been successful in laying a solid foundation for the ISY in the United States and abroad. ISY planning committees have been established in many nations, including the United States and the other major space powers. The International Committee on Space Research (COSPAR) and its parent body, the International Council of Scientific Unions (ICSU), the chief coordinating agent for the immensely successful International Geophysical Year (IGY) of 1957-58, have established ISY coordinating committees. The ISY's promising evolution offers positive testimony to United States' leadership in world space activities.

The Committee strongly supports the ISY and has earmarked $250,000 in the Research and Program Management account to assist in the organization of the national and international aspects of the ISY.

Title II—National Space Grant College and Fellowship Program Committee Comments

Title II of the bill establishes the National Space Grant College and Fellowship Program and authorizes $10 million for each of fiscal years 1988 and 1989 and $15 million for each of fiscal years 1990 and 1991 to carry out this new program. The purpose of this program is to promote activities in colleges and universities that will increase the understanding, assessment, development and utilization of space resources, and expand the educational, scientific and research base in all space-related fields.

The Committee has found that NASA's currents to attract and recruit scientists and engineers to fill its ranks is sporadic and ineffective. In the 1960's NASA supported an average of 500 doctoral students per year. The current program supports about 80 students. More than 56 percent of NASA's engineers and scientists, for example, are over the age of 45. Thus, it is clear that NASA is not creating nor maintaining a base of talent to draw upon as the older generation nears retirement.

NASA's professional corps has been the single most important factor in the successes of our space program. Throughout the early years, thousands of the nation's brightest minds came to NASA to be a part of that historic effort. The Committee is deeply concerned that NASA has lost the ability to attract the diversity and the caliber of scientists and engineers vital to the success of the future space program.

To address this deficiency, the Committee has included the National Space Grant College and Fellowship Program in the fiscal year 1988 NASA Authorization bill. The Committee has modeled this program after the Sea Grant college program, which has been a successful multidisciplinary effort involving the academic, governmental, and industrial communities. The Sea Grant program has produced a cadre of young scientists dedicated to marine-related issues. The Committee believes that this approach can also be successful in space activities. The language requires that grants provided by NASA be matched by private contributions. This will ensure a continuing level of interest and participation by a broad spectrum of our nation in the space program.

Thus, the Committee is most anxious to begin the implementation of this program. The legitimate concerns of NASA have been addressed, with respect to administrative flexibility. Other concerns with respect to regional balance are also reflected in the language of the title.

The Committee strongly believes that the National Space Grant College and Fellowship program will be an important step in our common effort to revitalize the nation's space program.

During markup of the NASA Authorization bill, an amendment to the Space Grant College and Fellowship Program was proposed by Senator Danforth and accepted. The exact language contained in this amendment and the Committee's interpretation are contained in the Committee Comments for Research and Program Management.

The Final Space Grant College and Fellowship Program provisions contained in Title II of this bill are identical to those contained in S. 752, with the exception of the Danforth Amendment.

Title III—Amendments to the Land Remote Sensing Commercialization Act of 1984

S. 502, a bill to amend the Land Remote Sensing Commercialization Act of 1984, was introduced on Februrary 5, 1987, by Senators Riegle, Hollings, Gore, Kerry, Rockefeller, Adams, and Bentsen.

This bill consists of technical amendments to the Land Remote Sensing Commercialization Act that would clarify the Congressional intent with regard to the distribution of experimental data and its use by research and development organizations. The bill also would permit system operators to restrict the reproduction or dissemination of unenhanced data by foreign or domestic users.

The same language as contained in S. 502 was passed by the House and Senate during the 99th Congress. Unfortunately, this bill was incorporated into the fiscal year 1987 NASA Authorization bill that was vetoed by the President.

To facilitate consideration of these amendments in a timely fashion. S. 502 has been incorporated into S. 1164, the fiscal year 1988 NASA Authorization bill, as Title III.

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 21, 1987.

Hon. ERNEST F. HOLLINGS,
Chairman, Committee on Commerce, Science, and Transportation, U.S. Senate, Dirksen Senate Office Building, Washington, DC.

DEAR MR. CHAIRMAN: The Congressional Budget Office has prepared the attached cost estimate for S. 1164, the National Aeronautics and Space Administration Authorization Act of 1988.

If you wish further details on this estimate, we will be pleased to provide them.

With best wishes,
Sincerely,

EDWARD M. GRAMLICH,
Acting Director.

CONGRESSIONAL BUDGET OFFICE COST ESTIMATE

1. Bill number: S. 1164.
2. Bill title: National Aeronautics and Space Administration Authorization Act of 1988.
3. Bill status: As amended and ordered reported by the Senate Committee on Commerce, Science, and Transportation on May 14, 1987.

4. Bill purpose: This bill authorizes the appropriation of an estimated $9,961 million in fiscal year 1988 for the ongoing activities of the National Aeronautics and Space Administration (NASA). In addition, the bill initiates the National Space Grant College and Fellowship program within NASA and authorizes the appropriation of $10 million in each of fiscal years 1988 and 1989 and $15 million in fiscal years 1990 and 1991 for the making of grants under that program.

The fiscal year 1988 authorization specified in the bill for NASA totals $9,621 milion. The bill also authorizes the appropriation in fiscal year 1988 of such sums as may be necessary to return the shuttle fleet to flight status. Of the specified authorization, $3,721 million is for research and development, $4,081 million is for space flight, control, and data communication, $211 million is for construction of facilities, and $1,608 million is for research and program management.

In addition to the NASA authorizations, the bill authorizes the appropriation of about $4.6 million for the Office of Space Commercialization in the Department of Transportation. The bill also amends the Land Remote-Sensing Commercialization Act of 1984.

5. Estimated cost to the Federal Government: The following table shows funding amounts specifically authorized by S. 1164 and estimated outlays based upon these amounts.

[By fiscal years, in millions of dollars]

	1988	1989	1990	1991	1992
Specified authorization level:					
Function 250: Civilian space	8,854.9	10.0	15.0	15.0	
Function 400:					
Aeronautics	766.1				
Commercial space	4.6				
Total specified authorizations	9,625.6	10.0	15.0	15.0	
Estimated outlays	6,507.8	2,764.5	678.6	47.0	16.1

In addition, the bill authorizes the appropriation of such sums as may be necessary in fiscal year 1988 to return the shuttle system to operational flight status. Based upon preliminary information, the estimated authorization level and estimated outlays associated with this requirement would be as shown in the table below.

[By fiscal years, in millions of dollars]

	1988	1989	1990	1991	1992
Estimated authorization level	350.0				
Estimated outlays	246.8	81.9	21.3		

The table below shows the total authorization and outlay levels for S. 1164.

[By fiscal year, in millions of dollars]

	1988	1989	1990	1991	1992
Total authorization levels (specified and estimated)	9,975.6	10.0	15.0	15.0	
Total estimated outlays	6,754.6	2,846.4	700.0	47.0	16.1

Including outlays from previous years' appropriations, total NASA outlays in fiscal year 1988 are estimated to be $9,996 million, assuming appropriation of the amounts authorized in this bill.

The costs of this bill fall within budget functions 250 and 400.

Basis of estimate: The authorization levels in the first table are the amounts specified in the bill. The outlay estimates for ongoing programs assume that all funds authorized are appropriated prior to the beginning of fiscal year 1988 and that spending will reflect historical patterns. The outlay estimates for new programs assume that spending will follow historical patterns of similar government programs.

The fiscal year 1988 authorization level required to return the shuttle system to flight status is a CBO estimate based upon preliminary information. Estimated outlays are assumed to follow historical spending patterns for shuttle system operations.

6. Estimated cost to State and local governments: None.

7. Estimate comparison: None.

8. Previous CBO estimate: None.

9. Estimate prepared by: Paul M. DiNardo.

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, universites, 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 authorized the appropriation of funds for the Office of Commercial Space Transportation in the Department of Commerce and establishes a National Space Grant College and Fellowship Program. The Office of Commercial Space Transportation licenses and regulates the commercial expendable launch vehicle industry in order to protect the public health and safety and comply with existing United States 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.

As for the National Space Grant College and Fellowship Program, it builds on an existing NASA program and does not represent a burdensome regulatory regime. Recipients of the grants, awards, contracts, or fellowships will be expected to comply with the guidelines that are promulgated.

The Office of Commercial Space Transportation and the National Space Grant College and Fellowship Program have no effect on individual privacy and should not have an unacceptable regulatory effect on the individuals or businesses who choose to participate.

None of the above mentioned programs would have an inflationary impact, and the only additional paperwork requirement would be the submission of applications for the National Space Grant College and Fellowship Program.

Section-by-Section Analysis

TITLE I

SECTION 101

The short title of title I is the "National Aeronautics and Space Administration Authorization Act, 1988".

SECTION 102

This section authorizes $9.621 billion for the National Aeronautics and Space Administration in fiscal year 1988.

These monies are distributed to four appropriations accounts:

1. *Research and Development.*—$3.721 billion for space station, space science and applications, space transportation capability development, commercial programs, aeronautical research and technology, transatmospheric research and technology and space research and technology.

The major assumptions in this area are full funding for the space station in fiscal year 1988, restoration of funding for the Advanced Communications Technology Satellite program, and initiation of a new Civilian Space Technology Initiative.

2. *Space Flight Control and Data Communications.*—$4.081 billion for space shuttle production and operations capability, space transportation operations, space tracking and data acquisition, and expendable launch vehicle operations.

The major assumptions in this account are deferral of funding for the structural spares program for a fifth orbiter pending further assessment of the expendable launch vehicle program and the new advanced launch system program; and initiation of a ELV procurement program at NASA for NASA payloads that would be based on a quid pro quo with the Air Force or a launch service agreement with a commercial operator.

3. *Construction of Facilities.*—$0.210 billion 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 the space station facilities can be delayed one year because the overall program has been delayed for that period of time, and the priority status of repairing the 12 foot wind tunnel at the NASA Ames Research Center. This tunnel is critical to both civil and military aircraft development.

Subsection (h) of this account is also amended to permit NASA to expend up to $500,000 for modifications to GSA-controlled facilities. Formerly the cap was $100,000 but this precluded upgrading the health care unit and auditorium at NASA Headquarters.

4. *Research and Program Management.*—$1.598 billion for all civil service staff, maintenance of facilities and support of R&D programs and contract activities, and technical and administrative support of research and development programs.

The major assumptions in this account are that NASA will increase the civil service employee base by 625 new slots and that the Space Grant College and Fellowship program will be initiated in fiscal year 1988. Of these new jobs, 270 are for Headquarters, 25 for the Inspector General's Office, 128 for the Johnson Space Center, 27 for the Kennedy Space Center, 160 for the Marshall Space Flight Center, and 15 for the National Space Technology Lab.

SECTIONS 103, 104, AND 105

These sections establish strict parameters for the Administrator of NASA concerning the amount of flexibility he/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 106

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 107

This section instructs NASA to distribute its research and development funds on a geographical basis where possible. The Committee annually legislates this requirement and feels it is in the national interest.

SECTION 108

This section authorizes $4.55 million for fiscal year 1988 for the Office of Commercial Space Transportation in the Department of Transportation. This Office oversees the regulation and licensing of commercial expendable launch vehicle 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.

SECTION 109

This section amends the National Aeronautics and Space Act of 1958 to reestablish the National Space Council. The Council would be located within the White House and chaired by the Vice-President. It would include the representatives of NASA, and the Departments of Defense, State, Commerce, and Transportation. It would be the function of the Council to advise the President on space policy matters and to coordinate civilian activities with those in the national security arena. This section also provides for the creation of a nine member (non-Federal) User Advisory Group that would meet with the Vice President at least once a year and gives the Council the authority to employ a staff of not more than seven persons.

The Council provision was included in last year's NASA Authorization bill that was vetoed by the President.

SECTION 110

This section amends the National Aeronautics and Space Act of 1958 to permit the Administrator of NASA to accept conditional gifts and donations for the construction of a new space shuttle orbiter.

Currently, NASA may not accept conditional gifts. However, in the aftermath of the space shuttle *Challenger* accident, thousands of persons made donations to NASA that have been placed in a bank account. The current estimates of these "conditional" donations is $19,000.

SECTION 111

This section indicates that it is the Sense of the Congress that the U.S. must promptly restore its space transportation capabilities, and such restoration must be accomplished without deemphasizing other space programs.

This section also instructs the Administrator of NASA to take such steps as necessary to return the space shuttle fleet safely to flight status.

Section 111 also authorizes "such sums as may be necessary" to meet these requirements.

NASA is currently in the porocess of reviewing *additional* fiscal year 1988 shuttle anomaly resolution and Rogers Commission recommendations that have not been funded in Section 102 of this bill. This review is not likely to be completed until the end of May and then a budget amendment will need to be prepared, approved and submitted to the Congress.

In anticipation of this request, the Committee has included the "such sums language" with the intent of inserting the dollar value of the additional requirements if approved by the subcommittee, in the bill on the floor of the Senate or in Conference. This language gives the Committee this option and does not preclude discussion of this matter in Conference.

SECTION 112

This section authorizes multi-year contracting authority for launch services in order to avoid violation of the Anti-Deficiency Act, 31 U.S.C. 1341 *et seq.*, and similar fiscal or other laws and regulations which limit the monetary obligation or the contract period. Generally, NASA's non-construction appropriations cover no more than two fiscal years. The budget and appropriation process provides funding on an incremental basis and does not include sufficient funding to fully fund such launch service contracts which foreseeably could require advance payments over several years for the construction of the vehicle, and then provide the services for a program that could cover a decade. Normally payments for the services could not be made until the services are rendered. In such situations the termination liability for the construction costs alone could exceed the incremental funding provided in the initial fiscal period appropriation.

The provision to limit launch services to domestic companies is intended to foster privatization by providing NASA the necessary authority to limit the procurement of launch services to U.S. firms when this is in the public interest. Furthermore, this section would allow NASA to contract over periods of time and on terms and conditions which are necessary if those domestic firms are to undertake the investment and assume the risks inherent in preparing for services that will not be provided for serveral years hence. Accordingly, this section authorizes NASA, consistent with its charter to seek and encourage the fullest commercial use of space (42 U.S.C. 2451(c)), to limit the solicitation and award of such contracts to domestic U.S. firms, provided it is deemed in the public interest. The proviso does not make it mandatory to contract only with domestic firms regardless of any countermailing circumstances, although it is expected to have that effect until a domestic commercial launch industry is firmly established. Without the authority given in this section, the full and open competition requirements of the Competition in Contracting Act of 1984, P. L. 98-369, and related or similar laws and regulations could impair the development of the domestic launch services industry.

TITLE II

SECTION 201

This title may be cited as the "National Space Grant College and Fellowship Act".

SECTION 202

The Congress finds that NASA, through the National Space Grant College and Fellowship Program, can best promote commitment and interest in the understanding and development of space.

SECTION 203

This section notes the purposes of the Act. The principal purpose is to support activities in colleges and universities that will increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base, responsive research and training activities.

SECTION 204

This section contains the definitions that are used in the proposal.

SECTION 205

This section instructs the Administrator of NASA to establish and maintain a national space grant college and fellowship program to provide financial assistance, and to establish long-range planning guidelines and priorities, and to adequately evaluate the program.

This section also gives the Administrator the authority to accept conditional and unconditional gifts to fund these activities, to accept and use Federal funds from other Federal programs and to issue rules and regulations as may be necessary and appropriate.

SECTION 206

This section grants the Administrator the authority to make grants and enter into contracts to assist any space grant college and fellowship program if it supports the purposes of the act set out in section 203. It also limits the amount of any grant or contract to 66 percent of the proposed program except in special circumstances.

SECTION 207

This section instructs the Administrator to identify specific national needs and problems relating to space and to make grants or enter into contracts with respect to such needs and problems. There is no cap on the NASA share of these activities.

SECTION 208

This section grants the Administrator the authority to designate any institution of higher education as a space grant college and any association or other alliance of two or more persons, other than individuals, as a space grant regional consortium.

This section also establishes the requirements needed to be fulfilled to obtain such designations, including a balanced program of research education, training and advisory services related to space.

SECTION 209

This section instructs the Administrator to support a space grant fellowship program for qualified individuals at the graduate level of education in fields related to space.

The total amount for space grant fellowships shall not exceed 50 percent of the total funds appropriated pursuant to this title.

SECTION 210

This section instructs the Administrator of NASA to establish an independent committee known as the Space Grant Review Panel to assist the Administrator in formulating applications and proposals for grants and contracts, the space grant fellowship award, the designation and operation of space grant college and regional consortium, the formulation and application of planning guidelines, etc.

SECTION 211

This section permits other Federal agencies to provide personnel, services, and facilities on a reimbursable basis or otherwise to assist in carrying out the provisions of this title.

SECTION 212

This section requires the Administrator to submit an annual report to the Congress and the President on the activities of the national space grant college and fellowship program.

SECTION 213

This section requires the Administrator to utilize the competitive, merit-based review employed by the Administration on the date of enactment of this Act in designating any space grant college or space grant regional consortium or in awarding of any fellowship, grant, or contract.

SECTION 214

This section authorizes $10 million for the program for each of fiscal years 1988 and 1989, and $15 million for the program for each of fiscal years 1990 and 1991.

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 201 of that Act

SEC. 201. (a) There is hereby established, in the Executive Office of the President, the National [Aeronautics and] Space Council (hereinafter called the "Council") which shall be composed of—

(1) the Vice President, who shall be Chairman of the Council;
(2) the Secretary of State;
(3) the Secretary of Defense;
(4) the Secretary of Transportation;
(5) the Administrator of the National Aeronautics and Space Administration; and
(6) the Chairman of the Atomic Energy Commission[.] *who shall be the Vice Chairman of the Council; and*
(7) such other members as the President may appoint.

[(b) The President shall from time to time designate one of the members of the Council to preside over meetings of the Council during the absence, disability, or unavailability of the Chairman.]

(b) In the absence of the Vice President, the Administrator shall preside over meetings of the Council.

⟦(c) Each member of the Council may designate another officer of his department or agency to serve on the Council as his alternate in his unavoidable absence.⟧

(c) Each member of the Council may designate an officer of their department or agency to serve on the Council as their alternative in their unavoidable absence.

(d) Each alternate member designated under subsection (c) of this section shall be designated to serve as such ⟦by and with the advice and consent of the Senate⟧ unless at the time of his designation he holds an office in the Federal Government to which he was appointed by and with the advice and consent of the Senate.

(e) It shall be the function of the Council to advise and assist the President, as he may request, with respect to ⟦the performance of functions in the aeronautics and space field, including⟧ the following functions:

⟦(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all departments and agencies of the United States engaged in such activities;

⟦(2) develop a comprehensive program of aeronautical and space activities to be conducted by departments and agencies of the United States;

⟦(3) designate and fix responsibility for the direction of major aeronautical and space activities;

⟦(4) provide for effective cooperation among all departments and agencies of the United States engaged in aeronautical and space activities, and specify, in any case in which primary responsibility for any category of aeronautical and space activities has been assigned to any department or agency, which of those activities may be carried on concurrently by other departments or agencies; and

⟦(5) resolve differences arising among departments and agencies of the United States with respect to aeronautical and space activities under this Act, including differences as to whether a particular project is an aeronautical and space activity.⟧

(1) survey of ongoing civilian space activities;

(2) review of long-range goals for civilian space activities;

(3) coordination of civilian space activities among civilian agencies and with agencies involved in national security space activities; and

(4) interagency cooperation in civilian space activities.

(f) * * *

(g)(1) The Council shall establish a Users' Advisory Group composed of nine non-Federal representatives of industries and other persons involved in space activities.

(2) The Vice President shall name a Chairman of the Users' Advisory Group.

(3) The Council shall from time to time, but not less often than once a year, meet with the Users' Advisory Group.

(4) The function of the Users' Advisory Group is to ensure that the interests of non-Federal entities involved in space activities, including in particular commercial entities, are adequately represented in the Council.

SEC. 202.-207. * * *

DONATIONS FOR SPACE SHUTTLE ORBITER

SEC. 208. (a) The Administrator may accept gifts and donations of services, money, and real, personal, tangible, and intangible property, and use such gifts and donations for the construction of a space shuttle orbiter.

(b)(1) The authority of the Administrator to accept gifts or donations pursuant to subsection (a) of this section shall terminate five years after the date of the enactment of this section.

(2) All gifts and donations accepted by the Administrator pursuant to subsection (a) of this section which are not needed for construction of a space shuttle orbiter shall be used by the Administrator for an appropriate purpose—

(A) in tribute to the dedicated crew of the space shuttle Challenger; and

(B) in furtherance of the exploration of space.

(c) The name of a space shuttle orbiter constructed in whole or in part with gifts or donations whose acceptance and use are authorized by subsection (a) of this section shall be selected by the Administrator of the National Aeronautics and Space Administration from among suggestions submitted by students in elementary and secondary schools.

ADDITIONAL VIEWS OF MR. ADAMS

The American space program, and the agency which runs it, are clearly in trouble. The *Challenger* disaster revealed technical and administrative weaknesses; our response to that tragedy has demonstrated a continuing inability to correct identified deficiencies in both the operation and the design of our space program.

This bill should help us correct some of those problems. I am pleased that the Committee has increased funding for, and emphasis on, expendable launch vehicles; I am also pleased that we have denied funding for a fifth shuttle. While I believe we could have gone further in each of those areas, I am satisfied that we have at least begun to deal with some of the basic questions which need to be addressed. As we move further away from the trauma of the *Challenger,* I believe we will be able to more objectively examine these issues and make even more dramatic shifts in strategy.

We need to make dramatic strategic shifts because, if the space program continues on its present course, it will fail. And that, I believe, would be a disaster. Space exploration is an economic, scientific, and psychological necessity for this nation. But this vital program will not be able to secure the funding it needs in the furture unless it is able to regain the support of the public in the present.

That support was not lost as a result of the *Challenger* accident; after all, the space program has suffered other setbacks in the past. No, public dissatisfaction seems to spring from a sense that the program has lost its vision. The American space program is now seen as being run by technocrats whose goal is to meet military needs; it must once again be perceived as a program headed by visionaries who understand the practical consequences of their action, but are driven by a quest for knowledge and a love of adventure.

In that context, we all recognize that there are practical consequences associated with space activity. The Soviet superiority in space is disturbing: their space station is allowing them to gain knowledge that we should have; their Expendable Launch Vehicles may allow them to enter a market we could have monopolized; their proposed planetary missions will give them a view of the cosmos which we must share. But a desire to "keep up" with the Soviets is not enough to ensure either public support or government funding. In fact, the uncertain relationship which currently exists between DOD and NASA raises profound questions about the nature of the program—and those doubts will need to be resolved in the near future. My point is simply that our space efforts must be motivated by more than a desire to compete with the Soviets; it must also be driven by a desire to compete with the best in ourselves.

In my view, the most critical decision facing NASA in the near future is not related to the ultimate design of the space station—though that is clearly a major issue—but rather to the nature of its ultimate mission. The recent resignation of at least one critical decision-maker engaged in evaluating the future options is not a good sign in this respect, but the process must continue. NASA must produce a vision for the future which takes the space program to the edge of the unknown once again.

At one point, NASA sought to depict shuttle flights as routine ventures. That was a mistake. The reality is that no flight into space is routine. Space is not an extension of the human environment. It is a hostile area which will not forgive mistakes. It is precisely that characteristic which makes exploration so necessary and gives it the potential to be so inspiring. NASA's decision about the direction it wishes to take will, to a large extent, determine just how willing the Congress and the country will be to fund its ventures.

While I endorse this basic thrust of this authorization, and while I remain committed to a strong space program, I simply wanted to take this opportunity to issue a warning: in a period of fiscal restraint, NASA needs to give us more than another mode of transportation—it must demonstrate that it has the imagination to transport us to the frontiers of human knowledge. Hopefully their internal efforts, and this bill, will help produce just such a result.

Public Law 100-147
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.

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 of 1988".

TITLE I—AUTHORIZATION OF APPROPRIATIONS FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEC. 101. (a) There is authorized to be appropriated to the National Aeronautics and Space Administration to become available October 1, 1987, for "Research and development", for the following programs:

(1) Permanently manned space station, $767,000,000.

(2) Space transportation capability development, $553,600,000.

(3) Physics and astronomy, $581,800,000.

(4) Life sciences, $74,600,000.

(5) Planetary exploration, $320,300,000, of which $42,300,000 is authorized only for the purpose of preparing the Mars Observer Spacecraft for launch in 1992 and for procuring spare parts for a Planetary Observer program.

(6) Space applications, $651,400,000, of which $84,000,000 is authorized only for the Advanced Communications Technology Satellite.

(7) Technology utilization, $18,300,000.

(8) Commercial use of space, $30,700,000.

(9) Aeronautical research and technology, $387,000,000.

(10) Transatmospheric research and technology, $66,000,000.

(11) Space research and technology, $234,000,000.

(12) Safety, reliability, and quality assurance, $16,200,000.

(13) Tracking and data advanced systems, $18,100,000.

(b) There is authorized to be appropriated to the National Aeronautics and Space Administration to become available October 1, 1987, for "Space flight, control and data communications", for the following programs:

(1) Space shuttle production and operational capability, $1,174,600,000, of which $76,000,000 is authorized only for initial lay-in spare parts for the space shuttle orbiter.

(2) Space transportation operations, $1,885,800,000, of which $106,700,000 is authorized only for flight spare parts for the space shuttle orbiter.

(3) Space and ground network, communications, and data systems, $924,900,000.

(4) Expendable launch vehicle operations, $60,000,000.

(c) There is authorized to be appropriated to the National Aeronautics and Space Administration to become available October 1, 1987, for "Construction of facilities", including land acquisition, as follows:

(1) Construction of LC 39 Operations Support Building, Kennedy Space Center, $22,800,000.

(2) Construction of Spacecraft Systems Development and Integration Facility, Goddard Space Flight Center, $8,600,000.

(3) Modifications for utility reliability, Goddard Space Flight Center, $2,900,000.

(4) Construction of Integrated Test Facility, Dryden Flight Research Facility, $10,500,000.

(5) Modifications to Hypersonic Propulsion Facility for Vaccum Systems, Langley Research Center, $3,100,000.

(6) Construction of addition to the Research Analysis Center, Lewis Research Center, $9,800,000.

✓ (7) Modifications for Fan/Compressor Research, Engine Research Building, Lewis Research Center, $6,500,000.

(8) Construction of Communications Development Antenna, Goldstone, California, Jet Propulsion Laboratories, $6,400,000.

(9) Repair of facilities at various locations, not in excess of $750,000 per project, $25,000,000.

(10) Rehabilitation and modification of facilities at various locations, not in excess of $750,000 per project, $32,000,000.

(11) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of $500,000 per project, $8,000,000.

(12) Environmental compliance and restoration, $23,900,000.

✓ (13) Repair and modernization of the 12-foot pressure wind tunnel at the Ames Research Center, $41,000,000.

(14) Facility planning and design not otherwise provided for, $16,000,000.

(d) There is authorized to be appropriated to the National Aeronautics and Space Administration to become available October 1, 1987, for "Research and program management", $1,583,000,000.

(e) The Administrator is authorized (to the extent provided in an appropriation Act) to transfer $22,000,000 from any funds which were made available for prior years, and which remain unobligated as of the date of the enactment of this Act, except for funds made available for Aeronautical and Space Research and Technology, Transatmospheric Research and Technology programs, Construction of Facilities activities, and Research and Program Management activities for the support of such programs, and use such funds for the preparation of the Mars Observer spacecraft for launch in 1992.

(f) Notwithstanding the provisions of subsection (h), appropriations authorized in this Act 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 National Aeronautics and Space Administration (hereinafter in this title referred to as the "Administration") for the performance of research and development contracts, and (2) 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 (hereinafter 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 Act 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 Technology of the House of Representatives of the nature, location, and estimated cost of such facility.

(g) 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 12 months beginning at any time during the fiscal year.

(h) Appropriations made pursuant to subsection (d) may be used, but not to exceed $35,000, for scientific consultations 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.

(i) Of the funds appropriated pursuant to subsections (a), (b), and (d), not in excess of $100,000 for each project, including collateral equipment, may be used for construction of new facilities and additions to existing facilities, and for repair, rehabilitation, or modification of facilities: *Provided*, That, of the funds appropriated pursuant to subsection (a) or (b), not in excess of $500,000 for each project, including collateral equipment, may be used for any of the foregoing for unforeseen programmatic needs: *Provided further*, That, of the funds appropriated pursuant to subsection (d), not in excess of $500,000 per project, including collateral equipment, may be used for repair, rehabilitation, or modification of facilities controlled by the General Services Administration.

SEC. 102. Authorization is granted whereby any of the amounts prescribed in paragraphs (1) through (13) of section 101(c) of this title—

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

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

to meet unusual cost variations, but the total cost of all work authorized under such paragraphs shall not exceed the total of the amounts specified in such paragraphs.

SEC. 103. Not to exceed one-half of 1 percent of the funds appropriated pursuant to section 101 (a) or (b) of this title may be transferred to and merged with the "Construction of facilities" appropriation, and when so transferred, together with $10,000,000 of funds appropriated pursuant to section 101(c) of this title (other than funds appropriated pursuant to paragraph (14) of such section) shall be available for expenditure to construct, expand, and modify laboratories and other installations at any location (including locations specified in section 101(c)), if (1) the Administrator determines that such action is necessary because of changes in the national program of aeronautical and space activities or new scientific or engineering developments, and (2) the Administrator determines 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 funds so made available 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 portion of such sums may be obligated for expenditure or expended to construct, expand, or modify laboratories and other installations unless a period of 30 days has passed after the Administrator or the Administrator's designee has transmitted to the President of the Senate and to the Speaker of the House of Representatives and to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a written report containing a full and complete statement concerning (A) the nature of such construction, expansion, or modification, (B) the cost thereof including the cost of any real estate action pertaining thereto, and (C) the reason why such construction, expansion, or modification is necessary in the national interest.

SEC. 104. Notwithstanding any other provision of this title, no amount appropriated pursuant to this title may be used for any program—

(1) deleted by the Congress from requests as originally made either to the Committee on Commerce, Science, and Transportation of the Senate or the Committee on Science, Space, and Technology of the House of Representatives;

(2) in excess of the amount actually authorized for that particular program by section 102 (a), (b), and (d); and

(3) which has not been presented to either such Committee;

unless a period of 30 days has passed after the receipt by the President of the Senate and the Speaker of the House of Representatives and each such committee of notice given by the Administrator or the Administrator's 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.

SEC. 105. No civil space station authorized under section 101(a)(1) of this title 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.

SEC. 106. (a) The Administrator is directed to undertake the construction of a permanently manned space station (hereinafter referred to as the "space station") to become operational in 1995. The space station will be used for the following purposes—

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

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

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

(4) the establishment of a space base for other civilian and commercial space activities.

(b) The space station shall be developed and operated in a manner that supports other science and space activities.

(c) In order to reduce the cost of operations of the space station and its ground support system, the Administrator shall undertake the development of such advanced technologies as may be appropriate within the level of funding authorized in this Act.

(d) The Administrator shall seek to have portions of the space station constructed and operated by the private sector, where appropriate.

(e) The Administrator shall promote international cooperation in the space station program by undertaking the development, construction, and operation of the space station in conjunction with (but not limited to) the Governments of Europe, Japan, and Canada.

(f) The space station shall be designed, developed, and operated in a manner that enables evolutionary enhancement.

SEC. 107. (a) For each of the fiscal years 1989 through 1996, the Administrator, along with the President's submission to the Congress of the annual budget request for the National Aeronautics and Space Administration, shall submit a capital development plan for the space station program. Each such plan shall include the estimated cost of all direct research and development; space flight, control and data communications; construction of facilities; and research and program management for the fiscal year involved and the two succeeding fiscal years.

(b) For fiscal year 1989, the capital development plan shall also include a statement outlining the total cost, schedule, and configuration of the Administration's space station proposal, as well as an analysis of the "Report of the Committee on the Space Station of the National Research Council". Such analysis shall examine alternatives for the configuration of the space station including but not limited to low cost alternatives.

SEC. 108. In order to ensure that the development of the space station is part of a balanced civilian space program, the Administrator is instructed to establish as a goal a funding profile that limits (1) space station total annual costs under the capital development plan in section 107 to 25 percent of the total budget request for the National Aeronautics and Space Administration and (2) all space station direct operations costs, except for those costs associated with the utilization of the space station, to 10 percent of the total budget request for the National Aeronautics and Space Administration.

SEC. 109. (a) It is the sense of the Congress that the launching and servicing of the space station should be accomplished by the most cost-effective use of space transportation systems, including the space shuttle and expendable launch vehicles.

(b) Not later than January 15, 1988, the Administrator shall submit a preliminary report on the cost-effective use of space transportation systems for the launch of space station elements during the development and operation of the space station. The Administrator shall consider—

(1) the potential use of future advanced or heavy lift expendable launch vehicles for purposes of the assembly and operation of the space station;

(2) the use of existing expendable launch vehicles of the National Aeronautics and Space Administration, the Department of Defense, and the Private Sector;

(3) the requirement for space shuttle launches; and

(4) the risk of capital losses from the use of expendable launch vehicles and the space shuttle.

SEC. 110. (a) The Administrator shall set and collect reasonable user fees for the use and maintenance of the space station.

(b) The Administrator shall set user fees so as to—

(1) promote the use of the space station consistent with the policy set forth in section 106;

(2) recover the costs of the use of the space station, including reasonable charges for any enhancement needed for such use; and

(3) conserve and efficiently allocate the resources of the space station.

(c) The Administrator may, on a case-by-case basis, waive or modify such user fees when in the Administrator's judgment such waiver or modification will further the goals and purposes of the National Aeronautics and Space Act of 1958, including—

(1) the advancement of scientific or engineering knowledge;

(2) international cooperation; and

(3) the commercial use of space.

SEC. 111. No later than September 30, 1988, the Administrator shall submit a detailed plan for collecting reimbursements for the utilization of the space station under section 110, including the services to be offered, the methodology and bases by which prices will be charged, and the estimated revenues.

SEC. 112. The Intergovernmental Agreement currently being negotiated between the United States Government and Canada, Japan, and member governments of the European Space Agency, and the Memorandum of Understanding currently being negotiated between the National Aeronautics and Space Administration and its counterpart agencies in Canada, Japan, and Europe concerning the detailed design, development, construction, operation, or utilization of the space station shall be submitted to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives. No such agreement shall take effect until 30 days have passed after the receipt by such committees of the agreement.

SEC. 113. (a) It is the sense of the Congress that it is in the national interest that consideration be given to 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.

(b) The Administrator shall report to the Congress on the extent to which such consideration has been given and such ways and means explored during fiscal year 1987, and shall submit such report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate by January 15, 1988.

SEC. 114. (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 incorporated in 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.

SEC. 115. Title II of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451 et seq.) is amended by adding at the end the following:

"DONATIONS FOR SPACE SHUTTLE ORBITER

"SEC. 208. (a) The Administrator may accept gifts and donations of services, money, and real, personal, tangible, and intangible property, and use such gifts and donations for the construction of a space shuttle orbiter.

"(b)(1) The authority of the Administrator to accept gifts or donations pursuant to subsection (a) of this section shall terminate five years after the date of the enactment of this section.

"(2) All gifts and donations accepted by the Administrator pursuant to subsection (a) of this section which are not needed for construction of a space shuttle orbiter shall be used by the Administrator for an appropriate purpose—

"(A) in tribute to the dedicated crew of the space shuttle Challenger; and

"(B) in furtherance of the exploration of space.

"(c) The name of a space shuttle orbiter constructed in whole or in part with gifts or donations whose acceptance and use are authorized by subsection (a) of this section shall be selected by the Administrator from among suggestions submitted by students in elementary and secondary schools.".

SEC. 116. (a) It is the sense of the Congress that the space shuttle is a critical national resource that should be preserved; that it should be used primarily for those missions which require its unique capabilities; and that a diversified family of expendable launch vehicles should be incorporated by use into the Nation's civilian space flight program.

(b) The Administrator shall establish a program for launching payloads by means of expendable launch vehicles and, if available, by commerical launch services.

(c) The Administrator shall take such action as may be necessary to ensure that expendable launch vehicles or, if available, commerical launch services are obtained for the launch of the following payloads:

(1) Roentgen Satellite (ROSAT), for launch in 1990.

(2) Tracking and Data Relay Satellite (TDRS)-F, or a planetary mission.

(3) Extreme Ultraviolet Explorer (EUVE), for launch in 1991.

(4) Mars Observer, for launch in 1992.

(d) The Administrator shall report to the Congress not later than January 15, 1988, on the Administrator's compliance with this section, and shall submit such report to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives.

SEC. 117. Title III of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451 et seq.) is amended by adding at the end the following:

"CONTRACTS REGARDING EXPENDABLE LAUNCH VEHICLES

"SEC. 311. (a) The Administrator may enter into contracts for expendabe launch vehicle services that are for periods in excess of the period for which funds are otherwise available for obligation, provide for the payment for contingent liability which may accrue in excess of available appropriations in the event the Government for its convenience terminates such contracts, and provide for advance payments reasonably related to launch vehicle and related equipment, fabrication, and acquisition costs, if any such contract limits the amount of the payments that the Federal Government is allowed to make under such contract to amounts provided in advance in appropriation Acts. Such contracts may be limited to sources within the United States when the Administrator determines that such limitation is in the public interest.

"(b) If funds are not available to continue any such contract, the contract shall be terminated for the convenience of the Government, and the costs of such contract shall be paid from appropriations originally available for performance of the contract, from other, unobligated appropriations currently available for the procurement of launch services, or from funds appropriated for such payments.".

SEC. 118. (a) It is the sense of the Congress that the capital investment in space satellites and vehicles should be enhanced and protected by establishing a system of servicing, rehabilitation, and repair capabilities in orbit (hereinafter referred to as "satellite servicing").

(b) The Administrator shall conduct a thorough and comprehensive study of satellite servicing with a view toward establishing national goals and objectives for utilizing such capabilities.

(c) In conducting the study of satellite servicing under this section, the Administrator shall give consideration to—

(1) the use of the space shuttle, the space station, and other space vehicles to carry out or support satellite servicing;

(2) all potential users of satellite servicing capabilities, including civilian, defense, private, and foreign satellites and space vehicles;

(3) experience to date with in-orbit satellite servicing including the costs of such operations and the fees charged users that are not from the National Aeronautics and Space Administration;

(4) the pertinence of satellite servicing to insurance, including the character, cost, and availability of insurance;

(5) the pertinence of satellite servicing to satellite and vehicle design;

(6) the pertinence of satellite servicing to the National Aeronautics and Space Administration and other space programs, including science and applications programs; and

(7) the prices to be charged for satellite servicing such that the full costs of such servicing can be recovered.

(d) The Administrator shall complete the study and present a full report on it to the Congress on or before January 15, 1988.

SEC. 119. The Administrator shall review the findings, recommendations, and proposed space agenda of the National Commission on Space as set forth in its report submitted under section 204(c) of the National Aeronautics and Space Administration Authorization Act, 1985 (Public Law 98-361; 98 Stat. 422), and shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives, within 60 days after the date of enactment of this Act, a recommendation for a long-range implementation plan, including an impact assessment of such implementation on personnel, budget, and other resources.

SEC. 120. Section 24 of the Commercial Space Launch Act (49 U.S.C. App. 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 $4,548,000 for fiscal year 1988.".

SEC. 121. (a) It is the sense of the Congress that the solid rocket motor project of the space shuttle program would benefit from competition, and that an advanced solid rocket motor would enhance the margin of safety, reliability, and performance of the space shuttle.

(b) By the date on which the President submits to the Congress the fiscal year 1990 budget request for the National Aeronautics and Space Administration, the Administrator shall issue a request for proposals to acquire by means of a competitive procurement an advanced solid rocket motor. The Administrator shall also consider ways and means to improve quality control, reduce operational hazards, reduce costs, increase competition, and enhance manufacturing processes, including, but not limited to, constructing a government-owned and contractor-operated solid rocket motor production facility and providing for a dual source of supply of the advanced solid rocket motor.

(c) Until a request for proposals has been issued under subsection (b) of this section, no contract for the purchase of additional solid rocket motors shall be extended or signed by the Administrator. The Administrator may proceed with the procurement of long-lead materials for the solid rocket motors from the current contractor only after the Administrator has certified to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives that such action is necessary to prevent a delay in the space shuttle launch schedule.

(d) The Administrator shall notify the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives if the competitive procurement specified in subsection (b) cannot be conducted. The Administrator shall transmit such notice along with a complete explanation of the reasons supporting such determination. Following such determination, but no sooner than 30 days following the transmission of the notice required under this subsection, the Administrator shall—

(1) conduct a competition to select a qualified second source of supply (in addition to the current contractor) for flight sets of the redesigned solid rocket motor that is currently under development; or

(2) recompete the current source of supply for flight sets of the redesigned solid rocket motor.

(e) No later than March 31, 1988, the Administrator shall present to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a comprehensive acquisition plan for the advanced solid rocket motor in accordance with this section.

TITLE II—NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM

SEC. 201. This title may be cited as the "National Space Grant College and Fellowship Act".

SEC. 202. The Congress finds that—

(1) the vitality of the Nation and the quality of life of the citizens of the Nation depend increasingly on the understanding, assessment, development, and utilization of space resources;

(2) research and development of space science, space technology, and space commercialization will contribute to the quality of life, national security, and the enhancement of commerce;

(3) the understanding and development of the space frontiers require a broad commitment and an intense involvement on the part of the Federal Government in partnership with State and local governments, private industry, universities, organizations, and individuals concerned with the exploration and utilization of space;

(4) the National Aeronautics and Space Administration, through the national space grant college and fellowship program, offers the most suitable means for such commitment and involvement through the promotion of activities that will result in greater understanding, assessment, development, and utilization; and

(5) Federal support of the establishment, development, and operation of programs and projects by space grant colleges, space grant regional consortia, institutions of higher education, institutes, laboratories, and other appropriate public and private entities is the most cost-effective way to promote such activities.

SEC. 203. The purposes of this title are to—

(1) increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational

base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques;

(2) utilize the abilities and talents of the universities of the Nation to support and contribute to the exploration and development of the resources and opportunities afforded by the space environment;

(3) encourage and support the existence of interdisciplinary and multidisciplinary programs of space research within the university community of the Nation, to engage in integrated activities of training, research and public service, to have cooperative programs with industry, and to be coordinated with the overall program of the National Aeronautics and Space Administration;

(4) encourage and support the existence of consortia, made up of university and industry members, to advance the exploration and development of space resources in cases in which national objectives can be better fulfilled than through the programs of single universities;

(5) encourage and support Federal funding for graduate fellowships in fields related to space; and

(6) support activities in colleges and universities generally for the purpose of creating and operating a network of institutional programs that will enhance achievements resulting from efforts under this title.

SEC. 204. As used in this title, the term—

(1) "Administration" means the National Aeronautics and Space Administration;

(2) "Administrator" means the Administrator of the National Aeronautics and Space Administration;

(3) "aeronautical and space activities" has the meaning given to such term in section 103(1) of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2452(1));

(4) "field related to space" means any academic discipline or field of study (including the physical, natural, and biological sciences, and engineering, space technology, education, economics, sociology, communications, planning, law, international affairs, and public administration) which is concerned with or likely to improve the understanding, assessment, development, and utilization of space;

(5) "panel" means the space grant review panel established pursuant to section 210 of this title;

(6) "person" means any individual, any public or private corporation, partnership, or other association or entity (including any space grant college, space grant regional consortium, institution of higher education, institute, or laboratory), or any State, political subdivision of a State, or agency or officer of a State or political subdivision of a State;

(7) "space environment" means the environment beyond the sensible atmosphere of the Earth;

(8) "space grant college" means any public or private institution of higher education which is designated as such by the Administrator pursuant to section 208 of this title;

(9) "space grant program" means any program which—

(A) is administered by any space grant college, space grant regional consortium, institution of higher education, institute, laboratory, or State or local agency; and

(B) includes two or more projects involving education and one or more of the following activities in the fields related to space—

(i) research,

(ii) training, or

(iii) advisory services;

(10) "space grant regional consortium" means any association or other alliance which is designated as such by the Administrator pursuant to section 208 of this title;

(11) "space resource" means any tangible or intangible benefit which can only be realized from—

(A) aeronautical and space activities; or

(B) advancements in any field related to space; and

(12) "State" means any State of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, or any other territory or possession of the United States.

SEC. 205. (a) The Administrator shall establish and maintain, within the Administration, a program to be known as the national space grant college and fellowship program. The national space grant college and fellowship program shall consist of the financial assistance and other activities provided for in this title. The Administrator shall establish long-range planning guidelines and priorities, and adequately evaluate the program.

(b) Within the Administration, the program shall—

(1) apply the long-range planning guidelines and the priorities established by the Administrator under subsection (a) of this section;

(2) advise the Administrator with respect to the expertise and capabilities which are available through the national space grant college and fellowship program, and make such expertise available to the Administration as directed by the Administrator;

(3) evaluate activities conducted under grants and contracts awarded pursuant to sections 206 and 207 of this title to assure that the purposes set forth in section 203 of this title are implemented;

(4) encourage other Federal departments, agencies, and instrumentalities to use and take advantage of the expertise and capabilities which are available through the national space grant college and fellowship program, on a cooperative or other basis;

(5) encourage cooperation and coordination with other Federal programs concerned with the development of space resources and fields related to space;

(6) advise the Administrator on the designation of recipients supported by the national space grant college and fellowship program and, in appropriate cases, on the termination or suspension of any such designation; and

(7) encourage the formation and growth of space grant and fellowship programs.

(c) To carry out the provisions of this title, the Administrator may—

(1) accept conditional or unconditional gifts or donations of services, money, or property, real, personal or mixed, tangible or intangible;

(2) accept and use funds from other Federal departments, agencies, and instrumentalities to pay for fellowships, grants, contracts, and other transactions; and

(3) issue such rules and regulations as may be necessary and appropriate.

SEC. 206. (a) The Administrator may make grants and enter into contracts or other transactions under this subsection to assist any space grant and fellowship program or project if the Administrator finds that such program or project will carry out the purposes set forth in section 203 of this title. The total amount paid pursuant to any such grant or contract may equal 66 percent, or any lesser percent, of the total cost of the space grant and fellowship program or project involved, except that this limitation shall not apply in the case of grants or contracts paid for with funds accepted by the Administrator pursuant to section 205(c)(2) of this title.

(b) The Administrator may make special grants under this subsection to carry out the purposes set forth in section 203 of this title. The amount of any such grant may equal 100 percent, or any lesser percent, of the total cost of the project involved. No grant may be made under this subsection, unless the Administrator finds that—

(1) no reasonable means is available through which the applicant can meet the matching requirement for a grant under subsection (a) of this section;

(2) the probable benefit of such project outweighs the public interest in such matching requirement; and

(3) the same or equivalent benefit cannot be obtained through the award of a contract or grant under subsection (a) of this section or section 207 of this title.

(c) Any person may apply to the Administrator for a grant or contract under this section. Application shall be made in such form and manner, and with such content and other submissions, as the Administrator shall by regulation prescribe.

(d)(1) Any grant made, or contract entered into, under this section shall be subject to the limitations and provisions set forth in paragraphs (2) and (3) of this subsection and to such other terms, conditions and requirements as the Administrator considers necessary or appropriate.

(2) No payment under any grant or contract under this section may be applied to—

(A) the purchase of any land;

(B) the purchase, construction, preservation, or repair of any building; or

(C) the purchase or construction of any launch facility or launch vehicle.

(3) Notwithstanding paragraph (2) of this subsection, the items in subparagraphs (A), (B), and (C) of such paragraph may be leased upon written approval of the Administrator.

(4) Any person who receives or utilizes any proceeds of any grant or contract under this section shall keep such records as the Administrator shall by regulation prescribe as being necessary and appropriate to facilitate effective audit and evaluation, including records which fully disclose the amount and disposition by such recipient of such proceeds, the total cost of the program or project in connection with which such proceeds were used, and the amount, if any, of such cost which was provided through other sources. Such records shall be maintained for three years after the completion of such a program or project. The Administrator and the Comptroller General of the United States, or any of their duly authorized representatives, shall have access, for the purpose of audit and evaluation, to any books, documents, papers and records of receipts which, in the opinion of the Administrator or the Comptroller General, may be related or pertinent to such grants and contracts.

SEC. 207. (a) The Administrator shall identify specific national needs and problems relating to space. The Administrator may make grants or enter into contracts under this section with respect to such needs or problems. The amount of any such grant or contract may equal 100 percent, or any lesser percent, of the total cost of the project involved.

(b) Any person may apply to the Administrator for a grant or contract under this section. In addition, the Administrator may invite applications with respect to specific national needs or problems identified under subsection (a) of this section. Application shall be made in such form and manner, and with such content and other submissions, as the Administrator shall by regulation prescribe. Any grant made, or contract entered into, under this section shall be subject to the limitations and provisions set forth in section 206(d)(2) and (4) of this title and to such other terms, conditions, and requirements as the Administrator considers necessary or appropriate.

SEC. 208. (a)(1) The Administrator may designate—

(A) any institution of higher education as a space grant college; and

(B) any association or other alliance of two or more persons, other than individuals, as a space grant regional consortium.

(2) No institution of higher education may be designated as a space grant college, unless the Administrator finds that such institution—

(A) is maintaining a balanced program of research, education, training, and advisory services in fields related to space;

(B) will act in accordance with such guidelines as are prescribed under subsection (b)(2) of this section; and

(C) meets such other qualifications as the Administrator considers necessary or appropriate.

(3) No association or other alliance of two or more persons may be designated as a space grant regional consortium, unless the Administrator finds that such association or alliance—

(A) is established for the purpose of sharing expertise, research, educational facilities or training facilities, and other capabilities in order to facilitate research, education, training, and advisory services, in any field related to space;

(B) will encourage and follow a regional approach to solving problems or meeting needs relating to space, in cooperation with appropriate space grant colleges, space grant programs, and other persons in the region;

(C) will act in accordance with such guidelines as are prescribed under subsection (b)(2) of this section; and

(D) meets such other qualifications as the Administrator considers necessary or appropriate.

(b) The Administrator shall by regulation prescribe—

(1) the qualifications required to be met under subsection (a)(2)(C) and (3)(D) of this section; and

(2) guidelines relating to the activities and responsibilities of space grant colleges and space grant regional consortia.

(c) The Administrator may, for cause and after an opportunity for hearing, suspend or terminate any designation under subsection (a) of this section.

SEC. 209. (a) The Administrator shall support a space grant fellowship program to provide educational and training assistance to qualified individuals at the graduate level of education in fields related to space. Such fellowships shall be awarded pursuant to guidelines established by the Administrator. Space grant fellowships shall be awarded to individuals at space grant colleges, space grant regional consortia, other colleges and institutions of higher education, professional associations, and institutes in such a manner as to assure wide geographic and institutional diversity in the pursuit of research under the fellowship program.

(b) The total amount which may be provided for grants under the space grant fellowship program during any fiscal year shall not exceed an amount equal to 50 percent of the total funds appropriated for such year pursuant to this title.

(c) Nothing in this section shall be construed to prohibit the Administrator from sponsoring any research fellowship program, including any special emphasis program, which is established under an authority other than this title.

SEC. 210. (a) The Administrator shall establish an independent committee known as the space grant review panel, which shall not be subject to the provisons of the Federal Advisory Committee Act (5 U.S.C. App. 1 et seq.; Public Law 92-463).

(b) The panel shall take such steps as may be necessary to review, and shall advise the Administrator with respect to—

(1) applications or proposals for, and performance under, grants and contracts awarded pursuant to sections 206 and 207 of this title;

(2) the space grant fellowship program;

(3) the designation and operation of space grant colleges and space grant regional consortia, and the operation of space grant and fellowship programs;

(4) the formulation and application of the planning guidelines and priorities pursuant to section 205 (a) and (b)(1) of this title; and

(5) such other matters as the Administrator refers to the panel for review and advice.

(c) The Administrator shall make available to the panel any information, personnel and administrative services and assistance which is reasonable to carry out the duties of the panel.

(d)(1) The Administrator shall appoint the voting members of the panel. A majority of the voting members shall be individuals who, by reason of knowledge, experience, or training, are especially qualified in one or more of the disciplines and fields related to space. The other voting members shall be individuals who, by reason of knowledge, experience or training, are especially qualified in, or representative of, education, extension services, State government, industry, economics, planning, or any other activity related to efforts to enhance the understanding, assessment, development, or utilization of space resources. The Administrator shall consider the potential conflict of interest of any individual in making appointments to the panel.

(2) The Administrator shall select one voting member to serve as the Chairman and another voting member to serve as the Vice Chairman. The Vice Chairman shall act as Chairman in the absence or incapacity of the Chairman.

(3) Voting members of the panel who are not Federal employees shall be reimbursed for actual and reasonable expenses incurred in the performance of such duties.

(4) The panel shall meet on a biannual basis and, at any other time, at the call of the Chairman or upon the request of a majority of the voting members or of the Administrator.

(5) The panel may exercise such powers as are reasonably necessary in order to carry out the duties enumerated in subsection (b) of this section.

SEC. 211. Each department, agency or other instrumentality of the Federal Government which is engaged in or concerned with, or which has authority over, matters relating to space—

(1) may, upon a written request from the Administrator, make available, on a reimbursable basis or otherwise, any personnel (with their consent and without prejudice to their position and rating), service, or facility which the Administrator considers necessary to carry out any provision of this title;

(2) may, upon a written request from the Administrator, furnish any available data or other information which the Administrator considers necessary to carry out any provision of this title; and

(3) may cooperate with the Administration.

SEC. 212. (a) The Administrator shall submit to the Congress and the President, not later than January 1, 1989, and not later than February 15 of every odd-numbered year thereafter, a report on the activities of the national space grant and fellowship program.

(b) The Director of the Office of Management and Budget and the Director of the Office of Science and Technology Policy in the Executive Office of the President shall have the opportunity to review each report prepared pursuant to subsection (a) of this section. Such Directors may submit, for inclusion in such report, comments and recommendations and an independent evaluation of the national space grant college and fellowship program. Such comments and recommendations shall be submitted to the Administrator not later than 90 days before such a report is submitted pursuant to subsection (a) of this section and the Administrator shall include such comments and recommendations as a separate section in such report.

SEC. 213. The Administrator shall not under this title designate any space grant college or space grant regional consortium or award any fellowship, grant, or contract unless such designation or award is made in accordance with the competitive, merit-based review process employed by the Administration on the date of enactment of this Act.

SEC. 214. (a) There are authorized to be appropriated for the purposes of carrying out the provisions of this title sums not to exceed—

(1) $10,000,000 for each of fiscal years 1988 and 1989; and

(2) $15,000,000 for each of fiscal years 1990 and 1991.

(b) Such sums as may be appropriated under this section shall remain available until expended.

TITLE III—AMENDMENTS TO THE LAND REMOTE-SENSING COMMERCIALIZATION ACT OF 1984

SEC. 301. This title may be cited as the "Land Remote-Sensing Commercialization Act Amendments of 1987".

SEC. 302. The Congress finds and declares that—

(1) the implementation of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4201 et seq.) has begun and some of the major milestones contained in that Act have been met;

(2) Congress remains strongly committed to the guiding principles set forth in that Act;

(3) notwithstanding the accomplishments thus far, the relationships among the involved Federal agencies and the private sector have not yet been adequately defined; and

(4) inasmuch as the technical development and commercial applications of future land remote-sensing systems cannot now be predicted with certainty, it is in the national interest of the United States that the involved Federal agencies and the private sector remain flexible in carrying out their respective responsibilities under that Act.

SEC. 303. It is therefore the purpose of this title to set forth amendments to the Land Remote-Sensing Commercialization Act of 1984 to ensure that—

(1) the original intent of that Act is carried out in the most effective manner consistent with the guiding principles expressed therein;

(2) specific mechanisms for carrying out the original intent of that Act are provided in those cases where none have materialized thus far; and

(3) the working relationships among involved Federal agencies and private sector parties for the purpose of carrying out that Act are fully developed and mutually understood.

SEC. 304. Section 202(a)(4) of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4212(a)(4)) is amended by inserting before the semicolon at the end thereof the following: ", except in the case of research and development activities conducted in accordance with section 504".

SEC. 305. Title III of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4221 et seq.) is amended by adding at the end thereof the following new section:

"DISPOSITION OF GOVERNMENT ASSETS

"SEC. 308. Following the completion of a contract made pursuant to this title, the Secretary may, upon 30 days advance notice to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives, dispose of assets (other than real property) under the control of the Secretary in a manner which best ensures the continuation of the contractor's commercial activity.".

SEC. 306. Section 502 of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4262) is amended to read as follows:

"RESEARCH AND DEVELOPMENT ACTIVITIES OF FEDERAL AGENCIES

"SEC. 502. Each Federal agency is authorized and encouraged to provide data gathered in experimental remote-sensing space programs to related research and development programs funded by the Federal Government (including application programs) and to cooperative research programs if the Federal agency involved determines that the data will not be used—

"(1) for any commercial purpose; or

"(2) in substantial competition with data available from a licensee under this Act;

except pursuant to section 503.".

SEC. 307. Title V of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4261 et seq.) is amended by adding at the end thereof the following new section:

"RESEARCH AND DEVELOPMENT ACTIVITIES OF SYSTEM OPERATORS

"SEC. 504. Notwithstanding section 601, any system operator under title II, III, or IV of this Act, or any marketing entity under section 503 of this Act, may provide data for any research and development programs if—

"(1) a complete and timely disclosure of the results of such research and development is made in the open technical literature or is otherwise made publicly available;

"(2) the system operator or marketing entity provides to the Secretary an annual report of all research and development data transactions including the nature of any cooperative agreements and the prices charged for data; and

"(3) the data are not used for commercial purposes or in substantial competition with data available from a licensee under this Act.".

SEC. 308. Section 603 of the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4273) is amended to read as follows:

"NONREPRODUCTION

"SEC. 603. In addition to such other terms and conditions as the system operator may set forth in compliance with section 601 of this Act, the system operator may require that unenhanced data not be reproduced or disseminated by any foreign or domestic purchaser.".

Approved October 30, 1987.

LEGISLATIVE HISTORY—H.R. 2782 (S. 1164):

HOUSE REPORTS: No. 100-204 (Comm. on Science, Space, and Technology).
CONGRESSIONAL RECORD, Vol. 133 (1987):
July 9, considered and passed House.
July 10, considered and passed Senate, amended, in lieu of S. 1164.
Oct. 8, House concurred in Senate amendment with amendment.
Oct. 13, Senate concurred in House amendment.

100TH CONGRESS 1st Session | HOUSE OF REPRESENTATIVES | REPORT 100-189

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT-INDEPENDENT AGENCIES APPROPRIATIONS BILL, 1988

JUNE 25, 1987.—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. 2783]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

1987 appropriation	$10,434,000,000
Estimate, 1988	9,481,000,000
Recommended in bill	9,479,200,000
Decrease below estimate	−1,800,000

For fiscal year 1988 the Committee is recommending $9,479,200,000. This is $1,800,000 below the budget request, and is $1,145,000,000 above the comparable fiscal year 1987 appropriation.

The programs of the National Aeronautics and Space Administration are provided for in four appropriation accounts. An explanation pertaining to each account is detailed below.

RESEARCH AND DEVELOPMENT

1987 appropriation	$3,127,700,000
Estimate, 1988	3,623,200,000
Recommended in bill	3,661,200,000
Increase above estimate	+38,000,000

The Committee recommends a total of $3,661,200,000 for this account in fiscal year 1988. The recommendation includes the following increases, decreases, and changes to the program areas described below:

The full budget request of $767,000,000 has been included for space station in 1988. Although the Committee has endorsed the current Block I configuration of space station, it strongly supports the continued research and development of solar dynamic power as a new technology for application in a Block II space station. The Committee is also interested in NASA making available funds to train individuals in international and intercultural aspects of space development—particularly concerning the space station. A university with international/intercultural programs could be the focus of associated universities' efforts in this area.

−$25,000,000 from the orbital maneuvering vehicle (OMV).

−$5,000,000 from space telescope development. The Committee is recommending this action in an attempt to ensure that some discipline is applied to controlling the ongoing costs of the telescope while it awaits launch.

+$5,000,000 for spacelab/space station payload development which shall be devoted solely to *new* attached payloads for space station. The Committee suggests that these funds could be applied to development of the high resolution solar observatory (HRSO).

+$5,000,000 for initial work on an extended duration orbiter. In the past the Committee has heard testimony that the total cost of an extended duration orbiter (EDO) would be less than $100,000,000. The Committee believes that to extend the on-orbit time of the shuttle from approximately seven days to 14 days will be beneficial for both the construction and early activation of the space station and for other commercial and industrial applications. The Committee directs that NASA submit a report by September 30, 1987, outlining in detail a funding profile for development of an EDO, and further directs that the Agency request sufficient funds to cover the next EDO increment in its fiscal year 1989 budget submission.

−$10,000,000 from the ocean topography experiment (TOPEX).

−$5,000,000 from the global geospace science mission.

+$20,000,000 for microgravity shuttle/station payloads to be allocated solely for the development of *new* space station experimental hardware such as furnaces, separators, etc. For the past three years the Committee has consistently taken the position that to develop a space station infrastructure without the concomitant development of second and third generation microgravity experiments would leave the United States in an inferior competitive position. In short, foreign competition would have access to space (on board the station) that could lead to significant economic benefits—while the U.S. would be unprepared to capitalize in the same time frame.

In this connection, the Committee was disappointed that in both the 1987 and 1988 budgets little or no additional emphasis was placed on microgravity work. In response to this situation, the Committee allocated $7,500,000 in the 1987 NASA operating plan for additional microgravity experiments. At that time, it also requested that a plan be submitted to the Committee identifying how NASA would apply this augmentation. The Committee received a letter from the Administrator on April 3, 1987, explaining briefly NASA's proposed use of these funds—with an assurance that the report would be available within one month. However, that report was not formally submitted until June 12. Also, a similar report covering attached payloads has not been received. The Committee believes that this reflects a lack of urgency and dedication and suggests that NASA is not adequately addressing the critical issue of providing the United States with the capability to *use* the space station to compete on the international market.

+$70,000,000 for the advanced communications technology satellite (ACTS).

−$8,000,000 from commercial programs.

−$10,000,000 from transatmospheric research and technology.

−$15,000,000 from the civil space technology initiative, except that none of the reduction may be applied to the automation and robotics area.

+$1,000,000 for studies and initial work by NASA of the use of an Industrial Space Facility for microgravity research. The funds should be used to conduct an interagency study with the Departments of Defense and Commerce in order to develop a program for joint use of the Industrial Space Facility (ISF)—including the creation of an appropriate contractual strategy. The Committee believes that the ISF may represent a viable interim approach leading to the efficient and effective development and testing of early space station equipment. The ISF could also be useful in testing advanced technology to be used in development of space station systems and operations. While the Committee strongly supports NASA's use of the ISF for the purposes stated above, it wants to make clear that any agreement to use the facility should not violate standard budget principles. The Committee hopes that some arrangement can be accomplished which would permit advanced funding of a leased facility if the ISF is adjudged to be a workable vehicle for transitioning to the space station. The Committee expects that the study be completed and the report submitted by December 31, 1987.

+$15,000,000 for planetary observer mission spares.

Finally, in the research and development account, the Committee is "capping" the 1988 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. Orbital Maneuvering Vehicle—$55,000,000.
2. Hubble Space Telescope—$93,400,000.
3. Gamma Ray Observatory—$49,100,000.
4. Galileo—$55,300,000.
5. Magellan—$59,600,000.
6. Ulysses—$10,800,000.
7. Mars Observer—$29,300,000.
8. Upper Atmospheric Research Satellite—$95,400,000.

SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS

1987 appropriation	$5,715,000,000
Estimate, 1988	4,064,300,000
Recommended in bill	4,085,300,000
Increase above estimate	+21,000,000

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 $4,085,300,000 for this account in 1988. This is an increase of $21,000,000 above the budget request and is $470,000,000 above the comparable 1987 level. The recommendation includes the following increases, decreases, and changes to the program areas described below:

−$79,000,000 from shuttle structural spares. The Committee has treated these funds as lower priority in view of additional shuttle requirements described in the next item.

+$125,000,000 for shuttle space transportation systems. These funds represent the minimum necessary to maintain the latest shuttle launch date of June 1988. An additional $175,000,000 is required to meet Rogers Commission safety issues in 1988. If the Committee receives sufficient additional section 302(b) allocation, it will make every effort to provide the balance at a subsequent time.

−$40,000,000 from the $76,000,000 requested for replacement of a Tracking and Data Relay Satellite (TDRSS) lost on *Challenger*. The flight requirement for this vehicle is now scheduled in 1993 or later. However, with ongoing delays in the shuttle relaunch date, the Committee believes that this reduction can be made on a priority basis.

−$15,000,000 from tracking and data acquisition.

+$30,000,000 for two Delta II class expendable launch vehicles (ELVs) available only for launch of the Roentgen satellite (ROSAT) and the Extreme Ultraviolet Explorer (EUVE) in 1990 and 1991, respectively. Again, if sufficient additional Section 302(b) allocation is made available, the Committee will entertain funding other expendable launch vehicles for specific missions. In accordance with the agreement as outlined in a letter from NASA to the Committee dated August 9, 1984, funding for expendable launch vehicles is "capped" at $30,000,000 and, if included in the conference report, such funding may not be exceeded without the approval of the Committees on Appropriations.

CONSTRUCTION OF FACILITIES

1987 appropriation	$166,300,000
Estimate, 1988	195,500,000
Recommended in bill	169,700,000
Decrease below estimate	−25,800,000

The Committee recommends $169,700,000 for the construction of facilities in 1988. The reduction includes, without prejudice, $25,800,000 requested for space station facilities. The Committee believes that these projects can be delayed for one year without impacting the space station program. All other projects and funds for rehabilitation and minor construction have been included as requested.

RESEARCH AND PROGRAM MANAGEMENT

1987 appropriation	$1,425,000,000
Estimate, 1988	1,598,000,000
Recommended in bill	1,563,000,000
Decrease below estimate	−35,000,000

The Committee is recommending $1,563,000,000 for research and program management in fiscal year 1988, a decrease of $35,000,000 below the budget request. The reduction should be taken at the agency's discretion.

The Committee is concerned with past management practices regarding how costs are allocated between the two program appropriations—research and development and space flight, control and data communications—and the research and program management account. A Surveys and Investigations Staff report indicated that NASA centers have systematically broken down the legal barriers between appropriations through "taxes" on program accounts and "migration", or shifting of costs from the research and program management account to the program appropriations. Further, the centers have shifted costs from the R&PM account to program accounts in violation of Comptroller General decisions. These actions have made the present appropriation structure virtually useless.

The Surveys and Investigations Staff report was made available to NASA in early 1987. However, the agency still cannot properly identify how to reorder the appropriation account structure so as to ensure the integrity of the accounts and the proper allocation of charges.

The National Aeronautics and Space Administration is directed to submit revisions to the 1988 budget to move institutional costs from the research and development and space flight, control and data communications accounts to the research and program management account by October 1, 1987. This will allow the Committee to address this matter in the 1988 Continuing Resolution.

100TH CONGRESS } SENATE { REPORT
1st Session } { 100–192

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATION BILL, 1988

OCTOBER 6 (legislative day, SEPTEMBER 25), 1987.—Ordered to be printed

Mr. PROXMIRE, from the Committee on Appropriations, submitted the following

REPORT

[To accompany H.R. 2783]

The Committee on Appropriations to which was referred the bill (H.R. 2783) 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, 1988, and for other purposes, reports the same to the Senate with various amendments and presents herewith an explanation of the contents of the bill.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

1987 appropriation	$3,127,700,000
1988 budget estimate	3,651,200,000
House allowance	3,661,200,000
Committee recommendation	3,378,063,000

PROGRAM DESCRIPTION

The objectives of the National Aeronautics and Space Administration [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 will begin. 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.

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. The Space Science and Applications Program has been significantly restructured to reflect the standdown in shuttle flights.

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.

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 $3,378,063,000 for research and development activities. This amount is $273,137,000 less than the budget estimate and $283,137,000 less than the House allowance.

The Committee recommends $558,663,000 for development of the permanently manned space station. This facility is the next logical and critical step for our Nation's space program. While most of the debate and attention received by the space program recently has focused on the aftermath of the *Challenger* tragedy and failures in our expendable launch vehicle systems, it is the Committee's view that the fundamental issue before the Nation is whether the United States intends to pursue leadership in space science, technology, and exploration.

It is clear that the answer must be yes. The Soviet Union has mounted a resolutely ambitious and impressive space program which threatens to surpass our technological advantage. Our major Western trading partners are equally dedicated in demonstrating their technical capabilities and have already made sizable inroads in what was once almost exclusively a superpower competition.

Our Nation's space program demonstrates the ability of our people, institutions, and technical resources to grow and address new challenges in a changing World. This is the essence of our national experience and we cannot falter now. Furthermore, our investment in space technologies yields a large multiple in direct economic stimulation for the Nation as well as a wealth of new products and processes which save lives, improve our lifestyles, and enrich our economy.

The Committee's recommendation will permit space station development to proceed apace within the difficult budgetary constraints confronting all Federal activities. Although $208,337,000 less than the budget request and the House allowance, the Committee expects that no significant scheduling impact will occur in the deployment of productive elements of the space station in the mid-1990's. The Committee recommends that $100,000,000 of the $558,663,000 provided for space station development be derived by transfer from funds previously appropriated for orbiter production. It is the Committee's understanding that this transfer of funds will not have an impact on the delivery of the replacement orbiter.

The Committee believes it is essential that the United States begin to develop servicing technology in fiscal year 1988 which can accommodate many early space station needs and provide for the servicing and repair of attached payloads and free flyers. This step will have the result of creating significant long-term savings for NASA's space programs. As a result, the Committee directs NASA to spend a minimum of $10,000,000 in fiscal year 1988 for servicing technology for the space station so as to keep open the option of providing an early servicing capability.

Last year the Congress encouraged the administration to move expeditiously in development of a solar dynamic power system for the space station. The Committee is concerned that without a firm funding commitment to the solar dynamic concept, NASA will be forced to rely on less advanced technologies that will increase life cycle costs of station operations and decrease station flexibility and growth potential. The Committee, therefore, directs NASA to expend in fiscal year 1988 the funds necessary to ensure continued development of solar dynamic power for the space station.

The Committee is aware of significant private investment in the development of a man-tended industrial space facility. This program not only could yield productive opportunities for private industrial exploitation of the micro-gravity environment but represents a low-cost testbed for the Government-sponsored experiment for later application in the space station. The Committee views such cooperative Government-industry efforts as an important aspect of the Nation's space program and thus the Committee concurs with the House in recommending $1,000,000 for studies and initial work by NASA on the use of the facility for microgravity research. The Committee believes such a facility would be useful in maintaining a vigorous space science program, developing a robust user base, and obtaining flight experience that can contribute to the efficient development and use of a permanently manned station.

The Committee also recommends deletion of $20,000,000 proposed by the House for microgravity shuttle/space station payloads to be allocated solely for the development of new space station experimental hardware. The Committee believes that it is premature to develop station experimental hardware. The funds in question were not requested by the administration.

The Committee concurs with the House in recommending the following further adjustments in the administration's budget request:

−$25,000,000 from the orbital maneuvering vehicle program. This reduces program funding to $55,000,000 in fiscal year 1988, a $10,000,000 increase in the current budget.

+$5,000,000 for the initiation of work on an extended duration orbiter. The Committee believes that the extension of space shuttle orbiter stay time is a logical step toward a permanently manned space station and will enhance the prospects of constructing and servicing such a station with maximum efficiency and minimum cost.

−$5,000,000 from Hubble space telescope development, leaving a budget of $93,400,000. The Committee concurs with the concern expressed by the House over the prelaunch costs of maintaining the telescope.

−$10,000,000 from the ocean topography experiment program [TOPEX]. This reduces TOPEX funding to $80,000,000, an increase of $61,000,000 over the current budget.

−$5,000,000 from the global geoscience science [GGS] mission. The administration requested $25,000,000 for this new program to provide measurements necessary for the interaction between the Earth and the Sun.

−$28,000,000 for expendable launch vehicle procurement. Such costs for launch of space science payloads are normally funded under the "Space flight, control, and data communications" account and, therefore, these requested funds are addressed there.

Although concurring in the addition of $5,000,000 for spacelab/space station payload development, the Committee directs that these funds be applied to the development of a high resolution solar observatory [HRSO] as a vehicle-independent program to be carried out in the most cost-effective way. The project should not be tied exclusively to the space station. The Committee is concerned that the recently proposed termination of HRSO would leave NASA without a program for the study of the Sun from space and waste substantial sums already expended.

The Committee proposes the following adjustments to the House-approved amounts:

+$10,000,000 for explorer development. This increase would result in a $70,300,000 explorer program in fiscal year 1988 compared to the $60,300,000 program proposed in the administration's budget and by the House.

+$25,000,000 for the Mars observer mission. This would produce a total budget of $54,300,000 for Mars observer. The House approved the budget request of $29,300,000. The Committee is concerned over NASA's decision to reschedule the mission from 1990 until September 1992 and feels that every effort should be made to achieve the earliest possible launch either on the space shuttle or on an expendable launch vehicle. Consequently, the Committee directs NASA to submit by January 30, 1988, a report addressing the advantages and disadvantages of launching the Mars observer mission on the shuttle as opposed to an expendable launch vehicle, the technical modifications necessary to assure dual capability, and the funding requirements and vehicle/facility availability associated with both options, as well as cost of assuring dual capability for the mission.

+$18,400,000 for the Magellan Venus mapping mission, providing a total budget of $78,000,000 rather than $59,600,000 as proposed by the administration and approved by the House.

−$15,000,000 for planetary observer mission spares. The Committee understands that it is not essential to provide these funds in fiscal year 1988. No funds were requested by the administration while the House provided $15,000,000.

+$14,000,000 for the Advanced Communications Technology Satellite [ACTS]. The administration requested no funding for the program while the House provides $70,000,000. The Committee's recommendation would make a total of $84,000,000 available in fiscal year 1988. The Committee notes that this project is nearing completion and sees no valid reason for terminating Federal funding at this point in its development.

+$4,000,000 for commercial programs. This increases funding to $50,000,000 from a House-approved level of $46,000,000. The Committee is pleased that NASA is going forward with its plans to support two additional centers for the commercial development of space in the areas of automation and robotics and artificial intelligence, such as that proposed for establishment at West Virginia University, and to assist private space ventures in the commercial uses of space through cooperative arrangements.

+$2,000,000 for the Advanced Rotary Engine Program providing a total budget of $3,500,000. The administration requested and the House provided $1,500,000 for this program. The Committee has been informed that the augmentation of this program by $2,000,000 per year over the next 3 to 5 years should result in a significant increase in fuel efficiency and power density compared to current general aviation aircraft piston engines.

−$11,000,000 for transatmospheric research and technology. The House provided $56,000,000 for this program, a reduction of $10,000,000 below the administration's budget request. The amount recommended will continue the program at the current level of $45,000,000. The Committee understands certain advanced technology components, such as materials relied upon by engine and airframe designers, are not yet available. Consequently, it seems advisable to slow down the current development schedule.

−$2,200,000 for the civilian space technology initiative's propulsion program. The administration requested $39,200,000 for the program. The Committee recommends an appropriation of $22,000,000.

Of funds appropriated in fiscal year 1988, the Administrator may make available, subject to authorization, up to $10,000,000 to establish and fund a Space Grant College and Fellowship Program.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

1987 appropriation	$5,715,000,000
1988 budget estimate	4,064,300,000
House allowance	4,000,300,000
Committee recommendation	3,978,300,000

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 the replacement orbiter) including main engines, launch site and mission operational control requirements, initial structural and operational spares, production tooling, and related supporting activities.

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. 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 $3,978,300,000 for space flight, control, and data communications activities. This is $86,000,000 less than the budget request and $22,000,000 less than the House allowance.

The Committee views the restoration of the space shuttle system to full operation capability as the highest immediate priority. To this end, the Committee recommended, and there was enacted, appropriations of $526,000,000 in the Fiscal Year 1986 Supplemental Act and $300,000,000 in the Fiscal Year 1987 Supplemental Act. Furthermore, the Congress provided $2,100,000,000 in the fiscal year 1987 continuing resolution for orbiter production activities related to replacement of the *Challenger.*

As discussed earlier in this report, the Committee has been advised that approximately $100,000,000 of funds previously appropriated for the replacement of the *Challenger* may be made available for other purposes, and language has been recommended to permit the use of such funds for development of the space station. The Committee, however, believes that the remaining funds of the orbiter production appropriation should be applied in a manner which assures the earliest efficient delivery of the replacement orbiter consistent with safe and effective resumption of flight activity of the entire orbiter fleet. The Committee, therefore, directs that up to $100,000,000 of the remaining orbiter production funds be utilized to complete necessary modifications such as redesign of the external tank disconnect latch, correction of reaction control system primary thruster instability, contingency alert analyses, vertical tail modifications, payload bay door entry latches and modified drag chutes as well as for analyses to certify extended orbiter life and improvements to the existing orbiters, and for related work required to prepare the fleet for operational flight status. In addition, the Committee directs that of this amount, sufficient funds (up to $20,000,000) be applied for production of orbiter spare parts both to assure efficient operations and to maintain critical production capabilities. In view of the availability of these funds, the Committee concurs with the House in deleting $79,000,000 requested in 1988 for structural spares, and also recommends the deletion of $40,000,000 added by the House for shuttle recovery.

The Committee also notes that the recently released National Research Council report on the space station recommended that NASA begin work on another orbiter to assure adequate future manned space launch capability. The Committee believes that such an initiative is not only prudent but may have significant potential to maximize the utility and efficiency of the space station. For example, a fifth orbiter would permit greater on-station time of an orbiter, thereby reducing or eliminating the need for a crew emergency rescue vehicle [CERV].

The Committee also recommends restoring $20,000,000 of the House-passed reduction of $40,000,000 from the $76,000,000 requested by the administration for the replacement of a tracking and data relay satellite [TDRSS] lost on *Challenger.* Continuing delays in the next shuttle launch date make reduction feasible, but the Committee's recommendation will permit a more efficient level of activity in the program.

The Committee agrees with the House decision to make a general reduction of $15,000,000 in the "Tracking and data acquisition" account, a 1.5-percent reduction in the administration's $948,900,000 budget request. The Committee notes that even with this reduction, appropriations for this program will increase by $71,000,000 in fiscal year 1988.

Finally, the Committee recommends $28,000,000 for two Delta II class expendable launch vehicles as requested in Senate Document 100–12, a reduction of $2,000,000 in the amount provided by the House. These vehicles are dedicated to launch of the Roentgen satellite [ROSAT] and the extreme ultraviolet explorer [EUVE] in 1990 and 1991, respectively. As discussed previously in this report, these funds were requested for appropriation under the "Research and development" account. The Committee concurs with the House recommendation to fund this activity in this account.

CONSTRUCTION OF FACILITIES

1987 appropriation	$469,300,000
1988 budget estimate	195,500,000
House allowance	169,700,000
Committee recommendation	185,700,000

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 $185,700,000 for the construction of facilities. This is $9,800,000 less than the budget request and $16,000,000 more than the House allowance.

The Committee concurs with the House in deleting $25,800,000 requested for space station facilities. The Committee believes these projects can be delayed for 1 year without affecting the space station program.

The Committee recommends the appropriation of $16,000,000 to initiate the repair of the 12-foot pressure wind tunnel at NASA's Ames Research Center. Funds to initiate repair design activities were included in Public Law 100–71. The total cost of this project is estimated to be about $60,000,000.

RESEARCH AND PROGRAM MANAGEMENT

1987 appropriation	$1,425,000,000
1988 budget estimate	1,589,195,000
House allowance	1,558,000,000
Committee recommendation	1,558,000,000

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 concurs with the House in recommending $1,558,000,000 for research and program management. This is $31,195,000 less than the budget request.

The Committee notes that the amount recommended exceeds last year's appropriation by $133,000,000 and believes that this increase of almost 10 percent should be sufficient to allow NASA to handle its added space station responsibilities.

The Committee is pleased to note that NASA is making substantial progress in moving institutional costs from the "Research and development" account as well as the "Space flight control and data communications" account to the "Research and program management" account pursuant to language contained in House Report 100–189.

The Committee will work closely with NASA and with the House to achieve the goal of a reordered account structure that identifies costs that are properly attributable to the three accounts in question and restores the integrity of each of the accounts.

CONFERENCE REPORT (H. Rept. 100-498)

The Committee of Conference on the disagreeing votes of the two Houses on the amendments of the Senate to the joint resolution (H.J. Res. 395) "making further continuing appropriations for the fiscal year ending September 30, 1988, and for other purposes," having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

AN ACT

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, 1988, and for other purposes.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

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; $3,374,200,000, to remain available until September 30, 1989, of which $100,000,000 shall be derived by transfer from funds appropriated in section 101(g) of Public Law 99-591 for orbiter production: Provided, That of the funds made available by this Act, $225,000,000 is for space station only, which amount shall not become available for obligation until June 1, 1988, and pursuant to section 202 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.

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; $3,908,309,000, to remain available until September 30, 1989, including not to exceed $28,000,000 for expendable launch vehicles which shall be available only for the purchase of two Delta II vehicles for the launch of the Roentgen satellite (ROSAT) and the Extreme Ultraviolet Explorer (EUVE).

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, $178,272,000, to remain available until September 30, 1990: 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.

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, 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; $1,495,680,000: 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: Provided further, That apportionments granted pursuant to this Act for the appropriations to the National Aeronautics and Space Administration shall reflect the moving of up to $245,000,000 (on an annual basis) in institutional costs from the "Research and development" and "Space flight, control and data communications" accounts to the "Research and program management" account.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

Appropriates $3,274,200,000 for research and development, instead of $3,661,200,000 as proposed by the House and $3,378,063,000 as proposed by the Senate. In addition, the conferees have agreed to language included by the Senate permitting $100,000,000 of 1987 funding for a replacement orbiter to be transferred to the Research and development account for use in fiscal year 1988. This transfer has the effect of providing a total of $3,374,200,000 for the activities under this account in 1988.

The conferees agree to the following changes from the budget request:

−$342,660,000 from space station. This reduction provides a total of $425,000,000 for the program in 1988. Of that, $225,000,000 shall become available on June 1, 1988. This delayed obligation, which was not included in either the House or Senate bills, is made pursuant to section 202 of *P.L.* 100-119 which prohibits the *transfer* of an outlay from one fiscal *year* to an adjacent fiscal year *unless* it "is a necessary (but secondary) result of a significant policy change." Because of the impact of the budget cuts on the space station, the conferees believe that a programmatic policy change will be necessary. Therefore, the conferees direct NASA to provide the Committees on Appropriations a detailed plan rescoping and rescheduling the space station activities consistent with 1988 and 1989 revised budgets. In that connection, the conferees expect NASA to identify cost savings—with special emphasis on the non-prime and program support areas. It is noted, for example, that at an 1988 funding level of $425,000,000, the actual "hardware" component of station could constitute less than 30 percent of the total available dollars. This trend is not acceptable—particularly in view of the potential for significantly reduced funding below the anticipated 1989 level of $1.8 billion. The revised plan for space station should be submitted to the Committees on Appropriations no later than February 29, 1988.

Also, the conferees note that the Agency is committed to maintaining funding for science and applications at not less than 20 percent of total NASA resources. Although to date NASA has honored this commitment, the conferees are concerned that further budget constraints could negatively impact unmanned activities.

Further, the conferees recognize that many of the goals articulated in the "Mission To Planet Earth" scenario stress unmanned technology achievable within the next decade and meet a distinct and growing environmental need.

The conferees also urge NASA to continue work on solar dynamic power and satellite servicing to the extent practical within the limited funds available.

Therefore, it is imperative that NASA examine all possible approaches to constraining station costs. In that context, the conferees have "capped" station at $200,000,000—the funding available exclusive of the delayed $225,000,000 appropriation. Those funds will be released after the Committees on Appropriations have carefully reviewed the Agency's proposals to ensure the implementation of a workable space station that is consistent with the Administrator's previous programmatic commitments to the Committees.

+$20,000,000 for microgravity shuttle/ISF/space station payloads. The conferees have agreed to increase the space shuttle/space station payload microgravity activity for the development of new space station experimental hardware such as furnaces, separators, etc. The conferees expect that these funds will help improve the United States' competitive position by having available second and third generation microgravity experiments beginning in 1991. The conference committee expects that this new hardware will be developed initially for use on spacelab and/or the industrial space facility and ultimately used on space station. In that context, the committee of conference strongly urges NASA to add an additional spacelab mission in the third quarter of 1991. The conferees understand that the agency currently has under study the possibility of manifesting such a mission and that a decision should be forthcoming in the near term. The conferees expect NASA to advise the Committees on Appropriations by January 15, 1988, on the status of this important activity.

+$25,000,000 for the industrial space facility (ISF). The conferees believe the ISF may represent a viable interim approach leading to the efficient and effective development and testing of early space station hardware. In short, the ISF could provide a "bridge" from spacelab to space station. However, the conferees believe that it is essential to maintain standard budget's principles in funding this program. Therefore, the conferees direct NASA to conclude a satisfactory funding arrangement that will lead to a workable leased ISF vehicle in the 1991/1992 timeframe.

+$25,000,000 for the Mars Observer program. The conferees are making available these monies with the understanding that the agency may allocate the funding at its discretion between the Mars Observer Mission and additional planetary observer spares.

+$77,000,000 for the Advanced Communication Technology Satellite (ACTS). The ACTS program was first funded in a supplemental appropriation Act in 1982 under the auspices of the HUD-Independent Agencies Appropriations Subcommittee. Congress originated the program because of its concern with the future of the United States' communications satellite industry. It was hoped that this program could enhance U.S. technology and international competitive stature. The program was not supported by the administration, and no budget request has been made in the past three years for ACTS. The Congress has, however, provided funding during that period to maintain the viability of the ACTS effort. The conferees now understand that the current fiscal year 1988 estimate for ACTS, which had been approximately $84 million, has increased to $123 million. Also, the 1989 funding estimate suggests that the project will overrun an additional $17 million.

Because of the increasingly difficult budget problems facing NASA and other agencies within the HUD bill, the conferees have agreed to cap this program at $35 million. The conferees further direct NASA to restructure the program to ensure that total program costs will not exceed $475 million. The conferees believe that under the current budget climate this program must be brought under control before additional funds are released above the $35 million level.

−$4,000,000 from "commercial programs".

+$2,000,000 for the advance rotary engine program.

−$13,000,000 from transatmospheric research and technology (National Aerospace Plane).

+$25,000,000 from the orbital maneuvering vehicle (OMV).

−$5,000,000 from space telescope development.

+$5,000,000 for spacelab/space station payload development.

+$5,000,000 for initial work on an extended duration orbiter (EDO). The conferees, in approving $5 million for initial work on an extended duration orbiter acknowledge the report received from NASA in November. That report confirms the conferees' belief that the EDO is achievable in the short term at a reasonable cost and at great benefit to materials sciences and other disciplines. Additionally, it is clear that the EDO is a viable incremental step to a manned space station and the conferees expect that NASA will move forward with this project in a expeditious manner.

−$10,000,000 from the ocean topography experiment (TOPEX).

−$5,000,000 from the global geospace science mission.

−$15,000,000 from the civil space technology initiative, except that none of the reduction may be applied to the automation and robotics areas, and

+$10,000,000 for explorer development.

Finally, in the research and development account, the conferees are "capping" the 1988 amounts for a number of programs. In accordance with the agreement as outlined in the letter from NASA to the Committees dated August 9, 1984, these "caps" may not be exceeded without the approval of the Committees on Appropriations:

(1) Space station, $200,000,000

(2) Orbital maneuvering vehicle, $55,000,000

(3) Hubble space telescope, $93,400,000

(4) Gamma Ray Observatory, $49,100,000

(5) Galileo, $55,300,000

(6) Magellan, $59,600,000

(7) Ulysses, $10,800,000

(8) Mars Observe, $54,300,000

(9) Upper Atmospheric Research Satellite, $95,400,000

(10) Advanced Communications Technology Satellite (ACTS), $35,000,000.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

Appropriates $3,908,309,000 for space flight, control and data communications, instead of $3,978,300,000 as proposed by the Senate, and 4,000,300,000 as proposed by the House.

This funding level includes a general reduction of $129,000,000 to be applied at the discretion of the agency. However, to help offset this reduction, the conferees have agreed to the use of up to $125,000,000 of orbiter production funds to complete necessary modifications and undertake related work required to prepare the shuttle fleet for operational status. In addition, the committee of conference agrees that within the total funds made available under this account, a total of $36,000,000 is provided for the replacement tracking and data relay satellite (TDRSS) and $28,000,000 is provided *only* for the purchase of two Delta II launch vehicles.

CONSTRUCTION OF FACILITIES

Appropriates $178,272,000 for construction of facilities, instead of $185,700,000 as proposed by the Senate and $169,700,000 as proposed by the House. The conferees agree that within this total $16,000,000 is made available to initiate the repair of the 12-foot pressure wind tunnel at NASA Ames. Also, the conferees direct that $200,000 be provided for design work of the final component of the launch complex 39 operations support building.

RESEARCH AND PROGRAM MANAGEMENT

Appropriates $1,495,680,000 for research and program management, instead of $1,557,999,000 as proposed by the Senate and $1,558,000,000 as proposed by the House. Within the funds provided, a general reduction of $93,515,000 is assumed. The application of this reduction should be outlined in detail in the operating plan which will be reviewed and approved by the Committees on Appropriations.

The House report directed NASA to submit revisions to the 1988 budget to move institutional costs from the R&D and SFCDC accounts to the R&PM account by October 1, 1987. This reordering of the appropriation account structure was undertaken to ensure the integrity of the accounts and the proper allocation of changes. The Senate report concurred with these objectives.

On September 29, 1987, the NASA administrator sent a letter to the Committees outlining proposed budget and accounting changes to be effective on October 1, 1987. In addition to revising and standardizing the accounting codes structure, the Agency proposed increasing R&PM by $242,438,000 with offsetting decreases of $144,863,000 in R&D and $97,575,000 in SFCDC.

The conferees agree with the level of the proposed changes—but will make the formal transfer of funds between accounts in a future appropriations bill. However, in the interim, language has been included which will permit the Office of Management and Budget to increase the apportionment in the R&PM account to reflect the new accounting structure until funds are transferred in subsequent legislation. Apportionments for Research and development and Space flight accounts will be reduced concomitantly by like amounts.