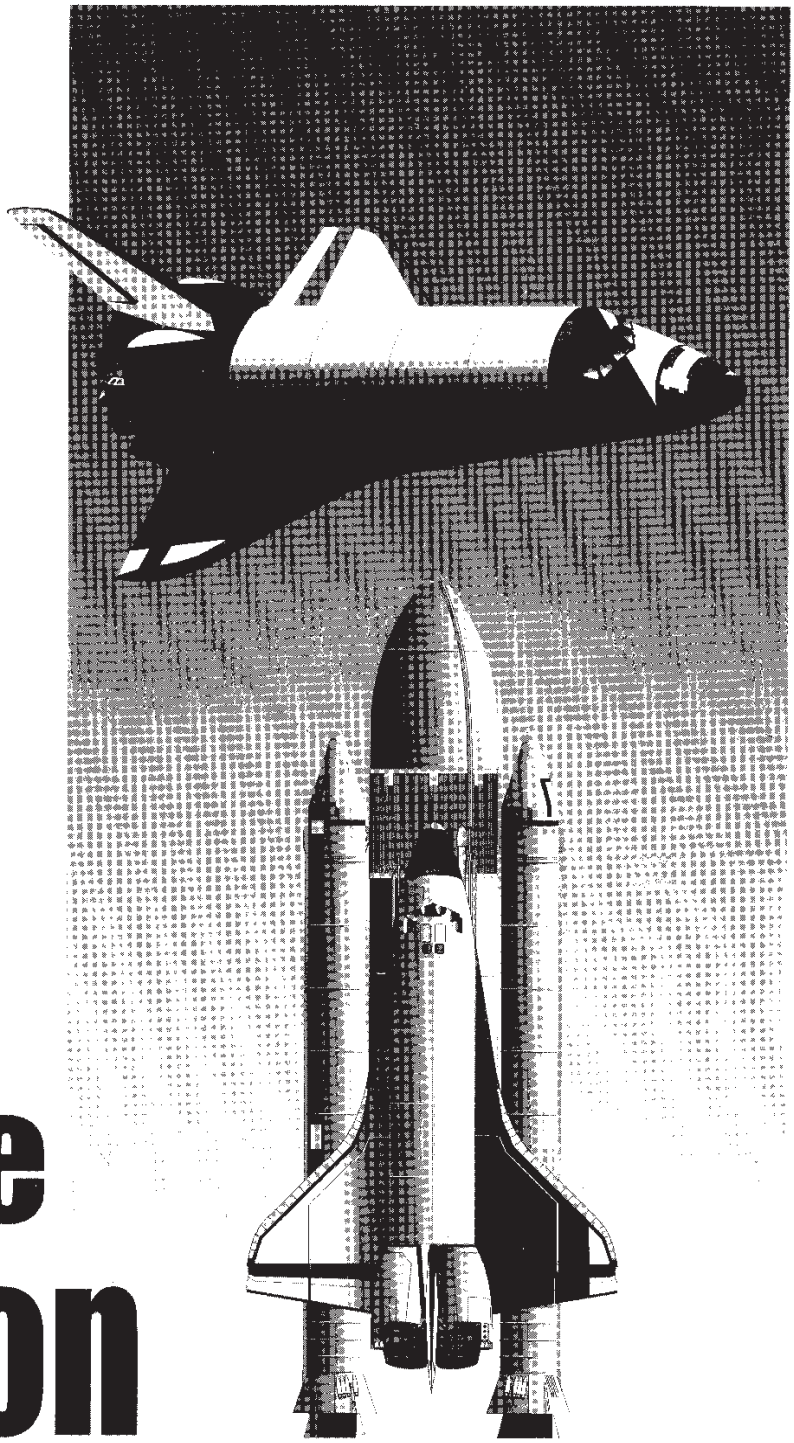

1981-1999 Space Shuttle Mission Chronology

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Note: Launch and landing data based on Shuttle Flight Data and In-Flight Anomaly List, Revision U, Johnson Space Center. Metric conversions are provided starting in 1992. Crew flight numbers are provided beginning in 1995.

MAJOR SHUTTLE PAYLOADS FLOWN CHRONOLOGICALLY

FLIGHT	PAYLOAD
STS-1	N/A
STS-2	OSTA-1
STS-3	OSS-1
STS-4	DOD and CFES
STS-5	ANIK C-3; SBS-C
STS-6	TDRS-1
STS-7	ANIK C-2; PALAPA B1
STS-8	INSAT-1B
STS-9	Spacelab-1
41-B	WESTAR-VI; PALAPA-B2
41-C	LDEF deploy
41-D	SBS-D; SYNCOM IV-2; TELSTAR
41-G	ERBS; OSTA-3
51-A	TELESAT-H; SYNCOM IV-1
51-C	DOD
51-D	TELESAT-I; SYNCOM IV-3
51-B	Spacelab-3
51-G	MORELOS-A; ARABSAT-A; TELSTAR-3D
51-F	Spacelab-2
51-I	ASC-1; AUSSAT-1; SYNCOM IV-4
51-J	DOD
61-A	D-1
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STS-30	Magellan
STS-28	DOD
STS-34	Galileo; SSBUV
STS-33	DOD
STS-32	SYNCOM IV-F5; LDEF Retrieval
STS-36	DOD
STS-31	HST deploy

FLIGHT	PAYLOAD
STS-41	Ulysses; SSBUV; ISAC
STS-38	DOD
STS-35	ASTRO-1
STS-37	GRO
STS-39	DOD: AFP-675; IBSS;SPAS-II
STS-40	SLS-1
STS-43	TDRS-E; SSBUV;SHARE-II
STS-48	UARS
STS-44	DOD: DSP
STS-42	IML-1
STS-45	ATLAS-1
STS-49	Intelsat VI repair
STS-50	USML-1
STS-46	TSS-1; EURECA deploy
STS-47	Spacelab-J
STS-52	USMP-1; LAGEOS II
STS-53	DOD; ODERACS
STS-54	TDRS-F; DXS
STS-56	ATLAS-2; SPARTAN-201
STS-55	Spacelab D-2
STS-57	SPACEHAB-1; EURECA retrieval
STS-51	ACTS/TOS; ORFEUS-SPAS
STS-58	SLS-2
STS-61	1st HST servicing
STS-60	WSF-1; SPACEHAB-2
STS-62	USMP-2; OAST-2
STS-59	SRL-1
STS-65	IML-2
STS-64	LITE; SPARTAN-201
STS-68	SRL-2
STS-66	ATLAS-3; CRISTA-SPAS
STS-63	SPACEHAB-3; Mir rendezvous
STS-67	ASTRO-2
STS-71	1st Mir docking
STS-70	TDRS-G
STS-69	SPARTAN 201-03; WSF-2

FLIGHT	PAYLOAD
STS-73	USML-2
STS-74	2nd Mir docking
STS-72	SFU; OAST-Flyer
STS-75	TSS-1R; USMP-3
STS-76	3rd Mir docking; Spacehab
STS-77	SPACEHAB; SPARTAN (IAE)
STS-78	LMS
STS-79	4th Mir docking; SPACEHAB
STS-80	ORFEUS-SPAS II; WSF-3
STS-81	5th Mir Docking; Spacehab
STS-82	2nd HST Servicing
STS-83	MSL-1
STS-84	6th Mir docking; Spacehab
STS-94	MSL-1 (reflight)
STS-85	CRISTA-SPAS
STS-86	7th Mir docking; Spacehab
STS-87	USMP-4; Spartan; CUE
STS-89	8th Mir docking; Spacehab
STS-90	Neurolab
STS-91	9th and final Mir docking
STS-95	Spartan; HOST; John Glenn reflight
STS-88	1st ISS (Unity module)
STS-96	2nd ISS
STS-93	Chandra X-Ray Observatory
STS-103	3rd Hubble Servicing

Current as of: January 2000

1981

STS-1

Columbia
Pad A
1st Shuttle mission
1st flight OV-102
R&D flight

Crew:
John W. Young, Commander
Robert L. Crippen, Pilot

Backup Crew:
Joe H. Engle, Commander
Richard H. Truly, Pilot

Orbiter Preps (move to):
OPF — March 25, 1979
VAB — Nov. 24, 1980
Pad — Dec. 29, 1980

Launch:
April 12, 1981, 7:00:03 a.m. EST. Launch April 10 postponed due to timing skew between the primary and backup general purpose computers. Backup flight software failed to synchronize with primary avionics software system. Countdown proceeded on schedule April 12. First 24 Shuttle liftoffs — STS-1 through 61-C — were from Pad A.

Landing:
April 14, 1981, 10:20:57 a.m. PST, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 8,993 feet. Rollout time: 60 seconds. Mission duration: two days, six hours, 20 minutes, 53 seconds. Landed revolution 37. Orbiter returned to KSC April 28, 1981.

Mission Highlights:
Major systems tested successfully on first flight of Space Transportation System. Orbiter sustained tile damage on launch and from overpressure wave created by solid rocket boosters. Subsequent modifications to water sound suppression system eliminated problem. Sixteen tiles lost and 148 damaged.

STS-2

(OSTA-1)

Columbia
Pad A
2nd Shuttle mission
2nd flight OV-102
Shortened mission

Crew:
Joe H. Engle, Commander
Richard H. Truly, Pilot

Backup Crew:
Thomas K. Mattingly, Commander
Henry W. Hartsfield, Jr., Pilot

Orbiter Preps (move to):
OPF — April 29, 1981
VAB — Aug. 10, 1981
Pad — Aug. 31, 1981

Launch:
November 12, 1981, 10:09:59 a.m. EST. Launch set for Oct. 9 rescheduled when nitrogen tetroxide spill occurred during loading of forward reaction control system. Launch Nov. 4 delayed and then scrubbed when countdown computer called for hold in count due to apparent low reading on fuel cell oxygen tank pressures. During hold, high oil pressures discovered in two of three auxiliary power units (APUs) that operate hydraulic system. APU gear boxes flushed and filters replaced, forcing launch reschedule. Launch Nov. 12 delayed two hours, 40 minutes to replace multiplexer/demultiplexer and additional nine minutes, 59 seconds to review systems status. Modifications to launch platform to overcome solid rocket booster overpressure problem were effective.

Landing:
November 14, 1981, 1:23:11 p.m. PST, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 7,711 feet. Rollout time: 53 seconds. Mission duration: two days, six hours, 13 minutes, 12 seconds. Landed revolution 37. Mission shortened by approximately three days due to number one fuel cell failure. Orbiter returned to KSC Nov. 25, 1981.

Mission Highlights:
Planned five-day mission cut nearly three days due to failure of one of three fuel cells that produce electricity and drinking water, but 90 percent of mission objectives achieved, including first time remote manipulator system tests. Mission scientists satisfied with data from Office of Space and Terrestrial Applications-1 (OSTA-1) Earth observation experiments mounted on Spacelab pallet in payload bay. No tiles lost, about a dozen damaged.

1982

STS-3

(OSS-1)

Columbia
Pad A
3rd Shuttle mission
3rd flight OV-102
Extended mission
Diverted landing
White Sands landing

Crew:
Jack R. Lousma, Commander
C. Gordon Fullerton, Pilot

Backup Crew: (after STS-3, backup crews were no longer named)
Thomas K. Mattingly, Commander
Henry W. Hartsfield Jr., Pilot

Orbiter Preps (move to):
OPF — Nov. 26, 1981
VAB — Feb. 3, 1982
Pad — Feb. 16, 1982

Launch:

March 22, 1982, 11:00:00 a.m. EST. Launch delayed one hour due to failure of heater on nitrogen gas ground support line.

Landing:

March 30, 1982, 9:04:46 a.m. MST, Runway 17, Northrup Strip, White Sands, N.M. Rollout distance: 13,732 feet. Rollout time: 83 seconds. Mission duration: eight days, zero hours, four minutes, 46 seconds. Landed revolution 130. Landing site changed from Edwards to White Sands due to wet conditions on Edwards dry lake bed landing site. High winds at White Sands resulted in one-day extension of mission. Some brake damage upon landing and dust storm caused extensive contamination of orbiter. Orbiter returned to KSC April 6, 1982.

Mission Highlights:

Testing of Space Shuttle systems for qualification for operational flights continued. Testing of remote manipulator system and measurements of thermal response of orbiter in various attitudes to sun conducted. Get Away Special test canister and Spacelab pallet-mounted experiments for NASA's Office of Space Science-1 (OSS-1) carried in payload bay. OSS-1 obtained data on near-Earth space environment, including contamination (gases, dust, etc.) introduced into space by orbiter itself. Other experiments: Monodisperse Latex Reactor (MLR), Electrophoresis Equipment Verification Test (EEVT), Heflex Bioengineering Test (HBT) and first Shuttle Student Involvement Program (SSIP) experiment. Problems encountered: space sickness, malfunctioning toilet, thermostat difficulty and unexplained static interfering with crew sleep. Auxiliary power unit registered overheating during ascent, but functioned properly during descent. Three communications links lost.

STS-4

(DOD and CFES)

Columbia

Pad A
4th Shuttle mission
4th flight OV-102
Final R&D flight

Crew:

Thomas K. Mattingly, Commander
Henry W. Hartsfield, Jr., Pilot

Orbiter Preps (move to):

OPF — April 7, 1982
VAB — May 19, 1982
Pad — May 26, 1982

Launch:

June 27, 1982, 11:00:00 a.m. EDT. Launch proceeded as scheduled with no delays. Two solid rocket booster casings lost when main parachutes failed and they impacted water and sank. Some rainwater penetrated protective coating of several tiles while orbiter on pad. On orbit, affected area turned toward sun, which vaporized water and prevented further tile damage from freezing water.

Landing

July 4, 1982, 9:09:31 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,878 feet. Rollout time: 73 seconds. Mission duration: seven days, one hour, nine minutes, 31 seconds. Landed revolution 113. First landing on 15,000-foot-long concrete runway at Edwards. Orbiter returned to KSC July 15, 1982.

Mission Highlights:

Final Space Transportation System research and development flight. In addition to classified Department of Defense payload, cargo included first Get Away Specials, which contained nine experiments from Utah State University; first commercial experiment involving Continuous Flow Electrophoresis System (CFES); Monodisperse Latex Reactor (MLR); Induced Environment Contamination Monitor (IECM), which was deployed, and two Shuttle Student Involvement Program (SSIP) experiments. Crew took data for two medical experiments on themselves, operated remote manipulator arm to swing IECM around orbiter, and took photos of lightning activity in Earth's atmosphere.

STS-5

(ANIK C-3; SBS-C)

Columbia

Pad A
5th Shuttle mission
5th flight OV-102
1st operational flight

Crew:

Vance D. Brand, Commander
Robert F. Overmyer, Pilot
Joseph P. Allen, Mission Specialist
William B. Lenoir, Mission Specialist

Orbiter Preps (move to):

OPF — July 16, 1982
VAB — Sept. 9, 1982
Pad — Sept. 21, 1982

Launch:

November 11, 1982, 7:19:00 a.m. EST. Launch proceeded as scheduled with no delays.

Landing:

November 16, 1982, 6:33:26 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,553 feet. Rollout time: 63 seconds. Mission duration: five days, two hours, 14 minutes, 26 seconds. Landed revolution 82. Orbiter returned to KSC Nov. 22, 1982.

Mission Highlights:

First Shuttle operational mission deployed two commercial communications satellites, ANIK C-3 for TELESAT Canada and SBS-C for Satellite Business Systems. Each equipped with Payload Assist Module-D (PAM-D) solid rocket motor, which fired about 45 minutes after deployment, placing each satellite into highly elliptical orbit. One Get Away Special and three Shuttle Student Involvement Program (SSIP) experiments conducted. First scheduled spacewalk in Shuttle program canceled due to malfunction of space suit.

1983

STS-6

(TDRS-1)

Challenger
Pad A
6th Shuttle mission
1st flight OV-099
1st Shuttle spacewalk

Crew:
Paul J. Weitz, Commander
Karol J. Bobko, Pilot
Donald H. Peterson, Mission Specialist
F. Story Musgrave, Mission Specialist

Orbiter Preps (move to):
OPF — July 6, 1982
VAB — Nov. 23, 1982
Pad — Nov. 30, 1982

Launch:
April 4, 1983, 1:30:00 p.m. EST. Launch set for Jan. 20 postponed due to hydrogen leak into number one main engine aft compartment discovered during 20-second Flight Readiness Firing (FRF) Dec. 18, 1982. Cracks in number one main engine confirmed to be cause of leak during second FRF performed Jan. 25, 1983. All three main engines removed while Shuttle on pad and fuel line cracks repaired. Main engines two and three reinstalled following extensive failure analysis and testing. Number one main engine replaced. Additional delay caused by contamination to Tracking and Data Relay Satellite-1 (TDRS-1) during severe storm. Launch on April 4 proceeded as scheduled.

Landing:
April 9, 1983, 10:53:42 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 7,244 feet. Rollout time: 49 seconds. Mission duration: five days, zero hours, 23 minutes, 42 seconds. Landed revolution 81. Orbiter returned to KSC April 16, 1983.

Mission Highlights:
Primary payload was first Tracking and Data Relay Satellite-1 (TDRS-1). Malfunction of Inertial Upper Stage booster resulted in placement of spacecraft into improper but stable orbit. Additional propellant aboard satellite used over next several months to gradually place TDRS-1 into properly circularized orbit. First spacewalk of Shuttle program performed by Peterson and Musgrave, lasting about four hours, 17 minutes.

Other payloads: Continuous Flow Electrophoresis System (CFES), Monodisperse Latex Reactor (MLR), Radiation Monitoring Experiment (RME), Night/Day Optical Survey of Lightning (NOSL), and three Get Away Special canisters. Mission used first lightweight external tank and lightweight solid rocket booster casings.

STS-7

(ANIK C-2; PALAPA B1)

Challenger
Pad A
7th Shuttle mission
2nd flight OV-099
1st U.S. woman in space
Diverted landing

Crew:
Robert L. Crippen, Commander
Frederick H. Hauck, Pilot
John M. Fabian, Mission Specialist
Sally K. Ride, Mission Specialist
Norman E. Thagard, Mission Specialist

Orbiter Preps (move to):
OPF — April 17, 1983
VAB — May 21, 1983
Pad — May 26, 1983

Launch:
June 18, 1983, 7:33:00 a.m. EDT. Launch proceeded as scheduled with no delays.

Landing:
June 24, 1983, 6:56:59 a.m. PDT, Runway 15, Edwards Air Force Base, Calif. Rollout distance: 10,450 feet. Rollout time: 75 seconds. Mission duration: six days, two hours, 23 minutes, 59 seconds. Landed revolution 98. Planned landing at KSC scrubbed due to poor weather conditions. Mission extended two revolutions to facilitate landing at Edwards. Orbiter returned to KSC June 29, 1983.

Mission Highlights:
Ride became first American woman to fly in space. Two communications satellites deployed, ANIK C-2 for TELESAT Canada and PALAPA-B1 for Indonesia, both attached to Payload Assist Module-D (PAM-D) motors. Seven Get Away Special canisters in cargo bay held variety of experiments including ones studying effects of space on social behavior of ant colony in zero gravity. Ten experiments mounted on Shuttle Pallet Satellite (SPAS-01) performed research in forming metal alloys in microgravity and use of remote sensing scanner. Orbiter's small control rockets fired while SPAS-01 held by remote manipulator system to test movement on extended arm. Experiments to investigate space sickness carried out. Other payloads: Office of Space and Terrestrial Applications-2 (OSTA-2); Continuous Flow Electrophoresis System (CFES); Monodisperse Latex Reactor (MLR); and one Shuttle Student Involvement (SSIP) experiment.

STS-8

(INSAT-1B)

Challenger

Pad A
8th Shuttle mission
3rd flight OV-099
1st night launch
1st night landing

Crew:

Richard H. Truly, Commander
Daniel C. Brandenstein, Pilot
Dale A. Gardner, Mission Specialist
Guion S. Bluford, Jr., Mission Specialist
William E. Thornton, Mission Specialist

Orbiter Preps (move to):

OPF — June 30, 1983
VAB — July 26, 1983
Pad — Aug. 2, 1983

Launch:

August 30, 1983, 2:32:00 a.m. EDT. Launch delayed 17 minutes due to weather.

Landing:

September 5, 1983, 12:40:43 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,371 feet. Rollout time: 50 seconds. Mission duration: six days, one hour, eight minutes, 43 seconds. Landed revolution 98. Orbiter returned to KSC Sept. 9, 1983.

Mission Highlights:

Bluford became first African-American to fly in space. INSAT-1B, a multipurpose satellite for India attached to Payload Assist Module-D (PAM-D) motor, was deployed. Nose of orbiter held away from sun 14 hours to test flight deck area in extreme cold. For Development Flight Instrumentation Pallet (DFI PLT), crew filmed performance of experimental heat pipe mounted in cargo bay; also, orbiter dropped to 139 miles altitude to perform tests on thin atomic oxygen to identify cause of glow that surrounds parts of orbiter at night. Remote manipulator system tested to evaluate joint reactions to higher loads. Biofeedback experiments: six rats flown in Animal Enclosure Module to observe animal reactions in space. Other payloads: Continuous Flow Electrophoresis System (CFES); Shuttle Student Involvement Program (SSIP) experiment; Incubator-Cell Attachment Test (ICAT); Investigation of STS Atmospheric Luminosities (ISAL); Radiation Monitoring Equipment (RME); and five Get Away Special experiment packages including eight cans of postal covers. Testing conducted between Tracking and Data Relay Satellite-1 (TDRS-1) and orbiter using Ku-band antenna, and investigations continued on Space Adaptation Syndrome.

STS-9

(Spacelab-1)

Columbia

Pad A
9th Shuttle mission
6th flight OV-102
1st rollback
1st flight 6 crewmembers in single spacecraft
1st Spacelab mission
Extended mission

Crew:

John W. Young, Commander
Brewster H. Shaw, Jr., Pilot
Owen K. Garriott, Mission Specialist
Robert A. R. Parker, Mission Specialist
Byron K. Lichtenberg, Payload Specialist
Ulf Merbold, Payload Specialist (European Space Agency)

Orbiter Preps (move to):

Flow A:
OPF — Nov. 23, 1982
VAB — Sept. 24, 1983
Pad — Sept. 28, 1983
Flow B (rollback):
OPF — Oct. 20, 1983
VAB — Nov. 3, 1983
Pad — Nov. 8, 1983

Launch:

November 28, 1983, 11:00:00 a.m. EST. Launch set for Sept. 30 delayed 28 days due to suspect exhaust nozzle on right solid rocket booster. Problem discovered while Shuttle was on pad. Shuttle returned to VAB and demated. Suspect nozzle replaced and vehicle restacked. Countdown Nov. 28 proceeded as scheduled.

Landing:

December 8, 1983, 3:47:24 p.m. PST, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 8,456 feet. Rollout time: 53 seconds. Mission duration: 10 days, seven hours, 47 minutes, 24 seconds. Landed revolution 167. Landing delayed approximately eight hours to analyze problems when general purpose computers one and two failed and inertial measurement unit one failed. During landing, two of three auxiliary power units caught fire. Orbiter returned to KSC Dec. 15, 1983.

Mission Highlights:

Flight carried first Spacelab mission and first astronaut to represent European Space Agency (ESA), Ulf Merbold of Germany. ESA and NASA jointly sponsored Spacelab-1 and conducted investigations which demonstrated capability for advanced research in space. Spacelab is an orbital laboratory and observations platform composed of cylindrical pressurized modules and U-shaped unpressurized pallets which remain in orbiter's cargo bay during flight.

Altogether 73 separate investigations carried out in astronomy and physics, atmospheric physics, Earth observations, life sciences, materials sciences, space plasma physics and technology. First time six persons carried into space on a single vehicle.

1984

41-B

(WESTAR-VI; PALAPA-B2)

Challenger

Pad A
10th Shuttle mission
4th flight OV-099
1st untethered spacewalk
1st KSC landing

Crew:

Vance D. Brand, Commander
Robert L. Gibson, Pilot
Bruce McCandless II, Mission Specialist
Ronald E. McNair, Mission Specialist
Robert L. Stewart, Mission Specialist

Orbiter Preps (move to):

OPF — Sept. 10, 1983
VAB — Jan. 6, 1984
Pad — Jan. 12, 1984

Launch:

February 3, 1984, 8:00:00 a.m. EST. Launch set for Jan. 29 postponed five days while orbiter still in OPF to allow changeout of all three auxiliary power units (APUs), a precautionary measure in response to APU failures on previous STS-9 mission.

Landing:

February 11, 1984, 7:15:55 a.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 10,807 feet. Rollout time: 67 seconds. Mission duration: seven days, 23 hours, 15 minutes, 55 seconds. Landed revolution 128. First end-of-mission landing at KSC.

Mission Highlights:

First untethered spacewalks by McCandless and Stewart, using manned maneuvering unit. WESTAR-VI and PALAPA-B2 satellites deployed, but failure of Payload Assist Module-D (PAM-D) rocket motors left them in radical low-Earth orbits. German-built Shuttle Pallet Satellite (SPAS), first flown on STS-7, became first satellite refurbished and flown again. SPAS remained in payload bay due to electrical problem with remote manipulator system (RMS). RMS manipulator foot restraint first used, practice procedures performed for Solar Maximum satellite retrieval and repair planned for next mission. Integrated Rendezvous Target (IRT) failed due to internal failure.

Five Get Away Special canisters flown in cargo bay and Cinema-360 camera used by crew. Other payloads: Acoustic Containerless Experiment System (ACES); Monodisperse Latex Reactor (MLR); and Radiation Monitoring Equipment (RME), and Isoelectric Focusing (IEF) payload.

41-C

(LDEF deploy)

Challenger

Pad A
11th Shuttle mission
5th flight OV-099
1st on-orbit spacecraft repair
Diverted landing

Crew:

Robert L. Crippen, Commander
Francis R. Scobee, Pilot
George D. Nelson, Mission Specialist
James D. A. Van Hoften, Mission Specialist
Terry J. Hart, Mission Specialist

Orbiter Preps (move to):

OPF — Feb. 11, 1984
VAB — March 14, 1984
Pad — March 19, 1984

Launch:

April 6, 1984, 8:58:00 a.m. EST. Launch proceeded as scheduled with no delays.

Landing:

April 13, 1984, 5:38:07 a.m. PST, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 8,716 feet. Rollout time: 49 seconds. Mission duration: six days, 23 hours, 40 minutes, seven seconds. Landed revolution 108. Mission extended one day when astronauts unable to grapple Solar Maximum Mission spacecraft. Planned landing at KSC scrubbed. Mission extended one revolution to facilitate landing at Edwards. Orbiter returned to KSC April 18, 1984.

Mission Highlights:

First direct ascent trajectory for Space Shuttle. Using manned maneuvering unit, astronauts replaced altitude control system and coronagraph/polarimeter electronics box in Solar Maximum satellite while it remained in orbit. Long Duration Exposure Facility (LDEF) deployed, carrying 57 experiments. Left on orbit with intention of retrieving during later mission. Other payloads: IMAX camera; Radiation Monitoring Equipment (RME); Cinema 360; Shuttle Student Involvement Program (SSIP) experiment.

41-D

(SBS-D; SYNCOM IV-2; TELSTAR)

Discovery

Pad A
12th Shuttle mission
1st flight OV-103
1st pad abort
Rollback

Crew:

Henry W. Hartsfield, Jr., Commander
Michael L. Coats, Pilot
Judith A. Resnik, Mission Specialist
Richard M. Mullane, Mission Specialist
Steven A. Hawley, Mission Specialist
Charles D. Walker, Payload Specialist

Orbiter Preps (move to):

OPF — Nov. 10, 1983
VAB — Dec. 9, 1983 (storage)
Flow A:
OPF — Jan. 10, 1984
VAB — May 12, 1984
Pad — May 19, 1984
Flow B (rollback):
VAB — July 14, 1984
OPF — July 17, 1984
VAB — Aug. 1, 1984
Pad — Aug. 9, 1984

Launch:

August 30, 1984, 8:41:50 a.m. EDT. Launch attempt June 25 scrubbed during T-9 minute hold due to failure of orbiter's back-up general purpose computer (GPC). Launch attempt June 26 aborted at T-4 seconds when GPC detected anomaly in orbiter's number three main engine. Discovery returned to OPF and number three main engine replaced. (To preserve launch schedule of future missions, 41-D cargo remanifested to include payload elements from both 41-D and 41-F flights; 41-F mission canceled.) Shuttle restacked and returned to pad. Third launch attempt Aug. 29 delayed when discrepancy noted in flight software. Launch Aug. 30 delayed six minutes, 50 seconds when private aircraft intruded into warning area off coast of Cape Canaveral.

Landing:

September 5, 1984, 6:37:54 a.m. PDT, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 10,275 feet. Rollout time: 60 seconds. Mission duration: six days, zero hours, 56 minutes, four seconds. Landed revolution 97. Landing planned for Edwards desert runway because it was Discovery's first flight. Orbiter returned to KSC Sept. 10, 1984.

Mission Highlights:

Three satellites deployed: Satellite Business System SBS-D, SYNCOM IV-2 (also known as LEASAT 2) and TELSTAR. The 102-foot-tall, 13-foot-wide Office of Application and Space Technology-1 (OAST-1) solar wing extended from payload bay. Wing carried different types of solar cells and extended to full height several times. It demonstrated large lightweight solar arrays for future in building large facilities in space such as Space Station. Other payloads: Continuous Flow Electrophoresis System (CFES) III; Radiation Monitoring Equipment (RME); Shuttle Student Involvement Program (SSIP) experiment; IMAX camera, being flown second time; and an Air Force experiment, Cloud Logic to Optimize Use of Defense Systems (CLOUDS).

41-G

(ERBS; OSTA-3)

Challenger

Pad A
13th Shuttle mission
6th flight OV-099
2nd KSC landing

Crew:

Robert L. Crippen, Commander
Jon A. McBride, Pilot
David C. Leestma, Mission Specialist
Sally K. Ride, Mission Specialist
Kathryn D. Sullivan, Mission Specialist
Paul D. Scully-Power, Payload Specialist
Marc Garneau, Payload Specialist (Canadian Space Agency)

Orbiter Preps (move to):

OPF — April 18, 1984
VAB — Sept. 8, 1984
Pad — Sept. 13, 1984

Launch:

October 5, 1984, 7:03:00 a.m. EDT. Launch proceeded as scheduled with no delays.

Landing:

October 13, 1984, 12:26:38 p.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,565 feet. Rollout time: 54 seconds. Mission duration: eight days, five hours, 23 minutes, 38 seconds. Landed revolution 133.

Mission Highlights:

First flight to include two women, Ride and Sullivan. Sullivan first American woman to walk in space. Earth Radiation Budget Satellite (ERBS) deployed less than nine hours into flight. Office of Space and Terrestrial Applications-3 (OSTA-3) carried three experiments in payload bay. Components of Orbital Refueling System (ORS) connected, demonstrating it is possible to refuel satellites in orbit. Other payloads: Large Format Camera (LFC); IMAX camera, flying for third time; package of Canadian Experiments (CANEX); Auroral Photography Experiment (APE); Radiation Monitoring Equipment (RME); Thermoluminescent Dosimeter (TLD); and eight Get Away Specials.

51-A

(TELESAT-H; SYNCOM IV-1)

Discovery

Pad A
14th Shuttle mission
2nd flight OV-103
3rd KSC landing

Crew:

Frederick H. Hauck, Commande
David M. Walker, Pilot
Anna L. Fisher, Mission Specialist
Dale A. Gardner, Mission Specialist
Joseph P. Allen, Mission Specialist

Orbiter Preps (move to):

OPF — Sept. 10, 1984
VAB — Oct. 18, 1984
Pad — Oct. 23, 1984

Launch:

November 8, 1984, 7:15:00 a.m. EST. Launch attempt Nov. 7 scrubbed during built-in hold at T-20 minutes due to wind shears in upper atmosphere. Countdown Nov. 8 proceeded as scheduled.

Landing:

November 16, 1984, 6:59:56 a.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 9,454 feet. Rollout time: 58 seconds. Mission duration: seven days, 23 hours, 44 minutes, 56 seconds. Landed revolution 127.

Mission Highlights:

Canadian communications satellite TELESAT-H (ANIK), attached to Payload Assist Module-D (PAM-D), deployed into geosynchronous orbit on flight day two. On third day, defense communications satellite SYNCOM IV-1 (also known as LEASAT-1) deployed. Allen and Gardner, wearing jet-propelled manned maneuvering units, retrieved two malfunctioning satellites: PALAPA-B2 and WESTAR-VI, both deployed on Mission 41-B. Fisher operated remote manipulator system, grappling satellites and deposited them in payload bay. Middeck payloads: Diffusive Mixing of Organic Solutions (DMOS), and Radiation Monitoring Equipment (RME).

1985

51-C

(DOD)

Discovery

Pad A
15th Shuttle mission
3rd flight OV-103
4th KSC landing
1st dedicated DOD mission

Crew:

Thomas K. Mattingly II, Commander
Loren J. Shriver, Pilot
James F. Buchli, Mission Specialist
Ellison S. Onizuka, Mission Specialist
Gary E. Payton, Payload Specialist

Orbiter Preps (move to):

OPF — Nov. 16, 1984
VAB — Dec. 21, 1984
Pad — Jan. 5, 1985

Launch:

January 24, 1985, 2:50:00 p.m. EST. Launch Jan. 23 scrubbed due to freezing weather conditions. (Orbiter Challenger scheduled for Mission 51-C, but thermal tile problems forced substitution of Discovery.)

Landing:

January 27, 1985, 4:23:23 p.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 7,352 feet. Rollout time: 50 seconds. Mission duration: three days, one hour, 33 minutes, 23 seconds. Landed revolution 49.

Mission Highlights:

First mission dedicated to Department of Defense. U.S. Air Force Inertial Upper Stage booster deployed and met mission objectives.

51-D

(TELESAT-I; SYNCOM IV-3)

Discovery

Pad A
16th Shuttle mission
4th flight OV-103
Extended mission
5th KSC landing

Crew:

Karol J. Bobko, Commander
Donald E. Williams, Pilot
M. Rhea Seddon, Mission Specialist
S. David Griggs, Mission Specialist
Jeffrey A. Hoffman, Mission Specialist
Charles D. Walker, Payload Specialist
Sen. E. J. Garn, Payload Specialist

Orbiter Preps (move to):

OPF — Jan. 28, 1985
VAB — March 23, 1985
Pad — March 28, 1985

Launch:

April 12, 1985, 8:59:05 a.m. EST. Launch set for March 19 rescheduled to March 28 due to remanifesting of payloads from canceled Mission 51-E. Delayed further due to damage to orbiter's payload bay door when facility access platform dropped. Launch April 12 delayed 55 minutes when ship entered restricted solid rocket booster recovery area.

Landing:

April 19, 1985, 8:54:28 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,298 feet. Rollout time: 63 seconds. Mission duration: six days, 23 hours, 55 minutes, 23 seconds. Landed revolution 110. Extensive brake damage and blown tire during landing prompted landing of future flights at Edwards Air Force Base until implementation of nose wheel steering.

Mission Highlights:

TELESAT-I (ANIK C-1) communications satellite deployed, attached to Payload Assist Module-D (PAM-D) motor. SYNCOM IV-3 (also known as LEASAT-3) deployed, but spacecraft sequencer failed to initiate antenna deployment, spin-up and ignition of perigee kick motor. Mission extended two days to make certain sequencer start lever in proper position. Griggs and Hoffman performed spacewalk to attach "flyswatter" devices to remote manipulator system. Seddon engaged LEASAT lever using remote manipulator system but post-deployment sequence did not begin. Other payloads: Continuous Flow Electrophoresis System (CFES) III, flying for sixth time; two Shuttle Student Involvement Program (SSIP) experiments; American Flight Echocardiograph (AFE); two Get Away Specials; Phase Partitioning Experiments (PPE); astronomy photography verification test; medical experiments; and "toys in space," an informal study of the behavior of simple toys in weightless environment, with results to be made available to school students.

51-B

(Spacelab-3)

Challenger

Pad A
17th Shuttle mission
7th flight OV-099
Rollback

Crew:

Robert F. Overmyer, Commander
Frederick D. Gregory, Pilot
Don L. Lind, Mission Specialist
Norman E. Thagard, Mission Specialist
William E. Thornton, Mission Specialist
Lodewijk van den Berg, Payload Specialist
Taylor G. Wang, Payload Specialist

Orbiter Preps (move to):

Flow A:
OPF — Oct. 13, 1984
VAB — Feb. 10, 1985
Pad — Feb. 15, 1985
Flow B (rollback):
VAB — March 4, 1985
OPF — March 7, 1985
VAB — April 10, 1985
Pad — April 15, 1985

Launch:

April 29, 1985, 12:02:18 p.m. EDT. Flight first manifested as 51-E; rolled back from pad due to timing problem with TDRS-B payload. Mission 51-E canceled; orbiter remanifested with 51-B payloads. Launch April 29 delayed two minutes, 18 seconds due to a launch processing system failure.

Landing:

May 6, 1985, 9:11:04 a.m. PDT, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 8,317 feet. Rollout time: 59 seconds. Mission duration: seven days, zero hours, eight minutes, 46 seconds. Landed revolution 111. Orbiter returned to KSC May 11, 1985.

Mission Highlights:

Primary payload was Spacelab-3. First operational flight for Spacelab orbital laboratory series developed by European Space Agency. Five basic discipline areas: materials sciences, life sciences, fluid mechanics, atmospheric physics, and astronomy. Main

mission objective with Spacelab-3 was to provide high-quality microgravity environment for delicate materials processing and fluid experiments. Two monkeys and 24 rodents observed for effects of weightlessness. Of 15 Spacelab primary experiments conducted, 14 considered successful. Two Get Away Specials on board.

51-G

(MORELOS-A; ARABSAT-A; TELESTAR-3D)

Discovery

Pad A
18th Shuttle mission
5th flight OV-103

Crew:

Daniel C. Brandenstein, Commander
John O. Creighton, Pilot
Shannon W. Lucid, Mission Specialist
Steven R. Nagel, Mission Specialist
John M. Fabian, Mission Specialist
Patrick Baudry, Payload Specialist, (CNES, French Space Agency)
Sultan Salman Al-Saud, Payload Specialist

Orbiter Preps (move to):

OPF — April 19, 1985
VAB — May 29, 1985
Pad — June 4, 1985

Launch:

June 17, 1985, 7:33:00 a.m. EDT. Launch proceeded as scheduled with no delays.

Landing:

June 24, 1985, 6:11:52 a.m. PDT, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 7,433 feet. Rollout time: 42 seconds. Mission duration: seven days, one hour, 38 minutes, 52 seconds. Landed revolution 112. Orbiter returned to KSC June 28, 1985.

Mission Highlights:

Three communications satellites, all attached to Payload Assist Module-D (PAM-D) motors, were deployed: MORELOS-A, for Mexico; ARABSAT-A, for Arab Satellite Communications Organization; and TELSTAR-3D, for AT&T. Also flown: deployable/retrievable Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN-1); six Get Away Special canisters; Strategic Defense Initiative experiment called the High Precision Tracking Experiment (HPTE); a materials processing furnace called Automated Directional Solidification Furnace (ADSF); and two French biomedical experiments.

51-F

(Spacelab-2)

Challenger

Pad A
19th Shuttle mission
8th flight OV-099
Pad abort
Abort-to-orbit
Extended mission

Crew:

C. Gordon Fullerton, Commander
Roy D. Bridges, Jr., Pilot
F. Story Musgrave, Mission Specialist
Karl G. Henize, Mission Specialist
Anthony W. England, Mission Specialist
Loren W. Acton, Payload Specialist
John-David F. Bartoe, Payload Specialist

Orbiter Preps (move to):

OPF — May 12, 1985
VAB — June 24, 1985
Pad — June 29, 1985

Launch:

July 29, 1985, 5:00:00 p.m. EDT. Launch countdown July 12 halted at T-3 seconds when malfunction of number two main engine coolant valve caused shutdown of all three main engines. Launch July 29 delayed one hour, 37 minutes due to problem with table maintenance block update uplink. Five minutes, 45 seconds into ascent, number one main engine shut down prematurely, resulting in an abort-to-orbit trajectory.

Landing:

August 6, 1985, 12:45:26 p.m. PDT, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 8,569 feet. Rollout time: 55 seconds. Mission duration: seven days, 22 hours, 45 minutes, 26 seconds. Landed revolution 127. Mission extended 17 revolutions for additional payload activities due to abort-to-orbit. Orbiter returned to KSC Aug. 11, 1985.

Mission Highlights:

Primary payload was Spacelab-2. Despite abort-to-orbit, which required mission replanning, mission declared success. Special part of modular Spacelab system, the Igloo, located at head of three-pallet train, provided on-site support to instruments mounted on pallets. Main mission objective was to verify performance of Spacelab systems and determine interface capability of orbiter, and measure environment induced by spacecraft. Experiments covered life sciences, plasma physics, astronomy, high-energy astrophysics, solar physics, atmospheric physics and technology research.

51-I

(ASC-1; AUSSAT-1; SYNCOM IV-4)

Discovery

Pad A
20th Shuttle mission
6th flight OV-103
Shortened mission

Crew:

Joe H. Engle, Commander
Richard O. Covey, Pilot
James D. A. van Hoften, Mission Specialist
John M. Lounge, Mission Specialist
William F. Fisher, Mission Specialist

Orbiter Preps (move to):

OPF — June 29, 1985
VAB — July 30, 1985
Pad — Aug. 6, 1985

Launch:

August 27, 1985, 6:58:01 a.m. EDT. Launch Aug. 24 scrubbed at T-5 minutes due to thunderstorms in vicinity. Launch Aug. 25 delayed when orbiter's number five on-board general purpose computer failed. Launch Aug. 27 delayed three minutes, one second due to combination of weather and unauthorized ship entering restricted solid rocket booster recovery area.

Landing:

September 3, 1985, 6:15:43 a.m. PDT, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 6,100 feet. Rollout time: 47 seconds. Mission duration: seven days, two hours, 17 minutes, 42 seconds. Landed revolution 112. Mission shortened one day when AUSSAT sunshield hung up on remote manipulator system camera and AUSSAT had to be deployed before scheduled. Orbiter returned to KSC Sept. 8, 1985.

Mission Highlights:

Three communications satellites deployed: ASC-1, for American Satellite Company; AUSSAT-1, an Australian Communications Satellite; and SYNCOM IV-4, the Synchronous Communications Satellite. ASC-1 and AUSSAT-1 both attached to Payload Assist Module-D (PAM-D) motors. SYNCOM IV-4 (also known as LEASAT-4) failed to function after reaching correct geosynchronous orbit. Fisher and van Hoften performed two extravehicular activities (EVAs) totaling 11 hours, 51 minutes. Part of time spent retrieving, repairing and redeploying LEASAT-3, deployed on Mission 51-D. Middeck Payload: Physical Vapor Transport Organic Solid Experiment (PVTOS).

51-J

(DOD)

Atlantis

Pad A
21st Shuttle mission
1st flight OV-104

Crew:

Karol J. Bobko, Commander
Ronald J. Grabe, Pilot
Robert L. Stewart, Mission Specialist
David C. Hilmers, Mission Specialist
William A. Pailes, Payload Specialist

Orbiter Preps (move to):

OPF — April 14, 1985
VAB — May 10, 1985 (storage)
OPF — May 28, 1985
VAB — July 18, 1985 (storage)
OPF — July 30, 1985
VAB — Aug. 12, 1985
Pad — Aug. 30, 1985

Launch:

October 3, 1985, 11:15:30 a.m. EDT. Launch delayed 22 minutes, 30 seconds due to main engine liquid hydrogen prevalve close remote power controller showing faulty 'on' indication.

Landing:

October 7, 1985, 10:00:08 a.m. PDT, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 8,056 feet. Rollout time: 65 seconds. Mission duration: four days, one hour, 44 minutes, 38 seconds. Landed revolution 64. Orbiter returned to KSC Oct. 11, 1985.

Mission Highlights:

Second mission dedicated to Department of Defense.

61-A

(D-1)

Challenger

Pad A
22nd Shuttle mission
9th flight OV-099

Crew:

Henry W. Hartsfield, Jr., Commander
Steven R. Nagel, Pilot
James F. Buchli, Mission Specialist
Guion S. Bluford, Jr., Mission Specialist
Bonnie J. Dunbar, Mission Specialist
Reinhard Furrer, Payload Specialist
Ernst Messerschmid, Payload Specialist
Wubbo J. Ockels, Payload Specialist (European Space Agency)

Orbiter Preps (move to):

OPF — Aug. 12, 1985
VAB — Oct. 12, 1985
Pad — Oct. 16, 1985

Launch:

October 30, 1985, 12:00:00 noon EST. Launch proceeded as scheduled with no delays.

Landing:

November 6, 1985, 9:44:53 a.m. PST, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 8,304 feet. Rollout time: 45 seconds. Mission duration: seven days, zero hours, 44 minutes, 53 seconds. Landed revolution 112. Orbiter returned to KSC Nov. 11, 1985.

Mission Highlights:

Dedicated German Spacelab (D-1) mission conducted in long module configuration, which featured Vestibular Sled designed to give scientists data on functional organization of human vestibular and orientation systems. Spacelab D-1 encompassed 75 numbered experiments, most performed more than once. Mission included basic and applied microgravity research in fields of materials science, life sciences and technology, and communications and navigation.

Though orbiter controlled from Johnson Space Center, scientific operations controlled from German Space Operations Center at Oberpfaffenhofen, near Munich. Other objectives: Global Low Orbiting Message Relay (GLOMR) satellite deployed from Get Away Special canister.

61-B

(MORELOS-B; AUSSAT-2; SATCOM KU-2)

Atlantis

Pad A
23rd Shuttle mission
2nd flight OV-104
Night launch

Crew:

Brewster H. Shaw, Jr., Commander
Bryan D. O'Connor, Pilot
Mary L. Cleave, Mission Specialist
Sherwood C. Spring, Mission Specialist
Jerry L. Ross, Mission Specialist
Rodolfo Neri Vela, Payload Specialist
Charles D. Walker, Payload Specialist

Orbiter Preps (move to):

OPF — Oct. 12, 1985
VAB — Nov. 7, 1985
Pad — Nov. 12, 1985

Launch:

November 26, 1985, 7:29:00 p.m. EST. Launch proceeded as scheduled with no delays.

Landing:

December 3, 1985, 1:33:49 p.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,759 feet. Rollout time: 78 seconds. Mission duration: six days, 21 hours, four minutes, 49 seconds. Landed revolution 109. Mission shortened one revolution due to lightning conditions at Edwards. Landed on concrete runway because lake bed was wet. Orbiter returned to KSC Dec. 7, 1985.

Mission Highlights:

Three communications satellites deployed: MORELOS-B (Mexico), AUSSAT-2 (Australia) and SATCOM KU-2 (RCA Americom). MORELOS-B and AUSSAT-2 attached to Payload Assist Module-D motors, SATCOM KU-2 to a PAM-D2 designed for heavier payloads.

Two experiments conducted to test assembling erectable structures in space: Experimental Assembly of Structures in Extravehicular Activity (EASE) and Assembly Concept for Construction of Erectable Space Structure (ACCESS). Experiments required two spacewalks by Spring and Ross lasting five hours, 32 minutes, and six hours, 38 minutes, respectively. Middeck payloads: Continuous Flow Electrophoresis System (CFES); Diffusive Mixing of Organic Solutions (DMOS); Morelos Payload Specialist Experiments (MPSE); and Orbiter Experiments (OEX). In payload bay: Get Away Special and IMAX Cargo Bay Camera (ICBC).

1986

61-C

(SATCOM KU-1)

Columbia

Pad A
24th Shuttle mission
7th liftoff OV-102
Diverted landing
Night landing
Extended mission

Crew:

Robert L. Gibson, Commander
Charles F. Bolden, Jr., Pilot
Franklin R. Chang-Diaz, Mission Specialist
Steven A. Hawley, Mission Specialist
George D. Nelson, Mission Specialist
Robert J. Cenker, Payload Specialist
Congressman Bill Nelson, Payload Specialist

Orbiter Preps (move to):

OPF — July 18, 1985
VAB — Sept. 6, 1985 (storage)
OPF — Sept. 26, 1985
VAB — Nov. 22, 1985
Pad — Dec. 2, 1985

Launch:

January 12, 1986, 6:55:00 a.m. EST. Launch set for Dec. 18, 1985 delayed one day when additional time needed to close out orbiter aft compartment. Launch attempt Dec. 19 scrubbed at T-14 seconds due to indication that right solid rocket booster hydraulic power unit exceeding RPM redline speed limits. (Later determined as false reading.) After 18-day delay, launch attempt Jan. 6, 1986 halted at T-31 seconds due to accidental draining of approximately 14,000 pounds of liquid oxygen from external tank. Launch attempt Jan. 7 scrubbed at T-9 minutes due to bad weather at both transoceanic abort landing sites (Moron, Spain and Dakar, Senegal). After two-day delay, launch set for Jan. 9 delayed due to launch pad liquid oxygen sensor breaking off and lodging in number two main engine prevalve. Launch set for Jan. 10 delayed two days due to heavy rains. Launch countdown Jan. 12 proceeded with no delays.

Landing:

January 18, 1986, 5:58:51 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,202 feet. Rollout time: 59 seconds. Mission duration: six days, two hours, three minutes, 51 seconds. Landed revolution 98. Planned landing at KSC, originally scheduled for Jan. 17, moved to Jan. 16 to save orbiter turnaround time. Landing attempts on Jan. 16 and 17 abandoned due to unacceptable weather at KSC. Landing set for Jan. 18 at KSC but persisting bad weather forced a one revolution extension of mission and landing at Edwards. Orbiter returned to KSC Jan. 23, 1986.

Mission Highlights:

SATCOM KU-1 (RCA Americom) satellite, attached to Payload Assist Module-D2 (PAM-D2) motor, was deployed. Comet Halley

Active Monitoring Program (CHAMP) experiment, a 35mm camera to photograph Comet Halley, did not function properly due to battery problems. Other payloads: Materials Science Laboratory-2 (MSL-2); Hitchhiker G-1; Infrared Imaging Experiment (IR-IE); Initial Blood Storage Experiment (IBSE); Hand-held Protein Crystal Growth (HPCG) experiment; three Shuttle Student Involvement Program (SSIP) experiments and 13 Get Away Specials (GAS), 12 of them mounted on a special GAS Bridge Assembly.

51-L

(TDRS-2; SPARTAN-203)

Challenger

Pad B
25th Shuttle mission
10th liftoff OV-099
Crew, vehicle lost 73 seconds after liftoff

Crew:

Francis R. Scobee, Commander
Michael J. Smith, Pilot
Judith A. Resnik, Mission Specialist
Ellison S. Onizuka, Mission Specialist
Ronald E. McNair, Mission Specialist
Sharon Christa McAuliffe, Teacher in Space Project
Gregory B. Jarvis, Payload Specialist

Orbiter Preps (move to):

OPF — Nov. 11, 1985
VAB — Dec. 16, 1985
Pad — Dec. 22, 1985

Launch:

January 28, 1986, 11:38:00 a.m. EST. First Shuttle liftoff scheduled from Pad B. Launch set for 3:43 p.m. EST, Jan. 22, slipped to Jan. 23, then Jan. 24, due to delays in Mission 61-C. Launch reset for Jan. 25 because of bad weather at transoceanic abort landing (TAL) site in Dakar, Senegal. To utilize Casablanca (not equipped for night landings) as alternate TAL site, T-zero moved to morning liftoff time. Launch postponed a day when launch processing unable to meet new morning liftoff time. Prediction of unacceptable weather at KSC led to launch rescheduled for 9:37 a.m. EST, Jan. 27. Launch delayed 24 hours again when ground servicing equipment hatch-closing fixture could not be removed from orbiter hatch. Fixture sawed off and attaching bolt drilled out before closeout completed. During delay, cross winds exceeded return-to-launch-site limits at KSC's Shuttle Landing Facility. Launch Jan. 28 delayed two hours when hardware interface module in launch processing system, which monitors fire detection system, failed during liquid hydrogen tanking procedures. Explosion 73 seconds after liftoff claimed crew and vehicle. Shuttle flights halted while extensive investigation into accident and assessment of Shuttle program conducted.

Mission Objectives:

Planned objectives were deployment of Tracking Data Relay Satellite-2 (TDRS-2) and flying of Shuttle-Pointed Tool for Astronomy (SPARTAN-203)/Halley's Comet Experiment Deployable, a free-flying module designed to observe tail and coma of Halley's comet with two ultraviolet spectrometers and two cameras. Other payloads were Fluid Dynamics Experiment (FDE); Comet Halley Active Monitoring Program (CHAMP); Phase Partitioning Experiment (PPE); three Shuttle Student Involvement Program (SSIP) experiments; and set of lessons for Teacher in Space Project (TISP).

1988

STS-26

(TDRS-C)

Discovery

Pad B
26th Shuttle mission
7th flight OV-103
Return to flight

Crew:

Frederick H. Hauck, Commander
Richard O. Covey, Pilot
John M. Lounge, Mission Specialist
David C. Hilmers, Mission Specialist
George D. Nelson, Mission Specialist

Orbiter Preps (move to):

OPF — Oct. 30, 1986
VAB — June 21, 1988
Pad — July 4, 1988

Launch:

September 29, 1988, 11:37:00 a.m. EDT. Launch delayed one hour, 38 minutes to replace fuses in cooling system of two of crew's new partial pressure launch/entry suits, and due to lighter than expected upper atmospheric winds. Suit repairs successful and countdown continued after waiver of wind condition constraint.

Landing:

October 3, 1988, 9:37:11 a.m. PDT, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 7,451 feet. Rollout time: 46 seconds. Mission duration: four days, one hour, zero minutes, 11 seconds. Landed revolution 64. Orbiter returned to KSC Oct. 8, 1988.

Mission Highlights:

Mission marked resumption of Shuttle flights after 1986 51-L accident. Primary payload, NASA Tracking and Data Relay Satellite-3 (TDRS-3) attached to an Inertial Upper Stage (IUS), became second TDRS deployed. After deployment, IUS propelled satellite to geosynchronous orbit. Secondary payloads: Physical Vapor Transport of Organic Solids (PVTOS); Protein Crystal Growth (PCG); Infrared Communications Flight Experiment (IRCFE); Aggregation of Red Blood Cells (ARC); Isoelectric Focusing Experiment (IFE); Mesoscale Lightning Experiment (MLE); Phase Partitioning Experiment (PPE); Earth-Limb Radiance Experiment (ELRAD); Automated Directional Solidification Furnace (ADSF); and two Shuttle Student Involvement Program (SSIP) experiments. Orbiter Experiments Autonomous Supporting Instrumentation System-1 (OASIS-1) recorded variety of environmental measurements during various inflight phases of orbiter.

Ku-band antenna in payload bay deployed; however, dish antenna command and actual telemetry did not correspond. Also, orbiter cabin Flash Evaporator System iced up, raising crew cabin temperature to mid-80s.

STS-27

(DOD)

Atlantis

Pad B
27th Shuttle mission
3rd flight OV-104

Crew:

Robert L. Gibson, Commander
Guy S. Gardner, Pilot
Richard M. Mullane, Mission Specialist
Jerry L. Ross, Mission Specialist
William M. Shepherd, Mission Specialist

Orbiter Preps (move to):

OPF — March 20, 1987
VAB — Oct. 22, 1988
Pad — Nov. 2, 1988

Launch:

December 2, 1988, 9:30:34 a.m. EST. Launch set for Dec. 1 during classified window lying within launch period between 6:32 a.m. and 9:32 a.m., postponed due to unacceptable cloud cover and wind conditions and reset for same launch period on Dec. 2.

Landing:

December 6, 1988, 3:36:11 p.m. PST, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 7,123 feet. Rollout time: 43 seconds. Mission duration: four days, nine hours, five minutes, 37 seconds. Orbiter returned to KSC Dec. 13, 1988.

Mission Highlights:

Third mission dedicated to Department of Defense.

1989

STS-29

(TDRS-D)

Discovery

Pad B
28th Shuttle mission
8th flight OV-103

Crew:

Michael L. Coats, Commander
John E. Blaha, Pilot
James F. Buchli, Mission Specialist
Robert C. Springer, Mission Specialist
James P. Bagian, Mission Specialist

Orbiter Preps (move to):

OPF — Oct. 9, 1988
VAB — Jan. 23, 1989
Pad — Feb. 3, 1989

Launch:

March 13, 1989, 9:57:00 a.m. EST. Launch manifested Feb. 18 reassessed for late February/early March launch to replace suspect liquid oxygen turbopumps on Discovery's three main engines and faulty master events controller. Launch March 13 delayed one hour, 50 minutes due to morning ground fog and upper winds.

Landing:

March 18, 1989, 6:35:50 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,339 feet. Rollout time: 53 seconds. Mission duration: four days, 23 hours, 38 minutes, 50 seconds. Landed revolution 80. Orbiter returned to KSC March 24, 1989.

Mission Highlights:

Primary payload, Tracking and Data Relay Satellite-4 (TDRS-4) attached to an Inertial Upper Stage (IUS), became third TDRS deployed. After deployment, IUS propelled satellite to geosynchronous orbit. Secondary payloads: Orbiter Experiments Autonomous Supporting Instrumentation System-1 (OASIS-1); Space Station Heat Pipe Advanced Radiator Experiment (SHARE); Protein Crystal Growth (PCG); Chromosomes and Plant Cell Division (CHROMEX); two Shuttle Student Involvement Program (SSIP) experiments; and Air Force experiment using orbiter as calibration target for ground-based experiment for Air Force Maui Optical Site (AMOS) in Hawaii. Crew also photographed Earth with hand-held IMAX camera.

STS-30

(Magellan)

Atlantis

Pad B
29th Shuttle mission
4th flight OV-104
1st U.S. planetary mission
in 11 years; 1st on Shuttle

Crew:

David M. Walker, Commander
Ronald J. Grabe, Pilot
Norman E. Thagard, Mission Specialist
Mary L. Cleave, Mission Specialist
Mark C. Lee, Mission Specialist

Orbiter Preps (move to):

OPF — Dec. 14, 1988
VAB — March 11,1989
Pad — March 22, 1989

Launch:

May 4, 1989, 2:46:59 p.m. EDT. Launch April 28 scrubbed at T-31 seconds due to problem with liquid hydrogen recirculation pump on number one main engine and vapor leak in four-inch liquid hydrogen recirculation line between orbiter and external tank. Repairs made and launch reset for May 4. Liftoff delayed until last five minutes of 64-minute window opening at 1:48 a.m. EDT due to cloud cover and high winds at KSC Shuttle runway, violating return-to-launch site limits.

Landing:

May 8, 1989, 12:43:26 p.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,295 feet. Rollout time: 64 seconds. Mission duration: four days, zero hours, 56 minutes, 27 seconds. Landed revolution 65. Orbiter returned to KSC May 15, 1989.

Mission Highlights:

Primary payload, Magellan/Venus radar mapper spacecraft and attached Inertial Upper Stage (IUS), deployed six hours, 14 minutes into flight. IUS first and second stage fired as planned, boosting Magellan spacecraft on proper trajectory for 15-month journey to Venus.

Secondary payloads: Mesoscale Lightning Experiment (MLE), microgravity research with Fluids Experiment Apparatus (FEA), and Air Force Maui Optical Site (AMOS) experiment.

One of five general purpose computers (GPC) failed and had to be replaced with a sixth onboard hardware spare. First time a GPC was switched on orbit.

STS-28

(DOD)

Columbia

Pad B
30th Shuttle mission
8th flight OV-102

Crew:

Brewster H. Shaw, Jr., Commander
Richard N. Richards, Pilot
David C. Leestma, Mission Specialist
James C. Adamson, Mission Specialist
Mark N. Brown, Mission Specialist

Orbiter Preps (move to):

OPF — Jan. 23, 1989
VAB — July 3, 1989
Pad — July 14, 1989

Launch:

August 8, 1989, 8:37:00 a.m. EDT. Liftoff occurred during classified launch window lying within launch period extending from 7:30 a.m. to 11:30 a.m. EDT, Aug. 8.

Landing:

August 13, 1989, 6:37:08 a.m. PDT, Runway 17, Edwards Air Force Base, Calif. Rollout distance: 6,015 feet. Rollout time: 47 seconds. Mission duration: five days, one hour, zero minutes, eight seconds. Landed revolution 81. Orbiter returned to KSC Aug. 21, 1989.

Mission Highlights:

Fourth mission dedicated to Department of Defense, and first flight of Columbia since Mission 61-C.

STS-34

(Galileo; SSBUV)

Atlantis

Pad B
31st Shuttle mission
5th flight OV-104

Crew:

Donald E. Williams, Commander
Michael J. McCulley, Pilot
Ellen S. Baker, Mission Specialist
Franklin R. Chang-Diaz, Mission Specialist
Shannon W. Lucid, Mission Specialist

Orbiter Preps (move to):

OPF — May 16, 1989
VAB — Aug. 21, 1989
Pad — Aug. 29, 1989

Launch:

October 18, 1989, 12:53:40 p.m. EDT. Launch set for Oct. 12 rescheduled due to faulty main engine controller on number two main engine. Launch set for Oct. 17 rescheduled due to weather constraints for a return-to-launch-site landing at KSC's Shuttle Landing Facility.

Landing:

October 23, 1989, 9:33:01 a.m. PDT, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 9,677 feet. Rollout time: 60 seconds. Mission duration: four days, 23 hours, 39 minutes, 21 seconds. Landed revolution 80. Orbiter returned to KSC Oct. 29, 1989.

Mission Highlights:

Primary payload, Galileo/Jupiter spacecraft and attached Inertial Upper Stage (IUS), deployed six hours, 30 minutes into flight. IUS stages fired, placing Galileo on trajectory for six-year trip to Jupiter via gravitational boosts from Venus and Earth and possible observational brushes with asteroids Gaspra and Ida.

Secondary payloads included Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment carried in cargo bay, and in crew cabin, Growth Hormone Crystal Distribution (GHCD); Polymer Morphology (PM), Sensor Technology Experiment (STEX); Mesoscale Lightning Experiment (MLE); IMAX camera; Shuttle Student Involvement Program (SSIP) experiment that investigated ice crystal formation in zero-gravity; and ground-based Air Force Maui Optical Site (AMOS) experiment.

STS-33

(DOD)

Discovery

Pad B
32nd Shuttle mission
9th flight OV-103
1st night launch since return

Crew:

Frederick D. Gregory, Commander
John E. Blaha, Pilot
F. Story Musgrave, Mission Specialist
Kathryn C. Thornton, Mission Specialist
Manley L. Carter, Jr., Mission Specialist

Orbiter Preps (move to):

OPF — Aug. 20, 1989
VAB — Oct. 5, 1989
Pad — Oct. 27, 1989

Launch:

November 22, 1989, 7:23:30 p.m. EST. Launch set for Nov. 20 rescheduled to allow changeout of suspect integrated electronics assemblies on twin solid rocket boosters.

Landing:

November 27, 1989, 4:30:18 p.m. PST, Runway 4, Edwards Air Force Base, Calif. Rollout distance: 7,764 feet. Rollout time: 46 seconds. Mission duration: five days, zero hours, six minutes, 48 seconds. Landed revolution 79. Orbiter returned to KSC Dec. 4, 1989.

Mission Highlights:

Fifth mission dedicated to Department of Defense.

1990

STS-32

(SYNCOM IV-F5; LDEF Retrieval)

Columbia
Pad A
33rd Shuttle mission
9th flight OV-102
Night landing

Crew:
Daniel C. Brandenstein, Commar
James D. Wetherbee, Pilot
Bonnie J. Dunbar, Mission Specialist
Marsha S. Ivins, Mission Specialist
G. David Low, Mission Specialist

Orbiter Preps (move to):
OPF — Aug. 22, 1989
VAB — Oct. 16, 1989
Pad — Nov. 28, 1989

Launch:
January 9, 1990, 7:35:00 a.m. EST. Launch scheduled for Dec. 18, 1989, postponed to complete and verify modifications to Pad A, being used for first time since January 1986. Launch Jan. 8, 1990 scrubbed due to weather conditions.

Landing:
January 20, 1990, 1:35:36 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,096 feet. Rollout time: 62 seconds. Mission duration: 10 days, 21 hours, zero minutes, 36 seconds. Landed revolution 172. Longest Space Shuttle flight to date. Orbiter returned to KSC Jan. 26, 1990.

Mission Highlights:
Objectives were deployment of SYNCOM IV-F5 defense communications satellite and retrieval of NASA's Long Duration Exposure Facility (LDEF). SYNCOM IV-F5 (also known as LEASAT 5) deployed first, and third stage Minuteman solid perigee kick motor propelled satellite to geosynchronous orbit. LDEF retrieved on flight day four using remote manipulator system.

Middeck payloads: Characterization of Neurospora Circadian Rhythms (CNCR); Protein Crystal Growth (PCG); Fluid Experiment Apparatus (FEA); American Flight Echocardiograph (AFE); Latitude/Longitude Locator (L3); Mesoscale Lightning Experiment (MLE); IMAX camera; and Air Force Maui Optical Site (AMOS) experiment.

STS-36

(DOD)

Atlantis
Pad A
34th Shuttle mission
6th flight OV-104
Night launch

Crew:
John O. Creighton, Commander
John H. Casper, Pilot
David C. Hilmers, Mission Specialist
Richard M. Mullane, Mission Specialist
Pierre J. Thuot, Mission Specialist

Orbiter Preps (move to):
OPF — Oct. 30, 1989
VAB — Jan. 19, 1990
Pad — Jan. 25, 1990

Launch:
February 28, 1990, 2:50:22 a.m. EST. Launch set for Feb. 22 postponed to Feb. 23, Feb. 24 and Feb. 25 due to illness of the crew commander and weather conditions. First time since Apollo 13 in 1970 that manned space mission was affected by illness of crew member. Launch set for Feb. 25 scrubbed due to malfunction of range safety computer. Launch set for Feb. 26 scrubbed due to weather conditions. (Note: external tank loaded only for launch attempts on Feb. 25 and 26, and launch on Feb. 28.) Launch Feb. 28 set for classified window lying within launch period extending from 12 midnight to 4 a.m. EST.

Landing:
March 4, 1990, 10:08:44 a.m. PST, Runway 23, Edwards Air Force Base, Calif. Rollout distance: 7,900 feet. Rollout time: 53 seconds. Mission duration: four days, ten hours, 18 minutes, 22 seconds. Landed revolution 72. Orbiter returned to KSC on March 13, 1990.

Mission Highlights:
Sixth mission dedicated to Department of Defense.

STS-31

(HST deploy)

Discovery
Pad B
35th Shuttle mission
10th flight OV-103

Crew:
Loren J. Shriver, Commander
Charles F. Bolden, Jr., Pilot
Steven A. Hawley, Mission Specialist
Bruce McCandless II, Mission Specialist
Kathryn D. Sullivan, Mission Specialist

Orbiter Preps (move to):
OPF — Dec. 5, 1989
VAB — March 5, 1990
Pad — March 15, 1990

Launch:
April 24, 1990, 8:33:51 a.m. EDT. Launch scheduled for April 18, then April 12, then April 10, following Flight Readiness Review (FRR). First time date set at FRR was earlier than that shown on previous planning schedules. Launch April 10 scrubbed at T-4 minutes due to faulty valve in auxiliary power unit (APU) number one. APU replaced and payload batteries recharged. Countdown briefly halted at T-31 seconds when computer software failed to shut down a fuel valve line on ground support equipment. Engineers ordered valve to shut and countdown continued.

Landing:

April 29, 1990, 6:49:57 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 8,889 feet. Rollout time: 61 seconds. Mission duration: five days, one hour, 16 minutes, six seconds. Landed revolution 80. First use of carbon brakes at landing. Orbiter returned to KSC on May 7, 1990.

Mission Highlights:

Primary payload, Hubble Space Telescope, deployed in a 380-statute-mile orbit. Secondary payloads: IMAX Cargo Bay Camera (ICBC) to document operations outside crew cabin and hand-held IMAX camera for use inside crew cabin; Ascent Particle Monitor (APM) to detect particulate matter in payload bay; Protein Crystal Growth (PCG) to provide data on growing protein crystals in microgravity; Radiation Monitoring Equipment III (RME III) to measure gamma ray levels in crew cabin; Investigations into Polymer Membrane Processing (IPMP) to determine porosity control in microgravity environment; Shuttle Student Involvement Program (SSIP) experiment to study effects of near-weightlessness on electrical arcs; and Air Force Maui Optical Site (AMOS) experiment.

STS-41

(Ulysses; SSBUV; ISAC)

Discovery

Pad B
36th Shuttle mission
11th flight OV-103

Crew:

Richard N. Richards, Commander
Robert D. Cabana, Pilot
William M. Shepherd, Mission Specialist
Bruce E. Melnick, Mission Specialist
Thomas D. Akers, Mission Specialist

Orbiter Preps (move to):

OPF — May 8, 1990
VAB — Aug. 27, 1990
Pad — Sept. 4, 1990

Launch:

October 6, 1990, 7:47:15 a.m. EDT. Liftoff occurred 12 minutes after two-and-a-half-hour launch window opened at 7:35 a.m. EDT, Oct. 6; brief delay at T-9 minutes was due to weather concerns. Additional 11-second hold occurred at T-5 minutes due to Ground Launch Sequencer glitch, and at T-31 seconds count halted for 22 seconds to correct orbiter purge, vent and drain (PVD) system glitch.

Landing:

October 10, 1990, 6:57:19 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 8,532 feet. Rollout time: 49 seconds (braking test). Mission duration: four days, two hours, 10 minutes, four seconds. Landed revolution 66. Orbiter returned to KSC Oct. 16, 1990.

Mission Highlights:

Primary payload, ESA-built Ulysses spacecraft to explore polar regions of Sun, deployed. Two upper stages, Inertial Upper Stage (IUS) and a mission-specific Payload Assist Module-S (PAM-S), combined together for first time to send Ulysses toward out-of-ecliptic trajectory. Other payloads and experiments: Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment; INTELSAT Solar Array Coupon (ISAC); Chromosome and Plant Cell Division Experiment (CHROMEX); Voice Command System (VCS); Solid Surface Combustion Experiment (SSCE); Investigations into Polymer Membrane Processing (IPMP); Physiological Systems Experiment (PSE); Radiation Monitoring Experiment III (RME III); Shuttle Student Involvement Program (SSIP) and Air Force Maui Optical Site (AMOS) experiment.

STS-38

(DOD)

Atlantis

Pad A
37th Shuttle mission
7th flight OV-104
Rollback
Night launch
Extended mission
Diverted landing
6th KSC landing; 1st since April 1985

Crew:

Richard O. Covey, Commander
Frank L. Culbertson, Jr., Pilot
Charles D. Gemar, Mission Specialist
Carl J. Meade, Mission Specialist
Robert C. Springer, Mission Specialist

Orbiter Preps (move to):

Flow A:
OPF — March 14, 1990
VAB — June 8, 1990
Pad — June 18, 1990
Flow B (rollback):
VAB — Aug. 9, 1990
OPF — Aug. 15, 1990
VAB — Oct. 2, 1990
Pad — Oct. 12, 1990

Launch:

November 15, 1990, 6:48:15 p.m. EST. Launch originally scheduled for July 1990. However, liquid hydrogen leak found on orbiter Columbia during STS-35 countdown prompted three precautionary mini-tanking tests on Atlantis at pad June 29, July 13 and July 25. Tests confirmed hydrogen fuel leak on external tank-side of external tank/orbiter 17-inch quick disconnect umbilical. Could not repair at pad and Atlantis rolled back to VAB Aug. 9, demated and transferred to OPF. During rollback, vehicle parked outside VAB about a day while Columbia/STS-35 stack transferred to pad for launch. Outside, Atlantis suffered minor hail damage to tiles during thunderstorm. After repairs made in OPF, Atlantis transferred to VAB for mating Oct. 2. During hoisting operations, platform beam that should have been removed from aft compartment fell and caused minor damage which was repaired. Vehicle rolled out to Pad A Oct. 12. Fourth mini-tanking test performed Oct. 24, with no excessive hydrogen or oxygen leakage detected. At Flight Readiness Review, launch date set for Nov. 9. Launch reset for Nov. 15 due to payload problems. Liftoff occurred during classified launch window lying within launch period extending from 6:30 to 10:30 p.m. EST, Nov. 15.

Landing:

November 20, 1990, 4:42:46 p.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,003 feet. Rollout time: 56 seconds. Mission duration: four days, 21 hours, 54 minutes, 31 seconds. Landed revolution 79. Mission extended one day due to unacceptable crosswinds at original planned landing site, Edwards. Continued adverse conditions led to decision to shift landing to KSC. First KSC landing for Atlantis, first end-of-mission landing at KSC since April 1985.

Mission Highlights:

Seventh mission dedicated to Department of Defense.

STS-35

(ASTRO-1)

Columbia

Pad B
38th Shuttle mission
10th flight OV-102
Rollbacks
Night launch
Shortened mission
Night landing

Crew:

Vance D. Brand, Commander
Guy S. Gardner, Pilot
Jeffrey A. Hoffman, Mission Specialist
John M. Lounge, Mission Specialist
Robert A. R. Parker, Mission Specialist
Ronald A. Parise, Payload Specialist
Samuel T. Durrance, Payload Specialist

Orbiter Preps (move to):

Flow A:
OPF — Jan. 30, 1990
VAB — April 16, 1990
Pad A — April 22, 1990
Flow B (rollback):
VAB — June 12, 1990
OPF — June 15, 1990
VAB — Aug. 2, 1990
Pad A —Aug. 9, 1990
Pad B — Oct. 8, 1990 (transfer due to STS-38)
VAB — Oct. 9, 1990 (rollback due to tropical storm)
Pad B — Oct. 14, 1990

Launch:

December 2, 1990, 1:49:01 a.m. EST. Launch first scheduled for May 16, 1990 from Pad 39A. Following Flight Readiness Review (FRR), announcement of firm launch date delayed to change out a faulty Freon coolant loop proportional valve in orbiter's coolant system. At subsequent Delta FRR, date set for May 30. Launch on May 30 scrubbed during tanking due to minor hydrogen leak in tail service mast on mobile launcher platform and major leak in external tank/orbiter 17-inch quick disconnect assembly. Hydrogen also detected in orbiter's aft compartment believed associated with leak involving 17-inch umbilical assembly.

Leakage at 17-inch umbilical confirmed by mini-tanking test June 6. Could not repair at pad and orbiter returned to VAB June 12, demated and transferred to OPF. Changeout of orbiter-side 17-inch umbilical assembly made with one borrowed from orbiter Endeavour; external tank fitted with new umbilical hardware. ASTRO-1 payload reserviced regularly and remained in Columbia's cargo bay during orbiter repairs and reprocessing.

Columbia rolled out to Pad A for second time Aug. 9 to support a Sept. 1 launch date. Two days before launch, avionics box on BBXRT portion of ASTRO-1 payload malfunctioned and had to be changed out and retested. Launch rescheduled for Sept. 6. During tanking, high concentrations of hydrogen detected in orbiter's aft compartment, forcing another postponement. NASA managers concluded that Columbia had experienced separate hydrogen leaks from beginning: one of umbilical assembly (now replaced) and one or more in aft compartment which had resurfaced. Suspicion focused on package of three hydrogen recirculation pumps in aft compartment. These were replaced and retested. Damaged Teflon cover seal in main engine number three hydrogen prevalve replaced. Launch rescheduled for Sept. 18. Fuel leak in aft compartment resurfaced during tanking and mission scrubbed again. STS-35 mission put on hold until problem resolved by special tiger team assigned by Space Shuttle director.

Columbia transferred to Pad B Oct. 8 to make room for Atlantis on Mission STS-38. Tropical storm Klaus forced rollback to VAB Oct. 9. Vehicle transferred to Pad B again Oct. 14. Mini-tanking test conducted Oct. 30, using special sensors and video cameras and employing a see-through Plexiglas aft compartment door. No excessive hydrogen leakage detected. Liftoff Dec. 2 delayed 21 minutes to allow Air Force range time to observe low-level clouds that might impede tracking of Shuttle ascent.

Landing:

December 10, 1990, 9:54:09 p.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,566 feet. Rollout time: 58 seconds. Mission duration: eight days, 23 hours, five minutes, eight seconds. Landed revolution 144. Orbiter returned to KSC on Dec. 20. Mission cut short one day due to impending bad weather at primary landing site, Edwards Air Force Base, Calif.

Mission Highlights:

Primary objectives were round-the-clock observations of celestial sphere in ultraviolet and X-ray astronomy with ASTRO-1 observatory consisting of four telescopes: Hopkins Ultraviolet Telescope (HUT); Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE); Ultraviolet Imaging Telescope (UIT); and Broad Band X-ray Telescope (BBXRT). Ultraviolet telescopes mounted on Spacelab elements in cargo bay were to be operated in shifts by flight crew. Loss of both data display units (used for pointing telescopes and operating experiments) during mission impacted crew-aiming procedures and forced ground teams at Marshall Space Flight Center to aim ultraviolet telescopes with fine-tuning by flight crew. BBXRT, also mounted in cargo bay, was directed from outset by ground-based operators at Goddard Space Flight Center and not affected.

Other experiments: Shuttle Amateur Radio Experiment-2 (SAREX-2); ground-based experiment to calibrate electro-optical sensors at Air Force Maui Optical Site (AMOS) in Hawaii; and crew-conducted Space Classroom Program: "Assignment: The Stars," to spark student interest in science, math and technology. Science teams at Marshall and Goddard Space Flight Centers estimated 70 percent of planned science data achieved.

Crew experienced trouble dumping waste water due to clogged drain, but managed using spare containers.

1991

STS-37

(GRO)

Atlantis

Pad B
39th Shuttle mission
8th flight OV-104
Extended mission

Crew:

Steven R. Nagel, Commander
Kenneth D. Cameron, Pilot
Jay Apt, Mission Specialist
Linda M. Godwin, Mission Specialist
Jerry L. Ross, Mission Specialist

Orbiter Preps (move to):

OPF — Nov. 20, 1990
VAB — March 8, 1991
Pad — March 15, 1991

Launch:

April 5, 1991, 9:22:44 a.m. EST. Launch set for 9:18 a.m., April 5 was briefly delayed due to low-level clouds in area. First flight of upgraded purpose computers.

Landing:

April 11, 1991, 6:55:29 a.m. PDT, Runway 33, Edwards AFB, Calif. Rollout distance: 6,364 feet. Rollout time: 54 seconds. Mission duration: five days, 23 hours, 32 minutes, 44 seconds. Landed revolution 93. Landing originally scheduled for April 10, but delayed one day due to weather conditions at Edwards and KSC. Orbiter returned to KSC April 18, 1991.

Mission Highlights:

Primary payload, Gamma Ray Observatory (GRO), deployed on flight day three. GRO high-gain antenna failed to deploy on command; finally freed and manually deployed by Ross and Apt during unscheduled contingency spacewalk, first since April 1985. Following day, two astronauts performed first scheduled spacewalk since November 1985 to test means for astronauts to move themselves and equipment about while maintaining planned Space Station Freedom.

GRO science instruments were Burst and Transient Source Experiment (BATSE), Imaging Compton Telescope (COMPTEL), Energetic Gamma Ray Experiment Telescope (EGRET) and Oriented Scintillation Spectrometer Experiment (OSSEE). Secondary payloads included Crew and Equipment Translation Aids (CETA), which involved scheduled six-hour spacewalk by astronauts Ross and Apt (see above); Ascent Particle Monitor (APM); Shuttle Amateur Radio Experiment II (SAREX II); Protein Crystal Growth (PCG); Bioserve/Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA); Radiation Monitoring Equipment III (RME III); and Air Force Maui Optical Site (AMOS) experiment.

STS-39

(DOD: AFP-675; IBSS; SPAS-II)

Discovery

Pad A
40th Shuttle mission
12th flight OV-103
Rollback
Diverted landing
7th KSC landing

Crew:

Michael L. Coats, Commander
L. Blaine Hammond, Jr., Pilot
Guion S. Bluford Jr., Mission Specialist
Richard J. Hieb, Mission Specialist
Gregory J. Harbaugh, Mission Specialist
Donald R. McMonagle, Mission Specialist
Charles Lacy Veach, Mission Specialist

Orbiter Preps (move to):

Flow A:
OPF — Oct. 17, 1990
VAB — Feb. 9, 1991
Pad — Feb. 15, 1991
Flow B (rollback):
VAB — March 7, 1991
OPF — March 15, 1991
VAB — March 25, 1991
Pad — April 1, 1991

Launch:

April 28, 1991, 7:33:14 a.m. EDT. Launch originally scheduled for March 9, but during processing work at Pad A, significant cracks found on all four lug hinges on the two external tank umbilical door drive mechanisms. NASA managers opted to roll back the vehicle to the VAB on March 7, and then to OPF for repair. Hinges replaced with units taken from orbiter Columbia, and reinforced. Discovery returned to pad on April 1, and launch re-set for April 23. Mission again postponed when, during prelaunch external tank loading, a transducer on high-pressure oxidizer turbopump for main engine number three showed readings out of specification. Transducer and its cable harness were replaced and tested. Launch was rescheduled for April 28.

Landing:

May 6, 1991, 2:55:37 p.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 9,235 feet. Rollout time: 56 seconds. Mission duration: eight days, seven hours, 22 minutes, 23 seconds. Landing diverted to KSC because of unacceptably high winds at planned landing site, Edwards. Landed revolution 134.

Mission Highlights:

Dedicated Department of Defense mission. Unclassified payload included Air Force Program-675 (AFP-675); Infrared Background Signature Survey (IBSS) with Critical Ionization Velocity (CIV), Chemical Release Observation (CRO) and Shuttle Pallet Satellite-II (SPAS-II) experiments; and Space Test Payload-1 (STP-1). Classified payload consisted of Multi-Purpose Release Canister (MPEC). Also on board was Radiation Monitoring Equipment III (RME III) and Cloud Logic to Optimize Use of Defense Systems-1A (CLOUDS-1).

STS-40

(SLS-1)

Columbia

Pad B
41st Shuttle mission
11th flight OV-102

Crew:

Bryan D. O'Connor, Commander
Sidney M. Gutierrez, Pilot
James P. Bagian, Mission Specialist
Tamara E. Jernigan, Mission Specialist
M. Rhea Seddon, Mission Specialist
F. Drew Gaffney, Payload Specialist
Millie Hughes-Fulford, Payload Specialist

Orbiter Preps (move to):

OPF — Feb. 9, 1991
VAB — April 26, 1991
Pad — May 2, 1991

Launch:

June 5, 1991, 9:24:51 a.m. EDT. Launch originally set for May 22, 1991. Mission postponed less than 48 hours before launch when it became known that a leaking liquid hydrogen transducer in orbiter main propulsion system which was removed and replaced during a leak testing in 1990, had failed an analysis by vendor. Engineers feared that one or more of the nine liquid hydrogen and liquid oxygen transducer protruding into fuel and oxidizer lines could break off and be ingested by the engine turbopumps, causing engine failure.

In addition, one of orbiter's five general purpose computers failed completely, along with one of the multiplexer demultiplexers that control orbiter hydraulics ordnance and orbiter maneuvering system/reaction control system functions in aft compartment.

New general purpose computer and multiplexer demultiplexer were installed and tested. One liquid hydrogen and two liquid

oxygen transducers were replaced upstream in propellant flow system near 17-inch disconnect area, which is protected by internal screen. Three liquid oxygen transducers replaced at engine manifold area, while three liquid hydrogen transducers here were removed and openings plugged. Launch reset for 8 a.m. EDT, June 1, but postponed again after several attempts to calibrate inertial measurement unit 2 failed. Unit was replaced and retested, and launch was rescheduled for June 5.

Landing:

June 14, 1991, 8:39:11 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,438 feet. Rollout time: 55 seconds. Mission duration: nine days, two hours, 14 minutes, 20 seconds. Landed revolution 146. Orbiter returned to KSC June 21.

Mission Highlights:

Fifth dedicated Spacelab mission, Spacelab Life Sciences-1, and first dedicated solely to life sciences, using the habitable module. Mission featured most detailed and interrelated physiological measurements in space since 1973-1974 Skylab missions. Subjects were humans, 30 rodents and thousands of tiny jellyfish. Primary SLS-1 experiments studied six body systems; of 18 investigations, ten involved humans, seven involved rodents, and one used jellyfish.

Six body systems investigated were cardiovascular/cardiopulmonary (heart, lungs and blood vessels); renal/endocrine (kidneys and hormone-secreting organs and glands); blood (blood plasma); immune system (white blood cells); musculoskeletal (muscles and bones); and neurovestibular (brains and nerves, eyes and inner ear). Other payloads included twelve Get Away Special (GAS) canisters installed on GAS bridge in cargo bay for experiments in materials science, plant biology and cosmic radiation; Middeck Zero-Gravity Dynamics Experiment (MODE); and seven Orbiter Experiments (OEX).

STS-43

(TDRS-E; SSBUV; SHARE-II)

Atlantis

Pad A
42nd Shuttle mission
9th flight OV-104
1st scheduled KSC landing since January 1986
8th KSC landing

Crew:

John E. Blaha, Commander
Michael A. Baker, Pilot
James C. Adamson, Mission Specialist
G. David Low, Mission Specialist
Shannon W. Lucid, Mission Specialist

Orbiter Preps (move to):

OPF — April 19, 1991
VAB — June 19, 1991
Pad — June 25, 1991

Launch:

August 2, 1991, 11:01:59 a.m. EDT. Launch originally set for July 23, but was moved to July 24 to allow time to replace a faulty integrated electronics assembly that controls orbiter/external tank separation. Mission postponed again about five hours before liftoff on July 24 due to a faulty main engine controller on number three main engine. Controller replaced and retested; launch reset for Aug. 1. Liftoff set for 11:01 a.m. delayed due to cabin pressure vent valve reading and postponed at 12:28 p.m. due to unacceptable return-to-launch site weather conditions. Launch reset for Aug. 2.

Landing:

August 11, 1991, 8:23:25 a.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 9,890 feet. Rollout time: 59 seconds. Mission duration: eight days, 21 hours, 21 minutes, 25 seconds. Landed revolution 142. First landing scheduled at KSC since 61-C in January 1986 (which was diverted to Edwards).

Mission Highlights:

Primary payload, Tracking and Data Relay Satellite-5 (TDRS-5) attached to an Inertial Upper Stage (IUS), deployed about six hours into flight, and IUS propelled satellite into geosynchronous orbit; TDRS-5 becomes fourth member of orbiting TDRS cluster. Secondary payloads were Space Station Heat Pipe Advanced Radiator Element II (SHARE II); Shuttle Solar Backscatter Ultra-Violet (SSBUV) instrument; Tank Pressure Control Equipment (TPCE); and Optical Communications Through Windows (OCTW). Other experiments included Auroral Photography Experiment (APE-B); Protein Crystal Growth III (PCG III); Bioserve/Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA); Investigations into Polymer Membrane Processing (IPMP); Space Acceleration Measurement System (SAMS); Solid Surface Combustion Experiment (SSCE); Ultraviolet Plume Instrument (UVPI); and the Air Force Maui Optical Site (AMOS) experiment.

STS-48

(UARS)

Discovery

Pad A
43rd Shuttle mission
13th flight OV-103
Diverted landing
Night landing

Crew:

John O. Creighton, Commander
Kenneth S. Reightler, Jr., Pilot
Mark N. Brown, Mission Specialist
Charles D. Gemar, Mission Specialist
James F. Buchli, Mission Specialist

Orbiter Preps (move to):

OPF — May 6, 1991
VAB — July 25, 1991
Pad — Aug. 12, 1991

Launch:

September 12, 1991, 7:11:04 p.m. EDT. Launch delayed 14 minutes by a faulty communication link between KSC and Mission Control in Houston.

Landing:

September 18, 1991, 12:38:42 a.m. PDT, Runway 22, Edwards AFB, Calif. Rollout distance: 9,384 feet. Rollout time: 50 seconds. Mission duration: five days, eight hours, 27 minutes, 38 seconds. Landed revolution 81. Landed scheduled for KSC, but diverted to Edwards due to bad weather. Orbiter returned to KSC Sept. 26, 1991.

Mission Highlights:

Primary payload, the Upper Atmosphere Research Satellite (UARS), deployed on the third day of the mission. During its planned 18-month mission, the 14,500-pound observatory will make the most extensive study ever conducted of the Earth's troposphere, the upper level of the planet's envelope of life-sustaining gases which also include the protective ozone layer. UARS has ten sensing and measuring devices: Cryogenic Limb

Array Etalon Spectrometer (CLAES); Improved Stratospheric and Mesospheric Sounder (ISAMS); Microwave Limb Sounder (MLS); Halogen Occultation Experiment (HALOE); High Resolution Doppler Imager (HRDI); Wind Imaging Interferometer (WINDII); Solar Ultraviolet Spectral Irradiance Monitor (SUSIM); Solar/Stellar Irradiance Comparison Experiment (SOLSTICE); Particle Environment Monitor (PEM) and Active Cavity Radiometer Irradiance Monitor (ACRIM II).

Secondary payloads were: Ascent Particle Monitor (APM); Middeck O-Gravity Dynamics Experiment (MODE); Shuttle Activation Monitor (SAM); Cosmic Ray Effects and Activation Monitor (CREAM); Physiological and Anatomical Rodent Experiment (PARE); Protein Crystal Growth II-2 (PCG II-2); Investigations into Polymer Membrane Processing (IPMP); and the Air Force Maui Optical Site (AMOS) experiment.

STS-44

(DOD; DSP)

Atlantis

Pad A
44th Shuttle mission
10th flight OV-104
Night launch
Shortened mission
Diverted landing

Crew:

Frederick D. Gregory, Commander
Terence T. Henricks, Pilot
Mario Runco, Jr., Mission Specialist
James S. Voss, Mission Specialist
F. Story Musgrave, Mission Specialist
Thomas J. Hennen, Payload Specialist

Orbiter Preps (move to):

OPF — Aug. 12, 1991
VAB — Oct. 18, 1991
Pad — Oct. 23, 1991

Launch:

November 24, 1991, 6:44:00 p.m. EST. Launch set for Nov. 19 delayed due to malfunctioning redundant inertial measurement unit on Inertial Upper Stage booster attached to Defense Support Program satellite. Unit replaced and tested. Launch reset for Nov. 24, delayed 13 minutes to allow an orbiting spacecraft to pass and to allow external tank liquid oxygen replenishment after minor repairs to valve in the liquid oxygen replenishment system in the mobile launcher platform.

Landing:

December 1, 1991, 2:34:44 p.m. PST, Runway 5, Edwards Air Force Base, Calif. Rollout distance: 11,191 feet. Rollout time: 107 seconds. Mission duration: six days, 22 hours, 50 minutes, 44 seconds. Landed revolution 110. Landing originally scheduled for KSC on Dec. 4, but ten-day mission shortened and landing rescheduled following Nov. 30 on-orbit failure of one of three orbiter inertial measurement units. Lengthy rollout due to minimal braking for test. Orbiter returned to KSC on Dec. 8, 1991.

Mission Highlights:

Dedicated Department of Defense mission. Unclassified payload included Defense Support Program (DSP) satellite and attached Inertial Upper Stage (IUS), deployed on flight day one. Cargo bay and middeck payloads: Interim Operational Contamination Monitor (IOCM); Terra Scout; Military Man in Space (M88-1); Air Force Maui Optical Site (AMOS); Cosmic Radiation Effects and Activation Monitor (CREAM); Shuttle Activation Monitor (SAM); Radiation Monitoring Equipment III (RME III); Visual Function Tester-1 (VFT-1); Ultraviolet Plume Instrument (UVPI); Bioreactor Flow and Particle Trajectory experiment; and Extended Duration Orbiter Medical Project, a series of investigations in support of Extended Duration Orbiter.

1992

STS-42

(IML-1)

Discovery

Pad A
45th Shuttle mission
14th flight OV-103
Extended mission

Crew:

Ronald J. Grabe, Comma
Stephen S. Oswald, Pilot
William F. Readdy, Mission Specialist
Norman E. Thagard, Mission Specialist
David C. Hilmers, Mission Specialist
Roberta L. Bondar, Payload Specialist (Canadian SpaceAgency)
Ulf D. Merbold, Payload Specialist (European Space Agency)

Orbiter Preps (move to):

OPF — Sept. 27, 1991
VAB — Dec. 12, 1991
Pad — Dec. 19, 1991

Launch:

January 22, 1992, 9:52:33 a.m. EST. Launch delayed one hour to allow evaluation of KSC field mill indicators and to assess transient power surge from an orbiter fuel cell.

Landing:

January 30, 1992, 8:07:17 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,841 feet (3,000 meters). Rollout time: 58 seconds. Mission duration: eight days, one hour, 14 minutes, 44 seconds. Landed revolution 129. Orbiter returned to KSC on Feb. 16, 1992.

Mission Highlights:

Primary payload was the International Microgravity Laboratory-1 (IML-1), making its first flight and using pressurized Spacelab module. International crew divided into two teams for around-the-clock research on human nervous system's adaptation to low gravity and effects of microgravity on other life forms such as shrimp eggs, lentil seedlings, fruit fly eggs, and bacteria. Materials processing experiments also conducted, including crystal growth from variety of substances such as enzymes, mercury iodide and a virus. On flight day six, mission managers concluded enough onboard consumables remained to extend mission one day to continue science experiments.

Secondary payloads were: 12 Get Away Special (GAS) canisters attached to a GAS Bridge Assembly in the cargo bay and containing a variety of U.S. and international experiments.

In middeck: Gelation of Sols: Applied Microgravity Research-1 (GOSAMR-1); IMAX camera; Investigations into Polymer Membrane Processing (IPMP); Radiation Monitoring Experiment III (RME III); and two Shuttle Student Involvement Program (SSIP) experiments.

STS-45

(ATLAS-1)

Atlantis

Pad A
46th Shuttle mission
11th flight OV-104
Extended mission
9th KSC landing

Crew:

Charles F. Bolden, Jr., Mission Commander
Brian Duffy, Pilot
Kathryn D. Sullivan, Payload Commander and Mission Specialist
David C. Leestma, Mission Specialist
Michael Foale, Mission Specialist
Dirk D. Frimout, Payload Specialist
Byron K. Lichtenberg, Payload Specialist

Orbiter Preps (move to):

OPF — Dec. 9, 1991
VAB — Feb. 13, 1992
Pad — Feb. 19, 1992

Launch:

March 24, 1992, 8:13:40 a.m. EST. Launch originally set for March 23, but delayed one day when higher than allowable concentrations of liquid hydrogen and liquid oxygen in orbiter aft compartment were detected during pre-launch tanking operations. Leaks could not be reproduced during troubleshooting, leading engineers to believe that they resulted from main propulsion system plumbing not being thermally conditioned to supercold propellants. Launch rescheduled for March 24. Liftoff delayed about 13 minutes due to low-level clouds at KSC Shuttle runway.

Landing:

April 2, 1992, 6:23:08 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,227 feet (2,812 meters). Rollout time: 60 seconds. Mission duration: eight days, 22 hours, nine minutes, 28 seconds. Landed revolution 143.

Mission Highlights:

Mission marked first flight of Atmospheric Laboratory for Applications and Science-1 (ATLAS-1), mounted on nondeployable Spacelab pallets in orbiter cargo bay. U.S., France, Germany, Belgium, United Kingdom, Switzerland, The Netherlands, and Japan provided 12 instruments designed to perform 14 investigations in four fields. Atmospheric science instruments/investigations: Atmospheric Lyman-Alpha Emissions (ALAE); Atmospheric Trace Molecule Spectroscopy (ATMOS); Grille Spectrometer (GRILLE); Imaging Spectrometric Observatory (ISO); Millimeter-Wave Atmospheric Sounder (MAS). Solar Science: Active Cavity Radiometer Irradiance Monitor (ACRIM); Measurement of the Solar Constant (SOLCON); Solar Spectrum from 180 to 3,200 Nanometers (SOLSPEC); Solar Ultraviolet Spectral Irradiance Monitor (SUSIM). Space Plasma Physics: Atmospheric Emissions Photometric Imaging (AEPI); Space Experiments with Particle Accelerators (SEPAC). Ultraviolet astronomy: Far Ultraviolet Space Telescope (FAUST). On flight day six, mission managers determined enough onboard consumables remained to extend flight one day to continue science experiments.

Co-manifested with ATLAS-1 and also located in cargo bay: Shuttle Solar Backscatter Ultraviolet/A (SSBUV/A). Single Get Away Special canister containing a crystal growth experiment also flown.

Middeck payloads: Investigations into Polymer Membrane Processing (IPMP); Space Tissue Loss-01 (STL-01); Radiation Monitoring Equipment III (RME III); Visual Function Tester-2 (VFT-2); Cloud Logic to Optimize Use of Defense System (CLOUDS); Shuttle Amateur Radio Experiment II (SAREX II).

STS-49

(Intelsat VI repair)

Endeavour

Pad B
47th Shuttle mission
1st flight OV-105
Extended mission
Four spacewalks
1st use orbiter drag chute

Crew:

Daniel C. Brandenstein, Commander
Kevin P. Chilton, Pilot
Bruce E. Melnick, Mission Specialist
Thomas D. Akers, Mission Specialist
Richard J. Hieb, Mission Specialist
Kathryn C. Thornton, Mission Specialist
Pierre J. Thuot, Mission Specialist

Orbiter Preps (move to):

Arrive KSC - May 7, 1991
VAB — May 8, 1991 (to complete manufacturing)
OPF — July 25, 1991 (begin STS-49 flow)
VAB — March 7, 1992
Pad — March 13, 1992

Launch:

May 7, 1992, 7:40:00 p.m. EDT. First flight of Endeavour. Following Flight Readiness Firing of Endeavour's three main engines April 6, 1992, Shuttle managers decided to replace all three due to irregularities detected in two of the high pressure oxidizer turbopumps; no impact to launch date expected. Launch originally set for May 4 at 8:34 p.m. EDT, but moved to May 7 for earlier launch window opening at 7:06 p.m. EDT to achieve better lighting conditions for photographic documentation of vehicle behavior during launch phase. Liftoff delayed 34 minutes due to transoceanic abort landing site weather conditions and technical problems with one of the orbiter master events controllers.

Landing:

May 16, 1992, 1:57:38 p.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,490 feet (2,893 meters). Rollout time: 58 seconds. Mission duration: eight days, 21 hours, 17 minutes, and 38 seconds. Landed revolution 141. First use of drag chute during landing; deployed after nosegear touchdown for data collection only. Orbiter returned to KSC on May 30, 1992.

Mission Highlights:

First U.S. orbital flight to feature four extravehicular activities (EVAs), two of these longest in U.S. space flight history to date (eight hours, 29 minutes and seven hours, 45 minutes), and longest to date by a female astronaut; first space flight ever to involve three crew members simultaneously working outside spacecraft; first time astronauts attached live rocket motor to orbiting satellite. Flight extended two days to complete mission objectives.

Crew successfully captured and redeployed INTELSAT VI (F-3) satellite stranded in unusable orbit since launch aboard Titan rocket in March 1990. Capture required three EVAs. First spacewalk on flight day four by Thuot, who was unable to attach capture bar to

INTELSAT from position on remote manipulator system arm. Second unscheduled but identical attempt by Thuot failed following day. After rest on flight day six, unprecedented three-person EVA performed on flight day seven. During longest EVA in U.S. space history to date (eight hours, 29 minutes), Hieb, Thuot and Akers grasped rotating INTELSAT by hand while Brandenstein maneuvered orbiter. After capture bar attached to satellite, orbiter remote manipulator system arm grappled bar and placed satellite atop perigee kick motor (PKM) in cargo bay. Satellite deployed early on flight day eight, and INTELSAT controllers signaled PKM to fire, sending INTELSAT VI into operating orbit of 45,000 nautical miles (83,340 kilometers).

On flight day eight, Akers and Thornton performed EVA as part of Assembly of Station by EVA Methods (ASEM) experiment to demonstrate and verify maintenance and assembly capabilities for Space Station Freedom. ASEM spacewalk, originally planned for two successive days, cut to one day due to lengthy INTELSAT retrieval operation.

Additional payloads: Commercial Protein Crystal Growth (CPCG) experiment; and two payloads of opportunity, Ultraviolet Plume Instrument (UVPI) experiment and Air Force Maui Optical Site (AMOS).

STS-50

(USML-1)

Columbia

Pad A
48th Shuttle mission
12th flight OV-102
1st Extended Duration Orbiter flight
Extended mission
Diverted landing
10th KSC landing

Crew:

Richard N. Richards, Mission Commander
Kenneth D. Bowersox, Pilot
Bonnie J. Dunbar, Payload Commander
Carl J. Meade, Mission Specialist
Ellen S. Baker, Mission Specialist
Lawrence J. DeLucas, Payload Specialist
Eugene H. Trinh, Payload Specialist

Orbiter Preps (move to):

OPF — Feb. 10, 1992
VAB — May 29, 1992
Pad — June 3, 1992

Launch:

June 25, 1992, 12:12:23 p.m. EDT. Liftoff delayed five minutes due to weather. First flight of Columbia after scheduled checkout and extensive modification period at Rockwell plant in California. More than 50 modifications completed, including installation of drag chute. First orbiter outfitted with Extended Duration Orbiter (EDO) hardware, including EDO cryogen pallet.

Landing:

July 9, 1992, 7:42:27 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,674 feet (3,253 meters). Rollout time: 59 seconds. Mission duration: 13 days, 19 hours, 30 minutes, four seconds. Landed revolution 221. Drag chute deployed, again with nosegear down. Landing delayed one day due to rain at primary landing site, Edwards AFB. First landing OV-102 at KSC and first with new synthetic tread tires. Mission duration eclipsed all previous U.S. manned space flights to date except three Skylab space station flights 1973-74.

Mission Highlights:

Primary payload, U.S. Microgravity Laboratory-1 (USML-1), made its first flight; featured pressurized Spacelab module. USML-1 first in planned series of flights to advance U.S. microgravity research effort in several disciplines. Experiments conducted were: Crystal Growth Furnace (CGF); Drop Physics Module (DPM); Surface Tension Driven Convection Experiments (STDCE); Zeolite Crystal Growth (ZCG); Protein Crystal Growth (PCG); Glovebox Facility (GBX); Space Acceleration Measurement System (SAMS); Generic Bioprocessing Apparatus (GBA); Astroculture-1 (ASC); Extended Duration Orbiter Medical Project (EDOMP); Solid Surface Combustion Experiment (SSCE).

Secondary experiments were: Investigations into Polymer Membrane Processing (IPMP); Shuttle Amateur Radio Experiment II (SAREX II); and Ultraviolet Plume Instrument (UVPI).

STS-46

(TSS-1; EURECA deploy)

Atlantis

Pad B
49th Shuttle mission
12th flight OV-104
Extended mission
11th KSC landing

Crew:

Loren J. Shriver, Mission Commander
Andrew M. Allen, Pilot
Jeffrey A. Hoffman, Payload Commander
Franklin R. Chang-Diaz, Mission Specialist
Marsha S. Ivins, Mission Specialist
Claude Nicollier, Mission Specialist (European Space Agency)
Franco Malerba, Payload Specialist (Italian Space Agency)

Orbiter Preps (move to):

OPF — April 2, 1992
VAB — June 4, 1992
Pad — June 11, 199

Launch:

July 31, 1992, 9:56:48 a.m. EDT. Liftoff delayed 48 seconds at L-5 minutes to allow verification that auxiliary power units were ready to start.

Landing:

August 8, 1992, 9:11:51 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,860 feet (3,310 meters). Rollout time: 66 seconds. Mission duration: seven days, 23 hours, 15 minutes, three seconds. Landed revolution 127. Last flight of OV-104 before scheduled checkout and modification period, later extended to include modifications for docking with Russian Mir space station. OV-104 shipped to Rockwell plant in California in October; next mission is STS-68 in late 1994.

Mission Highlights:

Primary objective was deployment of the European Space Agency's European Retrievable Carrier (EURECA) and operation of the joint NASA/Italian Space Agency Tethered Satellite System (TSS). Mission extended one day to complete science objectives. EURECA deployed one day later than scheduled because of problem with its data handling system. After deployment, spacecraft's thrusters were fired to boost EURECA to its planned operating altitude of about 310 statute miles (499 kilometers). However, thruster firing cut to six minutes instead of planned 24 minutes because of unexpected attitude data from EURECA.

Problem resolved and EURECA boosted to operational orbit on sixth day of mission. Payload to be retrieved on STS-57 in 1993.

TSS deployment also delayed one day because of EURECA. During TSS deployment, satellite reached a maximum distance of only 840 feet (256 meters) from orbiter instead of planned 12.5 miles (20 kilometers) because of jammed tether line. After numerous attempts over several days to free tether, TSS operations were curtailed and satellite stowed for return to Earth.

Secondary payloads were: Evaluation of Oxygen Integration with Materials/Thermal Management Processes (EOIM-III/TEMP 2A-3); Consortium for Materials Development in Space Complex Autonomous Payload (CONCAP II and CONCAP III); IMAX Cargo Bay Camera (ICBC); Limited Duration Space Environment Candidate Materials Exposure (LDCE); Air Force Maui Optical Site (AMOS); Pituitary Growth Hormone Cell Function (PHCF); and Ultraviolet Plume Instrument (UVPI).

STS-47

(Spacelab-J)

Endeavour

Pad B
50th Shuttle mission
2nd flight OV-105
Extended mission
12th KSC landing

Crew:

Robert L. Gibson, Mission Commander
Curtis L. Brown, Jr., Pilot
Mark C. Lee, Payload Commander
N. Jan Davis, Mission Specialist
Mae C. Jemison, Science Mission Specialist
Mamoru C. Mohri, Payload Specialist (National Space Development Agency of Japan)

Orbiter Preps (move to):

OPF — May 31, 1992
VAB — Aug. 17, 1992
Pad — Aug. 25, 1992

Launch:

September 12, 1992, 10:23:00 a.m. EDT. First on-time Shuttle launch since STS 61-B in November 1985.

Landing:

September 20, 1992, 8:53:23 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,567 feet (2,611 meters). Rollout time: 51 seconds. Mission duration: seven days, 22 hours, 30 minutes, 23 seconds. Landed revolution 126. First time drag chute deployed in operational mode, before nosegear touchdown. Postlanding assessment showed orbiter veered off runway centerline, possibly due to drag chute.

Mission Highlights:

Jemison became first African-American woman to fly in space, Lee and Davis, first married couple, and Mohri the first Japanese to fly on Shuttle. Primary payload, Spacelab-J (SL-J), utilized pressurized Spacelab module. Jointly sponsored by NASA and National Space Development Agency (NASDA) of Japan, SL-J included 24 materials science and 19 life sciences experiments, of which 34 were sponsored by NASDA, seven by NASA, and two collaborative efforts. Mission extended one day to further science objectives. Materials science investigations covered such fields as biotechnology, electronic materials, fluid dynamics and transport phenomena, glasses and ceramics, metals and alloys, and acceleration measurements. Life sciences investigations covered human health, cell separation and biology, development biology, animal and human physiology and behavior, space radiation, and biological rhythms. Test subjects included crew; Japanese koi fish (carp); cultured animal and plant cells; chicken embryos; fruit flies; fungi and plant seeds; and frogs and frog eggs.

Also flying in payload bay: 12 Get Away Special (GAS) canisters (10 holding experiments, two for ballast) attached to a GAS Bridge Assembly.

Middeck experiments were: Israeli Space Agency Investigation about Hornets (ISAIAH); Solid Surface Combustion Experiment (SSCE); Shuttle Amateur Radio Experiment (SAREX II); Air Force Maui Optical Site (AMOS); and Ultraviolet Plume Instrument (UVPI).

STS-52

(USMP-1; LAGEOS II)

Columbia

Pad B
51st Shuttle mission
13th flight OV-102
13th KSC landing

Crew:

James D. Wetherbee, Commander
Michael A. Baker, Pilot
Charles Lacy Veach, Mission Specialist
Tamara E. Jernigan, Mission Specialist
William M. Shepherd, Mission Specialist
Steven A. MacLean, Payload Specialist (Canadian Space Agency)

Orbiter Preps (move to):

OPF — July 10, 1992
VAB — Sept. 20, 1992
Pad — Sept. 26, 1992

Launch:

October 22, 1992, 1:09:39 p.m. EDT. Targeted launch date in mid-October slipped when managers decided to replace number three engine, prompted by concerns about possible cracks in liquid hydrogen coolant manifold on engine nozzle. Changing engine at pad less complex than continued X-ray analysis of suspect area. Liftoff set for 11:16 a.m. delayed about two hours due to crosswinds at KSC landing strip, violating return-to-launch-site criteria, and clouds at Banjul transoceanic abort landing site.

Landing:

November 1, 1992, 9:05:52 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,708 feet (3,264 meters). Rollout time: 63 seconds. Mission duration: nine days, 20 hours, 56 minutes, 13 seconds. Landed revolution 159. Drag chute again deployed before nosegear touchdown to allow further study of deployment dynamics.

Mission Highlights:

Primary objectives were deployment of Laser Geodynamic Satellite II (LAGEOS II) and operation of U.S. Microgravity Payload-1 (USMP-1). LAGEOS II, a joint effort between NASA and the Italian Space Agency, was deployed on flight day two and boosted into an initial elliptical orbit by the Italian Research Interim Stage (IRIS), flying for first time. LAGEOS II apogee kick motor later fired to circularize spacecraft orbit at operational altitude of 3,666 nautical miles (6,789 kilometers). USMP-1, activated on flight day one, included three experiments mounted on two connected Multipurpose Experiment Support Structures (MPESSs) mounted in cargo

bay. USMP-1 experiments were: Lambda Point Experiment (LPE), French-sponsored Material Pour L'Etude Des Phenomenes Interessant La Solidification Sur Terre Et En Orbite (MEPHISTO), and Space Acceleration Measurement System (SAMS).

Secondary payloads were the Canadian Experiment-2 (CANEX-2), a complement of experiments located in both cargo bay and middeck, including Space Vision System (SVS); Materials Exposure in Low-Earth Orbit (MELEO); Queen's University Experiment in Liquid-Metal Diffusion (QUELD); Phase Partitioning in Liquids (PARLIQ); Sun Orbiter Glow-2 (OGLOW-2); and Space Adaptation Tests and Observations (SATO). A small, specially-marked satellite, the Canadian Target Assembly (CTA) was deployed on flight day nine to support SVS. Also in cargo bay, the Attitude Sensor Package, featuring three European Space Agency independent sensors mounted on a Hitchhiker plate in cargo bay: Modular Star Sensor, Yaw Earth Sensor and Low Altitude Conical Earth Sensor, and the Tank Pressure Control Experiment/Thermal Phenomena (TPCE/TP), contained in a Get Away Special (GAS) canister.

Additional middeck payloads were Commercial Materials Dispersion Apparatus Instrument Technology Associates Experiments (CMIX); Commercial Protein Crystal Growth Experiment (CPCG); Chemical Vapor Transport Experiment (CVTE); Heat Pipe Performance Experiment (HPP); Physiological Systems Experiment (PSE); and Shuttle Plume Impingement Experiment (SPIE). Orbiter also used as reference point for calibrating Ultraviolet Plume Instrument (UVPI) on orbiting Strategic Defense Initiative Organization satellite.

STS-53

(DOD; ODERACS)

Discovery

Pad A
52nd Shuttle mission
15th flight OV-103
Final dedicated DOD flight
Diverted landing

Crew:

David M. Walker, Commander
Robert D. Cabana, Pilot
Guion S. Bluford, Jr., Mission Specialist
James S. Voss, Mission Specialist
Michael R. Clifford, Mission Specialist

Orbiter Preps (move to):

OPF — Feb. 16, 1992 (Extended stay included modification period, post- and preflight processing)
VAB — Aug. 8, 1992 (temporary)
OPF — Aug. 17, 1992
VAB — Nov. 3, 1992
Pad — Nov. 8, 1992

Launch:

December 2, 1992, 8:24:00 a.m. EST. Liftoff originally set for 6:59 a.m., but delayed to allow sunlight to melt ice on external tank, formed after tanking due to overnight temperatures in the upper 40s (four degrees Celsius range) and light wind. First flight of Discovery after scheduled extensive checkout and modification, performed at KSC following return from STS-42 in February 1992. Approximately 78 modifications completed, including installation of drag chute.

Landing:

December 9, 1992, 12:43:47 p.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,165 feet (3,098 meters). Rollout time: 73 seconds. Mission duration: seven days, seven hours, 19 minutes, 47 seconds. Landed revolution 116. Landing originally set for KSC, but diverted due to clouds in vicinity of landing strip. Drag chute deployed before nosegear touchdown. After landing, small leak detected in a forward thruster delayed crew egress before fan and winds dissipated leaking gas. Orbiter returned to KSC on Dec. 18, 1992.

Mission Highlights:

Final Shuttle flight for Department of Defense (DOD). Classified DOD payload deployed on flight day one, after which flight activities became unclassified. Two cargo bay payloads and nine middeck experiments flew.

Secondary payloads contained in or attached to Get Away Special (GAS) hardware in cargo bay included Glow Experiment (GLO)/Cryogenic Heat Pipe Experiment (CRYOHP) and Orbital Debris Radar Calibration Spheres (ODERACS).

Middeck payloads: Battlefield Laser Acquisition Sensor Test (BLAST); Cloud Logic to Optimize Use of Defense Systems (CLOUDS); Cosmic Radiation Effects and Activation Monitor (CREAM); Fluid Acquisition and Resupply Experiment (FARE); Hand-held, Earth-oriented, Real-time, Cooperative, User-friendly, Location-targeting and Environmental System (HERCULES); Microcapsules in Space-1 (MIS-1); Radiation Monitoring Experiment III (RME III); Space Tissue Loss (STL); Visual Function Tester-2 (VFT-2).

1993

STS-54

(TDRS-F; DXS)

Endeavour

Pad B
53rd Shuttle mission
3rd flight OV-105
14th KSC landing

Crew:

John H. Casper, Commander
Donald R. McMonagle, Pilot
Mario Runco, Jr., Mission Specialist
Gregory J. Harbaugh, Mission Specialist
Susan J. Helms, Mission Specialist

Orbiter Preps (move to):

OPF — Sept. 20, 1992
VAB — Nov. 23, 1992
Pad — Dec. 3, 1992

Launch:

January 13, 1993, 8:59:30 a.m. EST. Liftoff delayed about seven minutes due to concerns associated with upper atmospheric winds.

Landing:

January 19, 1993, 8:37:49 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,724 feet (2,659 meters). Rollout time: 49 seconds. Mission duration: five days, 23 hours, 38 minutes, 19 seconds. Landed revolution 96. Landing delayed one orbit due to ground fog at KSC.

Mission Highlights:

Primary payload was fifth Tracking and Data Relay Satellite (TDRS-6), deployed about six hours after liftoff; attached Inertial

Upper Stage (IUS) booster fired about one hour later to propel TDRS-6 to intermediate checkout orbit.

Also carried in cargo bay was Hitchhiker experiment, Diffuse X-ray Spectrometer (DXS), to collect data on X-ray radiation from diffuse sources in deep space.

Middeck payloads: Commercial General Bioprocessing Apparatus (CGBA) for life sciences research; Chromosome and Plant Cell Division in Space Experiment (CHROMEX) to study plant growth; Physiological and Anatomical Rodent Experiment (PARE) to examine skeletal system and adaptation of bone to space flight; Space Acceleration Measurement Equipment (SAMS) to measure and record microgravity acceleration environment of middeck experiments; and Solid Surface Combustion Experiment to measure rate of flame spread and temperature of burning filter paper.

On flight day five, Runco and Harbaugh spent nearly five hours walking in open payload bay, performing a series of extravehicular activity (EVA) tasks designed to increase NASA's knowledge of working in space; two mission specialists tested their abilities to move about freely in cargo bay, climb into foot restraints without using hands, and simulated carrying large objects in microgravity environment.

STS-56

(ATLAS-2; SPARTAN-201)

Discovery

Pad B
54th Shuttle mission
16th flight OV-103
Night launch
15th KSC landing
Extended mission

Crew:

Kenneth D. Cameron, Commander
Stephen S. Oswald, Pilot
Kenneth D. Cockrell, Mission Specialist
C. Michael Foale, Mission Specialist
Ellen Ochoa, Mission Specialist

Orbiter Preps (move to):

OPF — Dec. 19, 1992
VAB — March 2, 1993
Pad — March 15, 1993

Launch:

April 8, 1993, 1:29:00 a.m. EDT. First launch attempt on April 6 halted at T-11 seconds by orbiter computers when instrumentation on liquid hydrogen high point bleed valve in main propulsion system indicated off instead of on. Later analysis indicated valve was properly configured; 48-hour scrub turnaround procedures implemented. Final countdown on April 8 proceeded smoothly.

Landing:

April 17, 1993, 7:37:24 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,530 feet (2,905 meters). Rollout time: 63 seconds. Mission duration: nine days, six hours, eight minutes, 24 seconds. Landed revolution 148. Landing originally set for April 16 at KSC waved off due to weather.

Mission Highlights:

Primary payload of flight was Atmospheric Laboratory for Applications and Science-2 (ATLAS-2), designed to collect data on relationship between sun's energy output and Earth's middle atmosphere and how these factors affect ozone layer. Included six instruments mounted on Spacelab pallet in cargo bay, with seventh mounted on wall of bay in two Get Away Special canisters. Atmospheric instruments were Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment; Millimeter Wave Atmospheric Sounder (MAS); and Shuttle Solar Backscatter Ultraviolet/A (SSBUV/A) spectrometer (on cargo bay wall). Solar science instruments were Solar Spectrum Measurement (SOLSPEC) instrument; Solar Ultraviolet Irradiance Monitor (SUSIM); and Active Cavity Radiometer (ACR) and Solar Constant (SOLCON) experiments.

ATLAS-2 one element of NASA's Mission to Planet Earth program. All seven ATLAS-2 instruments first flew on ATLAS-1 during STS-45, and will fly third time in late 1994.

On April 11, crew used remote manipulator arm to deploy Shuttle Point Autonomous Research Tool for Astronomy-201 (SPARTAN-201), a free-flying science instrument platform designed to study velocity and acceleration of solar wind and observe sun's corona. Collected data was stored on tape for playback after return to Earth. SPARTAN-201 retrieved on April 13.

Crew also made numerous radio contacts to schools around world using Shuttle Amateur Radio Experiment II (SAREX II), and reported brief radio contact with Russian Mir space station, first such contact between Shuttle and Mir using amateur radio equipment.

Other cargo bay payloads: Solar Ultraviolet Experiment (SUVE), sponsored by Colorado Space Grant Consortium, and located in Get Away Special canister on cargo bay wall.

Middeck payloads: Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Experiment (CMIX); Physiological and Anatomical Rodent Experiment (PARE); Space Tissue Loss (STL-1); Cosmic Ray Effects and Activation Monitor (CREAM) experiment; Hand-held, Earth-oriented, Real-time, Cooperative, User-friendly, Location-targeting and Environmental System (HERCULES); Radiation Monitoring Equipment III (RME III); and Air Force Maui Optical Site (AMOS) calibration test.

STS-55

(Spacelab D-2)

Columbia

Pad A
55th Shuttle mission
14th flight OV-102
Pad abort
Extended mission
Diverted landing
Accumulated Shuttle flight time tops one year

Crew:

Steven R. Nagel, Mission Commander
Terence T. Henricks, Pilot
Jerry L. Ross, Payload Commander
Charles J. Precourt, Mission Specialist
Bernard A. Harris, Jr., Mission Specialist
Ulrich Walter, Payload Specialist
Hans William Schlegel, Payload Specialist

Orbiter Preps (move to):

OPF — Nov. 1, 1992
VAB — Feb. 2, 1993
Pad — Feb. 7, 1993

Launch:

April 26, 1993, 10:50:00 a.m. EDT. Launch first set for late February slipped to early March after questions arose about turbine blade tip seal retainers in high pressure oxidizer turbopumps on orbiter main engines. When engineers could not verify whether old or new retainers were on Columbia, NASA opted to replace all three turbopumps at pad as precautionary measure.

Launch date of March 14 slipped again after hydraulic flex hose

burst in aft compartment during Flight Readiness Test. All 12 hydraulic lines in aft removed and inspected; nine lines re-installed and three new lines put in.

Launch set for March 21 pushed back 24 hours due to range conflicts caused by Delta II one-day launch delay. Liftoff attempt March 22 aborted at T-3 seconds by orbiter computers due to incomplete ignition of number three main engine. Liquid oxygen preburner check valve leaked internally, causing overpressurized purge system which in turn precluded full engine ignition. First on-the-pad main engine abort since return-to-flight, and third in program history (51-F and 41-D other two). Valve leak later traced to contamination during manufacturing. NASA decided to replace all three main engines on Columbia with spares.

Launch reset for April 24, but scrubbed early launch morning when one of three inertial measurement units (IMUs) on orbiter gave possible faulty reading. Liftoff postponed 48 hours to allow removal and replacement of IMU. Final launch countdown April 26 proceeded smoothly. Last launch scheduled from Pad A until February 1994 to allow for pad refurbishment and modification.

Landing:

May 6, 1993, 7:29:59 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,125 feet (3,086 meters). Rollout time: 61 seconds. Mission duration: nine days, 23 hours, 39 minutes, 59 seconds. Landed revolution 160. Landing originally set for KSC, moved to Edwards because of cloud cover. With Columbia's return, Shuttle fleet had accumulated flight time totaling 365 days, 23 hours and 48 minutes.

Mission Highlights:

D-2 became second Spacelab flight under German mission management; around-the-clock operations performed by crew, divided into two teams. Some 88 experiments conducted, covering materials and life sciences, technology applications, Earth observations, astronomy and atmospheric physics. Material science investigations were: Material Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA); Werkstofflabor (WL); Holographic Optics Laboratory (HOLOP); and on Unique Support Structure (USS) located aft of D-2 in cargo bay, Material Science Autonomous Payload (MAUS), and Atomic Oxygen Exposure Tray (AOET). Also located on USS, Radiation Detectors (RD) experiments. One crystal growth experiment yielded 0.78-inch (20-mm) crystal of gallium arsenide, largest produced in space to date.

Life science research performed with Anthrorack (AR); Biolabor (BB); and Baroreflex (BA). Anthrorack, advanced mini-diagnostic laboratory, allowed most comprehensive medical screening to date of human adaptation to weightlessness. Harris, a medical doctor, set up first I.V. (intravenous) line in space, injecting Schlegel with saline as part of study to replace body fluids lost during adaptation to weightlessness. Other payload crew members also participated.

Tests with Robotics Experiment (ROTEX), an advanced robotic assembly provided by Germany, were highly successful. ROTEX robotic arm performed first by capturing free-floating object in space via remote control from Earth. Crew achieved two-way communications with Crew Telesupport Experiment, which featured onboard Macintosh computer to establish data link with ground control. Five crew members communicated with school children worldwide through Shuttle Amateur Radio Experiment (SAREX); Nagel also made contact with Russian cosmonauts aboard Mir space station.

Problems encountered were overheating orbiter refrigerator/freezer unit in middeck which forced reliance on backup to store experiment samples, and leaking nitrogen line in wastewater tank which required on-orbit fix. Communications with Columbia lost for about hour and a half on May 4 due to errant command from Mission Control in Houston. On May 2, mission managers determined enough electrical power remained to extend flight by one day.

STS-57

(SPACEHAB-1; EURECA retrieval)

Endeavour

Pad B
56th Shuttle mission
4th flight OV-105
Extended mission
16th KSC landing

Crew:

Ronald J. Grabe, Mission Commander
Brian Duffy, Pilot
G. David Low, Payload Commander
Nancy Jane Sherlock, Mission Specialist
Janice E. Voss, Mission Specialist
Peter J. K. Wisoff, Mission Specialist

Orbiter Preps (move to):

OPF — Jan. 19, 1993
VAB — March 24, 1993
Pad — April 28, 1993

Launch:

June 21, 1993, 9:07:22 a.m. EDT. Launch originally targeted for mid-May rescheduled to June to allow both liftoff and landing to occur in daylight. Liftoff set for June 3 slipped when managers decided to replace high pressure oxidizer turbopump on main engine number two, after concerns arose over misplaced inspection stamp (penetration verification stamp) on spring in pump. Additional time also allowed investigation of inexplicable loud noise heard after Shuttle arrived at launch pad; "big bang" eventually attributed to ball strut tie-rod assembly inside 17-inch (43-centimeter) liquid hydrogen line. Launch attempt on June 20 scrubbed at T-5 minutes due to low clouds and rain at return-to-launch site at KSC, and weather concerns at all three transoceanic abort landing sites. Launch countdown was longest since return to flight to allow servicing of payloads at pad.

Landing:

July 1, 1993, 8:52:16 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,954 feet (3,034 meters). Rollout time: 65 seconds. Mission duration: nine days, 23 hours, 44 minutes, 54 seconds. Landed revolution 155. Landing attempts on June 29 and 30 waved off due to unacceptable cloud cover and rain showers at KSC; Mission 61-C in 1986 last time there were two wave-offs. After landing, STS-57 crew in Endeavour talked to STS-51 crew in Discovery at Pad 39B, first orbiter-to-orbiter crew conversation since orbiting 51-D crew talked to 51-B crew at KSC in 1985. OV-105 scheduled for extended fifth flow checkup upon return.

Mission Highlights:

STS-57 marked first flight of commercially-developed SPACEHAB, pressurized laboratory designed to more than double pressurized workspace for crew-tended experiments. Altogether 22 experiments were flown, covering materials and life sciences, and wastewater recycling experiment for space station.

On June 24, crew captured and stowed at 12:36 p.m. EDT the approximately 9,424-pound (4,275-kilogram) European Retrievable Carrier (EURECA) deployed on Mission STS-46. However, EURECA ground controllers unable to stow spacecraft's two antennas, and on June 25, Low and Wisoff spent beginning of scheduled extravehicular activity (EVA) manually folding antennas. Remainder of 5-hour, 50-minute EVA spent on planned tasks; this was second in series of generic EVAs this year.

On June 22, all five crew members talked with President Clinton.

Other cargo bay payloads: Get Away Special (GAS) bridge

assembly holding one ballast can and 11 GAS can payloads, including Complex Autonomous Payload called Consortium for Materials Development in Space-IV (CONCAP-IV) and CAN DO experiment designed by Charleston, South Carolina school district; also Super Fluid Helium On Orbit Transfer (SHOOT) experiment to investigate resupply of liquid helium containers in space.

Middeck payloads: Fluid Acquisition and Resupply Experiment (FARE); Shuttle Amateur Radio Experiment-II (SAREX-II). No hardware required for Air Force Maui Optical Site (AMOS) calibration test.

STS-51

(ACTS/TOS; ORFEUS-SPAS)

Discovery

Pad B
57th Shuttle mission
17th flight OV-103
Pad abort
Extended mission
17th KSC landing
1st KSC end-of-mission night landing

Crew:

Frank L. Culbertson Jr., Commander
William F. Readdy, Pilot
James H. Newman, Mission Specialist
Daniel W. Bursch, Mission Specialist
Carl E. Walz, Mission Specialist

Orbiter Preps (move to):

OPF — April 17, 1993
VAB — June 18, 1993
Pad — June 26, 1993

Launch:

September 12, 1993, 7:45:00 a.m. EDT. First launch attempt on July 17 scrubbed during T-20 minute hold due to premature and unexplained charging of pyrotechnic initiator controllers (PICs), located on mobile launcher platform (MLP), for T-0 liquid hydrogen vent arm umbilical and solid rocket booster hold-down bolts. Problem traced to faulty circuit card in PIC rack on MLP.

Abbreviated countdown began July 23. Second liftoff attempt on July 24 halted at T-19 seconds due to problem with auxiliary power unit (APU) turbine assembly for one of two hydraulic power units (HPUs) on right solid rocket booster. APU removed and replaced at pad.

Launch rescheduled for Aug. 4, then changed to Aug. 12 due to concerns regarding Perseid meteor shower, which was expected to peak Aug. 11. Liftoff attempt Aug. 12 halted at T-3 second mark due to faulty sensor monitoring fuel flow on main engine number two. Fourth pad abort in Shuttle program history — second in 1993 — led to changeout of all three main engines at pad.

Launch rescheduled to Sept. 10, then slipped to Sept. 12 to allow time to complete review of Advanced Communications Technology Satellite design, production and testing history following loss of contact with Mars Observer spacecraft and NOAA-13 satellite.

Countdown proceeded smoothly to on-time Sept. 12 liftoff.

Landing:

September 22, 1993, 3:56:11 a.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 8,271 feet (2,521 meters). Rollout time: 50 seconds. Mission duration: nine days, 20 hours, 11 minutes, 11 seconds. Landed revolution 157. Landing opportunity Sept. 21 waved off due to possibility of rain showers within 30 miles (48 kilometers) of Shuttle Landing Facility. First end-of-mission night landing at KSC for Shuttle program.

Mission Highlights:

One of two primary payloads, Advanced Communications Technology Satellite (ACTS), deployed on flight day one. About 45 minutes after ACTS deploy, attached Transfer Orbit Stage (TOS) booster — flying on Shuttle for first time — fired to propel pioneering communications technology spacecraft to geosynchronous transfer orbit.

On flight day two, crew deployed second primary payload, Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite (ORFEUS-SPAS), first in series of ASTRO-SPAS astronomical missions. Extensive footage of orbiter recorded by IMAX camera mounted on SPAS. Joint German-U.S. astrophysics payload was controlled via SPAS Payload Operations Control Center (SPOC) at KSC, becoming first Shuttle payload to be managed from Florida. After six days of data collection, ORFEUS-SPAS retrieved with remote manipulator system arm and returned to cargo bay.

On Sept. 16, Mission Specialists Newman and Walz performed extravehicular activity (EVA) lasting seven hours, five minutes and 28 seconds. Final in series of generic spacewalks begun earlier in year. Astronauts also evaluated tools, tethers and foot restraint platform intended for upcoming Hubble Space Telescope servicing mission.

Other cargo bay payloads: Limited Duration Space Environment Candidate Material Exposure (LDCE). Middeck payloads: IMAX 70 mm camera; Commercial Protein Crystal Growth (CPCG) Block II; Chromosome and Plant Cell Division in Space (CHROMEX-04); High Resolution Shuttle Glow Spectroscopy (HRSGS-A); Aurora Photography Experiment (APE-B); Investigation into Polymer Membranes Processing (IPMP); and Radiation Monitoring Equipment III (RME III); Air Force Maui Optical Site (AMOS) calibration test also performed.

STS-58

(SLS-2)

Columbia

Pad B
58th Shuttle mission
15th flight OV-102
Extended mission

Crew:

John E. Blaha, Mission Commander
Richard A. Searfoss, Pilot
M. Rhea Seddon, Payload Commander
William S. McArthur Jr., Mission Specialist
David A. Wolf, Mission Specialist
Shannon W. Lucid, Mission Specialist
Martin J. Fettman, Payload Specialist

Orbiter Preps (move to):

OPF — May 15, 1993
VAB — Aug. 11, 1993
Pad — Sept. 17, 1993

Launch:

October 18, 1993, 10:53:10 a.m. EDT. First launch attempt on Oct. 14 scrubbed at T-31 second mark due to failed Range Safety computer. Second launch attempt on Oct. 15 scrubbed at T-9 minute mark due to failed S-band transponder on orbiter. Launch reset for Oct. 18. Countdown proceeded smoothly to liftoff, delayed only by several seconds because of aircraft in launch zone.

Landing:

November 1, 1993, 7:05:42 a.m. PST, Runway 22, Edwards

Air Force Base, Calif. Rollout distance: 9,640 feet (2,938 meters). Rollout time: one minute, one second. Mission duration: 14 days, 12 minutes, 32 seconds — longest Shuttle flight to date. Landed revolution 225.

Mission Highlights:

Second dedicated Spacelab Life Sciences mission (SLS-2). Fourteen experiments conducted in four areas: regulatory physiology, cardiovascular/cardiopulmonary, musculoskeletal and neuroscience. Eight of the experiments focused on crew; six on 48 rodents. Crew collected more than 650 different samples from themselves and rodents, increasing statistical base for life sciences research. Combined data from SLS-1 and SLS-2 will help build comprehensive picture of how humans and animals adapt to weightlessness.

Cardiovascular investigations: Inflight Study of Cardiovascular Deconditioning; Cardiovascular Adaptation to Zero Gravity; Pulmonary Function during Weightlessness. Regulatory physiology investigations: Fluid Electrolyte Regulation during Space flight; Regulation of Blood Volume during Space flight; Regulation of Erythropoiesis in Rats during Space flight; Influence of Space flight on Erythrokinetics in Man. Musculoskeletal investigations: Protein Metabolism during Space flight; Effects of Zero Gravity on the Functional and Biochemical Properties of Antigravity Skeletal Muscle; Effects of Microgravity on the Electron Microscopy, Histochemistry and Protease Activities of Rat Hindlimb Muscles; Pathophysiology of Mineral Loss during Space flight; Bone, Calcium and Spaceflight. Neuroscience investigations: Study of the Effects of Space Travel on Mammalian Gravity Receptors; Vestibular Experiments in Spacelab.

For one of the neurovestibular experiments, Rotating Dome Experiment, crew worked with first flight prototype of Astronaut Science Advisor (ASA), a laptop computer designed to assist astronauts conducting experiments; also called "principal investigator in a box" because it can increase efficiency of experiment activities.

Six rodents were killed and dissected during mission, yielding first tissue samples collected in space and not altered by re-exposure to Earth's gravity.

Other experiments: Orbital Acceleration Research Experiment (OARE); Shuttle Amateur Radio Experiment (SAREX). Also performed: Pilot Inflight Landing Operations Trainer (PILOT), portable laptop computer simulator to allow pilot and commander to maintain proficiency for approach and landing during longer missions.

With completion of her fourth space flight, Lucid accumulated most flight time for a female astronaut on the Shuttle, 838 hours.

STS-61

(1st HST servicing)

Endeavour

Pad B
59th Shuttle mission
5th flight OV-105
Night launch and landing
18th KSC landing
Record-setting spacewalks
First Hubble telescope servicing

Crew:

Richard O. Covey, Mission Commander
Kenneth D. Bowersox, Pilot
F. Story Musgrave, Payload Commander
Jeffrey A. Hoffman, Mission Specialist
Kathryn C. Thornton, Mission Specialist
Tom Akers, Mission Specialist
Claude Nicollier, Mission Specialist (European Space Agency)

Orbiter Preps (move to):

OPF — July 1, 1993
VAB — Oct. 21, 1993
Pad A — Oct. 28, 1993
Pad B — Nov. 15, 1993 (rollaround)

Launch:

December 2, 1993, 4:27:00 a.m. EST. Launch originally scheduled to occur from Launch Pad 39A, but after rollout, contamination found in Pad 39A Payload Changeout Room and decision made to move Shuttle and payloads to Pad 39B. Rollaround occurred on Nov. 15. First launch attempt on Dec. 1 scrubbed due to out-of-limit weather conditions at Shuttle Landing Facility in event of return-to-launch-site contingency. Launch Dec. 2 occurred on schedule.

Landing:

December 13, 1993, 12:25:37 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 7,922 feet (2,415 meters). Rollout time: 53 seconds. Mission duration: 10 days, 19 hours, 58 minutes, 37 seconds. Landed revolution 163. Second night landing at KSC. Orbiter returned one orbit earlier than originally planned to allow two landing opportunities at KSC.

Mission Highlights:

Final Shuttle flight of 1993 was one of most challenging and complex manned missions ever attempted. During record five back-to-back spacewalks totaling 35 hours and 28 minutes, two teams of astronauts completed first servicing of Hubble Space Telescope (HST). In many instances, tasks completed sooner than expected and few contingencies that did arise handled smoothly.

Hubble rendezvous, grapple and berthing occurred on flight day three, with Nicollier using remote manipulator system arm to position 43-foot (13-meter) long Hubble upright in payload bay. Throughout mission, commands to Hubble issued from Space Telescope Operations Control Center (STOCC) at Goddard Space Flight Center. After each servicing task completed, STOCC controllers verified electrical interfaces between replacement hardware and telescope.

On flight day four, first EVA team of Musgrave and Hoffman performed EVA #1, replacing two Rate Sensing Units (RSUs), each housing pair of gyroscopes; two Electronic Control Units which direct the RSUs; and eight electrical fuse plugs. Only unexpected problem occurred when Hoffman and Musgrave had difficulty closing compartment doors after replacing RSUs. Seven-hour, 54-minute spacewalk second longest in U.S. history to date, topped only by STS-49 EVA lasting eight hours, 29 minutes. During EVAs, Nicollier operated robot arm carrying one of two EVA crew members.

One of primary servicing goals — installation of new solar arrays — accomplished during EVA #2, performed on flight day five by Thornton and Akers and lasting six hours, 35 minutes. Timeline reworked to accommodate jettison of one of two original solar arrays, which could not be fully retracted due to kink in framework. Other solar array stowed in payload bay and replacement pair — set of modified spares — installed without difficulty.

Expected four-hour replacement of one of Hubble's five scientific instruments, Wide Field/Planetary Camera (WF/PC), completed in about 40 minutes by Hoffman and Musgrave during EVA #3 on flight day six. WF/PC II is upgraded spare modified to compensate for flaw in HST primary mirror. Also, two new magnetometers installed at top of telescope during the six-hour, 48-minute EVA.

EVA #4 performed on flight day seven by Thornton and Akers. High-Speed Photometer, one of Hubble scientific instruments, removed and replaced with Corrective Optics Space Telescope Axial Replacement (COSTAR) unit. Task took less time to complete than expected. COSTAR designed to redirect light to three of four remaining Hubble instruments to compensate for flaw in primary mirror of telescope. Thornton and Akers also installed co-processor to enhance memory and speed of Hubble computer. During six-hour, 50-minute EVA, Akers set new U.S. space-walking record of 29 hours, 39 minutes, topping Eugene Cernan's 20-year-old record of 24 hours, 14 minutes. Thornton is leading U.S.

female spacewalker with total of 21 hours, 10 minutes.

Final EVA performed by Hoffman and Musgrave on flight day eight. During seven-hour, 21-minute-long EVA #5, Hoffman and Musgrave replaced Solar Array Drive Electronics (SADE) unit and installed Goddard High Resolution Spectrograph Redundancy (GHRS) kit; also installed two protective covers over original magnetometers. After spacewalk completed, new solar arrays and two high-gain antennas deployed by STOCC. HST also re-boosted to slightly higher orbit of 321 nautical miles (595 kilometers) on flight day eight prior to last EVA.

Hubble redeployed on flight day nine. Release delayed several hours to allow troubleshooting of erratic data telemetry from Hubble subsystems monitor; problem had occurred before and was not related to servicing. President Clinton and Vice President Gore congratulated crew, and Swiss minister of internal affairs called following day to congratulate Nicollier.

1994

STS-60

(WSF-1; SPACEHAB-2)

Discovery
Pad A
60th Shuttle mission
18th flight OV-103
19th KSC landing
1st Russian cosmonaut on U.S. Shuttle

Crew:
Charles F. Bolden Jr., Mission Commander
Kenneth F. Reightler Jr., Pilot
Franklin R. Chang-Diaz, Payload Commander
N. Jan Davis, Mission Specialist
Ronald M. Sega, Mission Specialist
Sergei K. Krikalev, Mission Specialist (Russian Aviation and Space Agency)

Orbiter Preps (move to):
OPF — Sept. 22, 1993
VAB — Jan. 4, 1994
Pad — Jan. 10, 1994

Launch:
February 3, 1994, 7:10:00 a.m. EST. Countdown proceeded smoothly to ontime liftoff.

Landing:
February 11, 1994, 2:19:22 p.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 7,771 feet (2,369 meters). Rollout time: 50 seconds. Mission duration: eight days, seven hours, nine minutes, 22 seconds. Landed revolution 130. First attempt waved off due to unfavorable weather in KSC area.

Mission Highlights:
First Shuttle flight of 1994 marked the first flight of Russian cosmonaut on U.S. Space Shuttle as first element in implementing Agreement on NASA/Russian Space Agency Cooperation in Human Space Flight. Mission also marked second flight of SPACEHAB pressurized module and 100th Get Away Special payload to fly in space. Also on board was Wake Shield Facility-1 (WSF-1), making first in a planned series of flights.

SPACEHAB-2 activated shortly after reaching orbit. Taking up about one quarter of payload bay, the 1,100 cubic foot- (31 cu.m.) module carried 12 experiments. Four of these involved materials science topics, seven life sciences investigations, and a space dust collection experiment.

On flight day three, crew made first attempt to deploy WSF-1 using remote manipulator system arm. WSF-1 is deployable/retrievable experiment platform designed to leave a vacuum wake in low Earth orbit that is 10,000 times greater than achievable on Earth. In this ultra-vacuum environment, defect-free thin-film layers of gallium arsenide and other semiconductor materials can be grown. First deploy attempt waved off due to radio interference and difficulty reading status signs on WSF-1. After second deploy attempt on flight day four waved off due to problems with WSF-1 attitude control system, five out of seven planned films grown with WSF-1 platform suspended at end of RMS arm. WSF-1 berthed in cargo bay on flight day six.

Crew also conducted first NASA-Russian Space Agency joint in-flight medical and radiological investigations. Krikalev communicated with amateur radio operators in Moscow using Shuttle Amateur Radio Experiment (SAREX) equipment. On Feb. 7, crew talked with President Clinton during latter's tour of Mission Control in Houston, and on Feb. 9 Bolden and Krikalev talked with Russian Prime Minister Viktor Chernomyrdin, calling from Mission Control in Moscow.

Crew also deployed two payloads from Get Away Special canisters mounted on GAS bridge assembly in payload bay: six Orbital Debris Radar Calibration Spheres (ODERACS) ranging in size from two to six inches (5-15 centimeters) to aid calibration of radar tracking systems worldwide, and University of Bremen's BREMSAT, which measured conditions such as acceleration forces affecting satellite.

Other payloads: Capillary Pumped Loop Experiment (CAPL) mounted on top of GAS Bridge Assembly; three additional GAS experiments; and Auroral Photography Experiment-Phase B (APE-B).

STS-62

(USMP-2; OAST-2)

Columbia
Pad B
61st Shuttle mission
16th flight OV-102
20th KSC landing
Extended mission

Crew:
John H. Casper, Commander
Andrew M. Allen, Pilot
Charles D. Gemar, Mission Specialist
Marsha S. Ivins, Mission Specialist
Pierre J. Thuot, Mission Specialist

Orbiter Preps (move to):
OPF — Nov. 8, 1993
VAB — Feb. 3, 1994
Pad — Feb. 10, 1994

Launch:
March 4, 1994, 8:53:00 a.m. EST. Launch originally set for March 3 postponed at T-11 hour mark due to predicted unfavorable weather in KSC area. Countdown March 4 proceeded smoothly. Only deviation to operating procedures was delay in deploying solid rocket booster recovery ships because of high seas. Recovery ships left port launch day, and recovered boosters and their parachutes March 6.

Landing:

March 18, 1994, 8:09:41 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,151 feet (3,094 meters). Rollout time: 55 seconds. Mission duration: 13 days, 23 hours, 16 minutes, 41 seconds. Landed revolution 224.

Mission Highlights:

Primary payloads were U.S. Microgravity Payload-2 (USMP-2) and Office of Aeronautics and Space Technology-2 (OAST-2). USMP-2 included five experiments investigating materials processing and crystal growth in microgravity, while OAST-2 featured six experiments focusing on space technology and spaceflight. Both payloads located in payload bay, activated by crew and operated by teams on ground. USMP-2 experiments received emphasis at beginning of flight; later in mission Columbia's orbit lowered about 20 nautical miles to facilitate OAST-2 experiments.

Crew worked with experiments located both in middeck and payload bay. These included Dexterous End Effector (DEE), a new magnetic end effector and grapple fixture design being tested for use on remote manipulator system arm; Shuttle Solar Backscatter Ultraviolet/A (SSBUV/A) and Limited Duration Space Environment Candidate Material Exposure (LDCE), all in payload bay. Middeck experiments were Advanced Protein Crystal Growth; Physiological Systems Experiment (PSE); Commercial Protein Crystal Growth (CPCG); Commercial Generic Bioprocessing Apparatus (CGBA); Middeck 0-Gravity Dynamics Experiment (MODE); Bioreactor Demonstration Systems (BDS); Auroral Photography Experiment (APE-B). Air Force Maui Optical Site Calibration Test (AMOS) requires no onboard hardware.

Crew also conducted number of biomedical activities aimed at better understanding and countering effects of prolonged spaceflight.

STS-59

(SRL-1)

Endeavour

Pad A
62nd Shuttle mission
6th flight OV-105
Extended mission
Diverted landing

Crew:

Sidney M. Gutierrez, Mission Commander
Kevin P. Chilton, Pilot
Linda M. Godwin, Payload Commander
Jay Apt, Mission Specialist
Michael R. Clifford, Mission Specialist
Thomas D. Jones, Mission Specialist

Orbiter Preps (move to):

OPF — Dec. 13, 1993
VAB — March 14, 1994
Pad — March 19, 1994

Launch:

April 9, 1994, 7:05:00 a.m. EDT. Launch originally set for April 7 postponed at the T-27 hour mark for one day to allow for additional inspections of metallic vanes in SSME high pressure oxidizer preburner pumps. Launch on April 8 scrubbed due to weather, high crosswinds and low clouds at SLF and clouds at launch pad. Countdown April 9 proceeded smoothly.

Landing:

April 20, 1994, 9:54:30 a.m. PDT, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 10,691 feet (3,259 meters). Rollout time: 54 seconds. Mission duration: 11 days, 5 hours, 49 minutes, 30 seconds. Landed revolution 183. Landing originally planned for KSC on April 19 but two landing opportunities were waved off due to low clouds and possible thunderstorms in the area. An early landing opportunity on April 20 was also waved off in favor of landings at Edwards. Orbiter returned to KSC by Shuttle Carrier Aircraft on May 2, 1994.

Mission Highlights:

Primary payload was the Space Radar Laboratory (SRL-1), located in payload bay; activated by crew and operated by teams on ground. SRL-1 included the Spaceborne Imaging Radar-C and the X-band Synthetic Aperture Radar (SIR-C/X-SAR) and an atmospheric instrument called Measurement of Air Pollution from Satellites (MAPS). The German Space Agency (DARA) and the Italian Space Agency (ASI) provided the X-SAR instrument. SIR-C/X-SAR covered approximately 38.5 million miles of the Earth, the equivalent of 20 percent of the planet. More than 400 sites were imaged, including 19 primary observation sites (supersites) in Brazil, Michigan, North Carolina and Central Europe.

Thirteen countries were represented in the project with 49 principal investigators and more than 100 scientists, coordinated by the Jet Propulsion Laboratory (JPL). Some 133 hours of data were collected. The MAPS experiment measured the global distribution of carbon monoxide in the troposphere, or lower atmosphere.

Get-Away Special (GAS) experiments were sponsored by New Mexico State University, Matra Marconi Space (France), and the Society of Japanese Aerospace Companies.

Consortium for Materials Development in Space Complex Autonomous Payload-IV (CONCAP IV), carried in GAS hardware in the payload bay, was developed by the University of Alabama-Huntsville. It produced crystals and thin films through physical vapor transportation.

Middeck experiments included Visual Function Tester-4 (VFT-4), Space Tissue Loss-4 and -5; and Shuttle Amateur Radio Experiment (SAREX).

Mission also marked first flight of Toughened Uni-Piece Fibrous Insulation, known as TUFI, an improved thermal protection tile. Several test tiles were placed on orbiter's base heat shield between three main engines.

STS-65

(IML-2)

Columbia

Pad A
63rd Shuttle mission
17th flight OV-102
Extended mission
21st KSC landing

Crew:

Robert D. Cabana, Mission Commander
James D. Halsell Jr., Pilot
Richard J. Hieb, Payload Commander
Donald A. Thomas, Science Mission Specialist
Carl E. Walz, Mission Specialist
Leroy Chiao, Mission Specialist
Chiaki Naito-Mukai, Payload Specialist (National Space Development Agency of Japan)

Orbiter Preps (move to):

OPF — March 18, 1994
VAB — June 8, 1994
Pad — June 15, 1994

Launch:

July 8, 1994, 12:43:00 p.m. EDT. Launch proceeded on time following a smooth countdown.

Landing:

July 23, 1994, 6:38:00 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,211 feet (3,112 meters). Rollout time: 68 seconds. Mission duration: 14 days, 17 hours, 55 minutes, zero seconds. Longest Shuttle flight to date. Landed revolution 235. Landing opportunity on July 22 waved off due to possibility of rain showers in area. STS-65 was Columbia's last mission before scheduled modification and refurbishment at Rockwell's Palmdale plant. OV-102 departed for California atop Boeing 747 Shuttle Carrier Aircraft on Oct. 8, 1994. Returned to KSC in April 1995 with STS-73 next scheduled flight.

Mission Highlights:

Payload Specialist Chiaki Mukai became first Japanese woman to fly in space; she also set record for longest flight to date by female astronaut.

STS-65 marked second flight of International Microgravity Laboratory (IML-2), carrying more than twice the number of experiments and facilities as IML-1. Crew split into two teams to perform around-the-clock research. More than 80 experiments, representing more than 200 scientists from six space agencies, were located in Spacelab module in payload bay (one piece of equipment stowed in middeck lockers). Fifty of the experiments delved into life sciences, including bioprocessing, space biology, human physiology and radiation biology. Some of the equipment used for these investigations had flown on previous Spacelab flights, such as European Space Agency's Biorack, making its third flight. IML-2 Biorack housed 19 experiments featuring chemicals and biological samples such as bacteria, mammalian and human cells, isolated tissues and eggs, sea urchin larvae, fruit flies and plant seedlings. Over course of a single mission, specimens can evolve through several stages of life cycles, allowing study of effects of microgravity and cosmic radiation on living tissues.

German Space Agency (DARA) provided the NIZEMI, a slow rotating centrifuge that allowed study of how organisms react to different gravity levels. Samples studied included jellyfish and plants. For first time, researchers were able to determine how organisms react to forces one-and-a-half times Earth's gravity.

Nearly 30 experiments in materials processing were conducted with nine different types of science facilities. DARA provided the TEMPUS, flying for first time on IML-2, designed to allow study of solidification of materials from liquid state in a containerless environment. Science teams detected for first time a phase in a nickel-niobium sample that is masked by other forces on Earth.

Another facility, Advanced Protein Crystallization Facility developed by European Space Agency, was flying for second time. Some 5,000 video images were made of crystals grown during flight.

Mission further advanced concept of telescience, where researchers on ground can monitor in realtime experiments on board orbiter. Flight set new record of more than 25,000 payload commands issued from Spacelab Mission Operations Control at Huntsville, Ala.

In addition to IML-2 investigations, following payloads also were flown: Orbital Acceleration Research Experiment (OARE); Commercial Protein Crystal Growth (CPCG); Military Application of Ship Tracks (MAST); Shuttle Amateur Radio Experiment (SAREX); and Air Force Maui Optical Site (AMOS), which does not require onboard equipment.

Flight marked first time liftoff and reentry as experienced from crew cabin were captured on videotape. Crew took time during mission to honor 25th anniversary of Apollo 11, noting it also featured a spacecraft named Columbia.

Only orbiter-related glitch experienced was occurrence of transient spikes in Inertial Measurement Unit 1.

STS-64

(LITE; SPARTAN-201)

Discovery

Pad B
64th Shuttle mission
19th flight OV-103
Extended mission
Diverted landing
1st untethered U.S. spacewalk in 10 years

Crew:

Richard N. Richards, Commander
L. Blaine Hammond Jr., Pilot
Susan J. Helms, Mission Specialist
Carl J. Meade, Mission Specialist
Mark C. Lee, Mission Specialist
J. M. Linenger, Mission Specialist

Orbiter Preps (move to):

OPF — Feb. 11, 1994
VAB — Aug. 11, 1994
Pad — Aug. 19, 1994

Launch:

September 9, 1994, 6:22:55 p.m. EDT. Two and a half hour launch window opened at 4:30 p.m.; liftoff delayed due to weather concerns.

Landing:

September 20, 1994, 5:12:52 p.m. EDT, Runway 04, Edwards Air Force Base, Calif. Rollout distance: 9,656 feet (2,943 meters). Rollout time: 60 seconds. Mission duration: ten days, 22 hours, 49 minutes, 57 seconds. Landed revolution 176. Mission already extended one day was extended again after first landing opportunities at KSC on Sept. 19 were waved off due to stormy weather. Two additional opportunities at KSC on Sept. 20 were also waved off, and orbiter diverted to California. OV-103 returned to KSC on Sept. 27 and towed to Orbiter Processing Facility on Sept. 28, 1994.

Mission Highlights:

STS-64 marked first flight of Lidar In-space Technology Experiment (LITE) and first untethered U.S. extravehicular activity (EVA) in 10 years. LITE payload employs lidar, which stands for light detection and ranging, a type of optical radar using laser pulses instead of radio waves to study Earth's atmosphere. First spaceflight of lidar was highly successful technology test. LITE instrument operated for 53 hours, yielding more than 43 hours of high-rate data. Unprecedented views were obtained of cloud structures, storm systems, dust clouds, pollutants, forest burning and surface reflectance. Sites studied included atmosphere above northern Europe, Indonesia and the south Pacific, Russia and Africa. Sixty-five groups from 20 countries are making validation measurements with ground-based and aircraft instruments to verify LITE data. LITE science program is part of NASA's Mission to Planet Earth.

Mission Specialists Lee and Meade completed 28th EVA of Space Shuttle program on Sept. 16. During six-hour, 15-minute EVA, they tested new backpack called Simplified Aid for EVA Rescue (SAFER), designed for use in event crew member becomes untethered while conducting an EVA.

On fifth day of mission, Shuttle Pointed Autonomous Research Tool for Astronomy-201 (SPARTAN-201) free flyer was released using Remote Manipulator System arm. Making its second flight on Shuttle, SPARTAN-201 designed to collect data about acceleration and velocity of solar wind and to measure aspects of sun's corona. Data recorded for playback after return to Earth. SPARTAN-201 retrieved after two days of data collection.

Other cargo bay payloads: Shuttle Plume Impingement Flight Experiment (SPIFEX), a 33-foot (10-meter) long instrumented extension for Shuttle robot arm. SPIFEX designed to collect data about orbiter Reaction Control System (RCS) thrusters to aid understanding about potential effects of thruster plumes on large space structures, such as Mir space station or planned international space station. Robot Operated Processing System (ROMPS) was first U.S. robotics system operated in space, mounted in two Get Away Special (GAS) canisters attached to cargo bay wall. A GAS bridge assembly in cargo bay carried 12 cans, 10 holding self-contained experiments.

Middeck experiments included: Biological Research in Canister (BRIC) experiment to investigate effects of spaceflight on plant specimens; Military Application of Ship Tracks (MAST) to take high-resolution imagery of ship tracks and to analyze wake formation and dissipations; Solid Surface Combustion Experiment (SSCE) to supply information on flame propagation over fuels in space; Radiation Monitoring Equipment III (RME III) to measure ionizing radiation; Shuttle Amateur Radio Experiment II (SAREX II) to demonstrate feasibility of short-wave radio contacts between orbiter and ground-based amateur radio operators; and Air Force Maui Optical Station (AMOS) test, which required no onboard hardware.

STS-68

(SRL-2)

Endeavour

Pad A
65th Shuttle mission
7th flight OV-105
Pad abort
Extended mission
Diverted landing

Crew:

Michael A. Baker, Mission Commander
Terrence W. Wilcutt, Pilot
Thomas D. Jones, Payload Commander
Daniel W. Bursch, Mission Specialist
Peter J.K. Wisoff, Mission Specialist
Steven L. Smith, Mission Specialist

Orbiter Preps (move to):

Flow A:
OPF — May 2, 1994
VAB — July 21, 1994
Pad — July 27, 1994
Flow B (rollback):
VAB — Aug. 24, 1994
Pad — Sept. 13, 1994

Launch:

September 30, 1994, 7:16:00 a.m. EDT. First launch attempt Aug. 18 halted at T-1.9 seconds when orbiter computers shut down all three main engines after detecting an unacceptably high discharge temperature in high-pressure oxidizer turbopump turbine for main engine number three. Endeavour returned to VAB and all three engines replaced. Countdown for second launch attempt proceeded smoothly to ontime liftoff Sept. 30.

Landing:

October 11, 1994, 10:02:08 a.m. PDT, Runway 22, Edwards Air Force Base. Rollout distance: 8,495 feet (2,589 meters). Rollout time: 60 seconds. Mission duration: 11 days, five hours, 46 minutes, eight seconds. Landed revolution 182. Landing diverted to Edwards due to unacceptable weather at KSC. Post-landing video showed what appeared to be water dripping from area of centerline latch for orbiter/external tank doors; source later found to be cracked valve in water spray boiler number three. OV-105 returned to KSC atop 747 Shuttle Carrier Aircraft on Oct. 2, 1994.

Mission Highlights:

STS-68 marked second flight in 1994 of Space Radar Laboratory (first flight was STS-59 in April), part of NASA's Mission to Planet Earth. Flying SRL during different seasons allowed comparison of changes between first and second flights. SRL-2 activated on flight day one, and around-the-clock observations conducted by astronauts split into two teams. Besides repeating data takes over same locations as on first flight, unusual events also imaged, including erupting volcano in Russia and islands of Japan after earthquake there. Also tested was ability of SRL-2 imaging radars, Spaceborne Imaging Radar-C (SIR-C) and X-band Synthetic Aperture Radar (X-SAR), to discern difference between such human-induced phenomena as oil spill in ocean and naturally occurring film.

Mission also took advantage of opportunity to study fires set in British Columbia, Canada, for forest management purposes. Special readings were taken with another SRL element, Measurement of Air Pollution from satellites (MAPS), to gain better understanding of carbon monoxide emissions from burning forest. Flying for fourth time on Shuttle, MAPS is designed to measure global distribution of carbon monoxide.

On flight day six, mission extended one day by Mission Management Team. Maneuvering capability of orbiter was demonstrated anew in latter half of mission, when different data-gathering method was tried. Called interferometry, it required repeated, nearly coincidental imaging passes with SIR-C/X-SAR over target sites. In one instance, Endeavour piloted to within 30 feet (nine meters) of where it was flown on first flight in April. Collected data can be transcribed into detailed topographic images showing elevation and other features. Interferometric passes completed over central North America, Amazon forests of central Brazil, and volcanoes of Kamchatka Peninsula in Russia. Such images, if produced regularly over long term, could provide information on movements of Earth's surface as small as fraction of an inch, which could be invaluable in detecting pre-eruptive changes in volcanoes and movements in fault lines before earthquakes.

Other cargo bay payloads included five Get Away Specials (GAS): two sponsored by university student groups, one by Swedish Space Corp., and two by U.S. Postal Service holding 500,000 commemorative stamps honoring 25th anniversary of Apollo 11.

Middeck payloads: Commercial Protein Crystal Growth (CPCG) to study dynamics of protein crystallization and also to obtain protein crystals large enough to allow structural analysis; Biological Research in Canisters (BRIC-01), flying for first time and holding gypsy moth eggs to determine how microgravity affects moth development; CHROMEX-05, fifth in series designed to examine effects of microgravity on physiological processes in plants. Previous CHROMEX flights have shown that plants grown in space may not produce seed embryos; CHROMEX-05 designed to show whether infertility is due to microgravity or another environmental factor. Also in middeck: Cosmic Radiation Effects and Activation Monitor (CREAM), to collect data on cosmic rays; and Military Applications of Ship Tracks (MAST), part of five-year Navy effort to study effects of ships on marine environment.

Problems included a missing tile around overhead window; suspect temperature sensor on orbiter Reaction Control System (RCS) vernier thruster, which led to temporary cessation of SRL-2 radar observations; and failed primary RCS thruster.

STS-66

(ATLAS-3; CRISTA-SPAS)

Atlantis
Pad B
66th Shuttle mission
13th flight OV-104
(first since STS-46, 1992)
Diverted landing

Crew:

Donald R. McMonagle, Mission Commander
Curtis L. Brown Jr., Pilot
Ellen Ochoa, Payload Commander
Joseph R. Tanner, Mission Specialist
Scott E. Parazynski, Mission Specialist
Jean-Francois Clervoy, Mission Specialist (European Space Agency)

Orbiter Preps (move to):

OPF — May 30, 1994
VAB — Oct. 3, 1994
Pad — Oct. 10, 1994

Launch:

November 3, 1994, 11:59:43 a.m. EST. Launch set for 11:56 a.m. was delayed slightly while Shuttle managers assessed weather at transoceanic abort landing sites. Liftoff was Atlantis' first since an extended checkout and modification period at Rockwell plant in Palmdale (departed KSC October 1992 and returned May 1994). Orbiter returned to KSC outfitted with improved nosewheel steering, internal plumbing and electrical connections to accommodate an Extended Duration Orbiter pallet, and electrical wiring to enable OV-104 to be fitted with Orbiter Docking System for docking with Russian Space Station Mir.

Landing:

November 14, 1994, 7:33:45 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 7,657 feet (2,334 meters). Rollout time: 49 seconds. Mission duration: 10 days, 22 hours, 34 minutes, two seconds. Landed revolution 174. Landing diverted to California due to high winds, rain and clouds in Florida caused by Tropical Storm Gordon. Fourth diverted landing in 1994 and third in a row.

Mission Highlights:

STS-66 further advanced comprehensive effort to collect data about sun's energy output, chemical makeup of the Earth's middle atmosphere, and how these factors affect global ozone levels. Seven instruments on the Atmospheric Laboratory for Applications and Science-3 (ATLAS-3) also flew on first two ATLAS flights. No other collection of space-based instruments provides same extensive range of atmospheric measurements. Also considered a primary payload was the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite (CRISTA-SPAS), continuing joint NASA-German Space Agency (DARA) series of scientific missions. ATLAS-3 and CRISTA-SPAS considered as joint mission with single set of science objectives. During mission, crew divided into two teams for around-the-clock research.

ATLAS-3 instruments, mounted on a Spacelab pallet in cargo bay, included Atmospheric Trace Molecule Spectroscopy (ATMOS), which collected more data on trace gases in the atmosphere than on all three of its previous flights combined; Shuttle Solar Backscatter Ultraviolet Spectrometer (SSBUV), which took ozone measurements to calibrate ozone monitor on aging NOAA-9 satellite as well as cooperative measurements with other ATLAS-3 instruments; Active Cavity Radiometer Irradiance Monitor (ACRIM), which took extremely precise measurements of the sun's total radiation for 30 orbits as calibration reference for sister instrument on Upper Atmosphere Research Satellite (UARS) launched in 1991; Measurement of the Solar Constant (SOLCON), provided by Belgium, which also measured solar radiation but as reference point to track changes over years; Solar Spectrum Measurement (SOLSPEC), French instrument, measured sun's radiation as function of wavelength; and Solar Ultraviolet Spectral Irradiance Monitor (SUSIM), which collected its highest precision solar ultraviolet radiation measurements in its 15-year lifetime. Millimeter Wave Atmospheric Sounder (MAS), collected nine hours of observations, measuring distribution of water vapor, chlorine monoxide and ozone at altitudes between 12 and 60 miles (20-100 kilometers), before computer malfunction halted instrument operations.

CRISTA-SPAS released from orbiter's Remote Manipulator System arm on second day of mission. Flying at distance of about 25-44 miles (40-70 kilometers) behind Shuttle, payload collected data for more than eight days before being retrieved and returned to cargo bay. CRISTA instrument gathered first global information about medium- and small-scale disturbances in trace gases in middle atmosphere, which could lead to better models of the atmosphere and Earth's energy balance. Second CRISTA-SPAS instrument, the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) measured amounts of ozone-destroying hydroxyl and nitric oxide in the middle atmosphere and lower thermosphere from 24-72 miles (40-120 kilometers). MAHRSI yielded first complete global maps of hydroxyl in atmosphere.

For retrieval of CRISTA-SPAS, different approach method to spacecraft was successfully tested as prelude to upcoming U.S. Shuttle/Russian Space Station Mir docking flights. Called R-Bar approach, it is expected to save propellant while reducing risk of contamination to Mir systems from orbiter thruster jet firings.

1995

STS-63

(SPACEHAB-3; Mir rendezvous)

Discovery
Pad B
67th Shuttle mission
20th flight OV-103
Night launch
1st approach/flyaround with Mir
1st female Shuttle pilot
2nd Russian cosmonaut on U.S. Shuttle
22nd KSC landing

Crew:

James D. Wetherbee, Mission Commander (3rd Shuttle flight)*
Eileen M. Collins, Pilot (1st)
Bernard A. Harris Jr., Payload Commander (2nd)
C. Michael Foale, Mission Specialist (3rd)
Janice Voss, Mission Specialist (2nd)
Vladimir G. Titov, Mission Specialist (3rd spaceflight; 1st Shuttle) (Russian Aviation and Space Agency)

Orbiter Preps (move to):

OPF — Sept. 28, 1994
VAB — Jan. 5, 1995
Pad — Jan. 10, 1995

Launch:

February 3, 1995, 12:22:04 a.m. EST. Adjustments made to countdown sequence to better accommodate short five-minute window required for rendezvous with Mir, including adding more hold time at T-6 hours and T-9 minutes. Launch first scheduled for Feb. 2 postponed at L-1 when one of three inertial measurement units on orbiter failed. Countdown Feb. 3 proceeded smoothly. Launch marked first at 51.6-degree-inclination to the equator to put orbiter in line with Mir, also at 51.6-degree inclination.

Landing:

February 11, 1995, 6:50:19 a.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 11,008 feet (3,355 meters). Rollout time: one minute, 20 seconds. Mission duration: eight days, six hours, 28 minutes, 15 seconds. Landed revolution 129. First end-of-mission landing since runway was resurfaced in fall 1994 to decrease wear on orbiter tires and increase crosswind tolerances. After landing, cosmonauts aboard Mir radioed their congratulations to Discovery crew. Discovery became first orbiter in fleet to complete 20 missions. OV-103 transferred to Orbiter Processing Facility later same day.

Mission Highlights:

First Shuttle flight of 1995 included several history-making achievements: First flight of a female Shuttle pilot and, as part of Phase I of International Space Station program, second flight of Russian cosmonaut on Shuttle and first approach and flyaround by Shuttle with Russian Space Station Mir.

Beginning on flight day one, series of thruster burns performed daily to bring Discovery in line with Mir. Original plan called for orbiter to approach to no closer than 10 meters, or 32.8 feet, from Mir, and then complete flyaround of Russian space station. However, three of 44 orbiter Reaction Control System (RCS) thrusters — small firing jets used for on-orbit maneuvering — sprang leaks prior to rendezvous. Shortly after main engine cutoff, two leaks occurred in aft primary thrusters, one of which — called R1U — was key to rendezvous. Third leak occurred later in flight in forward primary thruster, but crew was able to fix problem.

After extensive negotiations and technical information exchanges between U.S. and Russian space teams, Russians concluded close approach could be safely achieved and STS-63 crew given 'go' to proceed. R1U thruster manifold was closed and backup thruster selected for approach. Ship-to-ship radio contact with Mir achieved well ahead of time, and Titov, who lived on Mir for more than a year, communicated excitedly with three cosmonauts aboard space station: Mir 17 Commander Alexander Viktorenko; Flight Engineer Elena Kondakova; and Valery Polyakov, a physician who broke Titov's record for extended time in space. After stationkeeping at a distance of 400 feet (122 meters) from Mir and with Wetherbee manually controlling orbiter, Discovery flown to 37 feet from Russian space station. "As we are bringing our spaceships closer together, we are bringing our nations closer together," Wetherbee said after Discovery was at point of closest approach. "The next time we approach, we will shake your hand and together we will lead our world into the next millennium."

"We are one. We are human," Viktorenko responded. Wetherbee then backed away to 400 feet (122 meters) and performed one and a quarter-loop flyaround of Mir while station was filmed and photographed. The Mir crew reported no vibrations or solar array movement as result of the approach.

Crew also worked extensively with payloads aboard Discovery. Flying in forward payload bay and activated on flight day one was SPACEHAB-3. The commercially developed module was making its third flight on the Shuttle and carried 20 experiments: 11 biotechnology experiments; three advanced materials development experiments; four technology demonstrations; and two pieces of supporting hardware measuring on-orbit accelerations. Improvements made to SPACEHAB system to reduce demand on crew time. New video switch added to lessen need for astronaut involvement in video operations, and experiment interface added to telemetry system to allow experiment investigator to link directly via computer with onboard experiment to receive data and monitor status. Charlotte, an experimental robotic device being flown for first time, also will reduce crew workload by taking over simple tasks such as changing experiment samples.

Among plant growth experiments were Astroculture, flying for fourth time on Shuttle. Objective of Astroculture is to validate performance of plant growth technologies in microgravity environment of space for application to a life support system in space. Investigation has applications on Earth, since it covers such topics as energy-efficient lighting and removal of pollutants from indoor air. One of the pharmaceutical experiments, Immune, also has Earth applications. Exploiting known tendency of spaceflight to suppress immune system, Immune experiment tested ability of a particular substance to prevent or reduce this suppression. Clinical applications could include treatment of individuals suffering from such immunosuppressant diseases as AIDS.

On flight day two, crew deployed Orbital Debris Radar Calibration System-II (ODERACS-II) to help characterize orbital debris environment for objects smaller than 10 centimeters (about four inches) in diameter. Six target objects released into orbit and tracked by ground-based radars allow precise calibration of radars so they can more accurately track smaller pieces of space debris in low Earth orbit.

Also on flight day two, crew lifted with orbiter remote manipulator system arm the SPARTAN-204 from its support structure in payload bay. SPARTAN remained suspended on arm for observation of orbiter glow phenomenon and thruster jet firings. SPARTAN-204 later released from arm to complete about 40 hours of free-flight, during which time its Far Ultraviolet Imaging Spectrograph instrument studied celestial targets in the interstellar medium, the gas and dust which fills the space between the stars and which is the material from which new stars and planets are formed.

SPARTAN-204 also used for extravehicular activity (EVA) near end of flight. Foale and Harris began EVA suspended at end of robot arm, away from payload bay, to test modifications to their spacesuits to keep spacewalkers warmer in extreme cold of space. Two astronauts were then scheduled to practice handling approximately 2,500-pound (1,134-kilogram) SPARTAN to rehearse space station assembly techniques, but both astronauts reported they were becoming very cold — this portion of walk performed during a night pass — and mass handling curtailed. 29th Shuttle spacewalk lasted 4 hours, 38 minutes. Harris first African-American to walk in space.

Other payloads: Along with ODERACS-II, Cryo System Experiment (CSE) and Shuttle Glow (GLO-2) payloads were mounted on Hitchhiker support assembly in cargo bay; an IMAX camera also located here. In middeck, Solid Surface Combustion Experiment (SSCE) flew for eighth time. Air Force Maui Optical Site (AMOS) test requires no onboard hardware.

* Beginning in 1995, chronology includes spaceflight number crew member is embarking on.

STS-67

(ASTRO-2)

Endeavour

Pad A
68th Shuttle mission
8th flight OV-105
11th night launch
1st Internet linkup
Extended mission
Diverted landing

Crew:

Stephen S. Oswald, Mission Commander (3rd Shuttle flight)
William G. Gregory, Pilot (1st)
Tamara E. Jernigan, Payload Commander (3rd)
Wendy B. Lawrence, Mission Specialist/Flight Engineer (1st)
John M. Grunsfeld, Mission Specialist (1st)
Samuel T. Durrance, Payload Specialist (2nd)
Ronald Parise, Payload Specialist (2nd)

Orbiter Preps (move to):

OPF — Oct. 20, 1994
VAB — Feb. 2, 1995
Pad — Feb. 8, 1995

Launch:

March 2, 1995, 1:38:13 a.m. EST. After a smooth countdown, liftoff delayed for about a minute due to concerns about a heater system on the flash evaporator system. A backup heater was used and the countdown proceeded.

Landing:

March 18, 1995, 1:47:01 p.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,975 feet (3,040 meters). Rollout time: 59 seconds. Mission duration: 16 days, 15 hours, eight minutes, 48 seconds. Landed revolution 262. Orbiter diverted to Edwards after landing opportunities in Florida waved off on March 17 and earlier in day on March 18. Orbiter returned to Florida on March 27 and taken to Orbiter Processing Facility March 28.

Mission Highlights:

Endeavour logged 6.9 million miles (11 million kilometers) in completing longest Shuttle flight to date, allowing sustained examination of "hidden universe" of ultraviolet light. Primary payload, Astro Observatory, flown once before — on STS-35 in December 1990 — but second flight had almost twice the duration. Planned Astro-2 observations built on discoveries made by Astro-1, as well as seeking answers to other questions.

Astro-2 marked second flight of three ultraviolet telescopes flown on Astro-1, mounted on Instrument Pointing System on Spacelab pallet in cargo bay. Hopkins Ultraviolet Telescope (HUT), developed at The Johns Hopkins University, performs spectroscopy in far ultraviolet region of spectrum to identify physical processes and chemical composition of a celestial object. Improvements made to HUT after Astro-1 made it three times more sensitive. Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), built at University of Wisconsin, measures photometry and polarization of ultraviolet radiation from astronomical objects. Ultraviolet Imaging Telescope (UIT), sponsored by NASA's Goddard Space Flight Center, takes wide-field photographs of objects in ultraviolet light.

Crew began activating Astro-2 only hours after liftoff for around-the-clock observations. Observational sequences planned on daily basis in two-orbit, or three-hour blocks, with one telescope assigned priority. Astro-2 demonstrated benefits of human interaction in on-orbit astronomy. Besides being able to position orbiter most advantageously for observations, crew members also could manually acquire observation target if desired.

Astro-2 program aimed at exploring 23 different science programs, and all were achieved. HUT, considered complement to Hubble Space Telescope, completed more than 200 separate observations of more than 100 celestial objects. Investigators believed telescope collected enough data to meet its primary mission objective: detecting presence of intergalactic helium, telltale remnant of theoretical Big Bang explosion that began universe. HUT, in conjunction with Hubble telescope, took ultraviolet measurements of Jupiter's aurora; also studied Jupiter's moon Io, and Venusian and Martian atmospheres.

UIT cameras imaged about two dozen large spiral galaxies for inclusion in atlas of such galaxies, and made first ultraviolet images of entire moon. Also studied rare, hot stars that are 100 times as hot as sun; elliptical galaxies and some of faintest galaxies in universe. Investigators were disappointed upon developing UIT film to learn that one of its two cameras had malfunctioned undetected on orbit, but an initial assessment showed that 80 percent of science objectives still would be met.

WUPPE yielded a "treasure chest of data," according to its principal investigator, greatly expanding database on ultraviolet spectropolarimetry. Targets for study of interstellar medium included dust clouds in Milky Way and nearby galaxy, Large Magellanic Cloud. WUPPE also studied several types of stars, including Wolf-Rayet and Be stars. Also able to capitalize on opportunity to study three recently exploding novae.

STS-67 became first advertised Shuttle mission connected to Internet. Users of more than 200,000 computers from 59 countries logged on to Astro-2 home page at Marshall Space Flight Center; more than 2.4 million requests were recorded during mission, many answered by crew on-orbit.

Other payloads: Two Get Away Special canisters located in payload bay held Australian-built Endeavour telescope; also built to study ultraviolet realm, it achieved one hundred percent of pre-mission objectives. In-cabin payloads were Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Experiments-03 (CMIX-03), which featured an array of biomedical, pharmaceutical, biotechnology, cell biology, crystal growth and fluids science investigations, including one with potential for anti-colon cancer treatment. Protein Crystal Growth experiments included two setups in middeck lockers. Also flown was Middeck Active Control Experiment (MACE) to study how disturbances caused by a payload impacts another payload attached to same support structure.

Only on-orbit problem of note included a leaking Reaction Control System thruster that briefly delayed Astro-2 activities.

STS-71

(1st Mir docking)

Atlantis

Pad A
69th Shuttle mission
14th flight OV-104
100th U.S. human space launch
First Shuttle-Mir docking
23rd KSC landing

Crew:

Robert L. "Hoot" Gibson, STS-71 Mission Commander (5th Shuttle flight)
Charles J. Precourt, Pilot (2nd)
Ellen S. Baker, Payload Commander (3rd)
Gregory J. Harbaugh, Mission Specialist (3rd)
Bonnie J. Dunbar, Mission Specialist (4th)

Embarking to Mir — Mir 19 crew:
Anatoly Y. Solovyev, Mir 19 Commander (4th)
Nikolai M. Budarin, Mir 19 Flight Engineer (1st)

Returning from Mir — Mir 18 crew:
Vladimir N. Dezhurov, Mir 18 Commander (1st)
Gennady M. Strekalov, Mir 18 Flight Engineer (5th)
Norman E. Thagard, Mir 18 Cosmonaut Researcher and U.S. astronaut (5th Shuttle flight/1st Soyuz/Mir flight)

Orbiter Preps (move to):

OPF — Nov. 22, 1994
VAB — April 20, 1995
Pad — April 26, 1995

Launch:

June 27, 1995, 3:32:19 p.m. EDT. Launch was originally targeted for late May, but slipped into June to accommodate Russian space program activities necessary for first Space Shuttle/Mir Space Station docking, including series of spacewalks to reconfigure station for docking and launch of new Spektr module to Mir containing U.S. research hardware. Launch set for June 23 scrubbed when rainy weather and lightning prevented loading of external tank earlier that day. Second try June 24 scrubbed at T-9-minute mark, again due to persistent stormy weather in central Florida, coupled with short 10-minute launch window. Liftoff re-set for June 27, and final countdown proceeded smoothly.

Landing:

July 7, 1995, 10:54:34 a.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 8,364 feet (2,549 meters). Rollout time: 51 seconds. Mission duration: nine days, 19 hours, 22 minutes, 17 seconds. Landed revolution 153. Runway switched from 33 to 15 about 20 minutes before touchdown due to concerns of Chief Astronaut Robert Cabana, flying Shuttle Training Aircraft, about clouds blocking runway landing aids from view. After landing, President Clinton phoned congratulations to crew on successful mission and extended invitation to visit White House.

Mission Highlights:

STS-71 marked a number of historic firsts in human spaceflight history: 100th U.S. human space launch conducted from Cape; first U.S. Space Shuttle-Russian Space Station Mir docking and joint on-orbit operations; largest spacecraft ever in orbit; and first on-orbit changeout of Shuttle crew.

Docking occurred at 9 a.m. EDT, June 29, using R-Bar or Earth radius vector approach, with Atlantis closing in on Mir from directly below. R-bar approach allows natural forces to brake orbiter's approach more than would occur along standard approach directly in front of space station; also, R-bar approach minimizes number of orbiter jet firings needed for approach. Manual phase of docking began with Atlantis about a half-mile below Mir, with Gibson at controls on aft flight deck. Stationkeeping performed when orbiter was about 250 feet (76 meters) from Mir, pending approval from Russian and U.S. flight directors to proceed. Gibson then maneuvered orbiter to a point at about 30 feet (9 meters) from Mir before beginning final approach to station. Closing rate was close to targeted 0.1 feet (0.03 meters) per second and closing velocity was approximately 0.107 feet (0.03 meters) per second at contact. Interface contact was nearly flawless: less than one inch (2.54 centimeters) lateral misalignment and an angular misalignment of less than 0.5-degrees per axis. Docking occurred about 216 nautical miles (249 statute miles/399 kilometers) above Lake Baykal region of the Russian Federation. Orbiter Docking System (ODS) with Androgynous Peripheral Docking System served as actual connection point to a similar interface on the docking port on Mir's Krystall module. ODS located in forward payload bay of Atlantis, performed flawlessly during docking sequence.

When linked, Atlantis and Mir formed largest spacecraft ever in orbit, with a total mass of almost one-half million pounds (about 225 tons/226,800 kilograms) orbiting some 218 nautical miles above the Earth. After hatches on each side opened, STS-71 crew passed into Mir for welcoming ceremony. On same day, Mir 18 crew officially transferred responsibility for station to Mir 19 crew, and two crews switched spacecraft.

For next five days, about 100 hours total, joint U.S.-Russian operations conducted, including biomedical investigations, and transfer of equipment to and from Mir. Fifteen separate biomedical and scientific investigations were conducted, using Spacelab module installed in aft portion of Atlantis' payload bay, and covering seven different disciplines: cardiovascular and pulmonary functions; human metabolism; neuroscience; hygiene, sanitation and radiation; behavioral performance and biology; fundamental biology; and microgravity research. Mir 18 crew served as test subjects for investigations. Three Mir 18 crew members also carried out intensive program of exercise and other measures to prepare for re-entry into gravity environment after more than three months in space.

Numerous medical samples as well as disks and cassettes transferred to Atlantis from Mir, including more than 100 urine and saliva samples, about 30 blood samples, 20 surface samples, 12 air samples, several water samples and numerous breath samples taken from Mir 18 crew members. Also moved into orbiter was a broken Salyut-5 computer. Transferred to Mir were more than 1,000 pounds (454 kilograms) of water generated by the orbiter for waste system flushing and electrolysis; specially designed spacewalking tools for use by the Mir 19 crew during a spacewalk to repair a jammed solar array on the Spektr module; and transfer of oxygen and nitrogen from Shuttle's environmental control system to raise air pressure on the station, requested by Russians to improve Mir consumables margin.

Spacecraft undocked on July 4, following a farewell ceremony, with Mir hatch closing at 3:32 p.m. EDT, July 3, and hatch on Orbiter Docking System shut 16 minutes later. Gibson compared separation sequence to a "cosmic" ballet: Prior to Mir-Atlantis undocking, Mir 19 crew temporarily abandoned station, flying away from it in their Soyuz spacecraft so they could record images of Atlantis and Mir separating. Soyuz unlatched at 6:55 a.m. EDT, and Gibson undocked Atlantis from Mir at 7:10 a.m. EDT.

Returning crew of eight equaled largest crew (STS 61-A, October 1985) in Shuttle history. To ease their re-entry into gravity environment after more than 100 days in space, Mir 18 crew members Thagard, Dezhurov and Strekalov lay supine in custom-made Russian seats installed prior to landing in orbiter middeck.

Inflight problems included a glitch with general purpose computer 4 (GPC 4), which was declared failed when it did not synchronize with GPC 1; subsequent troubleshooting indicated it was an isolated event, and GPC 4 operated satisfactorily for remainder of mission.

STS-70

(TDRS-G)

Discovery

Pad B
70th Shuttle mission
21st flight OV-103
9th rollback
First use new Mission Control Center, JSC
Last TDRS deployed from Shuttle
Extended mission
24th KSC landing
Quickest turnaround landing (STS-71) to launch (STS-70)

Crew:

Terence "Tom" Henricks, Commander (3rd Shuttle flight)
Kevin R. Kregel, Pilot (1st)
Nancy Jane Currie, Mission Specialist (2nd)
Donald A. Thomas, Mission Specialist (2nd)
Mary Ellen Weber, Mission Specialist (1st)

Orbiter Preps (move to):

Flow A:
OPF — 2/11/95
VAB — 5/03/95
Pad — 5/11/95
Flow B (rollback):
VAB — 6/8/95
Pad — 6/15/95

Launch:

July 13, 1995, 9:41:55 a.m. EDT. Liftoff first targeted for June 22, after STS-71 Shuttle-Mir docking mission scheduled earlier same month. However, due to Russian space program scheduling delays affecting STS-71, mission managers opted to flip-flop 70 and 71 launch dates, and accelerated processing flow to ready Discovery and her payloads for liftoff no earlier than June 8, with Atlantis to follow on STS-71 later in June. This schedule thrown off following extended Memorial Day holiday weekend, when Northern Flicker Woodpeckers at Pad 39B poked about 200 holes in foam insulation of Discovery's external tank. Attempts to repair damage at pad were unsuccessful, and Shuttle stack returned to VAB on June 8, with new launch date set for July 13. Holes ranged in size from large excavations about four inches (10 centimeters) to single pecks and claw marks. Countdown to July 13 liftoff proceeded smoothly; brief 55-second hold at T-31 seconds occurred when engineers had to verify signal from range safety system was being properly received by destruct device on external tank. Interval between landing of STS-71 on July 7 and launch of STS-70 six days later on July 13 marked quickest turnaround to date between Shuttle missions. Post-landing inspection of STS-70 boosters showed gas path in right-hand solid rocket motor nozzle internal joint number 3, extending from the motor chamber to, but not past, the primary O-ring. STS-70 gas path similar to what was seen in nozzle joint number 3 post-flight on previous mission, STS-71. Gas paths or small air pockets are result of nozzle fabrication involving backfilling of the joint with insulation material. Similar paths had been expected and observed following previous flights, but Missions STS-71 and STS-70 marked first time slight heat effect was noted on the primary O-ring.

Landing:

July 22, 1995, 8:02:00 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,465 feet (2,580 meters). Rollout time: 57 seconds. Mission duration: Eight days, 22 hours, 20 minutes, five seconds. Landed revolution 143. First landing opportunities on July 21 at KSC waved off due to fog and low visibility. First opportunity on July 22 at KSC also waved off. STS-70 was Discovery's final flight prior to being shipped to California for periodic refurbishment and modification. OV-103 departed Sept. 27 atop Shuttle Carrier Aircraft for Rockwell facility in Palmdale; was to return to KSC in July 1996. Next flight will be second Hubble Space Telescope servicing flight in early 1997.

Mission Highlights:

Primary objective of mission accomplished when Tracking and Data Relay Satellite-G deployed from orbiter payload bay about six hours after liftoff. Approximately one hour after deployment, Inertial Upper Stage (IUS) booster attached to TDRS-G completed first of two scheduled burns to place TDRS-G in geosynchronous orbit. Once it completes on-orbit checkout, TDRS-G will become operational spare, completing existing TDRS network of advanced tracking and communications satellites.

During remainder of mission, five crew members completed variety of experiments. Biological Research in Canister (BRIC) experiments study effects of microgravity on wide range of physiological processes in plants, insects and small invertebrate animals. BRIC-4 examined how hormone system and muscle formation of tobacco hornworm affected by microgravity; BRIC-5 tested whether cell division changes in daylily are due to microgravity or other causes. Also, Bioreactor Development System (BDS), composed of device developed at Johnson Space Center, used colon cancer cells to test bioreactor performance in microgravity; this experiment worked extremely well, yielding tissue cultures better than any seen previously.

National Institutes of Health-R-2 featured suite of experiments examining how microgravity affects different aspects of rodent pre- and post-natal development.

Commercial Protein Crystal Growth (CPCG) experiment featured Protein Crystallization Facility (PCF) on its eighth flight. On STS-70, crystals of alpha interferon protein — used to treat human viral hepatitis B and C — were grown.

Other experiments: Space Tissue Loss-B (STL-B), studying effect of microgravity on embryogenesis; and Hand-Held, Earth-Oriented, Cooperative, Real-Time, User-Friendly, Location Targeting and Environmental System (HERCULES), a space-based geolocating system that features video camera and electronic still camera to document locations on Earth and tag every frame with latitude and longitude to within three nautical miles. Crew had difficulty at first aligning HERCULES camera, but eventually obtained 95% of planned photographic targets.

Also, Microencapsulation in Space-B (MIS-B), making its second flight aboard the Shuttle. MIS-B designed to produce better microencapsulated antibiotic; this type of antibiotic has proven extremely effective in treating wound infections, as it releases antibiotic at precise and predictable rate to cure infection. First flight of MIS-B yielded purer microcapsules than could be obtained on Earth, but only a small quantity was produced. Researchers hoped second flight of MIS-B on STS-70 would yield greater quantity of antibiotic.

Midcourse Space Experiment (MSX) required no onboard hardware; military MSX satellite used Shuttle during mission as tracking and calibration target. Military Applications of Ship Tracks (MAST) required crew to photograph ship tracks as part of effort to determine how pollutants generated by ships modify reflective properties of clouds. Radiation Monitoring Equipment-III (RME-III) is prototype dosimeter instrument which has been flying on Shuttle since STS-31, and measures exposure to ionizing radiation on Shuttle; data from RME-III is archived and used to update and refine models of space radiation environment in low-Earth orbit.

Objective of Window Experiment (WINDEX), another military experiment, is to gain understanding of chemistry and dynamics of low- Earth orbit by collecting variety of data about such phenomena as Shuttle thruster plumes, water dumps and atmospheric nightglow.

Visual Function Tester-4 (VFT-4) designed to gain better understanding of whether astronauts' vision is affected by microgravity. VFT-4 instrument measures eyesight at near- and close range to test theories on what happens to human eye in space. Astronauts since Gemini days in early '60s have noticed that in space it takes

longer to adjust and focus on near objects, and STS-70 crew confirmed this observation.

Crew also spoke with ground radio operators as part of Shuttle Amateur Radio Experiment (SAREX), counting around 50 contacts a day for several days of flight.

No significant problems were experienced with the orbiter. STS-70 marked first flight of new Block I main engine featuring new high-pressure liquid oxidizer turbopump built by Pratt & Whitney. Engine 2036 flew in number one position; other two main engines were of existing Phase II design.

STS-69

(SPARTAN 201-03; WSF-2)

Endeavour

Pad A
71st Shuttle mission
9th flight OV-105
10th rollback
25th KSC landing

Crew:

David M. Walker, Commander
(4th Shuttle flight)
Kenneth D. Cockrell, Pilot (2nd)
James S. Voss, Payload Commander (3rd)
Michael L. Gernhardt, Mission Specialist (1st)
James H. Newman, Mission Specialist (2nd)

Orbiter Preps (move to):

OPF — March 28, 1995
VAB — June 28, 1995
Pad — July 6, 1995
VAB (rollback) — Aug. 1 (due to Hurricane Erin)
Pad — Aug. 8

Launch:

September 7, 1995, 11:09:00 a.m. EDT. Launch originally set for Aug. 5 postponed indefinitely to allow further review of solid rocket motor nozzle joint hardware from two previous missions, STS-70 and STS-71 (See also STS-70 chronology entry). Inspection team formed to assess significance of gas path in nozzle internal joint number 3, extending from insulation in the motor chamber to, but not past, primary O-ring, and resulting in slight heat effect to primary O-ring seal. Team concluded nozzle joint design was sound and that gas paths were being created when insulation material, known as RTV or Room Temperature Vulcanizing, was applied. Small air pockets were forming in thermal insulation that could later become pathways for hot gas during motor operation. Attention then focused on developing procedures to allow Non-Destructive Evaluation (NDE) inspection of insulation material on specific joints as well as testing repair techniques. Repairs were completed on STS-69 nozzle joint insulation at the pad and new launch date of Aug. 31 set. Nozzle joint insulation on boosters assigned to Missions STS-73 and STS-74 also repaired at KSC, but work did not impact schedule. Aug. 31 launch try was scrubbed about five and a half hours before liftoff due to failure of one of orbiter's three fuel cells. Fuel cell No. 2 indicated higher than allowable temperatures during activation as countdown proceeded. Fuel cell was removed and replaced. Liftoff on Sept. 7 was preceded by a smooth countdown.

Landing:

September 18, 1995, 7:37:56 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 10,230 feet (3,118 meters). Rollout time: 56 seconds. Mission duration: 10 days, 20 hours, 28 minutes, 56 seconds. Landed revolution 171. Landing occurred on the first opportunity at KSC.

Mission Highlights:

STS-69 marked first time two different payloads were retrieved and deployed during same mission. Also featured an extravehicular activity to practice for International Space Station activities and to evaluate space suit design modifications.

First of two primary payloads, Spartan 201-03, deployed on flight day two. This was third Spartan 201 mission in planned series of four. Primary objective was to study outer atmosphere of sun and its transition into solar wind that constantly flows past Earth. Timing of Spartan 201-03 flight intended to coincide with passage of the Ulysses spacecraft over the sun's north polar region to expand range of data being collected about origins of solar wind. Spartan 201-03 configuration featured two scientific instruments, the Ultraviolet Coronal Spectrometer (UVCS) and the White Light Coronagraph (WLC). UVCS measured characteristics of light emitted by neutral hydrogen atoms in the solar corona, the outermost portion of the sun's atmosphere from which the solar wind evolves. The WLC imaged the changing shape and form of the corona.

Concerns arose about performance of the two instruments when Spartan was retrieved after about two days of data-gathering. As orbiter approached free-flying spacecraft, it was rotating slowly and located in a different attitude than expected for retrieval. However, later analysis confirmed UVCS and WLC operated smoothly, with WLC obtaining good data over 95 percent of planned observing sequence and UVCS preliminary data found to be excellent. Analysis was under way to determine why Spartan behaved as it did prior to retrieval.

Second primary payload, Wake Shield Facility-2 (WSF-2) deployed on flight day five and became first spacecraft to maneuver itself away from orbiter rather than other way around, by firing small cold gas nitrogen thruster to maneuver away from Endeavour. WSF-2 second in planned series of four flights. WSF is a 12-foot-(3.7-meter) diameter stainless steel disk designed to generate an ultravacuum environment in space within which to grow thin films for next generation advanced electronics.

Seven planned thin film growth runs planned, but after three successful growths, WSF-2 placed itself in safe mode. Mission planners decided to extend WSF-2 flying time by about 24 hours to allow all seven thin film growths to be performed. However, as preparations began to resume operations after a 20-hour hiatus, payload controllers on the ground could not trigger the flow of thin film material and the WSF-2 was once again shut down. Film growth activities resumed after a six-hour cool-down of the WSF-2 instruments, and when spacecraft was retrieved on flight day eight, four successful thin film growth runs had been completed.

WSF-2 unberthed and hung over side of Endeavour's cargo bay one final time for Charging Hazards and Wake Studies (CHAWS) experiment, an Air Force-sponsored experiment to collect data on buildup of electrical fields around an orbiting space vehicle.

On flight day ten, Voss and Gernhardt conducted six-hour, 46-minute spacewalk, completing final primary objective of STS-69. They evaluated thermal improvements made to their extravehicular activity suits and reported they remained comfortable, and also tested variety of tools and techniques that may be used in assembly of International Space Station.

Additional payloads: International Extreme Ultraviolet Hitchhiker (IEH-1), to measure and monitor long-term variations in magnitude of absolute extreme ultraviolet flux coming from sun; Solar Extreme Ultraviolet Hitchhiker (SEH), to accurately measure solar flux in the extreme ultraviolet region of solar spectrum; and Consortium for Materials Development in Space Complex Autonomous Payload (CONCAP IV-3), third flight of an experiment that studies growth of organic nonlinear optical crystals and thin films.

Also Shuttle GLO Experiment (GLO-3) to study luminous shroud

observed by astronauts on previous Shuttle missions; Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR), pair of telescopes that measure extreme ultraviolet and far ultraviolet emissions and complemented SEH described above; Capillary Pumped Loop/Get Away Special Bridge Assembly (CAPL-2/GBA) consisting of CAPL-2 Hitchhiker payload, Thermal Energy Storage-2 (TES-2) payload in a GAS container as well as four other GAS experiments on single cross-bay structure.

In-cabin payloads included Space Tissue Loss/National Institutes of Health-Cells (STL-NIH-C); Commercial Generic Bioprocessing Apparatus-7 (CGBA); Biological Research in Canister (BRIC); Electrolysis Performance Improvement Concept Study (EPICS) and Commercial MDA ITA Experiments (CMIX-4).

STS-69 also was second flight of a "dog crew," a flight crew tradition that began on STS-53, on which both Walker and Voss flew. As the Dog Crew II, each STS-69 astronaut adopted a dogtag or nickname: Walker was Red Dog; Cockrell was Cujo; Voss, Dog Face; Newman, Pluto, and Gernhardt, Under Dog.

STS-73

(USML-2)

Columbia

Pad B
72nd Shuttle mission
18th flight OV-102
26th KSC landing
Extended mission

Crew:

Kenneth D. Bowersox, Mission Commander (3rd)
Kent V. Rominger, Pilot (1st)
Kathryn C. Thornton, Payload Commander (4th)
Catherine G. Coleman, Science Mission Specialist (1st)
Michael E. Lopez-Alegria, Mission Specialist (1st)
Fred W. Leslie, Payload Specialist (1st)
Albert Sacco Jr., Payload Specialist (1st)

Orbiter Preps (move to):

VAB (temporary storage) — April 14, 1995
OPF — April 21, 1995
VAB — Aug. 22, 1995
Pad — Aug. 28, 1995

Launch:

October 20, 1995, 9:53:00 a.m. EDT. A successful launch after six scrubs tied STS-73 with STS 61-C (Jan. 12-18, 1986) for most number of launch scrubs. 1). Liftoff originally set for Sept. 25 was scrubbed shortly after tanking began, when hydrogen leak was detected in main engine no. 1 main fuel valve. Valve replaced at pad. 2). Launch re-set for Oct. 5, but weather effects due to Hurricane Opal led to L-1 day decision to postpone launch one day to Oct. 6. 3). Oct. 6 launch attempt scrubbed prior to external tank loading when it was determined that hydraulic fluid had been inadvertently drained from hydraulic system 1 following the main engine no. 1 fuel valve replacement. Compressibility test demonstrated system was satisfactory for launch, and liftoff re-set to occur Oct. 7. 4). Launch attempt Oct. 7 scrubbed at T-20 seconds when master events controller 1 (MEC 1) failed to operate properly and mission managers determined it needed to be replaced. Launch re-set for Oct. 14 was then 5). re-scheduled to Oct. 15 to allow additional time to inspect the main engine oxidizer ducts as a result of finding a crack in a test engine oxidizer duct at Stennis. Also during this delay, a faulty general purpose computer 1 (GPC 1) had to be replaced. 6). Launch attempt Oct. 15 postponed at T-5 minutes due to low clouds and rain. Launch tentatively re-set to Oct. 19 pending successful Atlas launch Oct. 18; however, Atlas launch was delayed and STS-73 launch moved to Oct. 20. Countdown to liftoff Oct. 20 was delayed three minutes due to range computer glitch.

Landing:

November 5, 1995, 6:45:21 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,032 feet (2,753 meters). Rollout time: 55 seconds. Mission duration: 15 days, 21 hours, 52 minutes, 28 seconds. Landed revolution 256. Landing occurred on first opportunity at KSC. STS-73 became second longest Shuttle flight.

Mission Highlights:

STS-73 marked second flight of U.S. Microgravity Laboratory (USML) and built on foundation of its predecessor, which flew on Columbia during Mission STS-50 in 1992. Research during USML-2 concentrated within same overall areas of USML-1, with many experiments flying for second time. Crew divided into two teams to work around the clock in 23-foot (seven-meter) long Spacelab module located in Columbia's payload bay.

Research was conducted in five areas: Fluid physics; materials science; biotechnology; combustion science; and commercial space processing. USML-2 activities were directed by NASA's Spacelab Mission Operations Control facility at Marshall Space Flight Center.

Experiments went smoothly. In some cases, results re-confirmed existing theories, while in other cases results were new and unique. Highlights included unprecedented results from the Surface Tension Driven Convection Experiment, which flew for second time and studied in great detail basic fluid mechanics and heat transfer of thermocapillary flows, motions created within fluids by non-uniform heating of their free surfaces. Oscillations observed on USML-2 samples had never been observed on Earth, and researchers controlling experiment from the ground were able to pinpoint when fluid flows transitioned from stable to unstable. Research has direct applications on Earth, in that unwanted fluid flows during melting and resolidifying can create defects in high-tech crystals, metals, alloys and ceramics.

Flying for first time was Fiber Supported Droplet Combustion experiment. More than 25 droplets of variety of fuels were ignited, confirming theories about how fuels burn in microgravity. Results revealed larger droplet extension diameter — size of drop as it burns out — than are capable of being studied on Earth, with burning times 10 times longer. Data confirmed scientific predictions about burn rate and amount of fuel left over after fire goes out. This will allow investigators to refine theories and possibly develop new ones about byproducts such as soot and smog.

Five small potatoes were grown on-orbit from tubers in the Astroculture plant growth facility. USML-2 marked final test flight of Astroculture hardware, with unit set to become available commercially for sale or lease. Technologies incorporated in Astroculture hardware design already are finding application on Earth; for example, technology behind light-emitting diodes (LEDs) that provide high levels of light on-orbit within limited electrical power is finding its way into energy-efficient lighting systems for large-scale commercial plant nurseries. Successful on-orbit growth demonstrated Astroculture's usefulness as plant growth facility and showed edible foods could be grown in space.

Record number of Protein Crystal Growth (PCG) samples — around 1,500 — were flown on USML-2 and initial results indicated many had produced crystals which were further studied after landing. Other crystal growth experiments were equally successful. In the Crystal Growth Furnace, which flew for first time on USML-1, a crystal was grown for first time as a liquid bridge to minimize contact with container wall, thus decreasing number of defects in crystal. Eight semiconductor crystals were grown, also a very thin crystal and two crystals which could lead to products such as computer chips that are faster and use less power than traditional

computer chips.

Crew took time out from Spacelab work to tape ceremonial first pitch for Game Five of baseball World Series, marking first time the thrower was not actually in the ballpark for the pitch.

Orbiter Columbia performed without serious problems, with only notable glitch being two vernier thruster jets failing several times throughout mission; function was restored by cycling them on and off. Also, equipment failure at ground terminal for NASA's Tracking and Data Relay Communications (TDRS) satellites necessitated two extended communications outages between Columbia and Earth in order to perform repair.

STS-74

(2nd Mir docking)

Atlantis

Pad A
73rd Shuttle mission
15th flight OV-104
Shuttle/Mir Mission-2
27th KSC landing

Crew:

Kenneth D. Cameron, Commander (3rd Shuttle flight)
James D. Halsell Jr., Pilot (2nd)
Chris A. Hadfield, Mission Specialist (1st) (Canadian Space Agency)
Jerry L. Ross, Mission Specialist (5th)
William S. "Bill" McArthur Jr., Mission Specialist (2nd)

Orbiter Preps (move to):

OPF — July 7, 1995
VAB — Oct. 3, 1995
Pad — Oct. 12, 1995

Launch:

November 12, 1995, 7:30:43.071 a.m. EST. Planned rendezvous with Mir necessitated brief launch window of about seven minutes. Liftoff originally set for Nov. 11 was scrubbed due to unacceptable weather at the Transoceanic Abort Landing (TAL) sites. Countdown following day proceeded smoothly to on-time liftoff.

Landing:

November 20, 1995, 12:01:27 p.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,607 feet (2,623 meters). Rollout time: 57 seconds. Mission duration: eight days, four hours, 30 minutes, 44 seconds. Landed revolution 129.

Mission Highlights:

STS-74 marked second docking of U.S. Space Shuttle to Russian Space Station Mir, continuing Phase I activities leading to construction of International Space Station later this decade. Mission illustrated international flavor of space station effort: Shuttle crew included Hadfield, fourth Canadian to fly on Shuttle but first Canadian mission specialist. Hardware in payload bay included Canadian-built Remote Manipulator System (RMS) arm, U.S.-built Orbiter Docking System (ODS), Russian-built Docking Module and solar array and U.S.-Russian-built solar array. Awaiting Atlantis aboard Mir were two Russian cosmonauts and a German cosmonaut, along with Russian and European Space Agency research samples and equipment.

Unlike first docking flight during which crew exchange took place, second docking focused on delivery of equipment to Mir. Primary payload of mission was Russian-built Docking Module (DM), designed to become permanent extension on Mir to afford better clearances for Shuttle-Mir linkups. Two solar arrays were stowed on DM for later transfer to Mir by spacewalking cosmonauts.

On flight day three, Hadfield operated RMS robot arm to lift DM from stowed position in aft section of payload bay, rotated it to vertical, and moved it to within five inches above ODS in forward part of bay. ODS is being flown on all Shuttle-Mir docking flights and serves as passageway between two spacecraft. Cameron then fired downward steering jets to push Atlantis against DM. Once mating confirmed, robot arm ungrappled from DM, hatches between DM and ODS opened, and centerline camera mounted inside top hatch of DM.

On flight day four, Atlantis caught up with Mir. Terminal Phase Initiation (TI) burn started with Atlantis eight nautical miles (9.2 statute miles/14.8 kilometers) behind Mir to begin final phase of rendezvous. Air-to-air communications between Atlantis and Mir 20 crew began around this time also. Approach to Mir same as for STS-71, along the R-bar, with Atlantis closing in on station from directly below. Handheld lasers used by Shuttle crew during final approach to supplement distance and closing rates made by orbiter navigational equipment.

Manual phase of rendezvous began when Atlantis was about half-mile (804.7 meters) from Mir, with Cameron taking control of orbiter using aft flight deck controls. At 170 feet (51.8 meters) from Mir, Cameron halted approach while Mir was maneuvered into alignment for docking. After go from flight directors in Moscow and Houston, Cameron moved Atlantis to 30 feet (9.1 meters) from Mir, and then halted momentarily again to make final adjustments. Key camera for final approach was elbow camera on RMS arm.

Hatches between Mir and Atlantis were opened at 4:02 a.m. EST, Nov. 15. Control of DM transferred to Mir 20 crew commanded by Yuri Gidzenko and also including Flight Engineer Sergei Avdeyev and cosmonaut - Researcher Thomas Reighter of the European Space Agency. During mated operations, nearly 1,000 pounds (453.6 kilograms) of water transferred to Mir. Numerous experiment samples, including blood, urine and saliva, were moved to orbiter for return to Earth. Shuttle crew also brought up gifts, including Canadian maple sugar candies and a guitar (second guitar on Mir). Lithium hydroxide canisters — a late addition — were transferred to Mir in case faulty environmental control system failed again and station's air needed to be "scrubbed."

Two spacecraft separated at 4:15 a.m. EST, Nov. 18, after which flyaround of station was initiated when Atlantis was 400 feet (121.9 meters) away.

No significant problems occurred with orbiter or any of cargo bay equipment.

1996

STS-72

(SFU; OAST-Flyer)

Endeavour

Pad 39B
74th Shuttle mission
10th flight OV-105
28th KSC landing
Night launch and landing

Crew:

Brian Duffy, Commander (3rd Shuttle flight)
Brent W. Jett Jr., Pilot (1st)
Daniel T. Barry, Mission Specialist (1st)

Leroy Chiao, Mission Specialist (2nd)
Winston E. Scott, Mission Specialist (1st)
Koichi Wakata, Mission Specialist (1st) (National Space Develoment Agency of Japan)

Orbiter preps (move to):

OPF — Sept. 18, 1995
VAB — Nov. 30, 1995
Pad — Dec. 6, 1995

Launch:

January 11, 1996, 4:41:00 a.m. EST. Countdown to first Shuttle launch of year proceeded smoothly except for 23-minute delay due to communication glitches between various sites on ground, and to avoid potential collision with space debris.

Landing:

January 20, 1996, 2:41:41 a.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 8,770 feet (2,673 meters). Rollout time: 66 seconds. Mission duration: eight days, 22 hours, 1 minute, 47 seconds. Landed revolution 141. Endeavour returned to Florida on first opportunity.

Mission Highlights:

First Shuttle flight of 1996 highlighted by retrieval of a Japanese satellite, deployment and retrieval of a NASA science payload, and two spacewalks.

Mission Specialist Wakata operated remote manipulator system arm on flight day three to pluck Japanese Space Flyer Unit (SFU) from orbit, completing 10-month scientific mission involving almost a dozen experiments ranging from materials science to biological studies. SFU was launched aboard a Japanese H-2 rocket March 18, 1995 from Tanegashima Space Center. Both solar arrays on SFU had to be jettisoned prior to retrieval when sensors indicated improper latching following retraction.

On flight day four, Wakata again operated Endeavour's robot arm, this time to deploy Office of Aeronautics and Space Technology-Flyer (OAST-Flyer), sending experiment-laden platform on its way to a two-day free-flight at a distance of approximately 45 miles (72 kilometers) from the orbiter. OAST-Flyer comprised of Spartan platform holding four experiments: Return Flux Experiment (REFLEX) to test accuracy of computer models predicting spacecraft exposure to contamination; Global Positioning System (GPS) Attitude Determination and Control Experiment (GADACS), to demonstrate GPS technology in space; Solar Exposure to Laser Ordnance Device (SELODE) to test laser ordnance devices; and Spartan Packet Radio Experiment (SPRE), an amateur radio communications experiment. OAST-Flyer retrieved on flight day six, with Wakata again operating the remote manipulator system arm to retrieve the platform.

Two extravehicular activities (EVAs) conducted as part of continuing series to prepare for on-orbit construction of International Space Station. During first EVA on flight day five lasting 6 hours, nine minutes, Mission Specialists Chiao and Barry evaluated new portable work platform and a structure known as the rigid umbilical, which may be used on station to hold various fluid and electrical lines.

During second spacewalk on flight day seven, conducted by Chiao and Scott and lasting six hours, 53 minutes, portable work platform again evaluated. Also tested were a space station utility box designed to hold avionics and fluid line connects. Scott also tested spacesuit's warmth in severe cold up to minus 104 degrees F. (-75 degrees C.).

Additional cargo bay payloads: Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument flying for eighth time and designed to measure ozone concentrations in atmosphere. Also a Hitchhiker carrier holding Shuttle Laser Altimeter-01 (SLA-01)/Get Away Special (GAS) payload. SLA-01 first of four planned remote sensing flights to accurately measure distance between Earth's surface and orbiter; five other GAS canisters held variety of experiments.

In-cabin payloads: Physiological and Anatomical Rodent Experiment/National Institutes of Health-Rodents (PARE/NIH-R3), one in series of experiments designed to study effect of microgravity on rodent anatomy and physiology; Space Tissue Loss/National Institutes of Health-C (STL/NIH-C5) to validate models of microgravity's effects on bone, muscle and cells; Protein Crystal Growth-Single Locker Thermal Enclosure (PCG-STES) for growing high-quality protein crystals; and Commercial Protein Crystal Growth-8 (CPCG-8) payload, which featured crystal growth of new form of recombinant human insulin.

STS-75

(TSS-1R; USMP-3)

Columbia

Pad B
75th Shuttle mission
19th flight OV-102
Extended mission
29th KSC landing

Crew:

Andrew M. Allen, Mission Commander (3rd Shuttle flight)
Scott J. "Doc" Horowitz, Pilot (1st)
Franklin R. Chang-Diaz, Payload Commander (5)
Jeffrey A. Hoffman, Mission Specialist (5)
Maurizio Cheli, Mission Specialist (1st) (European Space Agency)
Claude Nicollier, Mission Specialist (2nd) (European Space Agency)
Umberto Guidoni, Payload Specialist (1st) (Italian Space Agency)

Orbiter Preps (move to):

OPF — Nov. 5, 1995
VAB — Jan. 23, 1996
Pad — Jan. 29, 1996

Launch:

February 22, 1996, 3:18:00 p.m. EST. Liftoff occurred on-time following smooth countdown. Six seconds after liftoff, crew reported left main engine chamber pressure tape meter was reading only 40 percent thrust instead of 104 percent prior to throttle-down. Mission controllers in Houston reported telemetry showed all three engines were performing nominally and there was no effect on the ascent phase Problem was later traced to a malfunctioning tape meter mechanism.

Landing:

March 9, 1996, 8:58:21 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,459 feet (2,578 meters). Rollout time: one minute, four seconds. Mission duration: 15 days, 17 hours, 40 minutes, 21 seconds. Landed revolution 252. Landing opportunities March 8 waved off due to unfavorable weather conditions. First KSC landing opportunity at KSC March 9 waved off, again due to weather.

Mission Highlights:

Re-flight of U.S./Italian Tethered Satellite System (TSS-1R) marred by loss of satellite on flight day three, although valuable scientific data was still gathered. Other primary payload, U.S. Microgravity Payload-3 (USMP-3), performed nominally. TSS considered primary payload at beginning of mission and USMP-3 primary following TSS operations.

TSS flew previously on Mission STS-46 in June 1992, but

mission curtailed due to jammed tether. TSS concept designed to study electrodynamics of a tether system in electrically charged portion of Earth's atmosphere called the ionosphere. Satellite provided by Italy and tether/deployer assembly U.S.-built. Twelve investigations — six NASA, five Italian Space Agency (ASI) and one U.S. Air Force — planned. Deployment of TSS-1R on STS-75 delayed one day to allow troubleshooting of onboard TSS computers by flight crew. Excellent scientific data was being gathered when tether snapped on flight day three as satellite was just short of full deployment of 12.8 miles (20.5 kilometers). Satellite immediately began speeding away from orbiter as a result of orbital forces and the crew was never in any danger. Reason for tether break not immediately clear and investigative board convened on ground to determine cause. Crew retracted deployer and remaining tether following day.

Meanwhile, scientists did gather useful data from curtailed deployment. Currents measured during deployment phase were at least three times greater than predicted by analytical modeling, and amount of power generated was directly proportional to the current. Tether voltages of as high as 3,500 volts were developed across the tether, and current levels of about 480 milliamps were achieved. Researchers also able to study how gas from satellite's thrusters interacts with ionosphere. Also collected first-time measurements of ionized shock wave around the TSS satellite, a phenomenon that cannot be studied in the laboratory and is difficult to mathematically model. Another first was collection of data on the plasma wakes created by moving body through electrically charged ionosphere. Some experiments conducted using free-flying satellite and attached tether before it re-entered Earth's atmosphere and broke up.

USMP-3, flying on Shuttle for third time, included U.S. and international experiments, all of which had flown at least once before: Advanced Automated Directional Solidification Furnace (AADSF), a crystal growth facility; Critical Fluid Light Scattering Experiment (Zeno), to study element Xenon at its critical point; Isothermal Dendritic Growth Experiment (IDGE), to study formation of dendrites, tree-shaped crystals that in metals manufacturing dictate final properties of material; Materials for the Study of Interesting Phenomena of Solidification on Earth and in Orbit (MEPHISTO) to study how metals solidify in microgravity using a furnace.

USMP-3 experiments conducted primarily through telescience, where principal investigators could control research from Marshall Space Flight Center's Spacelab Mission Operations Control Center. In MEPHISTO investigation, changes in microgravity environment caused by orbiter thruster firings were correlated with fluid flows in crystal sample. Also able to monitor point at which crystal sample underwent critical change during solidification process.

IDGE experiment yielded twice expected amount of data. Best images of dendrites ever transmitted were gathered. This also was first experiment controlled by principal investigator at a remote non-NASA site, foreshadowing types of research which will be conducted on International Space Station, where researchers may be based at universities.

Zeno allowed investigators to observe with unprecedented clarity behavior of Xenon at critical point, when it exists as both gas and liquid.

Space Acceleration Measurement Systems (SAMS) and Orbital Acceleration Research Experiment (OARE), both of which have flown previously, provided data about on-orbit environment. In middeck, crew worked with Middeck Glovebox Facility (MGBX) featuring three combustion experiments, all of which were successful. Glovebox and Forced Flow Flamespreading Test experiment, both slated to fly on Russian Space Station Mir later this year, and glovebox also will fly on International Space Station. Also flying in middeck was Commercial Protein Crystal Growth (CPCG-09) experiment to process nine proteins into crystals to better understand their molecular structure.

STS-76

(3rd Mir docking; SPACEHAB)

Atlantis

Pad B
76th Shuttle mission
16th flight OV-104
3rd Shuttle-Mir docking
Night launch
Extended mission
Diverted landing

Crew:

(Six up, five down)
Kevin P. Chilton, Mission Commander (3rd Shuttle flight)
Richard A. Searfoss, Pilot (2nd)
Ronald M. Sega, Payload Commander (2nd)
Michael Richard "Rich" Clifford, Mission Specialist (3rd)
Linda M. Godwin, Mission Specialist (3rd)

Embarking to Mir — Mir 21 crew member:
Shannon W. Lucid, Mission Specialist and Cosmonaut Researcher (5th Shuttle, 1st Mir)

Orbiter Preps (move to):

OPF — Nov. 20, 1995
VAB — Feb. 19, 1996
Pad — Feb. 28, 1996

Launch:

March 22, 1996, 3:13:04 a.m. EST. Launch set for March 21 pending resolution of issue concerning wiper O-rings on nozzle-to-case joints on both Redesigned Solid Rocket Motors (RSRMs) flown on previous mission, STS-75. Different situation from STS-71/STS-70 O-ring issue that occurred in 1995 and affected nozzle internal joint. STS-75 gas paths went through polysulfide adhesive to, but not past, wiper O-ring on nozzle-to-case joints. Similar gas paths observed on previous missions, but STS-75 marked first time two different gas paths observed in one nozzle-to-case joint, and on both RSRMs. After review, managers concluded nozzle-to-case joint design was robust and safe to fly, and launch preparations proceeded. First launch attempt set for March 21 scrubbed prior to commencement of tanking operations March 20, due to concerns about high winds. Launch reset for March 22 proceeded smoothly to on-time liftoff. During ascent, leak occurred in hydraulic system powered by Auxiliary Power Unit (APU) number 3. Leak stopped after hydraulic system shutdown on-orbit. Mission managers concluded system would remain stable and proceeded with plans for full-duration mission.

Landing:

March 31, 1996, 5:28:57 a.m. PST, Runway 22, Edwards Air Force Base, Calif. Rollout distance: 8,357 feet (2,547 meters). Rollout time: 55 seconds. Mission duration: nine days, five hours, 15 minutes, 53 seconds. Landed revolution 145. Mission managers re-scheduled landing from March 31 to March 30 in anticipation of rain and clouds at KSC landing site, but landing attempts at KSC March 30 and 31 waved off due to weather before orbiter finally diverted to California. More conservative weather criteria employed for landing due to leak in APU number 3 hydraulic system and special measures taken during re-entry to minimize use of this particular APU. Following waveoff March 30, payload bay door reopening process interrupted when release indicators for payload bay door centerline latches 9 through 12 on both sides failed to indicate release, suggesting latches had not operated properly. Astronauts ventured into SPACEHAB module in aft payload bay to visually inspect the latches, which appeared to have opened as

intended. Crew used manual mode to complete opening of doors without further incident, and glitch attributed to microswitches. Also, during prelanding preparations, three of 38 Reaction Control System (RCS) thrusters failed, but backup thrusters were available to perform same functions. Not considered a night landing because it occurred 11 minutes before sunrise; flight rules define night launch/landing as one occurring no earlier than 15 minutes after sunset and no later than 15 minutes before sunrise.

Mission Highlights:

Third linkup between U.S. Space Shuttle and Russian Space Station Mir highlighted by transfer of veteran astronaut Shannon Lucid to Mir to become first American woman to live on station. Her stay on Mir kicked off continuous U.S. presence in space for next two years.

Payload bay configuration included Orbiter Docking System in forward area and SPACEHAB single module toward the aft. STS-76 marked first flight of SPACEHAB pressurized module to support Shuttle-Mir dockings; single module primarily served as stowage area for large supply of equipment slated for transfer to space station, but also carried European Space Agency's Biorack experiment rack for on-orbit research.

Atlantis hooked up with Mir on flight day 3, following same R-bar approach employed on STS-74. Actual connection between Orbiter Docking System and Docking Module attached to Kristall module docking port occurred at 9:34 p.m. EST, March 24. Hatches opened a little less than two hours later. Awaiting Atlantis' arrival were Mir 21 Commander Yuri Onufrienko and Flight Engineer Yuri Usachev, who were launched to Mir on Feb. 21. In August, they were joined by Mir 22 Commander Gennady Manakov, Flight Engineer Pavel Vinogradov and French Space Agency cosmonaut researcher Claudie Andre-Deshays. After two-week stay Andre-Deshays returned to Earth with Onufrienko and Usachev while Manakov and Vinogradov remained on board with Lucid.

During five days of docked operations, about 1,500 pounds (680 kilograms) of water and two tons of scientific equipment, logistical material and resupply items transferred to Mir; experiment samples and miscellaneous equipment brought over to orbiter. In Biorack, 11 separate scientific investigations were conducted. Study topics included effect of microgravity and cosmic radiation on plants, tissues, cells, bacteria and insects and effects of microgravity on bone loss. Also transferred to station were Mir Glovebox Stowage (MGBX) equipment to replenish glovebox already on station; Queen's University Experiment in Liquid Diffusion (QUELD) flown in orbiter middeck locker; and High Temperature Liquid Phase Sintering (LPS) experiment.

On flight day six, Godwin and Clifford conducted first U.S. extravehicular activity (EVA) around two mated spacecraft. During 6:02:28 EVA, they attached four Mir Environmental Effects Payload (MEEP) experiments to station's Docking Module. Experiments designed to characterize environment around Mir over an 18-month period. Two spacewalkers wore Simplified Aid For EVA Rescue (SAFER) propulsive devices first flight-tested during STS-64.

Other payloads: Shuttle Amateur Radio Experiment (SAREX); KidSat, a project that gives middle school students opportunity to participate in space exploration; and Trapped Ions in Space (TRIS), a Naval Research Laboratory experiment flown in Get Away Special canister in cargo bay.

STS-77

(SPACEHAB; SPARTAN (IAE))

Endeavour

Pad B
77th Shuttle mission
11th flight OV-105
30th KSC landing

Crew:

John H. Casper, Commander (4th Shuttle flight)
Curtis L. Brown Jr., Pilot (3rd)
Andrew S. W. Thomas, Mission Specialist (1st)
Daniel W. Bursch, Mission Specialist (3rd)
Mario Runco Jr., Mission Specialist (3rd)
Marc Garneau, Mission Specialist (2nd) (Canadian Space Agency)

Orbiter Preps (move to):

OPF — Sept. 18, 1995
VAB — April 8, 1996
Pad — April 16, 1996

Launch:

May 19, 1996, 6:30:00 a.m. EDT. Original launch date of May 16 changed to May 19 due to Eastern Range schedule. Countdown proceeded smoothly to on-time liftoff May 19.

Landing:

May 29, 1996, 7:09:18 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,291 feet (2,832 meters). Rollout time: 42 seconds. Mission duration: 10 days, zero hours, 39 minutes, 18 seconds. Landed revolution 161, the first opportunity at KSC.

Mission Highlights:

Fourth Shuttle flight of 1996 highlighted by four rendezvous activities with two different payloads. Primary payloads, all located in the cargo bay, were the SPACEHAB-4 pressurized research module; the Inflatable Antenna Experiment (IAE) mounted on Spartan 207 free-flyer; and a suite of four technology demonstration experiments known as Technology Experiments for Advancing Missions in Space (TEAMS). More than 90 percent of the payloads were sponsored by NASA's Office of Space Access and Technology.

SPACEHAB-4 single module carried nearly 3,000 pounds (1,361 kilograms) of support equipment and variety of experiments covering such fields as biotechnology, electronic materials, polymers and agriculture, including: Advanced Separation Process for Organic Materials (ADSEP); Commercial Generic Bioprocessing Apparatus (CGBA); Plant Generic Bioprocessing Apparatus (PGBA); Fluids Generic Bioprocessing Apparatus-2 (FGBA-2); Commercial Protein Crystal Growth (CPCG); Gas Permeable Polymer Membrane (GPPM); Handheld Diffusion Test Cell (HHDTC); Commercial Float Zone Furnace (CFZF); and the Space Experiment Facility (SEF). Also considered part of SPACEHAB payload complement but located in middeck lockers were IMMUNE-3 and NIH-C7 payloads. CFZF, sponsored by NASA and the German and Canadian space agencies, was considered top priority SPACEHAB-4 payload; designed to produce large, ultra-pure crystals of such semiconductor materials as gallium arsenide. FGBA-2, an on-orbit soft-drink dispenser, required some troubleshooting, and SEF experiment declared failed when command problems with payload could not be fixed.

Spartan free-flyer deployed on flight day two using orbiter Remote Manipulator System (RMS) arm. The 132-pound (60-kilogram) IAE antenna structure, mounted on three struts, was inflated to its full size of 50 feet (15 meters) in diameter, about the size of a tennis court. Potential benefits of inflatable antennas over conventional rigid structures include their lower development costs, greater reliability, and lower mass and volume requiring less stowage space and potentially a smaller launch vehicle. Actual on-orbit performance of the antenna — its surface smoothness — documented with cameras and sensors for later analysis.

Satellite deploy and rendezvous activities also conducted with Passive Aerodynamically-Stabilized Magnetically-Damped Satellite (PAMS), one of four Technology Experiments for Advancing Missions in Space (TEAMS) research payloads. TEAMS payloads located in Hitchhiker carrier in payload bay. Satellite Test Unit (STU) on PAMS deployed on flight day four.

Other TEAMS experiments were Global Positioning System (GPS) Attitude and Navigation Experiment (GANE); Vented Tank Resupply Experiment (VTRE) and Liquid Metal Thermal Experiment (LMTE).

Secondary experiments included Brilliant Eyes Ten Kelvin Sorption Cryocooler Experiment (BETSCE), an instrument designed to supercool infrared and other sensors through cyclical release and absorption of hydrogen; Aquatic Research Facility (ARF), a joint Canadian Space Agency/NASA project that allows investigation of wide range of small aquatic species, including starfish, mussels and sea urchins; Biological Research in a Canister (BRIC 07) to study endocrine functioning; Tank Pressure Control Experiment/ Reduced Fill Level (TPCE/RFL) to develop pressure control for cryogenic tankage; and series of experiments flying in Get Away Special canisters.

Casper spoke with Mir cosmonaut and U.S. astronaut Shannon Lucid, who was entering her 65th day aboard the Mir space station.

No significant on-orbit problems with orbiter were reported.

STS-78

(LMS)

Columbia

Pad B
78th Shuttle mission
20th flight OV-102
Longest Shuttle flight to date
31st KSC landing

Crew:

Terence T. "Tom" Henricks, Mission Commander (4th Shuttle flight)
Kevin R. Kregel, Pilot (2nd)
Susan J. Helms, Payload Commander (3rd)
Richard M. Linnehan, Mission Specialist (1st)
Charles E. Brady Jr., Mission Specialist (1st)
Jean-Jacques Favier, Payload Specialist (1st) (CNES, French Space Agency)
Robert Brent Thirsk, Payload Specialist (1st) (Canadian Space Agency)

Orbiter Preps (move to):

OPF — March 9, 1996
VAB — May 21, 1996
Pad — May 30, 1996

Launch:

June 20, 1996, 10:49:00 a.m. EDT. Liftoff proceeded on time. In-cabin camera provided first video images from flight deck, beginning with crew ingress and continuing through main engine cutoff. Post-launch assessment of spent solid rocket boosters revealed hot gas path in motor field joints to, but not past capture feature O-ring. This marked first occurrence of combustion product penetration into the J-joint of redesigned solid rocket motor (RSRM). Flight safety was not compromised, and motor performance met design specification requirements. Probable cause attributed to new, more environmentally friendly adhesive and cleaning fluid.

Landing:

July 7, 1996, 8:36:45 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,339 feet (2,847 meters). Rollout time: 45 seconds. Mission duration: 16 days, 21 hours, 47 minutes, 45 seconds. Landed revolution 272. Longest Shuttle flight to date. Landed on first opportunity at KSC. First live downlink video during orbiter's descent. After landing, Henricks and Kregel participated in Olympic Torch ceremony at KSC Visitor Center.

Mission Highlights:

Five space agencies (NASA/USA; European Space Agency/ Europe; French Space Agency/France; Canadian Space Agency/ Canada; and Italian Space Agency/Italy) and research scientists from 10 countries worked together on primary payload of STS-78, Life and Microgravity Spacelab (LMS). More than 40 experiments flown were grouped into two areas: life sciences, which included human physiology and space biology, and microgravity science, which included basic fluid physics investigations, advanced semiconductor and metal alloy materials processing, and medical research in protein crystal growth.

LMS investigations conducted via most extensive telescience to date. Investigators located at four remote European and four remote U.S. locations, similar to what will happen with International Space Station. Mission also made extensive use of video imaging to help crew members perform inflight maintenance procedures on experiment hardware.

Previous life science investigations have delved into what physiological changes take place in microgravity environment; integrated LMS experiments explored why these changes occur. Most extensive studies ever conducted on bone and muscle loss in space. STS-78 marked first time researchers collected muscle tissue biopsy samples both before and after flight. Crew members also were scheduled to undergo Magnetic Resonance Imaging (MRI) scans almost immediately after landing. Findings from comparison of the biopsy samples, along with various musculoskeletal tests conducted during mission, could lead to effective countermeasures to reduce inflight muscle atrophy.

Other life science investigations: First ever comprehensive study of sleep cycles, 24-hour circadian rhythms and task performance in microgravity. Spacecraft orbiting Earth pass through 16 sunrises and sunsets in single 24-hour period, which could disrupt normal body rhythms. During two 72-hour time blocks, crew members completed questionnaires and measured such functions as eye movement and muscle activity during sleep. In the Performance Assessment Work Station, crew members performed series of drills involving math problems and other mental tests to measure microgravity effects on cognitive, or thinking, skills.

Microgravity science investigations included Advanced Gradient Heating Facility, in which samples of pure aluminum containing zirconia particles were solidified. Could lead to more inexpensive ways to make mixtures of metals and ceramics, particularly useful to the metal casting industry. The Advanced Protein Crystallization Facility is first ever designed to use three methods for growing protein crystals. In Electrohydrodynamics of Liquid Bridges, which focused on changes that occur in a fluid bridge suspended between two electrodes. This research could find applications in industrial processes where control of a liquid column or spray is used, including in ink-jet printing.

Crew performed in-flight fixes to problem hardware on the Bubble, Drop and Particle Unit (BDPU), designed to study fluid physics.

Orbiter itself played key part in test that could help raise Hubble Space Telescope to higher orbit in 1997 during second servicing mission. Columbia's vernier Reaction Control System jets were gently pulsed to boost orbiter's altitude without jarring payloads. Same exercise could be conducted with orbiter Discovery during Mission STS-82 to raise HST's orbit without impacting its solar arrays.

No significant in-flight problems experienced with orbiter.

STS-79

(4th Mir docking; SPACEHAB)

Atlantis

Pad A
79th Shuttle mission
17th flight OV-104
Lucid sets U.S., world human spaceflight records
4th Shuttle-Mir docking
1st U.S. crew exchange
11th, 12th rollbacks
32nd KSC landing

Crew:

William F. Readdy, Commander (3rd Shuttle flight)
Terrence W. Wilcutt, Pilot (2nd)
Tom Akers, Mission Specialist (4th)
Jay Apt, Mission Specialist (4th)
Carl E. Walz, Mission Specialist (3rd)

Embarking to Mir:
John E. Blaha, Mission Specialist and Mir 22/NASA 3 flight engineer (5th Shuttle flight)

Returning from Mir:
Shannon W. Lucid, Mir 21/NASA 2 Cosmonaut Researcher and Mission Specialist (5th Shuttle flight)

Orbiter Preps (move to):

Flow A:
OPF —April 13, 1996
VAB — June 24, 1996
Pad — July 1, 1996

Flow B (1st rollback):
VAB — July 10, 1996 (Hurricane Bertha; SRB changeout)
OPF — Aug. 3, 1996
VAB — Aug. 13, 1996
Pad — Aug. 20, 1996

Flow C (2nd rollback):
VAB — Sept. 4, 1996 (Hurricane Fran)
Pad — Sept. 5, 1996

Launch:

September 16, 1996, 4:54:49 a.m. EDT. Launch originally set for July 31 slipped when mission managers decided to switch out Atlantis' twin solid rocket boosters. STS-79 boosters assembled using same new adhesive as boosters flown on previous mission, STS-78, in which hot gas path into J-joints of motor field joints was observed post-retrieval. Although managers concluded original STS-79 boosters were safe to fly, they decided to replace them with a set slated for STS-80 that used original adhesive. Booster changeout took place after Atlantis was already back in Vehicle Assembly Building due to threat from Hurricane Bertha. New launch date of Sept. 12 targeted and Atlantis returned to pad. Launch date delayed to Sept. 16 when Shuttle was returned to VAB due to threat from Hurricane Fran, marking first time Shuttle rolled back twice in single processing flow due to hurricane threats. Countdown proceeded smoothly to ontime liftoff Sept. 16. Approximately 13 minutes into flight, auxiliary power unit no. 2 powered down prematurely. After review and analysis, Mission Management Team concluded mission could proceed to nominal end-of-mission as planned.

Landing:

September 26, 1996, 8:13:15 a.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 10,981 feet (3,347 meters). Rollout time: one minute, two seconds. Mission duration: ten days, 3 hours, 18 minutes, 26 seconds. Landed revolution 160, on first opportunity at KSC. Lucid able to walk off orbiter into Crew Transport Vehicle with assistance, and later the same day received congratulatory call from President Clinton.

Mission Highlights:

STS-79 highlighted by return to Earth of U.S. astronaut Lucid after 188 days in space, first U.S. crew exchange aboard Russian Space Station Mir, and fourth Shuttle-Mir docking. Lucid's long-duration spaceflight set new U.S. record as well as world record for a woman. She embarked to Mir March 22 with STS-76 mission. Lucid was followed on Mir by astronaut John Blaha during STS-79, giving her distinction of membership in four different flight crews — two U.S. and two Russian.

STS-79 also marked second flight of SPACEHAB module in support of Shuttle-Mir activities and first flight of SPACEHAB Double Module configuration. Shuttle-Mir linkup occurred at 11:13 p.m. EDT, Sept. 18, following R-bar approach. Hatches opened at 1:40 a.m., Sept. 19, and Blaha and Lucid exchanged places at 7 a.m. EDT. Awaiting Blaha on Mir were Valery Korzun, Mir 22 commander, and Alexander Kaleri, flight engineer.

During five days of mated operations, two crews transferred more than 4,000 pounds (1,814 kilograms) of supplies to Mir, including logistics, food and water generated by orbiter fuel cells. Three experiments also were transferred: Biotechnology System (BTS) for study of cartilage development; Material in Devices as Superconductors (MIDAS) to measure electrical properties of high-temperature superconductor materials; and Commercial Generic Bioprocessing Apparatus (CGBA), containing several smaller experiments, including self-contained aquatic systems.

About 2,000 pounds (907 kilograms) of experiment samples and equipment transferred from Mir to Atlantis; total logistical transfer to and from station of more than 6,000 pounds (2,722 kilograms) was most extensive to date.

During her approximately six-month stay on Mir, Lucid conducted research in following fields: advanced technology, Earth sciences, fundamental biology, human life sciences, microgravity research and space sciences. Specific experiments included: Environmental Radiation Measurements to ascertain ionizing radiation levels aboard Mir; Greenhouse-Integrated Plant Experiments, to study effect of microgravity on plants, specifically dwarf wheat; and Assessment of Humoral Immune Function During Long-Duration Space Flight, to gather data on effect of long-term spaceflight on the human immune system and involving collection of blood serum and saliva samples. Some research conducted in newest and final Mir module, Priroda, which arrived at station during Lucid's stay.

Three experiments remained on Atlantis: Extreme Temperature Translation Furnace (ETTF), a new furnace design allowing space-based processing up to 871 degrees Fahrenheit (1,600 degrees Centigrade) and above; Commercial Protein Crystal Growth (CPCG) complement of 128 individual samples involving 12 different proteins; and Mechanics of Granular Materials, designed to further understanding of behavior of cohesionless granular materials, which could in turn lead to better understanding of how Earth's surface responds during earthquakes and landslides.

As with all Shuttle-Mir flights, risk-mitigation experiments were conducted to help reduce development risk for the International Space Station. Flying for first time was the Active Rack Isolation System (ARIS), an experiment rack designed to cushion payloads from vibration and other disturbances.

Conducted near end of flight was test using orbiter's small vernier jets to lower Atlantis' orbit. Similar maneuver may be employed at end of second Hubble Space Telescope servicing mission, STS-82, to re-boost Hubble to a higher orbit while still in orbiter payload bay.

STS-80

(ORFEUS-SPAS II; WSF-3)

Columbia

Pad B
80th Shuttle mission
21st flight OV-102
Longest Shuttle flight to date
Musgrave sets 2 human spaceflight records
1st time 2 free-flyers deployed and retrieved
33rd KSC landing

Crew:

Kenneth D. Cockrell, Commander (3rd Shuttle flight)
Kent V. Rominger, Pilot (2nd)
Tamara E. Jernigan, Mission Specialist (4th)
Thomas D. Jones, Mission Specialist (3rd)
Story Musgrave, Mission Specialist (6th)

Orbiter Preps (move to):

OPF — July 7, 1996
VAB — Oct. 9, 1996
Pad — Oct. 16, 1996

Launch:

November 19, 1996, 2:55:47 p.m. EST. Launch date of Oct. 31 first threatened by changeout of STS-79 boosters with those slated to fly on STS-80 and delay of STS-79 liftoff. Hurricane preparations because of Hurricane Fran in early September halted STS-80 booster stacking operations in the Vehicle Assembly Building (VAB), prompting mission managers to reschedule launch date to Nov. 8. At Flight Readiness Review (FRR) Oct. 28, mission managers declined to formalize launch date pending analysis of erosion in STS-79 booster nozzles. At Delta FRR Nov. 4, launch date changed to no earlier than Nov. 15 to allow engineers more time to complete study of nozzle erosion. At follow-up FRR Nov. 11, Nov. 15 set as official launch date, pending a commercial Atlas launch Nov. 13, and launch countdown began. Just two days later, launch postponed to Nov. 19 due to scrub of Atlas launch and predicted bad weather in KSC vicinity for period of several days, and count remained in an extended hold. Launch Nov. 19 occurred about three minutes after scheduled opening of window due to hold at T-31 seconds to assess hydrogen concentrations in aft engine compartment. Initial post-retrieval inspection of STS-80 nozzles indicated pocketing and wash erosion, but less extensive than that which was noted on STS-79 nozzles; analysis was continuing.

Landing:

December 7, 1996, 6:49:05 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,721 feet (2,658 meters) Rollout time: one minute, two seconds. Mission duration: 17 days, 15 hours, 53 minutes, 18 seconds. Landed revolution 279. Landing originally scheduled for Dec. 5, but Columbia waved off two days in a row due to weather conditions in Florida. Longest Shuttle flight to date. At age 61, Musgrave became oldest human being to fly in space. He also set new record for most Shuttle flights (six) and tied fellow astronaut John Young's record for most spaceflights total.

Mission Highlights:

Final Shuttle flight of 1996 highlighted by successful deployment, operation and retrieval of two free-flying research spacecraft. Two planned extravehicular activities (EVAs) canceled.

Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer-Shuttle Pallet Satellite II (ORFEUS-SPAS II) deployed on flight day one to begin approximately two weeks of data-gathering. Making its second flight aboard the Shuttle, ORFEUS-SPAS II featured three primary scientific instruments: the ORFEUS-Telescope with the Far Ultraviolet (FUV) Spectrograph and Extreme Ultraviolet (EUV) Spectrograph. A secondary but highly complementary payload was the Interstellar Medium Absorption Profile Spectrograph (IMAPS). Non-astronomy payloads on ORFEUS-SPAS included the Surface Effects Sample Monitor (SESAM), the ATV Rendezvous Pre-Development Project (ARP) and the Student Experiment on ASTRO-SPAS (SEAS).

ORFEUS-SPAS II mission dedicated to astronomical observations at very short wavelengths to: Investigate nature of hot stellar atmospheres; investigate cooling mechanisms of white dwarf stars; determine nature of accretion disks around collapsed stars; investigate supernova remnants; and investigate interstellar medium and potential star-forming regions.

All ORFEUS-SPAS II mission goals were achieved and there were no significant problems with either instruments or support hardware. Some 422 observations of almost 150 astronomical objects were completed, including the moon, nearby stars, distant Milky Way stars, stars in other galaxies, active galaxies and quasar 3C273. In comparison to the first ORFEUS-SPAS mission in 1993, the ORFEUS-SPAS II instruments were more sensitive and yielded higher-quality data. In addition, more than twice the data was obtained than on the first ORFEUS-SPAS flight.

Wake Shield Facility-3 (WSF-3) deployed on flight day 4. WSF is a 12-foot diameter, free-flying stainless steel disk designed to generate ultravacuum environment in which to grow semiconductor thin films for use in advanced electronics. Third flight was highly successful, with maximum seven thin film growths of semiconductor materials achieved and satellite hardware performing nearly flawlessly. WSF-3 retrieved after three days of free-flight.

Two planned six-hour EVAs by Jernigan and Jones were designed to evaluate equipment and procedures that will be used during construction and maintenance of the International Space Station. However, crew could not open outer airlock hatch and when troubleshooting did not reveal cause, mission managers concluded it would not be prudent to attempt the two EVAs and risk damage to hatch or seals. Crew was able to evaluate new Pistol Grip Tool, similar to handheld drill, in middeck. Post-landing assessment of hatch indicated a small screw had become loose from an internal assembly and lodged in an actuator — a gearbox-type mechanism that operates linkages that secure the hatch — preventing crew from opening hatch. Hatch opened easily when replacement actuator installed. Analysis was under way to determine what additional checks needed to be made on hatches to preclude recurrence of problem. All airlock hatch actuators later removed and recertified for flight.

Other experiments: Space Experiment Module (SEM) to provide increased educational access to space; NIH-R4, fourth in series of collaborative experiments developed by NASA and National Institutes of Health, to investigate role of calcium in blood pressure regulation; NASA/CCM-A, one of series of Shuttle bone cell experiments; Biological Research in Canister (BRIC)-09 experiment to study influence of microgravity on genetically-altered tomato and tobacco seedlings; Commercial MDA ITA experiment (CMIX-5), the last in series of Shuttle experiments; and Visualization in an

Experimental Water Capillary Pumped Loop (VIEW-CPL), a middeck experiment, to investigate method for spacecraft thermal management. Crew also worked with Space Vision System, designed to monitor position and alignment of structures in space.

1997

STS-81

(5th Shuttle-Mir docking)

Atlantis
Pad B
81st Shuttle mission
18th flight OV-104
5th Shuttle-Mir docking
4th U.S. crew member on Mir
34th KSC landing

Crew:
Michael A. Baker, Commander (4th Shuttle flight)
Brent W. Jett Jr., Pilot (2nd)
Peter J.K. "Jeff" Wisoff, Mission Specialist (3rd)
John M. Grunsfeld, Mission Specialist (2nd)
Marsha S. Ivins, Mission Specialist (4th)

Embarking to Mir – Mir 22/23 crew member: Jerry M. Linenger, Mission Specialist and Cosmonaut Researcher (2nd Shuttle, 1st Mir)
Returning from Mir – Mir 22 crew member: John E. Blaha, Mission Specialist and Cosmonaut Researcher (5th Shuttle, 1st Mir)

Orbiter Preps (move to):
OPF — Sept. 26, 1996
VAB — Dec. 5, 1996
Pad — Dec. 10, 1996

Launch:
January 12, 1997, 4:27:23 a.m. EST. Liftoff occurred on time following smooth countdown.

Landing:
January 22, 1997, 9:22:44 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,350 feet (2,850 meters). Rollout time: One minute, nine seconds. Mission duration: 10 days, four hours, 55 minutes, 21 seconds. Landed revolution 160, on the second KSC opportunity for the day.

Mission Highlights:
First Shuttle flight of 1997 highlighted by return of U.S. astronaut John Blaha to Earth after 118-day stay aboard Russian Space Station Mir and the largest transfer to date of logistics between the two spacecraft. Atlantis also returned carrying the first plants to complete a life cycle in space — a crop of wheat grown from seed to seed. This fifth of nine planned dockings continued Phase 1B of the NASA/Russian Space Agency cooperative effort, with Linenger becoming the third U.S. astronaut in succession to live on Mir. Same payload configuration flown on previous docking flight — featuring SPACEHAB Double module — flown again.

Blaha joined Mir 22 crew of Commander Valeri Korzun and Flight Engineer Aleksandr Kaleri on Sept. 19, 1996, when he arrived there with the crew of STS-79. Linenger was to work with the Mir 22 crew until the arrival in February of the Mir 23 crew of Commander Vasili Tsibliev, Flight Engineer Aleksandr Lazutkin and German researcher Reinhold Ewald. Ewald was to return to Earth with the Mir 22 cosmonauts after a brief stay on the station. Astronaut Michael Foale will replace Linenger on Mir when the STS-84 mission arrives in May 1997.

Docking occurred at 10:55 p.m. EST, Jan. 14, followed by hatch opening at 12:57 a.m., Jan. 15. Linenger officially traded places at 4:45 a.m. with Blaha who spent 118 days on the station and 128 days total on-orbit. During five days of mated operations, crews transferred nearly 6,000 pounds (2,722 kilograms) of logistics to Mir, including around 1,600 pounds of water; around 1,138 pounds of U.S. science equipment; and 2,206 pounds of Russian logistical equipment. About 2,400 pounds of materials returned with Atlantis from Mir.

Crew also tested on Shuttle the Treadmill Vibration Isolation and Stabilization System (TVIS), designed for use in the Russian Service Module of the International Space Station. Another activity related to International Space Station involved firing the orbiter's small vernier jet thrusters during mated operations to gather engineering data.

Undocking occurred at 9:15 p.m. EST, Jan. 19, followed by flyaround of Mir.

No significant in-flight anomalies experienced with orbiter.

STS-82

(2nd HST servicing)

Discovery
Pad A
82nd Shuttle mission
22nd flight OV-103
2nd Hubble Space Telescope servicing mission
9th Shuttle night landing/4th night landing at KSC
35th KSC landing

Crew:
Kenneth D. Bowersox , Commander (4th Shuttle flight)
Scott J. "Doc" Horowitz, Pilot (2nd)
Mark C. Lee, Payload Commander (4th)
Steven A. Hawley, Mission Specialist (4th)
Gregory J. Harbaugh, Mission Specialist (4th)
Steven L. Smith, Mission Specialist (2nd)
Joseph R. "Joe" Tanner, Mission Specialist (2nd)

Orbiter Preps (move to):
OPF — June 30, 1996
VAB — Jan. 11, 1997
Pad — Jan. 17, 1997

Launch:
February 11, 1997, 3:55:17 a.m. EST. Launch originally targeted for Feb. 13 moved up to Feb. 11 to provide more range opportunities. Countdown proceeded smoothly to on-time liftoff Feb. 11. First flight of Discovery after Orbiter Maintenance Down Period (OMDP).

Landing:
February 21, 1997, 3:32:26 a.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 7,066 feet (2,154 meters) Rollout time: one minute, zero seconds. Mission duration: nine days, 23 hours, 37 minutes, nine seconds. Landed on revolution 150. Landed on second opportunity after first waved off due to

low clouds. Ninth night landing in Shuttle program history and fourth at KSC.

Mission Highlights:

STS-82 demonstrated anew the capability of the Space Shuttle to service orbiting spacecraft as well as the benefits of human spaceflight. Six-member crew completed servicing and upgrading of the Hubble Space Telescope during four planned extravehicular activities (EVAs) and then performed a fifth unscheduled spacewalk to repair insulation on the telescope.

HST deployed in April 1990 during STS-31. It was designed to undergo periodic servicing and upgrading over its 15-year life span, with first servicing performed during STS-61 in December 1993. Hawley, who originally deployed the telescope, operated the orbiter Remote Manipulator System arm on STS-82 to retrieve HST for second servicing at 3:34 a.m. EST, Feb. 13, and positioned it in payload bay less than half an hour later.

Relying on more than 150 tools and crew aids, Lee and Smith performed EVAs 1, 3 and 5, and Harbaugh and Tanner did EVAs 2 and 4. EVA 1 began at 11:34 p.m. EST, Feb. 13, and lasted six hours, 42 minutes. One of Hubble's solar arrays was unexpectedly disturbed by gust of air from Discovery's airlock when it was depressurized, but was not damaged. Lee and Smith removed two scientific instruments from Hubble, the Goddard High Resolution Spectrograph (GHRS) and Faint Object Spectrograph (FOS), and replaced them with the Space Telescope Imaging Spectrograph (STIS) and Near Infrared Camera and Multi-Object Spectrometer (NICMOS), respectively. STIS will provide two-dimensional spectroscopy, allowing the instrument to gather 30 times more spectral data and 500 times more spatial data than existing spectrographs on Hubble, which look at one place at a time.

EVA 2 began at 10:25 p.m., Feb. 14, and lasted seven hours, 27 minutes. Harbaugh and Tanner replaced a degraded Fine Guidance Sensor and a failed Engineering and Science Tape Recorder with new spares. Also installed a new unit called the Optical Control Electronics Enhancement Kit, which will further increase the capability of the Fine Guidance Sensor. During this EVA astronauts noted cracking and wear on thermal insulation on side of telescope facing sun and in the direction of travel.

EVA 3 began at 9:53 p.m., Feb. 15, and lasted seven hours, 11 minutes. Lee and Smith removed and replaced a Data Interface Unit on Hubble, as well as an old reel-to-reel- style Engineering and Science Tape Recorder with a new digital Solid State Recorder (SSR) that will allow simultaneous recording and playback of data. Also changed out one of four Reaction Wheel Assembly units that use spin momentum to move telescope toward a target and maintain it in a stable position. After this EVA, mission managers decided to add EVA 5 to repair the thermal insulation on HST.

EVA 4 began at 10:45 p.m., Feb. 16, and lasted six hours, 34 minutes. Harbaugh and Tanner replaced a Solar Array Drive Electronics package which controls the positioning of Hubble's solar arrays. Also replaced covers over Hubble's magnetometers and placed thermal blankets of multi-layer material over two areas of degraded insulation around the light shield portion of the telescope just below the top of the observatory. Meanwhile, inside Discovery Horowitz and Lee worked on the middeck to fabricate new insulation blankets for HST.

Final spacewalk, EVA 5, lasted five hours, 17 minutes. Lee and Smith attached several thermal insulation blankets to three equipment compartments at the top of the Support Systems Module section of the telescope which contain key data processing, electronics and scientific instrument telemetry packages. STS-82 EVA total of 33 hours, 11 minutes is about two hours shy of total EVA time recorded on first servicing mission.

Discovery's maneuvering jets fired several times during mission to reboost telescope's orbit by eight nautical miles. Hubble redeployed on Feb. 19 at 1:41 a.m. and is now operating at the highest altitude it has ever flown, a 335- by 321-nautical-mile orbit. Initial checkout of new instruments and equipment during mission showed all were performing nominally. Calibration of two new science instruments was to take place over a period of several weeks with first images and data anticipated in about eight to 10 weeks. Two more servicing missions planned for 1999 and 2002.

Performance of Discovery was nominal throughout the mission.

STS-83

(MSL-1)

Columbia

Pad A
83rd Shuttle mission
22nd flight OV-102
Shortened mission
(3rd due to technical problem)
36th KSC landing

Crew:

James D. Halsell Jr., Commander (3rd Shuttle flight)
Susan L. Still, Pilot (1st)
Janice Voss, Payload Commander (3rd)
Michael L. Gernhardt, Mission Specialist (2nd)
Donald A. Thomas, Mission Specialist (3rd)
Roger K. Crouch, Payload Specialist (1st)
Gregory T. Linteris, Payload Specialist (1st)

Orbiter Preps (move to):

OPF — Dec. 7, 1996
VAB — March 5, 1997
Pad — March 11, 1997

Launch:

April 4, 1997, 2:20:32 p.m. EST. Launch originally set for April 3 delayed 24 hours on April 1 due to a requirement to add additional thermal insulation to a water coolant line in the orbiter's payload bay. Managers determined that the line, which cools various electronics on the orbiter, was not properly insulated and could possibly freeze on-orbit. Liftoff delayed 20 minutes, 32 seconds, due to an orbiter access hatch seal which had to be replaced.

Landing:

April 8, 1997, 2:33:11 p.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,602 feet (2,622 meters) Rollout time: 59 seconds. Mission duration: three days, 23 hours, 12 minutes, 39 seconds. Landed on revolution 64, on the first KSC opportunity for the day.

Mission Highlights:

First flight of the Microgravity Science Laboratory-1 (MSL-1) cut short due to concerns about one of three fuel cells, marking only third time in Shuttle program history a mission ended early. (STS-2, 1981 and STS-44, 1991 were other two times). Fuel cell No. 2 had shown some erratic readings during prelaunch startup, but was cleared to fly after additional checkout and test. Shortly after on-orbit operations began, the fuel cell no. 2 substack no. 3 differential voltage began trending upward. There are three fuel cells on each orbiter, each containing three substacks made up of two banks of 16 cells. In one substack of fuel cell no. 2, the difference in output voltage between the two banks of cells was increasing. The fuel cells use a reaction of liquid hydrogen and liquid oxygen to generate electricity and produce drinking water. Although one fuel cell produces enough electricity to conduct on-orbit and landing operations, Shuttle flight rules require all three to be functioning well to ensure crew safety and provide sufficient backup capability during reentry and landing.

When a purge failed to halt the upward trend, the fuel cell was disconnected from the orbiter's power system. Additional purges and other measures failed to correct the anomaly, and around 10 a.m., April 6, the Mission Management Team opted to end the mission early. Fuel cell no. 2 was shut down later that afternoon.

Crew was able to conduct some science in the MSL-1 Spacelab module despite the early return. Work was performed in the German electromagnetic levitation furnace facility (TEMPUS) on an experiment called Thermophysical Properties of Undercooled Metallic Melts. This experiment studies the amount of undercooling that can be achieved before solidification occurs. Another experiment performed was the Liquid-Phase Sintering II experiment in the Large Isothermal Furnace. This investigation uses heat and pressure to test theories about how the liquefied component bonds with the solid particles of a mixture without reaching the melting point of the new alloy combination.

Also conducted were two fire-related experiments. The Laminar Soot Processes experiment allowed scientists to observe for the first time the concentration and structure of soot from a fire burning in microgravity. An experiment on the Structure of Flame Balls completed two runs. This experiment is designed to determine under what conditions a stable flameball can exist, and if heat loss is responsible in some way for the stabilization of the flame ball during burning.

A decision to refly the mission in its entirety was made by the Mission Management Team in the days following Columbia's return. The reflight was first unofficially designated STS-83R and then officially named STS-94.

STS-84

(6th Shuttle-Mir docking)

Atlantis

Pad A
84th Shuttle mission
19th flight OV-104
6th Shuttle-Mir docking
5th U.S. crew member on Mir
37th KSC landing

Crew:

Charles J. Precourt, Commander (3rd Shuttle flight)
Eileen M. Collins, Pilot (2nd)
Jean-Francois Clervoy, Payload Commander (2nd) (European Space Agency)
Carlos I. Noriega, Mission Specialist (1st)
Edward T. Lu, Mission Specialist (1st)
Elena V. Kondakova , Mission Specialist (1st Shuttle, 2nd spaceflight) (Russian Aviation and Space Agency)

Embarking to Mir – Mir 23/24 crew member: C. Michael Foale, Mission Specialist and Cosmonaut Researcher (4th Shuttle, 1st Mir)

Returning from Mir – Mir 22/23 crew member: Jerry M. Linenger, Mission Specialist and Cosmonaut Researcher (2nd Shuttle, 1st Mir)

Orbiter Preps (move to):

OPF — Jan. 22, 1997
VAB — April 19, 1997
Pad — April 24, 1997

Launch:

May 15, 1997, 4:07:48 a.m. EDT. Liftoff occurred on time following smooth countdown.

Landing:

May 24, 1997, 9:27:44 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,384 feet (2,555 meters). Rollout time: 51 seconds. Mission duration: Nine days, five hours, 19 minutes, 56 seconds. Landed on revolution 144, on the second KSC opportunity after being waved off from the first due to low clouds in the vicinity.

Mission Highlights:

Sixth Shuttle-Mir docking highlighted by transfer of fourth successive U.S. crew member to the Russian Space Station. U.S. astronaut Mike Foale exchanged places with Jerry Linenger, who arrived at Mir Jan. 15 with the crew of Shuttle Mission STS-81. Linenger spent 123 days on Mir and just over 132 days in space from launch to landing, placing him second behind U.S. astronaut Shannon Lucid for most time spent on-orbit by an American. Another milestone reached during his stay was one-year anniversary of continuous U.S. presence in space that began with Lucid's arrival at Mir March 22, 1996.

Other significant events during Linenger's stay included first U.S.-Russian spacewalk. On April 29, Linenger participated in five-hour extravehicular activity (EVA) with Mir 23 Commander Vasily Tsibliev to attach a monitor to the outside of the station. The Optical Properties Monitor (OPM) was to remain on Mir for nine months to allow study of the effect of the space environment on optical properties, such as mirrors used in telescopes.

On Feb. 23, a fire broke out on the 11-year-old station. It caused minimal damage but required station's inhabitants to wear protective masks for about 36 hours until cabin air was cleaned. Besides Linenger, crew members aboard Mir at the time included two Mir 22 cosmonauts and a German cosmonaut, and two Mir 23 cosmonauts.

STS-84 docking with Mir occurred May 16 at 10:33 p.m. EDT above the Adriatic Sea. Hatches between two spacecraft opened at 12:25 a.m., May 17. Greetings exchanged between STS-84 crew and Mir 23 Commander Vasily Tsibliev, Flight Engineer Alexander Lazutkin and Linenger, followed by a safety briefing. Linenger and Foale officially traded places at 10:15 a.m. EDT.

Transfer of items to and from Mir proceeded smoothly and was completed ahead of schedule. One of first items transferred to station was an Elektron oxygen-generating unit. Altogether about 249 items were moved between the two spacecraft, and about 1,000 pounds of water moved to Mir, for a total of about 7,500 pounds of water, experiment samples, supplies and hardware.

Research program planned for Foale featured 35 investigations total (33 on Mir, two on STS-84, and another preflight/postflight) in six disciplines: advanced technology, Earth observations and remote sensing, fundamental biology, human life sciences, space station risk mitigation, and microgravity sciences. Twenty-eight of these were conducted during previous missions and were to be continued, repeated or completed during Foale's stay. Seven new experiments were planned in biological and crystal growth studies and materials processing.

Undocking occurred at 9:04 p.m. EDT, May 21. Unlike prior dockings, no flyaround of the station by the orbiter was conducted, but orbiter was stopped three times while backing away to collect data from a European sensor device designed to assist future rendezvous of a proposed European Space Agency resupply vehicle with the International Space Station.

Other activities conducted during the mission included investigations using the Biorack facility, located in the SPACEHAB Double Module in Atlantis' payload bay, a photo survey of Mir during docked operations, environmental air samplings and radiation monitoring.

Orbiter performance was nominal from launch to landing.

STS-94

(MSL-1 reflight)

Columbia

Pad A
85th Shuttle mission
23rd flight OV-102
STS-83 reflight
38th KSC landing

Crew:

James D. Halsell Jr., Commander (4th Shuttle flight, including STS-83)
Susan L. Still, Pilot (2nd)
Janice Voss, Payload Commander (4th)
Michael L. Gernhardt, Mission Specialist (3rd)
Donald A. Thomas, Mission Specialist (4th)
Roger K. Crouch, Payload Specialist (2nd)
Gregory T. Linteris, Payload Specialist (2nd)

Orbiter Preps (move to):

OPF — April 9, 1997
VAB — June 4, 1997
Pad — June 11, 1997

Launch:

July 1, 1997, 2:02:00 p.m. EDT. Liftoff was delayed about 12 minutes because of unacceptable weather conditions in the launch area in the event a return-to-launch-site abort was necessary. The launch window originally was targeted to open at 2:37 p.m., July 1. On June 30, NASA managers decided to move it back 47 minutes to 1:50 p.m. to avoid forecasted afternoon thundershowers.

Landing:

July 17, 1997, 6:46:34 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,892 feet (2710 meters). Rollout time: 55 seconds. Mission duration: 15 days, 16 hours, 44 minutes, 34 seconds. Landed on revolution 251. Landing occurred on first opportunity.

Mission Highlights:

STS-94 marked the first reflight of same vehicle, crew and payloads, following shortened STS-83 mission in April due to indications of a fuel cell problem. Primary payload was the Microgravity Science Laboratory-1 (MSL-1). A quick turnaround in processing Columbia for the reflight was accomplished in part by the first reservicing of a primary payload, MSL-1, in the orbiter.

The crew maintained 24-hour/two-shift operations. Using the Spacelab module as a test-bed, MSL-1 tested some of the hardware, facilities and procedures that will be used on the International Space Station. The 33 investigations conducted also yielded new knowledge in the principal scientific fields of combustion, biotechnology and materials processing.

Combustion experiments resulted in the discovery of a new mechanism of flame extinction caused by radiation of soot, and in the ignition of the weakest flames (as low as one watt, or 1/50 the power of a birthday candle) ever burned in laboratory conditions in space or on Earth, as well as the longest burning flames in space (500 seconds). Although only 144 fires or combustion experiment runs were scheduled, more than 200 were completed. The combustion investigations provided valuable information for improved fire safety on future spacecraft and for development of cleaner, more efficient internal combustion engines.

Experiments processed in the Electromagnetic Containerless Processing Facility (TEMPUS) yielded the first measurements of specific heat and thermal expansion of glass-forming metallic alloys, and the highest temperature (a maximum of 2,000 degrees Centigrade) and largest undercooling (to 340 degrees C) ever achieved in space. These measurements are necessary for modeling industrial materials systems to manufacture new and better products.

The mission also produced progress in learning how to control and position liquid drops which could lead to improvements in chemical manufacturing, petroleum technology and the cosmetics and food industries.

More than 700 crystals of various proteins were grown during the 16-day mission. Since crystals grow larger and purer in space, this research will help scientists to better understand their structures and to design more effective drugs to treat such diseases as cancer, diabetes and AIDS.

Samples in the Large Isothermal Furnace were processed to study the diffusion of tracers, or impurities, in melted germanium, an element used as a semiconductor and alloying agent. This was the first time diffusion in semiconductors has been studied in space.

The Astro/Plant Generic Bioprocessing Apparatus (AstroPGBA) studied the effect of microgravity on various plants, including a source of an antimalarial drug; another used in chemotherapy treatment of cancer; and a species widely used in the paper and lumber industries.

The Expedite the Processing of Experiments to Space Station (EXPRESS) Rack flew for the first time on MSL-1 (both the STS-83 and STS-94 missions) to demonstrate quick and easy installation of experiment and facility hardware on orbit. It will be used on the International Space Station.

The 25 primary experiments, four glovebox investigations and four accelerometer studies on MSL-1 were contributed by scientists from NASA, the European Space Agency, the German Space Agency and the National Space Development Agency of Japan. A record number of commands – more than 35,000 – were sent from Spacelab Mission Operations Control Center at Marshall Space Flight Center to MSL-1 experiments.

STS-85

(CRISTA-SPAS-02)

Discovery

Pad A
86th Shuttle mission
23 flight OV-103
Extended mission
39th KSC landing

Crew:

Curtis L. Brown Jr., Mission Commander (4th Shuttle flight)
Kent V. Rominger, Pilot (3rd)
Jan Davis, Payload Commander (3rd)
Robert L. Curbeam Jr., Mission Specialist (1st)
Stephen K. Robinson, Mission Specialist (1st)
Bjarni V. Tryggvason, Payload Specialist (1st) (Canadian Space Agency)

Orbiter Preps (move to):

OPF — Feb. 21, 1997
VAB — July 7, 1997
Pad — July 14, 1997

Launch:

August 7, 1997, 10:41:00 a.m. EDT. On-time liftoff following smooth countdown.

Landing:

August 19, 1997, 7:07:59 a.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,792 feet (2,680 meters). Rollout time: One minute, eight seconds. Mission duration: 11

days, 20 hours, 26 minutes, 59 seconds. Landed on revolution 190. Landing opportunity Aug. 18 waved off due to threat of ground fog in local area.

Mission Highlights:

STS-85 carried a complement of payloads in the cargo bay that focused on Mission to Planet Earth objectives as well as preparations for International Space Station assembly: the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite-2 (CRISTA-SPAS-02); the Japanese Manipulator Flight Development (MFD); the Technology Applications and Science-01 (TAS-1) and the International Extreme Ultraviolet Hitchhiker-02 (IEH-02).

This was second flight of CRISTA-SPAS payload. CRISTA-SPAS-02 also represented the fourth mission in a cooperative venture between the German Space Agency (DARA) and NASA. Payload included three telescopes and four spectrometers, deployed on flight day one, to gather data about Earth's middle atmosphere. After more than 200 hours of free flight, CRISTA-SPAS was retrieved on Aug. 16. Complementary instrument, the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) also performed well. Data from STS-85 and first CRISTA-SPAS flight, STS-66 in 1994, expected to yield new insight into distribution of ozone in Earth's atmosphere. Once science operations were complete, CRISTA-SPAS used in simulation exercise to prepare for first International Space Station (ISS) assembly flight, STS-88, with the payload being manipulated as if it were the Functional Cargo Block (FGB) that will be attached to ISS Node 1.

TAS-1 was a Hitchhiker payload carrying eight experiments designed to demonstrate faster, better, cheaper avionics and processes: Solar Constant Experiment (SOLCON), Infrared Spectral Imaging Radiometer (ISIR) and Shuttle Laster Altimeter (SLA), all part of NASA's Mission to Planet Earth program; and the Critical Viscosity of Xenon (CVX), Space Experiment Module (SEM); Two Phase Flow (TPF); Cryogenic Flight Experiment (CFE) and Stand Alone Acceleration Measurement Device and the Wide-Band Stand Alone Acceleration Measurement Device (SAAMD/WBSAAMD). All the experiments were completed successfully.

MFD designed to evaluate use of the Small Fine Arm that will be part of the future Japanese Experiment Module's Remote Manipulator System on ISS. Despite some glitches, MFD completed a series of exercises by crew on orbit as well as operators on ground. Two unrelated Japanese experiments, Two-Phase Fluid Loop Experiment (TPFLEX) and Evaluation of Space Environment and Effects on Materials (ESEM), were mounted near the Small Fine Arm in the payload bay.

IEH-02 was flying a second time and consisted of four experiments, all of which performed well on-orbit: Solar Extreme Ultraviolet Hitchhiker-2 (SEH); Ultraviolet Spectrography Telescope for Astronomical Research (UVSTAR); Distribution and Automation Technology Advancement – Colorado Hitchhiker and Student Experiment of Solar Radiation (DATA-CHASER); and Shuttle Glow Experiment-5 and -6, all with common objective to investigate solar extreme ultraviolet (EUV) flux and EUV emissions of the Jupiter Io Plasma Torus system.

In-cabin payloads: Bioreactor Demonstration System-3 (BDS-3), a cell biology research payload which has flown previously. On this flight, BDS used for growing colon cancer cells to a larger size than can be achieved on Earth. Protein Crystal Growth - Single Locker Thermal Enclosure System (PCG-STES); Midcourse Space Experiment (MSX); Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX); Southwest Ultraviolet Imaging System (SWUIS), used to observe the Hale-Bopp comet; two Get Away Special (GAS) payloads; Biological Research in Canisters-10 (BRIC-10), one in a series of flights; and the Solid Surface Combustion Experiment (SSCE).

Crew also worked with the Orbiter Space Vision System (OSVS), which will be used during ISS assembly. OSVS features series of dots strategically placed on various payload and vehicle stuctures that permit precise alignment and pointing capability.

Orbiter performance was nominal throughout the mission.

STS-86

(7th Shuttle-Mir docking)

Atlantis

Pad A
87th Shuttle mission
20th flight OV-104
Night launch
7th Shuttle-Mir docking
6th U.S. crew member on Mir
1st U.S.-Russian EVA
Extended mission
40th KSC landing

Crew:

James D. Wetherbee, Commander (4th Shuttle flight)
Michael J. Bloomfield, Pilot (1st)
Jean-Loup J.M. Chretien, Mission Specialist (1st) (CNES, French Space Agency)
Wendy B. Lawrence, Mission Specialist (2nd)
Scott E. Parazynski, Mission Specialist (2nd)
Vladimir Georgievich Titov, Mission Specialist (2nd Shuttle, 4th spaceflight) (Russian Aviation and Space Agency)

Embarking to Mir — Mir 24 crew member: David A. Wolf, Mission Specialist and Cosmonaut Researcher (2nd Shuttle, 1st Mir)

Returning from Mir — Mir 23/24 crew member: C. Michael Foale, Mission Specialist and Cosmonaut Researcher (5th Shuttle, 1st Mir)

Orbiter preps (move to):

OPF — May 24,1997
VAB — Aug. 11, 1997
Pad — Aug. 18, 1997

Launch:

September 25, 1997, 10:34:19 p.m. EDT. On-time liftoff occurred after final approval for flight to Mir given earlier in day by NASA Administrator Daniel Goldin, following his review of independent and internal safety assessments regarding safety of Mir and Shuttle-Mir missions. The reviews included assessments conducted routinely prior to Shuttle-Mir dockings and two independent studies prompted by a spate of problems on the station, including a fire (see STS-84 entry) and a collision (see STS-86 mission highlights below).

Landing:

October 6, 1997, 5:55:09 p.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance: 11,947 feet (3,641 meters). Rollout time: one minute, 22 seconds. Mission duration: 10 days, 19 hours, 20 minutes, 50 seconds. Landed on revolution 170, on the first opportunity after two opportunities Oct. 5 were waved off due to low clouds. Last flight of Atlantis prior to departure to California for second Orbiter Maintenance Down Period (OMDP). Scheduled to return to KSC in late August 1998 to begin preparations for STS-92, third International Space Station assembly flight.

Mission Highlights:

The seventh Mir docking mission continued the presence of a U.S. astronaut on the Russian space station with the transfer of physician David A. Wolf to Mir. Wolf became the sixth U.S. astronaut in succession to live on Mir to continue Phase 1B of the NASA/Russian Space agency cooperative effort.

Foale returned to Earth after spending 145 days in space, 134 of them aboard Mir. His estimated mileage logged was 58 million miles (93 million kilometers), making his the second longest U.S.

space flight, behind Shannon Lucid's record of 188 days. His stay was marred by a collision June 25 between a Progress resupply vehicle and the station's Spektr module, damaging a radiator and one of four solar arrays on Spektr. The mishap occurred while Mir 23 Commander Vasily Tsibliev was guiding the Progress capsule to a manual docking and depressurized the station. The crew sealed the hatch to the leaking Spektr module, leaving inside Foale's personal effects and several NASA science experiments, and repressurized the remaining modules.

An internal spacewalk by Tsibliev and Mir 23 Flight Engineer Alexander Lazutkin was planned to reconnect power cables to the three undamaged solar arrays, but during a routine medical exam July 13 Tsibliev was found to have an irregular heartbeat. Foale then began training for the spacewalk, but during one of the training exercises, a power cable was inadvertently disconnected, leaving the station without power. On July 21, it was announced that the internal spacewalk would not be conducted by the Mir 23 crew but their successors on Mir 24. On July 30, NASA announced that Wendy Lawrence, originally assigned to succeed Foale on Mir, was being replaced by Wolf. The change was deemed necessary to allow Wolf to act as a backup crew member for the spacewalks planned over the next several months to repair Spektr. Unlike Wolf, Lawrence could not fit in the Orlan suit that is used for Russian spacewalks and she did not undergo spacewalk training.

Following their arrival at the station Aug. 7, Mir 24 Commander Antaoly Solovyev and Flight Engineer Pavel Vinogradov conducted the internal spacewalk inside the depressurized Spektr module Aug. 22, reconnecting 11 power cables from the Spektr's solar arrays to a new custom-made hatch for the Spektr. During the spacewalk, Foale remained inside the Soyuz capsule attached to Mir, in constant communication with the cosmonauts as well as ground controllers.

On Sept. 5, Foale and Solovyev conducted a six-hour external extravehicular activity to survey damage outside Spektr and to try and pinpoint where the breach of the module's hull occurred. Two undamaged arrays were manually repositioned to better gather solar energy, and a radiation device left previously by Jerry Linenger was retrieved.

Docking of Atlantis and Mir took place at 3:58 p.m. EDT, Sept. 27, with the two mission commanders opening the spacecraft hatches at 5:45 p.m. Wolf officially joined the Mir 24 at noon EDT, Sept. 28. At the same time, Foale became a member of the STS-86 crew and began moving his personal belongings back into Atlantis. Wolf will be replaced by the seventh and last U.S. astronaut to transfer to Mir, Andrew S. W. Thomas, when the orbiter Endeavour docks with the Russian space station during the STS-89 mission in January 1998.

First joint U.S.-Russian extravehicular activity during a Shuttle mission, which was also the 39th in the Space Shuttle program, was conducted by Titov and Parazynski. During the five-hour, one-minute spacewalk Oct. 1, the pair affixed a 121-pound Solar Array Cap to the docking module for future use by Mir crew members to seal off the suspected leak in Spektr's hull. Parazynski and Titov also retrieved four Mir Environmental Effects Payloads (MEEPS) from the outside of Mir and tested several components of the Simplified Aid for EVA Rescue (SAFER) jet packs. The spacewalk began at 1:29 p.m. EDT and ended at 6:30 p.m.

During the six days of docked operations, the joint Mir 24 and STS-86 crews transferred more than four tons of material from the SPACEHAB Double Module to Mir, including approximately 1,700 pounds of water, experiment hardware for International Space Station Risk Mitigation experiments to monitor the Mir for crew health and safety, a gyrodyne, batteries, three air pressurization units with breathing air, an attitude control computer and many other logistics items. The new motion control computer replaced one that had experienced problems in recent months. The crew also moved experiment samples and hardware and an old Elektron oxygen generator to Atlantis for return to Earth. Undocking took place at 1:28 p.m. EDT, Oct 3. After undocking, Atlantis performed a 46-minute flyaround visual inspection of Mir. During this maneuver, Solovyev and Vinogradov opened a pressure regulation valve to allow air into the Spektr module to see if STS-89 crew members could detect seepage or debris particles that could indicate the location of the breach in the damaged module's hull.

During the flight, Wetherbee and Bloomfield fired small jet thrusters on Atlantis to provide data for the Mir Structural Dynamics Experiment (MISDE), which measures disturbances to space station components and its solar arrays. Other experiments conducted during the mission were the Commercial Protein Crystal Growth investigation; the Cell Culture Module Experiment (CCM-A), the Cosmic Radiation Effects and Activation Monitor (CREAM) and the Radiation Monitoring Experiment-III (RME-III); the Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLE) experiment; and the Midcourse Space Experiment. Two NASA educational outreach programs were also conducted, Seeds in Space-II and Kidsat.

Orbiter performance was nominal.

STS-87

(USMP-4, Spartan-201 rescue)

Columbia

Pad B
88th Shuttle mission
24th flight OV-102
8th Shuttle flight of 1997
41st KSC landing

Crew:

Kevin R. Kregel, Commander (3rd Shuttle flight)
Steven W. Lindsey, Pilot (1st)
Kalpana Chawla, Mission Specialist (1st)
Takao Doi, Mission Specialist (1st) (National Space and Development Agency of Japan)
Winston E. Scott, Mission Specialist (2nd)
Leonid K. Kadenyuk, Payload Specialist (1st) (NSAU, Ukrainian Space Agency)

Orbiter Preps (move to):

OPF — July 17, 1997
VAB — Oct. 24, 1997
Pad — Oct. 29, 1997

Launch:

November 19, 1997, 2:46:00 p.m. EST. Eighth Shuttle flight of 1997 — first time since 1992 eight flights were conducted in one year. Sixth on-time liftoff in '97, and all eight flights launched on day set in Flight Readiness Review. First use of Pad 39B since January following completion of extensive modifications to pad structures.

Landing:

December 5, 1997, 7:20:04 a.m. EST, Runway 33, Kennedy Space Center, Fla. Rollout distance: 8,004 feet (2,440 meters). Rollout time: 57 seconds. Mission duration: 15 days, 16 hours, 34 minutes, four seconds. Landed on revolution 252.

Mission Highlights:

Primary payload of flight, the U.S. Microgravity Payload-4, performed well. Research using other major payload, SPARTAN-201-04 free-flyer, was not completed.

SPARTAN deploy delayed one day to Nov. 21 to allow time for companion spacecraft, the Solar and Heliospheric Observatory (SOHO) already on-orbit, to come back on-line. Chawla used orbiter's mechanical arm to release SPARTAN at 4:04 p.m. Spacecraft failed to execute a pirouette maneuver several minutes later, suggesting there was a problem with the attitude control system for fine pointing toward solar targets. Chawla then regrappled the

SPARTAN, but did not receive a firm capture indication. When she backed the arm away once more, a rotational spin of about two degrees per second was apparently imparted to the satellite. Kregel tried to match the satellite's rotation by firing Columbia's thrusters for a second grapple attempt, but this was called off by the flight director.

After a plan was formulated to retrieve the free-flyer, Scott and Doi began a seven-hour, 43-minute spacewalk Nov. 24 and captured the SPARTAN by hand at 9:09 p.m. EST. The two astronauts then completed a series of activities that continue preparations for on-orbit assembly of the International Space Station. Doi became the first Japanese citizen to walk in space. USMP-4 research was deemed to be highly successful. This fourth flight of the U.S. Microgravity Payload focused on materials science, combustion science and fundamental physics. Experiments included the Advanced Automated Directional Solidification Furnace (AADSF); Confined Helium Experiment (CHeX); Isothermal Dendritic Growth Experiment (IDGE); Materials for the Study of Interesting Phenomena of Solidification on Earth and in Orbit (MEPHISTO); Microgravity Glovebox Facility (MGBX), featuring several experiments: the Enclosed Laminar Flames (ELF), Wetting Characteristics of Immiscibles (WCI) and Particle Engulfment and Pushing by a Solid/Liquid Interface (PEP); Space Acceleration Measurement System (SAMS); and Orbital Acceleration Research Experiment (OARE). Highlights included fastest dedritic growth rate ever measured and highest level of supercooling ever obtained for pivalic acid, a transparent material used by researchers to model metals, in IDGE. With CHeX, the most precise temperature measurement ever made in space was achieved.

Other payloads: Get Away Special canister containing four experiments; the Collaborative Ukrainian Experiment (CUE), featuring a collection of 10 plant space biology experiments in the middeck; and several Hitchhiker payloads in the payload bay. Orbiter performance was nominal throughout the mission.

1998

STS-89

(8th Shuttle-Mir docking)

Endeavour

Pad A
89th Shuttle mission
12th flight OV-105
8th Shuttle-Mir docking
7th U.S. crew member on Mir
42nd KSC landing

Crew:

Terrence W. Wilcutt, Commander (3rd Shuttle flight)
Joe Frank Edwards Jr., Pilot (1st)
Michael P. Anderson, Mission Specialist (1st)
Bonnie J. Dunbar, Mission Specialist (5th)
James F. Reilly II, Mission Specialist (1st)
Salizhan Shakirovich Sharipov, Mission Specialist (1st space flight) (Russian Aviation and Space Agency)

Embarking to Mir — Mir 24/25 crew member: Andrew S. W. Thomas, Mission Specialist and Cosmonaut Researcher (2nd Shuttle, 1st Mir)

Returning from Mir — Mir 24 crew member: David A. Wolf, Mission Specialist and Cosmonaut Researcher (3rd Shuttle, 1st Mir)

Orbiter Preps (move to):

OPF 1 — March 28, 1997
VAB — April 8, 1997 (temporary storage)
OPF 3 — April 21, 1997
VAB — May 23, 1997 (temporary storage)
OPF 1 — June 4, 1997 (begin preflight processing)
VAB — Dec. 12, 1997
Pad — Dec. 19, 1997

Launch:

January 22, 1998, 9:48:15 p.m. EST. Endeavour returned to space after completing its first Orbiter Maintenance Down Period, becoming first orbiter other than Atlantis to dock with Mir. On May 22, 1997, mission managers announced Endeavour would fly STS-89 instead of Discovery. Launch originally targeted for Jan. 15, 1998, changed first to no earlier than Jan. 20 and then Jan. 22, per request from the Russian space program to allow completion of activities on Mir. First launch overseen by one of two new rotational launch directors, Dave King, following retirement of veteran Launch Director Jim Harrington.

Landing:

January 31, 1998, 5:35:09 p.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 9,790 feet (2,984 meters). Rollout time: One minute, 10 seconds. Mission duration: eight days, 19 hours, 46 minutes, 54 seconds. Landed on orbit 139. Logged 3.6 million statute miles. Landed on first opportunity at KSC, marking 13th consecutive landing in Florida and 20th in the last 21 missions.

Mission Highlights:

Docking of Endeavour to Mir occurred at 3:14 p.m., Jan. 24, at an altitude of 214 nautical miles. Hatches opened at 5:25 p.m. the same day. Transfer of Andy Thomas to Mir and return of David Wolf to the U.S. orbiter occurred at 6:35 p.m., Jan. 25. Initially, Thomas thought his Sokol pressure suit did not fit, and the crew exchange was allowed to proceed only after Wolf's suit was adjusted to fit Thomas. Once on Mir, Thomas was able to make adequate adjustments to his own suit (which would be worn should the crew need to return to Earth in the Soyuz capsule) and this remained on Mir with him. Wolf spent a total of 119 days aboard Mir, and after landing, his total on-orbit time was 128 days.

Hatches between the two spacecraft closed at 5:34 p.m., Jan. 28, and two spacecraft undocked at 11:57 a.m., Jan. 29. More than 8,000 pounds (3,629 kilograms) of scientific equipment, logistical hardware and water were taken from Endeavour to Mir.

On Jan. 31, a new crew docked with Mir to begin a three-week handover. Thomas and his Mir 24 crewmates, Commander Anatoly Solvyev and Flight Engineer Pavel Vinogradov, greeted Mir 25 Commander Talgat Musabayev, Flight Engineer Nikolai Budarin and French researcher Leopold Eyharts following a soft docking on Jan. 31, just hours before the STS-89 crew touched down in Florida. Eyharts was to return to Earth Feb. 19 with the two Mir 24 cosmonauts, leaving Thomas, Musabayev and Budarin on Mir. Thomas, the last U.S. astronaut assigned to complete a lengthy stay on Mir, will return to Earth after a four-month stay as Phase I activities draw to a close.

STS-90

(Neurolab)

Columbia

Pad B
90th Shuttle mission
25th flight of OV-102
43rd KSC landing
Final Spacelab module mission
First KSC Astronaut

Crew:

Richard A. Searfoss, Commander (3rd Shuttle flight)
Scott D. Altman, Pilot (1st)
Richard M. Linnehan, Payload Commander and Mission Specialist (2nd)
Dafydd "Dave" Rhys Williams, Mission Specialist (1st), (Canadian Space Agency)
Kathryn P. "Kay" Hire, Mission Specialist (1st)
Jay C. Buckey, Payload Specialist (1st)
James A. "Jim" Pawelczyk, Payload Specialist (1st)

Orbiter Preps (move to):

OPF — Dec. 5, 1997
VAB — March 16, 1998
Pad — March 23, 1998

Launch:

April 17, 1998, 2:19:00 p.m. EDT. Launch postponed on April 16 for 24 hours due to difficulty with one of Columbia's two network signal processors, which format data and voice communications between the ground and the Space Shuttle. Network signal processor 2 was replaced, and liftoff on April 17 occurred on time.

Landing:

May 3, 1998, 12:08:59 p.m. EDT, Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,998 feet (3,047 meters). Rollout time: 58 seconds. Mission duration: 15 days, 21 hours, 49 minutes, 59 seconds. Landed on orbit 256, on first KSC opportunity for day. Logged 6.375 million statute miles. Marked 14th consecutive Shuttle landing at KSC and 21st in the last 22 missions.

Mission Highlights:

Neurolab's 26 experiments targeted one of the most complex and least understood parts of the human body – the nervous system. Primary goals were to conduct basic research in neurosciences and expand understanding of how the nervous system develops and functions in space. Test subjects were crew members and rats, mice, crickets, snails and two kinds of fish. Cooperative effort of NASA, several domestic partners and the space agencies of Canada (CSA), France (CNES) and Germany (DARA), as well as the European Space Agency (ESA) and the National Space Development Agency of Japan (NASDA). Most experiments conducted in pressurized Spacelab long module located in Columbia's payload bay. This was 16th and last scheduled flight of the ESA-developed Spacelab module although Spacelab pallets will continue to be used on the International Space Station.

Research conducted as planned, with the exception of the Mammalian Development Team, which had to reprioritize science activities because of the unexpected high mortality rate of neonatal rats on board.

Other payloads included the Shuttle Vibration Forces experiment, the Bioreactor Demonstration System-04, and three Get-Away Special (GAS) canister investigations.

Working with engineers on the ground a week into the flight, the on-orbit crew used aluminum tape to bypass a suspect valve in the Regenerative Carbon Dioxide Removal System that had threatened to cut short the mission.

Mission Management Team considered, but decided against, extending the mission one day because the science community indicated an extended flight was not necessary and weather conditions were expected to deteriorate after planned landing on Sunday, May 3.

STS-90 Mission Specialist Kay Hire was Kennedy Space Center's first employee to be chosen as an astronaut candidate.

STS-91

(9th and final Shuttle-Mir docking)

Discovery

Pad A
91st Shuttle mission
24th flight OV-103
9th Shuttle-Mir docking
Return of 7th and last U.S. astronaut to live and work aboard Mir
First flight of Super Lightweight External Tank
First docking mission for Discovery
44th KSC landing

Crew :

Charles J. Precourt, Commander (4th Shuttle flight)
Dominic L. Pudwill Gorie, Pilot (1st)
Wendy B. Lawrence, Mission Specialist (3rd)
Franklin R. Chang-Diaz, Mission Specialist (6th)
Janet Lynn Kavandi, Mission Specialist (1st)
Valery Victorovitch Ryumin, Mission Specialist (1st Shuttle, 1st Mir, 4th spaceflight)

Returning from Mir – Mir 25 crew member: Andrew S. W. Thomas, Mission Specialist and Cosmonaut Researcher (2nd Shuttle, 1st Mir)

Orbiter Preps (move to):

OPF 3 — Aug. 19, 1997 (temporary storage)
OPF 2 — Oct. 1, 1997 (temporary storage)
OPF 2 — Oct 30, 1997 (begin preflight processing)
VAB — April 12, 1998
Pad — May 2, 1998

Launch:

June 2, 1998, 6:06:24 p.m. EDT. The countdown proceeded smoothly except for a slight delay in operations to load the external tank with cryogenic propellant to evaluate a few technical issues. As planned, launch managers determined the exact orbital location of the Mir space station during the countdown's T-9-minute built-in hold. The decision was then made to launch Discovery at 6:06 p.m. to achieve optimum Shuttle system performance and to accommodate Shuttle-Mir rendezvous activities.

Landing:

June 12, 1998, 2:00:18 p.m. EDT, Runway 15, Kennedy Space Center, Fla. Rollout distance 11,730 feet (3,576 meters). Rollout time: one minute, four seconds. Mission duration: nine days, 19 hours, 54 minutes, two seconds. Landed on orbit 155. Logged 3.8 million statute miles. Landed on first opportunity at KSC, marking the 15th consecutive landing in Florida and 22nd in the last 23 missions.

Mission Highlights:

Docking of Discovery to Mir , the first for that orbiter, occurred at 12:58 p.m., June 4, at an altitude of 208 miles. Hatches opened at 2:34 p.m. the same day. At hatch opening, Andy Thomas officially became a member of Discovery's crew, completing 130 days of living and working on Mir. The transfer wrapped up a total of 907 days spent by a total of seven U.S. astronauts aboard the Russian space station as long-duration crew members. During the next four days, the Mir 25 and STS-91 crews transferred more than 1,100 pounds of water, and almost 4,700 pounds of cargo experiments and supplies were exchanged between the two spacecraft. During this time, long-term U.S. experiments aboard the Mir were moved into Discovery's middeck locker area and the SPACEHAB single module in the orbiter's payload bay, including the Space Acceleration Measurement System (SAMS) and the tissue engineering co-culture (COCULT) investigations, as well as two crystal growth experiments. The crews also conducted Risk Mitigation Experiments (RME) and Human Life Sciences (HLS) investigations. When the hatches closed for undocking at 9:07 a.m., June 8, and the spacecraft separated at 12:01 p.m. that day, the final Shuttle-Mir docking mission was concluded and Phase 1 of the International Space Station (ISS) program came to an end.

The Alpha Magnetic Spectrometer (AMS) flew for the first time on this mission. The AMS, designed to look for dark and missing matter in the universe, was powered up on Flight Day 1. Data originally planned to be sent to ground stations through Discovery's KU-band communications system was recorded onboard because of a problem with the KU-band system that prevented it from sending high-rate communications, including television signals, to the ground. The system was able to receive uplink transmissions. On June 3 the crew was able to set up a bypass system that allowed AMS data to be downlinked via S-band/FM communications when the orbiter came within range of a ground station. Data that could not be recorded by ground stations was recorded onboard throughout the mission.

The KU-band system failure was determined to be located in a component that was not accessible to the crew. The failure prevented television transmission throughout the mission. Television broadcasts from Mir were prevented by a problem between a Russian ground station and the mission control center outside of Moscow, limiting communications to audio only on NASA television.

Other experiments conducted by the Shuttle crew during the mission included a checkout of the orbiter's robot arm to evaluate new electronics and software and the Orbiter Space Vision System for use during assembly missions for the ISS. Also onboard in the payload bay were eight Get Away-Special experiments, while combustion, crystal growth and radiation monitoring experiments were conducted in Discovery's middeck crew cabin area.

STS-95

(John Glenn's Flight)

Discovery

Pad B
92nd Shuttle mission
25th flight OV-103
45th KSC landing
1st U.S. President to attend a Shuttle launch
1st flight Space Shuttle Main Engine-Block II

Crew:

Curtis L. Brown, Commander (5th Shuttle flight)
Steven W. Lindsey, Pilot (2nd)
Scott E. Parazynski, Mission Specialist (3rd)
Stephen K. Robinson, Mission Specialist (2nd)
Pedro Duque, Mission Specialist (1st) (European Space Agency)
Chiaki Mukai, Payload Specialist (2nd) (National Space and Development Agency of Japan)
John H. Glenn Jr., Payload Specialist (1st Shuttle, 2nd spaceflight)

Orbiter Preps (move to):

OPF — June 15, 1998
VAB — Sept. 14, 1998
Pad — Sept. 21, 1998

Launch:

October 29, 1998, 2:19:34 p.m. EST. At 12:30 p.m., the hatch was closed with crew inside the Space Shuttle Discovery, just as President Bill Clinton's Air Force One plane touched down at the Cape Canaveral Air Force Station skid strip. The countdown proceeded to T-9 minutes, but was held an additional 8.5 minutes while the launch team discussed the status of a master alarm heard during cabin leak checks after hatch closure. Once the count picked up and the Orbiter Access Arm was retracted, the Range Safety Officer (RSO) requested a hold at T-5 minutes due to aircraft in the restricted air space around KSC. Once the aircraft cleared the area, the RSO gave the all-clear signal and the countdown proceeded. Following main engine start, and prior to booster ignition, the drag chute compartment door fell off but posed no problem for the mission. Managers decided not to deploy the chute upon landing.

Landing:

November 7, 1998, 12:04 p.m. EST, Runway 33, Kennedy Space Center, Fla. No drag chute deployed. Just after landing, Astronaut John Glenn said, "One G and I feel fine." Rollout distance: 9,508 feet. Rollout time: 59 seconds. Mission duration: eight days, 21 hours, 44 minutes. Landed on orbit 135. Logged 3.6 million statute miles. Discovery landed on first opportunity at KSC, marking the 16th consecutive landing at KSC and 23rd in the last 24 Shuttle missions. This was Discovery's 13th landing at KSC and the 45th KSC landing in the history of the Shuttle program.

Mission Highlights:

The primary objectives of STS-95 included conducting a variety of science experiments in the pressurized SPACEHAB module, the deployment and retrieval of the Spartan free-flyer payload, and operations with the Hubble Space Telescope Orbiting Systems Test (HOST) and the International Extreme Ultraviolet Hitchhiker payloads being carried in the payload bay. The scientific research mission also returned space pioneer John Glenn to orbit — 36 years, eight months and nine days after he became the first American to orbit the Earth.

A slate of more than 80 experiments filled the nearly nine days in space. In addition to a variety of medical and material research, the crew released the Petite Amateur Naval Satellite, or PANSAT, to test innovative technologies to capture and transmit radio signals that normally would be lost because the original signals were too weak or contained too much interference. The crew also released the Spartan free-flying satellite to study the sun and the solar wind in a research effort to help scientists better understand a phenomenon that sometimes can cause widespread disruptions of communications and power supplies on Earth.

Medical research during the mission included a battery of tests on Payload Specialist Glenn and Mission Specialist Pedro Duque to further research how the absence of gravity affects balance and perception, immune system response, bone and muscle density, metabolism and blood flow, and sleep.

The Hubble Space Telescope Orbital Systems Test provided an on-orbit test bed for hardware that will be used during the third Hubble servicing mission.

STS-88

(1st Space Station Flight)

Endeavour

Pad A
93rd Shuttle mission
13th flight OV-105
46th KSC landing

Crew:

Robert D. Cabana, Commander (4th Shuttle flight)
Frederick W. "Rick" Sturckow, Pilot (1st)
Nancy J. Currie, Mission Specialist (3rd)
Jerry L. Ross, Mission Specialist (6th)
James H. Newman, Mission Specialist (3rd)
Sergei Konstantinovich Krikalev, Mission Specialist and Cosmonaut, (4th spaceflight, 2nd Shuttle, 2nd Mir)

Orbiter Preps (move to):

OPF — Feb. 1, 1998
VAB — Oct. 13, 1998
Pad — Oct. 21, 1998

Launch:

December 4, 1998, 3:35:34.075 a.m. EST. The originally scheduled launch of Endeavour on Dec. 3 was postponed for 24 hours when time ran out on the launch window. About 4 minutes prior to launch after orbiter hydraulic systems were powered on, a master alarm associated with hydraulic system number 1 in the crew cabin was noted. The countdown was held at T-31 seconds to further assess the situation. Shuttle system engineers attempted to quickly complete an assessment of the suspect hydraulic system and eventually gave an initial "go" to resume the countdown. With only seconds to respond, launch controllers were unable to resume the countdown in time to launch within the allotted remaining window. The launch was completed on time on Dec. 4.

Landing:

December 15, 1998, 10:53:29 p.m. EST, Runway 15, Kennedy Space Center, Fla. Rollout distance: 8,343 feet. Rollout time: 44 seconds. Mission duration: 11 days, 19 hours and 18 minutes. Landed on orbit 186, logging 4.6-million miles. It marked the 10th nighttime landing in the Shuttle program, the fifth at Kennedy Space Center, the 17th straight landing at Kennedy Space Center, the 24th in the last 25 Shuttle missions to land at the Florida spaceport, the 46th KSC landing in the history of the Shuttle program, and the ninth landing of Endeavour at KSC.

Mission Highlights:

During the 12-day mission to begin assembly of the International Space Station (ISS), all objectives were met. On Dec. 5, the 12.8-ton Unity connecting module was first connected to Endeavour's docking system; on Dec. 6, using the 50-foot-long robot arm, the Zarya control module was captured from orbit and mated to Unity; and astronauts Ross and Newman conducted three spacewalks to attach cables, connectors and hand rails. The two modules were powered up after the astronauts' entry.

Other EVA objectives were met as Ross and Newman tested a Simplified Aid for EVA Rescue (SAFER) unit, a self-rescue device should a spacewalker become separated from the spacecraft during an EVA; nudged two undeployed antennas on Zarya into position; removed launch restraint pins on Unity's four hatchways for mating future additions of station modules and truss structures; installed a sunshade over Unity's two data relay boxes to protect them against harsh sunlight; stowed a tool bag on Unity and disconnected umbilicals used for the mating procedure with Zarya; installed a handrail on Zarya; and made a detailed photographic survey of the Station.

Astronauts completed assembly of an early S-band communications system that allows flight controllers in Houston to send commands to Unity's systems and keep tabs on the health of the station, plus conducted a successful test of the videoconferencing capability of the early communications system which the first permanent crew will use. Krikalev and Currie also replaced a faulty unity in Zarya.

A new spacewalk record was established as Ross completed his seventh walk, totaling 44 hours, nine minutes. Newman moved into third place with four walks totaling 28 hours, 27 minutes.

Significant dates and times of the mission: Unity and Zarya were successfully engaged at 9:48 p.m., Dec. 6, and Unity came to life at 10:49 p.m., Dec. 7. At 2:54 p.m., Dec. 10, Cabana and Russian cosmonaut Sergei Krikalev floated into the new Station together, followed by the rest of the crew; at 4:12 p.m., Cabana and Krikalev opened the hatch to Zarya and entered; at 5:41 p.m., Dec. 11, Cabana and Krikalev closed the hatch to Zarya; and at 7:26 p.m., they closed the door to Unity. ISS flew free at 3:25 p.m., Dec. 13, as Pilot Rick Sturckow separated Endeavour from the Station.

Secondary objectives that were met were the successful deployment of the Shuttle's KU-band antenna and the Hitchhiker payload, including the MightySat and SAC-A satellites.

Problem areas/unexpected events: When the Unity-Zarya fittings would not align properly, it was necessary for the robot arm to loosely grapple Zarya. In addition, several construction items (slidewire carrier, worksite interface socket, retractable tether, trunnion pin cover) floated away from the orbiter; some floodlights failed during EVA; an incompatible connection was found between the activated carbon ion exchange and the hose assembly, but repaired; a camera on the Orbiter Space Vision System experienced binding during fast-rate operation, but could be used for slow-rate; and uncertainties surfaced about the unexpected depletion of the SAFER propellant, gaseous nitrogen.

STS-96

(2nd International Sp Station Flight)

Discovery

Pad B
94th Shuttle mission
26th flight OV-103
47th KSC landing

Crew:

Kent V. Rominger, Commander (4th Shuttle flight)
Rick D. Husband, Pilot (1st)
Ellen Ochoa, Mission Specialist (3rd)
Tamara E. Jernigan, Mission Specialist (5th)
Daniel T. Barry, Mission Specialist (2nd)
Julie Payette, Mission Specialist (1st) (Canadian Space Agency)
Valery Ivanovich Tokarev, Mission Specialist (1st) (Russian Aviation and Space Agency)

Orbiter Preps (move to):

OPF — Nov. 7, 1998
VAB — April 15, 1999
Pad — April 23, 1999
Return to VAB — May 16, 1999 (Rollback due to hail damage)
Return to Pad — May 20, 1999

Launch:

May 27, 1999, 6:49:42 a.m. EDT. The originally scheduled launch of Discovery on May 20 was postponed because of hail damage sustained May 8 by the external tank while on the pad. It was determined that some of the tank's foam insulation could not be reached for repairs with the orbiter on the pad. The orbiter was returned to the VAB, and inspections revealed more than 650 divots in the tank's outer foam. Workers repaired about 460 critical divots over four days to minimize ice formation prior to launch. The countdown proceeded smoothly, with the only concern the presence of a sailboat in the solid rocket booster recovery area. As planned, launch managers determined the exact orbital location of the International Space Station during the countdown's T-9-minute built-in hold. The decision was then made to launch Discovery at 6:49 a.m. EDT to achieve optimum Shuttle system performance and to accommodate Shuttle-Space Station docking activities.

Landing:

June 6, 1999, 2:02:43 a.m. EDT. Runway 15, Kennedy Space Center, Fla. Rollout distance: 8,866 feet. Rollout time: 56 seconds. Mission duration: nine days, 19 hours, 13 minutes, 57 seconds. Landed on orbit 154. Logged 3.8 million statute miles. Landed on first opportunity at KSC, marking 18th consecutive landing in Florida and 25th in the last 26 missions.

Mission Highlights:

All major objectives were accomplished during the mission. On May 29, Discovery made the first docking to the International Space Station (ISS). Rominger eased the Shuttle to a textbook linkup with Unity's Pressurized Mating Adapter #2 as the orbiter and the ISS flew over the Russian-Kazakh border.

The 45th space walk in Space Shuttle history and the fourth of the ISS era lasted 7 hours and 55 minutes, making it the second-longest ever conducted. Jernigan and Barry transferred a U.S.-built crane called the Orbital Transfer Device, and parts of the Russian crane Strela from the Shuttle's payload bay and attached them to locations on the outside of the station. The astronauts also installed two new portable foot restraints that will fit both American and Russian space boots, and attached three bags filled with tools and handrails that will be used during future assembly operations. The cranes and tools fastened to the outside of the Station totaled 662 pounds.

Once those primary tasks were accomplished, Jernigan and Barry installed an insulating cover on a trunnion pin on the Unity module, documented painted surfaces on both the Unity and Zarya modules, and inspected one of two Early Communications System (E-Com) antennas on the Unity.

During the incursion inside the ISS, Barry and Husband replaced a power distribution unit and transceiver for E-Com in the Unity module, restoring that system to its full capability. Payette and Tokarev replaced 18 battery recharge controllers in the Russian-built Zarya module, and Barry and Tokarev also installed a series of "mufflers" over fans inside Zarya to reduce noise levels in that module. The mufflers caused some air circulating duct work to collapse, and Rominger sent down a video inspection of the mufflers.

The crew transferred 3,567 pounds of material – including clothing, sleeping bags, spare parts, medical equipment, supplies, hardware and about 84 gallons of water – to the interior of the station. The astronauts also installed parts of a wireless strain gauge system that will help engineers track the effects of adding modules to the Station throughout its assembly, cleaning filters and checking smoke detectors. Eighteen items weighing 197 pounds were moved from the Station to Discovery for a return to Earth.

The astronauts spent a total of 79 hours, 30 minutes inside the Station before closing the final hatch on the orbiting outpost. Rominger and Husband commanded a series of 17 pulses of Discovery's reaction control system jets to boost the Station to an orbit of approximately 246 by 241 statute miles. After spending 5 days, 18 hours and 17 minutes linked to the Station, Discovery undocked at 6:39 p.m. EDT as Husband fired Discovery's jets to move to a distance of about 400 feet for 2 _ lap flyaround. The crew used the flyaround to make a detailed photographic record of the ISS.

After the flyaround, mission specialist Payette deployed the STARSHINE satellite from the orbiter's cargo bay. The spherical, reflective object entered an orbit two miles below Discovery. The small probe became instantly visible from Earth as part of a project allowing more than 25,000 students from 18 countries to track its progress.

Other payloads included the Shuttle Vibration Forces experiment and the Integrated Vehicle Health Monitoring HEDS Technology Demonstration.

STS-93

(Chandra X-ray Observatory)

Columbia

Pad B
95th Shuttle mission
26th flight OV-102
48th KSC landing

Crew:

Eileen M. Collins, Commander (3rd Shuttle flight)
Jeffrey S. Ashby, Pilot (1st)
Steven A. Hawley, Mission Specialist (5th)
Catherine G. "Cady" Coleman, Mission Specialist (2nd)
Michel Tognini, Mission Specialist (2nd) (CNES, French Space Agency)

Orbiter Preps:

OPF — May 4, 1998
VAB — Feb. 10, 1999 (Temporary storage)
OPF — April 15, 1999
VAB — June 2, 1999
Pad 39 B — June 7, 1999

Launch:

July 23, 1999, at 12:31:00 a.m. EDT. The originally scheduled launch on July 20 was scrubbed at about the T-7 second mark in the countdown. Following a virtually flawless countdown, the orbiter's hazardous gas detection system indicated a 640 ppm concentration of hydrogen in Columbia's aft engine compartment, more than double the allowable amount. System engineers in KSC's Firing Room No. 1 noted the indication and initiated a manual cutoff of the ground launch sequencer less than one-half second before the Shuttle's three main engines would have started. Following preliminary system and data evaluation, launch managers determined the hydrogen concentration indication was false. A second launch attempt 48 hours later was scrubbed due to weather at KSC. A 24-hour turnaround was initiated and the third launch attempt succeeded with Columbia lifting off the pad on July 23.

During the countdown for launch on the third attempt, a communications problem occurred that resulted in the loss of the forward link to Columbia. The problem was corrected at the Merritt Island Launch Area (MILA) ground facility and communications was restored. As a result of this problem, the time of the planned launch

was slipped seven minutes to 12:31 a.m. EDT on July 23.

About 5 seconds after liftoff, flight controllers noted a voltage drop on one of the shuttle's electrical buses. Because of this voltage drop, one of two redundant main engine controllers on two of the three engines shut down. The redundant controllers on those two engines — center and right main engines - functioned normally, allowing them to fully support Columbia's climb to orbit.

The orbit attained, however, was 7 miles short of that originally projected due to premature main engine cutoff an instant before the scheduled cutoff. This problem was eventually traced to a hydrogen leak in the No. 3 main engine nozzle. The leak was caused when a liquid oxygen post pin came out of the main injector during main engine ignition, striking the hotwall of the nozzle and rupturing three liquid hydrogen coolant tubes.

The orbiter eventually attained its proper altitude and successfully deployed the Chandra X-ray Observatory into its desired orbit.

Landing:

July 27, 1999 at 11:20:37 p.m. EDT. Runway 33, Kennedy Space Center, Fla. Rollout distance 6,851 feet. Rollout time: 43.3 seconds. Mission duration: 4 days, 22 hours, 49 minutes, 37 seconds. Landed on orbit 80, logging 1.8 million miles. It marked the 12th nighttime landing in the shuttle program and the 7th at Kennedy Space Center.

Mission Highlights:

STS-93 was the first mission in Space Shuttle history to be commanded by a woman, Commander Eileen Collins. Also, this was the shortest scheduled mission since 1990.

On the first day of the scheduled five-day mission, the Chandra X-ray Observatory was deployed from Columbia's payload bay. Chandra's two-stage Inertial Upper Stage (IUS) propelled the observatory into a transfer orbit of 205 miles by 44,759 miles in altitude.

Following the second IUS burn, Chandra's solar arrays were deployed and the IUS separated from the observatory as planned.

During the rest of the mission secondary payloads and experiments were activated. The Southwest Ultraviolet Imaging System (SWUIS) was used aboard Columbia to capture ultraviolet imagery of Earth, the Moon, Mercury, Venus and Jupiter.

Astronauts monitored several plant growth experiments and collected data from a biological cell culture experiment. They used the exercise treadmill and the Treadmill Vibration Information System to measure vibrations and changes in microgravity levels caused by on-orbit workouts.

High Definition Television equipment was tested for future use on both the shuttle and the International Space Station to conform to evolving broadcasting industry standards for television products.

STS-103

(3rd Hubble Space Telescope Servicing Mission)

Discovery

Pad B
96th Shuttle mission
27th flight OV-103
49th KSC landing

Crew:

Curtis L. Brown Jr., Commander (6th Shuttle flight)
Scott J. Kelly, Pilot (1st)
Steven L. Smith, Payload Commander (3rd)
C. Michael Foale, Mission Specialist (5th)
John M. Grunsfeld, Mission Specialist (3rd)
Claude Nicollier, Mission Specialist (4th) (European Space Agency)
Jean-Francois Clervoy (3rd) (European Space Agency)

Orbiter Preps:

OPF — 06/06/99
VAB — 11/04/99
Pad 39 B — 11/13/99

Launch:

Dec. 19, 1999, at 7:50:00 p.m. EST. Discovery faced nine delays and scrubs, some mechanical and some due to the weather, before launching successfully.

Before facing those postponements, the third Hubble Space Shuttle servicing mission had been advanced in the mission schedule. The servicing mission was originally scheduled for June 2000, but when the third of Hubble's six gyroscopes failed, the mission was split into two separate missions. The first mission, STS-103, was scheduled for Oct. 14 with the second mission to follow in 2001. (Hubble needs at least three of its six gyroscopes to be functioning to enable the telescope to point precisely at distant astronomical targets for scientific observation.)

In mid-August Shuttle managers decided to extend wiring inspections and maintenance across the Shuttle fleet after wiring problems were detected aboard Columbia. That orbiter was inspected and determined to have wiring problems after an irregularity occurred during the launch of STS-93 on July 23, 1999. Following inspections of Discovery, a new target launch date of no earlier than Oct. 28 was announced (first launch delay).

Because of the amount of wiring repairs needed, the planning date was shifted to no earlier than Nov. 19 (second delay). Shuttle managers decided to preserve the option to launch either STS-103 or STS-99, the Space Radar Topography Mission, first.

On Nov. 13, a fourth gyroscope on Hubble failed and the observatory was put into "safe mode," a state of dormancy in which the telescope aims itself constantly at the sun to provide electrical power to its systems.

As repairs to Discovery came to a close, launch was targeted for Dec. 2. The launch date was put under review after a half-inch-long drill bit was discovered to be lodged in main engine No. 3. A new launch date of Dec. 6 was set (third delay). Rollout to the pad proceeded and Discovery's main engine No. 3 was replaced while the orbiter was on the pad.

After Discovery reached the pad, additional damaged wiring, which was found in an umbilical between the orbiter and the external tank, was detected and a new launch date of Dec. 9 was set to allow for repair and testing (fourth delay). The launch was then reset to Dec. 11 (fifth delay). The new target date allowed KSC workers to observe the Thanksgiving Holidays.

The mission was again put on hold after a dented main propulsion system line, which carries liquid hydrogen fuel for the Shuttle main engines, was found during closeout inspections of Discovery's engine compartment. A new target date of earlier than December 16 was set (sixth delay).

By Dec. 13, workers at Launch Pad 39B had completed inspections
and leak checks on Shuttle Discovery's replaced liquid hydrogen recirculation line that was replaced and the target date confirmed to be Dec. 16.

On Tuesday, Dec. 14, 1999, the launch countdown for STS-103 began on schedule at 1:30 a.m. Later that day during routine inspections of the external tank's pressure lines, a suspect weld was detected. To ensure that the proper welding materials and procedures were used, a thorough review of process and paperwork used during the fabrication of the lines was conducted. It was determined that the same manufacturer performed welds on the 17-inch propellant feed lines and struts in the AFT engine compart-

ment when Discovery was constructed. A 24-hour delay was called to give the Shuttle team time to review the manufacturing inspection records for those lines as well. It was determine the welds were correctly made and the launch was rescheduled to Dec. 17 (seventh delay).

On Dec.17, with an 80 percent chance of unfavorable weather, external tank cyrogenic loading was started at 11:29 a.m. EST. Tanking operations were complete at 3 p.m. EST. The launch countdown proceeded to the T-minus 9 minute mark and held due to weather constraints. At 8:52pm EST the launch director scrubbed the launch due to violations of weather launch commit criteria and the launch was rescheduled to Dec. 18 (eighth delay).

Due to the prediction of poor weather on Dec. 18, the mission management team decided to preserve a launch option and re-scheduled Discovery's launch from Dec. 18 to Dec. 19 at 7:50p.m. EST (ninth delay).

On Dec. 19, 1999, the weather outlook was favorable, so Shuttle managers decided to proceed with the STS-103 launch countdown. The Shuttle launched on time at the beginning of the 42 minute window.

To ensure that all flight and ground systems were secured for the transition to Year 2000, the mission was shortened from 10 days to 8 days.

Landing:

Dec. 27, 1999 at 7:01:34 p.m. EST. Runway 33, Kennedy Space Center, Fla. Rollout distance 7,005 feet. Rollout time: 47 seconds. Mission duration: 7 days, 23 hours, 10 minutes, 47 seconds. Landed on orbit 119, logging more than 3.267 million miles. It marked the 13th nighttime landing in the shuttle program and the 8th at Kennedy Space Center.

Mission Highlights:

STS-103 restored the Hubble Space Telescope to working order and upgraded some of its systems, allowing the decade-old observatory to get ready to begin its second scheduled decade of astronomical observations.

The first few days of the 8-day mission, the crew prepared for the rendezvous and capture of the Hubble Space Telescope and the three maintenance spacewalks to follow. After a 30-orbit chase. Commander Brown and Kelly maneuvered the orbiter to a point directly beneath Hubble, then moved upward toward it. Mission Specialist Clervoy grappled Hubble using the orbiter's robotic arm and placed it on the Flight Support System in the rear of Discovery's cargo bay.

EVA No. 1: Mission Specialists Steven Smith and John Grunsfeld conducted the mission's first spacewalk. The two made numerous repairs, including replacing the telescope's three Rate Sensor Units – each containing two gyroscopes. They also installed six Voltage/Temperature Improvement Kits between Hubble's solar panels and its six 10-year-old batteries. The kits, the size of cell telephones, were designed to prevent any overheating or overcharging of those batteries. A few minor objectives were left undone, such as taking close-up photos of the Voltage/Temperature Improvement Kits. The 8-hour, 15-minute spacewalk was second to the longest space walk from Endeavour on STS-49 in May 1992. A few minor problems helped account for the length of the spacewalk. The astronauts had difficulty in removing one of the old RSUs, and opening valves and removing caps on the Near Infrared Camera and Multi-Object Spectrometer. The tasks were eventually completed.

EVA No. 2: During the mission's second spacewalk, Mission Specialists Michael Foale and Claude Nicollier installed a new advanced computer – 20 times faster than Hubble's old one – and a new, 550-pound fine guidance sensor. This 8-hour, 10 minute spacewalk was the third longest in history. With all major activities accomplished, controllers reported that power was reaching both of the new pieces of equipment. "The brains of Hubble have been replaced," said Mission Specialist Grunsfeld. About 30 minutes later, Hubble began thinking with those new brains.

EVA No. 3: Smith and Grunsfeld again teamed up to make the mission's third and final space walk. Like the first two, it also lasted more than 8 hours, making it the fourth longest in history. The team installed a transmitter that sends scientific data from Hubble to the ground. It replaced one that failed in 1998. The astronauts used special tools developed for the task because transmitters, usually very reliable, were not designed to be replaced in orbit. Smith and Grunsfeld also installed a solid state digital recorder, replacing an older mechanical reel-to-reel.

Hubble was released from Discovery's cargo bay on Christmas Day.

Mission STS-103 is only the second time in the Space Program that a crew has spent Christmas in space.

Notes

NASA