KSC Release No. 12-92
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Space Shuttle Mission Chronology

1997

1). STS-81

2). STS-82

3). STS-83

4). STS-84

5). STS-94

6). STS-85

7). STS-86

8). STS-87

(In chronological order)

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:

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 inflight 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: 9 days, 23 hours, 37 minutes, 09 seconds. Landed 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 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 lifespan, 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. This means that many regions in a planet's atmosphere or many stars within a galaxy can be recorded in one exposure, making the telescope faster and more efficient. STIS expected to shed further light on supermassive black holes. NICMOS features more capable infrared detectors and will give astronomers their first clear view of the universe at near infrared wavelengths between 0.8 and 2.5 micrometers.

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 EVA, 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 total of 33 hours, 11 minutes, of EVAs 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 ten weeks. Two more servicing missions planned for 1999 and 2002.

Performance of Discovery was nominal through out 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: 3 days, 23 hours, 12 minutes, 39 seconds. Landed 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 each. In one substack of fuel cell 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 shut down. Additional purges and other measures failed to correct the anomaly, and around 10 a.m., April 6, the Mission Management Team ordered the mission to end early. Fuel cell 2 was shut down for good later that afternoon and safed.

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. The Structure of Flame Balls at Low Lewis-number experiment, completed two runs. This experiment is designed to determine under what conditions a stable flame ball can exist and if heat loss is responsible in some way for the stablilization 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 designated STS-83R and then renamed 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 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:

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 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 on 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 some 249 items were moved between the two spacecraft, and some 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:

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. on 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 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 ignition of the weakest flames (as low as one watt, or 1/50th 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. Crew performed over 100 test runs – more than double number planned – in Middeck Glovebox Facility in areas of liquid and bubble behavior, fluids-based heat transfer devices and solid-liquid mixtures. Droplets of a hydrocarbon, heptane, were burned at the lowest atmospheric pressure achieved during a mission.

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 better understand their structures and 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 an 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 in 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 (Canadian Space Agency) (1st)

Orbiter Preps:

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

Launch:

August 7, 1997, 10:41:00 a.m. EDT. Ontime 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 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-2); 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-2 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. The three CRISTA telescopes collected 38 full atmospheric profiles of the middle atmosphere. A total of 22 sounding rockets and 40 balloons were launched to provide correlating data. 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 GrowthLocker 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 (CNES, French Space Agency) (1st)
Wendy B. Lawrence, Mission Specialist (2nd)
Scott E. Parazynski, Mission Specialist (2nd)
Vladimir Georgievich Titov, Mission Specialist (Russian Space Agency) (2nd Shuttle, 4th spaceflight)

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:

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 revolution 170, on the first opportunity after two opportunities on 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 space walk 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 space walk, 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 space walk 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 space walks planned over the next several months to repair Spektr. Unlike Wolf, Lawrence could not fit in the Orlan suit which is used for Russian space walks and did not undergo space walk training.

Following their arrival at the station Aug. 7, Mir 24 Commander Antaoly Solovyev and Flight Enginneer Pavel Vinogradov conducted the internal space walk 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 space walk, Foal 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 was conducted by Titov and Parazynski, which was also the 39th in the Space Shuttle program. During the 5-hour, one-minute spacewalk on 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 the Mir and tested several components of the Simplified Aid for EVA Rescue (SAFER) jetpacks. 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 (NASDA, Japanese Space Agency) (1st)
Winston E. Scott, Mission Specialist (2nd)
Leonid K. Kadenyuk, Payload Specialist (NSAU, Ukrainian Space Agency)

Orbiter Preps:

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, 04 seconds. Landed revolution 252.

Mission Highlights:

Primary payload of flight, the U.S. Microgravity Payload-4, performed well. Research using other major payload, SPARTAN-201-04 freeflyer, 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 freeflyer, Scott and Doi began a seven-hour, 43-minute space walk 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 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 Solification 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 Engulgment 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 metas, in IDGE. With CHeX, the most precise temperature measurement ever made in space was achieved.

With MEPHISTO, researchers were able to separate for first time two separate processes of solidification. Also were able to measure the speed of smooth crystal growth. With AADSF, like MEPHISTO featuring a furnace, allowed growth of large, near-perfect crystals of

various types of semiconductor materials, as well as an exceptionally uniform crystal of mercury-cadmium-telluride.

PEP experiment, conducted with the Glovebox facility, examined the solidification of of liquid metal alloys. For first time, researchers observed large clusters of particles being pushed, forcing them to reassess theories for how alloys solidify. ELF, another Glovebox experiment, established first probablity chart for flame stabilization in microgravity. This was mission's only combustion experiment. it focused on laminar gas flows, a key phenomenon in the combustion process. Data gathered on-orbit should help refine computer simulations studying aircraft engine safety and furnace efficiency.

Other payloads: Get Away Special canister containing four experiments; the Collborative 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.