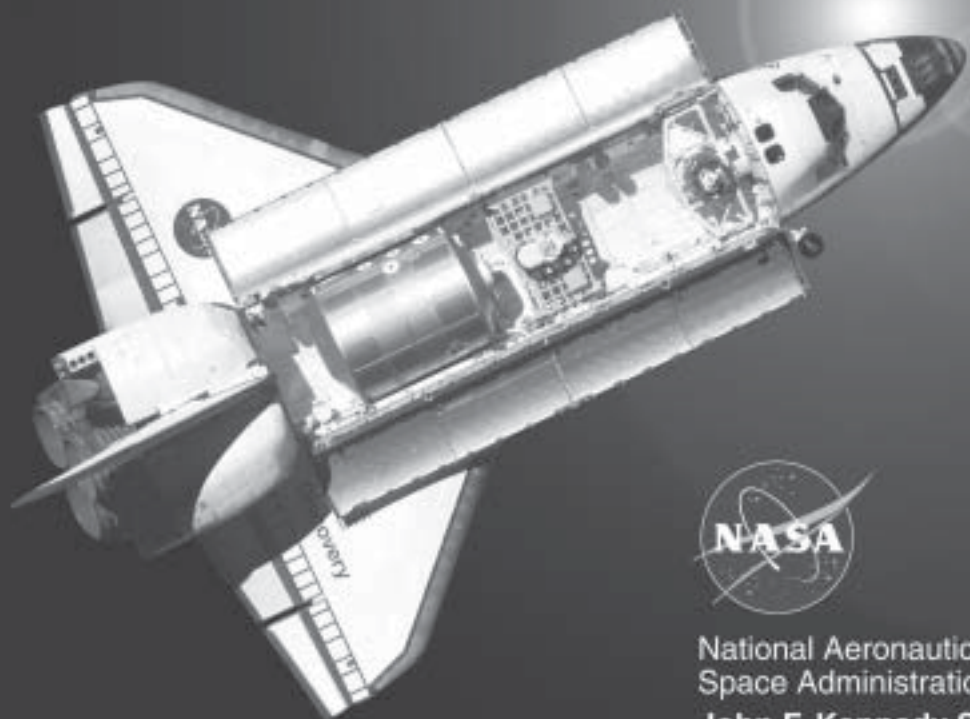


Volume 2

# Space Shuttle Mission Chronology: 2000-2003



National Aeronautics and  
Space Administration  
John F. Kennedy Space Center



# Table of Contents

<b>Flight</b>		<b>Page</b>
	<b>2000</b>	
STS-99 .....		1
STS-101 .....		2
STS-106 .....		3
STS-92 .....		4
STS-97 .....		5
	<b>2001</b>	
STS-98 .....		6
STS-102 .....		8
STS-100 .....		9
STS-104 .....		10
STS-105 .....		11
STS-108 .....		12
	<b>2002</b>	
STS-109 .....		13
STS-110 .....		15
STS-111 .....		16
STS-112 .....		17
STS-113 .....		18
	<b>2003</b>	
STS-107 .....		20

# MAJOR SHUTTLE PAYLOADS FLOWN CHRONOLOGICALLY

FLIGHT	ORBITER	PRIMARY PAYLOAD
STS-99	Endeavour	Shuttle Radar Topography Mission
STS-101	Atlantis	ISS /Equipment
STS-106	Atlantis	ISS/magnetometer
STS-92	Discovery	ISS/Z1 truss; PMA 3
STS-97	Endeavour	ISS/P6 truss
STS-98	Atlantis	ISS/U.S. Lab Destiny
STS-102	Discovery	ISS/MPLM* Leonardo; Expedition 2 crew exchange
STS-100	Endeavour	ISS/Canadarm2; MPLM Raffaello
STS-104	Atlantis	ISS/Quest Airlock; High Pressure Gas Assembly
STS-105	Discovery	ISS/MPLM Leonardo; Expedition 3 crew exchange
STS-108	Endeavour	ISS/MPLM Raffaello; Expedition 4 crew exchange; STARSHINE 2
STS-109	Columbia	Hubble Servicing Mission
STS-110	Atlantis	ISS/S0 truss; Mobile Transporter
STS-111	Endeavour	ISS/ Mobile Base System; Expedition 5 crew exchange
STS-112	Atlantis	ISS/S1 truss
STS-113	Endeavour	ISS/P1 truss
STS-107	Columbia	Research mission: SPACEHAB; Hitchhiker pallet, FREESTAR, SIMPLEX, RAMBO

\*Multi-Purpose Logistics Module

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# STS-99 (Shuttle Radar Topography Mission)



## Endeavour Pad A

97th Shuttle mission  
14th flight OV-105  
50th KSC landing

## Crew:

Kevin R. Kregel, Commander (4th Shuttle flight)  
Dominic Gorie, Pilot (2nd)  
Janet L. Kavandi, Mission Specialist (2nd)  
Janice Voss, Mission Specialist (5th)  
Mamoru Mohri, Mission Specialist (2nd),  
National Space and Development Agency  
of Japan  
Gerhard P.J. Thiele, Mission Specialist (1st),  
European Space Agency

## Orbiter Preps (move to):

**OPF bay 2** -- Dec. 16, 1998  
**VAB** -- Dec. 2, 1999  
**Pad 39A** -- Dec. 13, 1999

## Launch:

**Feb. 11, 2000, at 12:43:40 p.m. EST.** STS-99 faced a series of launch delays and one scrub before launching successfully. The mission was originally scheduled to fly on Sept. 16, 1999. But in mid-August, the launch date was postponed until October because of wiring concerns throughout the Shuttle fleet. With so much of Endeavour's wiring requiring inspection, the target date for launch was shifted to no earlier than Nov. 19. Shuttle managers later decided to preserve the option to launch either STS-99, or STS-103, the Third Hubble Servicing Mission, first. It was decided in October that STS-103 would fly first, and the launch of STS-99 was set for Jan. 13, 2000. In December that date came under review, and a new launch date of no earlier than Jan. 31 was set.

The scheduled launch on Jan. 31, 2000, was scrubbed because of unacceptable weather conditions. However, late in the count, an anomaly occurred with the No. 2 enhanced master events controller (EMEC), which also would have prevented the launch on that day. The EMEC was removed and replaced and the launch rescheduled until 12:30 p.m. EST on Feb. 11. About three hours prior to the scheduled launch, an unexpected pressure drop was detected in hy-

draulic system 1. The pressure drop was determined to be the result of a normal sequence of prelaunch events. Discussions of the pressure drop resulted in a 13-minute, 40-second launch delay.

## Landing:

**Feb. 22, 2000, 6:22:23 p.m. EDT.** Runway 33, Kennedy Space Center, Fla. Rollout distance: 9,943 feet. Rollout time: 1 minute, 2 seconds. Mission duration: 11 days, 5 hours, 38 minutes. Landed on orbit 181. Logged about 4.7 million statute miles. Landed on the second of two Florida landing opportunities. The first opportunity was at 4:50 p.m., but cross winds at the Shuttle Landing Facility violated established weather constraints. The landing marked the 21st consecutive landing at KSC, and the 50th landing at KSC overall.

## Mission Highlights:

The Shuttle Radar Topography Mission mast was deployed successfully to its full length, and the antenna was turned to its operation position. After a successful checkout of the radar systems, mapping began at 12:31 a.m., less than 12 hours after launch. Crewmembers, split into two shifts so they could work around the clock, began mapping an area from 60 degrees north to 56 degrees south. Data was sent to Jet Propulsion Laboratory for analysis and early indications showed the data to be of excellent quality.

Mapping proceeded fairly smoothly, but during an attitude-hold period for payload mapping during the second day of flight, it was determined that orbiter propellant usage had doubled from 0.07 to 0.15 percent an hour. The increase was caused by a failure of the payload cold-gas thrust system that was used to offset the gravity gradient torque of the mast.

As a result of this failure, orbiter propellant was being used at a higher-than-planned rate to maintain the attitude of the vehicle. Measures to reduce the expenditure were evaluated and based on the analysis, enough propellant could be saved to complete the planned 9-day plus science mission.

The first of a series of "flycast" maneuvers during the mission was also made on the second day of flight. The flycast maneuver was designed to reduce strain on the almost-200-foot mast extending from Endeavour's cargo bay when adjustments to Endeavour's orbit were needed.

The orbiter, which flies tail-first during mapping operations, is moved to a nose-first attitude with the mast extending upward. A brief reaction control system pulse begins the maneuver. The mast deflects slightly backwards, then rebounds forward. As it reaches vertical, a stronger thrust is applied, arresting the mast's motion and increasing the orbiter's speed.

Radar data gathering concluded at 6:54 a.m. EST on the tenth day of flight after a final sweep across Australia. During 222 hours and 23 minutes of mapping, Endeavour's radar images filled 332 high density tapes and covered 99.98 percent of the planned mapping area ñ land between

60 degrees north latitude and 56 degrees south latitude ñ at least once and 94.6 percent of it twice. Only about 80,000 square miles in scattered areas remained unimaged, most of them in North America and most already well mapped by other methods. Enough data was gathered to fill the equivalent of 20,000 CD's.

Also aboard Endeavour was a student experiment called EarthKAM, which took 2,715 digital photos during the mission through an overhead flight-deck window. The NASA-sponsored program lets middle school students select photo targets and receive the images via the Internet. The pictures are used in classroom projects on Earth science, geography, mathematics and space science. More than 75 middle schools around the world participated in the experiment, which set a record. On four previous flights combined, EarthKAM sent down a total of 2,018 images.

# STS-101 (ISS Flight 2A.2a)



## Atlantis Pad A

98th Shuttle mission  
21st flight OV-104  
22nd consecutive KSC landing

## Crew:

James D. Halsell Jr., Commander (5th Shuttle flight)  
Scott J. Horowitz, Pilot (3rd)  
Mary Ellen Weber, Mission Specialist (2nd)  
James S. Voss, Mission Specialist (4th)  
Jeffrey N. Williams, Mission Specialist (1st)  
Susan J. Helms, Mission Specialist (4th)  
Yury Usachev, Mission Specialist and  
cosmonaut (1st on Shuttle, twice on Mir)

## Orbiter Preps (move to):

**OPF bay 3 ñ** Sept. 27, 1998; Feb. 17, 1999;  
Sept. 24, 1999  
**VAB ñ** Dec. 10, 1998 (storage); Feb. 8, 1999  
(transfer aisle); July 26, 1999 (storage);  
Aug. 25, 1999 (transfer aisle); Sept. 1, 1999  
(high bay 2); March 17, 2000  
**Pad A ñ** March 25, 2000

## Launch:

**May 19, 2000 at 6:11:10 a.m. EDT.** After three launch delays in April caused by high winds at the launch site and overseas emergency landing strips, Atlantis blasted off from KSC's Launch Pad 39A on time. A crew of six American

astronauts and one Russian cosmonaut were on their way to pay a home improvement house call on the fledgling International Space Station (ISS).

## Landing:

**May 29, 2000, at 2:20:19 a.m. EDT.** Runway 15, Kennedy Space Center, Fla. Rollout distance: 8892 feet. Rollout time: 62 seconds. Wheel stop occurred at 2:21:17 a.m. EDT. Mission duration: 9 days, 20 hours, 9 minutes and 9 seconds. Landed on orbit 155. Logged 4,076,000 miles. Landed on first opportunity at KSC, marking the 22nd consecutive landing in Florida and 29th in the last 30 missions. Also the 14th nighttime landing in Shuttle history.

## Mission Highlights:

On their 10-day mission, the astronauts completed one spacewalk (EVA), equipped the ISS with new or replacement gear and transferred more than a ton of supplies into the Space Station for use by future residents of the ISS.

## EVA ñ 6 hours, 44 minutes:

The EVA marked the fifth spacewalk for construction of the ISS, the 49th conducted from a Space Shuttle, and the 85th overall conducted by U.S. astronauts. Mission Specialists James Voss and Jeffrey Williams secured a United States-built crane installed on the Station last year; installed the final parts of a Russian-built crane, Strela, on the Pressurized Mating Adapter-1 that connects the Unity node to the Zarya control module; replaced a faulty antenna for one of the station's communications systems; and installed several handrails and a camera cable on the ISS exterior.

Mission Specialist Mary Ellen Weber operated the Shuttle's robotic arm, which she used to maneuver Voss during much of the spacewalk.

Work inside the Space Station followed. Before entering the Space Station, the crew opened various hatches into and within the different modules, in this order: PMA-2, Unity node, PMA-1, Zarya, and instrumentation cargo compartment on Zarya. Over the course of three days, the crew installed four batteries and associated electronics; 10 new smoke detectors in the Zarya module; four new cooling fans; additional cables for the Zarya computer to enhance capabilities; a new communications memory unit; and a new power distribution box for the U.S.-built communications system.

Next came the transfer of supplies ñ more than 3,300 pounds of gear ranging from clothes, tools, can openers,



sewing kits and trash bags to a treadmill, an exercise bicycle ergometer and IMAX film camera. The crew also filled four 12-gallon water containers for use by future resident astronauts aboard the ISS.

During the mission, Commander Halsell and Pilot Horowitz also fired Atlantis' jets three times to boost the ISS about 27 miles into a slightly higher orbit of 225 miles.

When stowage was complete, the crew reversed the procedure to close the hatches in the Space Station, with the final hatch shut at 4:40 a.m. EDT., May 26.

Undocking with the Space Station occurred at 7:02 p.m. EDT, May 26. Pilot Horowitz backed Atlantis away and then flew a half-circle around the station before firing Atlantis' jets in a final separation burn at 7:41 p.m. EDT.

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## STS-106 (ISS Flight 2A.2b)



### Atlantis Pad B

99th Shuttle mission  
22nd Flight of OV-104  
52nd KSC landing

### Crew:

Terrence W. Wilcutt, Commander (4th Shuttle flight)  
Scott D. Altman, Pilot (2nd)  
Edward Lu, Mission Specialist (2nd)  
Yuri I. Malenchenko, Mission Specialist (1st)  
Boris V. Morokov, Mission Specialist (1st)  
Richard A. Mastracchio, Mission Specialist (1st)  
Daniel C. Burbank, Mission Specialist (1st)

### Orbiter Preps (move to):

**OPF bay 3 ñ** May 29, 2000  
**VAB ñ** Aug. 7, 2000  
**Pad 39B ñ** Aug. 13, 2000

### Launch:

**Sept. 8, 2000, 8:45:47 a.m. EDT.** STS-106 launched as planned at 8:45 a.m. with no unscheduled holds during the flawless countdown.

### Landing:

**Sept. 20, 2000, 3:58:01 a.m. EDT.** Runway 15, Kennedy Space Center, Fla. Rollout distance: 9,127 feet. Rollout time: 1 minute 13 seconds. Mission duration: 11 days, 19 hours, 12 minutes, 15 seconds. Landed on orbit 185. Logged 4.9 million statute miles. Landed on first opportunity at KSC, marking 23<sup>rd</sup> consecutive landing in Florida and the 30<sup>th</sup> landing of a Shuttle at KSC in the last 31 flights.

### Mission Highlights:

STS-106, during its 11-day mission to the International Space Station (ISS), completed all assigned mission objectives to prepare the Station for the first crew scheduled to launch in October. The mission to the 143-foot-long Station focused on unloading nearly three tons of cargo from the orbiter and a Progress supply craft already docked to the opposite end of the ISS.

On flight day two, Atlantis completed a successful rendezvous and docking with the ISS in early morning setting the stage for six days of outfitting.

### EVA: 6 hours and 14 minutes:

The EVA was completed successfully on day three, 16 minutes ahead of the planned schedule, by Lu and Malenchenko. The spacewalk's objective focused on routing and connecting nine power, data and communications cables between the Zvezda module and the other Russian-built module, Zarya, as well as installing the six-foot-long magnetometer to the Station to serve as a compass showing the Station in respect to the Earth.

Lu and Malenchenko used tethers and handrails along the ISS to make their way to a point more than 100 feet above the cargo bay, the farthest any tethered spacewalker has ventured outside the Shuttle. They completed this with the assistance of their inside crewmates Burbank and Mastracchio who deftly maneuvered them around with the robotic arm. This spacewalk celebrates the sixth spacewalk in support of the Station assembly and the 50th spacewalk in Space Shuttle history.

On flight day four the crew entered the International Space Station through Pressurized Mating Adapter-2 (PMA-2) to begin the transfer operations of more than three tons of hardware and supplies. Atlantis' crew was the first to see the interior of the Russian Zvezda service module since it was launched from the Baikonur Cosmodrome in July. Additionally, a reboost was performed using the orbiter's Reaction Control System (RCS) to place the Station in a higher orbit.

Transfer of supplies and maintenance tasks continued well into the fifth day, while orbiter consumables remained above the required levels allowing managers to extend the mission one additional day. Activities on flight day five included the installation of three batteries inside Zvezda. In order to reduce the weight for launch, Zvezda was launched with only five of its eight batteries in place.

Lu and Malenchenko spent much of flight day seven installing voltage and current stabilizers in Zvezda. Components of the Elektron system, equipment sent into orbit to separate water into oxygen and hydrogen, were installed and will be activated after the first crew arrives.

The crew transferred more than 6,000 pounds of material ñ including six, 100 pound bags of water, all of the food for the first resident crew, office supplies, onboard envi-

ronmental supplies, a vacuum cleaner and a computer and monitor ñ to the interior of the Station.

The astronauts spent a total of 5 days, 9 hours and 21 minutes inside the Station before closing the hatch on the orbiting outpost. Wilcutt and Altman commanded a series of four altitude boosts to place the Station in an orbit of approximately 241 by 233 statute miles, raising the average altitude by 14 miles. After spending 7 days, 21 hours and 54 minutes linked to the Station, Atlantis undocked at 6:45 p.m. EDT as Wilcutt and Altman fired Atlantis' jets to move to a distance of about 450 feet for a double-loop flyaround.

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## STS-92 (ISS Flight 3A)

### Discovery Pad A

100th Shuttle mission  
28th Flight of OV-103  
1st Edwards Air Force Base  
landing since 1996

### Crew:

Brian Duffy, Commander (4th Shuttle flight)  
Pamela A. Melroy, Pilot (1st)  
Leroy Chiao, Mission Specialist (3rd)  
William iBilli S. McArthur, Mission Specialist (3rd)  
Peter iJeffi J.K. Wisoff, Mission Specialist (4th)  
Michael E. Lopez-Alegria, Mission Specialist (2nd)  
Koichi Wakata, Mission Specialist (2nd)

### Orbiter Preps (move to):

**OPF bay 1 ñ** Dec. 27, 1999  
**VAB ñ** Aug. 24, 2000  
**Pad 39B ñ** Sept. 11, 2000

### Launch:

**Oct. 11, 2000, 7:17:00 p.m. EDT.** STS-92 was scheduled to launch on Oct. 5, 2000. However, prior to loading cryogenics into the external tank, the mission was delayed when it was noted through film review on the previous mission (STS-106) that the right-hand external tank to orbiter attach bolt failed to retract properly. Following the scrub decision an orbiter liquid oxygen pogo accumulator re-circulation valve located in Discovery's Main Propulsion System failed to respond properly and a decision was made to remove and replace the valve. The launch was rescheduled for Oct. 9.

The second launch attempt was postponed prior to tanking due to higher than acceptable winds at the pad preventing fueling of the external tank. The launch was delayed 24 hours and rescheduled for Oct. 10. During the planned three-hour hold on the next launch attempt, a ground

support equipment pin with a tether, used on access platforms, was observed on the external tank-to-orbiter liquid oxygen feed line during final pad inspections. The launch was postponed at the T-20 minute mark due to potential damage the pin and tether might cause to the orbiter during launch.

Launch was rescheduled 24 hours later and occurred without more delay on Oct. 11 at 7:17 p.m. EDT.

### Landing:

**Oct. 24, 2000, 5 p.m. EDT.** Runway 22, Edwards Air Force Base, Calif. Rollout distance: 9,090 feet. Rollout time: 1 minute, 15 seconds. Mission duration: 12 days, 21 hours, 40 minutes, 25 seconds. Landed on orbit 202. Logged 5.3 million statute miles. Landing was originally scheduled at KSC on Oct. 22, 2000. However, landing opportunities at KSC were waived due to higher than allowable crosswinds at the SLF.

The next landing attempt was scheduled for Oct. 23, but winds remained in excess of limits at KSC. Landing opportunities at Edwards were also waived due to rain showers within 30 miles of the planned runway. Winds were again in excess of limits at KSC on the third day, and, as a result, all KSC opportunities were waived. The Space Shuttle Discovery landed on the first opportunity at Edwards Air Force Base.

### Mission Highlights:

STS-92, during its 12-day mission to the International Space Station (ISS), completed all assigned objectives to install the Zenith Z1 Truss and the third pressurized mating adapter (PMA 3) for use as a docking port for subsequent Shuttle missions.

In the afternoon of flight day two, Discovery and her crew completed a successful rendezvous and docking with the International Space Station setting the stage for six days of construction and outfitting.

On flight day three, Japanese Astronaut, Koichi Wakata, deftly maneuvered Discovery's robotic arm to lift the Zenith Z1 Truss from the Shuttle's payload bay and berthed it to a port on the Unity connecting module. Inside Unity, Pilot Pam Melroy and crewmate Jeff Wisoff opened the hatch where the new truss was attached and installed grounding connections between the framework and the Station.

Discovery's five mission specialists, Leroy Chiao, Bill McArthur, Jeff Wisoff, Mike Lopez-Alegria and Koichi Wakata, performed a total of four extravehicular activities (EVA) during the STS-92 mission. They included the following assignments:

### EVA No. 1 ñ 6-hours, 28-minutes:

Connection of electrical umbilicals to provide power to heaters and conduits located on the Z1 Truss; relocation and deployment of two communication antenna assemblies; and installation of a toolbox for use during on-orbit construction.





### **EVA No. 2 ñ 7 hours, 7 minutes:**

Attachment of the PMA 3 to the ISS and preparation of the Z1 Truss for future installation of the solar arrays that will be delivered aboard STS-97 in late November.

### **EVA No. 3 ñ 6-hours, 48-minutes:**

Installation of two DC-to-DC converter units atop the Z1 Truss for conversion of electricity generated by the solar arrays to the proper voltage.

### **EVA No. 4 ñ 6-hours, 56 minutes:**

Testing of the manual berthing mechanism; deployment of a tray that will be used to provide power to the U.S. Lab; and removal of a grapple fixture from the Z1 Truss. Two small rescue backpacks that could enable a drifting astronaut to regain the safety of the spacecraft were also tested.

On flight day nine, the crew of Discovery shifted their attention to the interior of the ISS as they completed connections for the newly installed Z1 Truss external framework and began transferring equipment and supplies for the first resident crew of the ISS who arrived in November. They also successfully completed testing of the four control moment gyroscopes that will be used to orient the ISS as it orbits Earth.

## **STS-97** **(ISS Flight 4A)**



### **Endeavour** **Pad B**

101st Shuttle mission  
15th Flight of OV-105  
53rd KSC landing

### **Crew:**

Brent Jett, Commander (3rd Shuttle flight)  
Michael Bloomfield, Pilot (2nd)  
Joseph Tanner, Mission Specialist (3rd)  
Carlos Noriega, Mission Specialist (2nd)  
Marc Garneau, Mission Specialist (3rd),  
Canadian Space Agency

### **Orbiter Preps (move to):**

**OPF bay 2 ñ Feb. 23, 2000**  
**VAB ñ Oct. 25, 2000**  
**Pad 39B ñ Oct. 31, 2000**

### **Launch:**

**Nov. 30, 2000 at 10:06:01 p.m. EST.** Endeavour blasted off on time from Launch Pad 39B at the Kennedy Space Center on the 101st mission in Space Shuttle his-

tory. The crew of five astronauts were on the sixth construction flight for the International Space Station (ISS). There were no unscheduled holds or delays during the flawless countdown.

### **Landing:**

**Dec. 11, 2000 at 6:04:20 p.m. EST.** Landed on first opportunity at KSC, Runway 15, Kennedy Space Center, Fla. Main Gear Touchdown: 6:03:25 p.m. EST. Nose Gear Touchdown: 6:03:34 p.m. EST. Wheel Stop: 6:04:20. Rollout time: 57 seconds. Mission Elapsed Time: 10 days, 19 hours, 58 minutes. Distance on orbit: 4,476,164 million miles. Endeavour landed on orbit 171, marking the 16th night landing and the 53rd KSC landing in Space Shuttle history.

### **Mission Highlights:**

On their 11-day mission, the astronauts completed three spacewalks, or EVAs, to deliver and connect the first set of U.S.-provided solar arrays to the ISS, prepare a docking port for arrival of the U.S. Laboratory Destiny, install Floating Potential Probes to measure electrical potential surrounding the Station, install a camera cable outside the Unity module, and transfer supplies, equipment and refuse between Endeavour and ISS.

On Flight Day 3, Commander Brent Jett linked Endeavour to the ISS while 230 statute miles above northeast Kazakhstan.

The successful checkout of the extravehicular mobility units (EMUs), the Simplified Aid for EVA Rescue (SAFER) units, the Remote Manipulator System (RMS), the Orbiter Space Vision System (OSVS) and the Orbiter Docking System (ODS) were all completed nominally. Also, the ODS centerline camera was installed with no misalignment noted.

From inside Endeavour, Mission Specialist Garneau used the RMS to remove the P6 truss from the payload bay, maneuvering it into an overnight park position to warm its components. Mission Specialists Joseph Tanner and Carlos Noriega moved through Endeavour's docking tunnel and opened the hatch to the ISS docking port to leave supplies and computer hardware on the doorstep of the Station.

On flight day 4, the Expedition One crew ñ Commander Bill Shepherd, Pilot Yuri Gidzenko and Flight Engineer Sergei Krikalev ñ entered the Unity module for the first time and retrieved the items left for them.

### **EVA No. 1 ñ 7 hours, 33 minutes:**

Tanner and Noriega mated the P6 to the Station's Z1 truss. The starboard or first half of the P6 solar array was unfurled only after several repeat commands were given because not all of the pins would release at first. The release of the port array was delayed to allow controllers to understand the problem encountered. Also deployed was one of three photovoltaic radiators that will dissipate heat generated by on-board electronics.

Later, the second solar wing was deployed slowly, with stops and starts. Two rows of solar panels stuck together but were loosened by retracting then extending the arrays again. The deployment brings the span of the solar arrays to 240 feet wide and 38 feet across.

#### **EVA No. 2 ñ 6 hours, 37 minutes:**

Tanner and Noriega worked to reconfigure electrical connections so that power from the P6 solar arrays can flow to the U.S. elements of the Station. They also prepared a docking port, Pressurized Mating Adapter 2, for its move from the forward end of the Unity module in January to another area on the Space Station. That will enable the U.S. Laboratory Destiny to be attached to Unity. The docking port then will be placed on the forward end of Destiny. Noriega and Tanner also moved the S-band antenna assembly to the top of the solar array tower and release restraints holding a radiator to the tower's side. Designed to help cool Destiny, the radiator was deployed after the spacewalk.

#### **EVA No. 3 ñ 5 hours, 10 minutes:**

A major task on this spacewalk was increasing tension on the solar array. By retracting the starboard wing, Noriega pulled the slack cables through each take-up reel. Tanner turned the spring-loaded tension reels then let them unwind while Noriega guided the cable onto the reel grooves, increasing the tension. In other activities, Tanner and Noriega installed a centerline camera cable outside the Unity module to transmit television images that will aid the next Shuttle crew to attach Destiny. They also installed the Floating Potential Probe, which measures the electrical potential of plasma around the Station.

Following Earth-based construction tradition when a building reaches its final height, the astronauts attached an evergreen tree ñ the image was on a transfer bag ñ to the FPP in a symbol of itopping outñ the Space Station. Get-ahead tasks included installing a sensor on a radiator and small antennas, and doing a photo survey.

This third spacewalk brought the total spacewalk time for the mission to 19 hours and 20 minutes. The total of spacewalk time outside the Space Station is now 88 hours and 54 minutes.

At 9:36 a.m. EST on Friday, Dec. 8, the crew paid the first visit to the Expedition One crew residing in the Space Station. Until then the Shuttle and the Station had kept one hatch closed to maintain respective atmospheric pressures, allowing the Shuttle crew to conduct their spacewalks and mission goals. After a welcome ceremony and briefing, the eight spacefarers conducted structural tests of the Station and its solar arrays, transferred equipment, supplies and refuse back and forth between the spacecraft, and checked out the television camera cable installed by Tanner and Noriega for the upcoming mission.

On Dec. 9, the two crews completed final transfers of supplies to the Station and other items being returned to Earth. The crew of Endeavour said farewell to the Expedition 1 crew at 10:51 a.m. EST and closed the hatches between the spacecraft.

After being docked together for 6 days, 23 hours and 13 minutes, Endeavour undocked from the Station at 2:13 p.m. EST. Piloted by Michael Bloomfield, it then made an hour-long, tail-first circle of the Station. The undocking took place 235 statute miles above the border of Kazakhstan and China. The final separation burn took place near the northeast coast of South America.

The final day was spent checking out the systems for landing and talking with reporters.

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## **STS-98 (ISS Flight 5A)**



### **Atlantis Pad 39A**

102nd Shuttle mission  
23rd flight OV-104  
47th EAFB landing

### **Crew:**

Ken Cockrell, Commander (4th Shuttle flight)  
Mark Polansky, Pilot (1st)  
Robert Curbeam, Mission Specialist (2nd)  
Thomas Jones, Mission Specialist (4th)  
Marsha Ivins, Mission Specialist (5th)

### **Orbiter Preps (move to):**

**OPF bay 2 ñ** May 29, 2000  
**VAB ñ** Dec. 4, 2000  
**Pad 39A ñ** Jan. 3, 2001  
**VAB ñ** Jan. 19, 2001  
**Pad 39A ñ** Jan. 26, 2001

### **Launch:**

**Feb. 7, 2001 at 6:13 p.m. EST.** The STS-98 mission was launched as planned. The T-9 minute hold was extended 1 minute 14 seconds because of a concern with electrical current indications recorded in ground telemetry. The recording occurred at the T-20 minute hold when power was transferred from the ground systems to the onboard fuel cells. A review of vehicle data showed the problem did not exist on the orbiter and the countdown proceeded.

Atlantis was returned to the VAB on the scheduled launch day of Jan. 19 due to uncertainty involving the in-

tegrity of the SRB cables. X-ray analysis and continuity or iwigggle tests were conducted on a total of 36 cables located in the system tunnels of both SRBs. Atlantis rolled back to the pad Jan. 26 for a new launch date of Feb. 7.

### **Landing:**

**Feb. 20, 2001 at 3:33 p.m. EST.** Runway 22, Edwards Air Force Base, Calif. Main gear touchdown: 3:33:05 p.m. EST. Nose gear touchdown: 3:33:17 p.m. EST. Wheel stop: 3:34:02 p.m. EST. Rollout time: 57 seconds. Mission duration: 12 days, 20 hours, 20 minutes, 04 seconds. Landed on orbit 203. Logged about 5.3 million miles. The landing marked the 47th landing at Edwards AFB.

KSC landing opportunities were waived at KSC on three successive days because of excessive crosswinds and clouds at the Shuttle Landing Facility. Atlantis landed at Edwards Air Force Base on the third day.

### **Mission Highlights:**

After docking to the International Space Station on day 2, Station and Shuttle crews opened hatches and unloaded supplies: three 12-gallon bags of water, a spare computer, cables to be installed inside the Station to power up Destiny, and various personal items for the Station crew.

On Feb. 10, the U.S. Laboratory Destiny was successfully installed on the International Space Station using the remote manipulator system (RMS) and concurrent extra-vehicular activities (EVAs).

Mission Specialist Marsha Ivins, using the RMS, grappled the pressurized mating adapter 2 on Node 1 and maneuvered it to the Z1 truss for a temporary stay. Then Ivins latched the RMS onto the U.S. Lab in the payload bay and lifted it out. She then flipped the 16-ton Lab 180 degrees and moved it into position to attach to Node 1. A set of automatic bolts tightened to hold it permanently in place.

On Feb. 11, Shepherd and Cockrell entered Destiny and activated air systems, fire extinguishers, alarm systems, computers and internal communications, plus continued equipment transfers from the Shuttle to the Station. They also filmed onboard scenes using an IMAX camera.

On Feb. 13, ground controllers switched control of the Station's orientation to electrically powered gyroscopes a milestone in Station assembly that will conserve propellants aboard the complex. Also, Cockrell and Ivins powered up Atlantis' robotic arm and used its cameras to view areas on a Station cooling radiator that appeared to have bubbling paint.

On Feb. 14, Shuttle and Station crews reopened hatches for transfer of equipment. The transfer was completed on Feb. 15. In all, 3,000 pounds of equipment and supplies a water, food, spare parts, a spare Russian carbon dioxide removal system, spare computer, clothes, movies and other items a were moved from Atlantis to the Station. About 850 pounds of trash were moved from the Station to Atlantis.

Atlantis departed the Station and Pilot Polansky flew

the orbiter halfway around it before moving off for a landing on Feb. 18.

### **EVA No. 1 a 7 hours, 34 minutes:**

Mission Specialists Curbeam and Jones began their EVA at 10:18 a.m. EST Feb. 10, 2001, to connect electrical, data and cooling lines. They also reopened the hatches between Atlantis and the Station. Commander Ken Cockrell and ISS Commander Bill Shepherd, using a laptop computer, remotely powered up key laboratory systems and cooling equipment in Destiny.

While Curbeam was attaching a cooling line, a small amount of frozen ammonia crystals leaked but was quickly stopped. The ammonia dissipated and vaporized and posed no problems as the crew continued their work. Decontamination actions were taken later to ensure no ammonia would enter Atlantis' cabin. Curbeam remained in the sun a half-hour to vaporize any ammonia crystals on his spacesuit while Jones brushed off the suit and equipment. The spacewalkers then performed a partial pressurization and venting of the shuttle airlock to flush out any ammonia before final repressurization. Cockrell and Pilot Mark Polansky and Ivins wore oxygen masks in the cabin for about 20 minutes as a protective measure.

### **EVA No. 2 a 6 hours, 50 minutes:**

At 10:40 a.m. EST Feb. 12, 2001, Jones and Curbeam exited Atlantis' airlock and moved to the Pressurized Mating Adapter (PMA) 2, or docking port. Ivins used the RMS to latch onto the PMA 2, stowed earlier on the Z1 truss, and removed it with the help of visual cues by Jones and Curbeam. The two spacewalkers then moved to the U.S. Lab and again provided visual cues as Ivins moved the PMA 2 into its new position on the end of the Lab. The PMA 2 will become the primary docking port for future Shuttle visits.

Other tasks for the spacewalkers included installing insulating covers over the pins that held Destiny in place during launch, attaching a vent to part of the Lab's air system, putting wires, handrails and sockets on the exterior of Destiny for future spacewalkers, and attaching a base for the future Space Station robotic arm (SSRMS). Working ahead, Jones and Curbeam connected several computer and electrical cables between the docking port and Lab, unveiled the Lab's large, high-quality window and attached an exterior shutter, and repositioned a movable foot platform.

### **EVA No. 3 a 5 hours, 25 minutes:**

Feb. 14, 2001, the two spacewalkers attached a spare communications antenna to the Station's exterior, double-checked connections between Destiny and PMA 2, released a cooling radiator on the Station, inspected solar array connections at the top of the Station, and tested the ability of a spacewalker to carry an immobile crew member back to the Shuttle airlock.



# STS-102

## (ISS Flight 5A.1)



### Discovery Pad 39B

103rd Shuttle mission  
29th flight OV-103  
12th nighttime KSC landing

### Crew:

James Wetherbee, Commander (5th Shuttle flight)  
James Kelly, Pilot (1st)  
Andrew Thomas, Mission Specialist (3rd)  
Paul Richards, Mission Specialist (1st)

#### *ISS Resident Crew, Expedition 2*

James Voss, Mission Specialist  
Susan Helms, Mission Specialist  
Yury Usachev, Mission Specialist,  
Russian Aviation and Space Agency

#### *Returning Crew, Expedition 1*

Bill Shepherd, Commander  
Yuri Gidzenko, Pilot,  
Russian Aviation and Space Agency  
Sergei Krikalev, Flight Engineer,  
Russian Aviation and Space Agency

### Orbiter Preps (move to):

**OPF bay 2** ñ Nov. 3, 2000  
**VAB** ñ Feb. 1/2, 2001  
**Pad 39B** ñ Feb. 12, 2001

### Launch:

**March 8, 2001 at 6:42:09 a.m. EST.** Launch occurred at sunrise. Discovery embarked on a mission to deliver the second resident crew to the International Space Station.

### Landing:

**March 21, 2001 at 2:31 a.m. EST.** Runway 15, Kennedy Space Center, Fla. Main gear touchdown 2:31:42; nose wheel touchdown 2:31:54; wheel stop 2:33:06. Rollout distance: 11,405 feet. Rollout time: 01:24. Mission duration: 12 days, 19 hours, 49 minutes. Landed on orbit 102. Logged about 5.3 million statute miles. Landed on the second of two Florida landing opportunities. The landing marked the 12th night landing at KSC, and the 17th night landing overall.

### Mission Highlights:

A sunrise launch carried the second resident crew to the ISS as well as the first Multi-Purpose Logistics Module, Leonardo, full of supplies and equipment plus science racks for transfer to the U.S. Laboratory Destiny.

Joint operations between the Shuttle crew and the Station crews resulted in unloading almost five tons of experiments and equipment from Leonardo and packing almost one ton of items for return to Earth. Discovery's spacewalkers ó James Voss, Susan Helms, Andrew Thomas and Paul Richards ó set the stage for continued expansion of the Station by installing a platform that will be used to mount a Canadian-built robotic arm, the Space Station Remote Manipulator System (SSRMS), to the Station on a future mission.

Discovery docked with the Station at 1:38 a.m. EST on March 10. Hatches between the two spacecraft opened at 3:51 a.m. EST. All 10 crew members greeted each other for several minutes in the Destiny module. The first Expedition 2 crew member to trade places was Yury Usachev, replacing Yuri Gidzenko on March 10. James Voss swapped places with Sergei Krikalev on March 11, and Susan Helms swapped with Bill Shepherd on March 14. A formal transfer of command was conducted on March 19 as Commander Bill Shepherd passed responsibility for the Station to Yury Usachev.

### EVA No. 1 ñ 8 hours, 56 minutes:

Helms and Voss began a record-breaking spacewalk at 12:12 a.m. March 11. They prepared the Pressurized Mating Adapter-3 to be moved from the Unity module to make room for Leonardo. They removed an antenna from the Common Berthing Mechanism to allow the PMA-3 to be temporarily stowed there while Leonardo was connected to the Station. They also removed a Lab Cradle Assembly from Discovery's cargo bay and installed it on the side of the U.S. Lab Destiny. There it will form the base for the SSRMS being delivered on a mission in April.

The spacewalk ended at 9:08 a.m. EST, marking the longest spacewalk in Shuttle history.

Mission Specialist Andrew Thomas lifted Leonardo out of Discovery's cargo bay at 11:10 p.m. EST on March 11 and maneuvered it into place on the Common Berthing Mechanism. The docking was completed at 1:02 a.m. EST March 12 when Commander Wetherbee activated the latches to seal the components.

### EVA No. 2 ñ 6 hours, 21 minutes:

Beginning the second spacewalk at 12:23 a.m. March 13, Richards and Thomas installed an External Stowage Platform for spare Station parts and attached a spare ammonia coolant pump to the platform. They also connected several cables on the exterior of Destiny that were placed previously by Helms and Voss during the first spacewalk. The cables will provide heater power and control for the yet-to-come robotic arm.

# STS-100 (ISS Flight 6A)



## Endeavour Pad 39A

104th Shuttle mission  
16th flight OV-105  
48th EAFB landing

## Crew:

Kent V. Rominger, Commander (5th Shuttle flight)  
Jeffrey S. Ashby, Pilot (2nd)  
Chris A. Hadfield, Mission Specialist (2nd), CSA  
Scott E. Parazynski, Mission Specialist (4th)  
John L. Phillips, Mission Specialist (1st)  
Umberto Guidoni, Mission Specialist (2nd), ESA  
Yuri Lonchakov, Mission Specialist (1st),  
Russian Aviation & Space Agency

## Orbiter Preps (move to):

OPF bay 2 ñ Dec. 11, 2000  
VAB ñ March 17, 2001  
Pad 39A ñ March 22, 2001

## Launch:

**April 19, 2001, at 2:40:42 p.m. EDT.** Space Shuttle Endeavour lifted off on time carrying a multi-national crew and payloads that included the Canadian-built Space Station Remote Manipulator System (SSRMS) and the Multi-Purpose Logistics Module Raffaello.

## Landing:

**May 1, 2001, at 12:10:42 p.m. EDT.** Runway 22, Edwards Air Force Base. Rollout distance: 7,964 feet. Rollout time: 01:14. Mission duration: 11 days, 12 hours, 54 minutes. Landed on orbit 186. Logged about 4.9 million statute miles. Landed on the first of two EAFB landing opportunities after being waved off two times at KSC due to unfavorable weather conditions.

## Mission Highlights:

Docking with the International Space Station occurred at 9:59 a.m. EDT April 21.

The advanced robotic arm, called Canadarm2, was attached to a pallet on the outside of Destiny. It later was directed to walk off the pallet and grab onto an electrical grapple fixture on the Lab which would provide data, power and telemetry to the arm. Days later the arm was used to hand off the cradle, on which it rested inside Endeavour's payload bay during launch, to the orbiter's arm. The exchange of the cradle from Station arm to Shuttle arm marked the first ever robotic-to-robotic transfer in space.

The 6,000 pounds of cargo inside the Multi-Purpose Logistics Module Raffaello were transferred to the Station, including two new scientific experiment racks for Destiny and the first three U.S. commercial payloads. In turn, 1,600 pounds of material were stored inside Raffaello for return to Earth.

On April 23, four days after launch, the hatches between Endeavour and the Space Station were opened, allowing the Shuttle crew and Station crew to greet another for the first time.

Other crew activities during the mission included attaching an Ultrahigh Frequency antenna on the outside of the Station and, inside, calibrating the Space Vision System, an alignment aid for operating the robotic arm, plus helping repair the Space Station's treadmill and filming for IMAX.

## EVA No. 1 ñ 7 hours, 10 minutes:

On April 22, Mission Specialists Scott Parazynski and Chris Hadfield removed the Ultrahigh Frequency antenna from the pallet and installed it on the U.S. Lab Destiny. Then they unfolded the Canadian arm and, while it was still secure in its pallet, attached one end to Destiny. Next they connected cables to give the arm computer communication with the Lab and secured the fasteners to keep the booms in rigid position.

## EVA No. 2 ñ 7 hours, 40 minutes:

On April 24, Hadfield and Parazynski connected the Power and Data Grapple Fixture circuits on Destiny for the SSRMS. They also removed an early communications antenna and transferred a spare Direct Current Switching Unit from Endeavour's payload bay to an equipment storage rack on Destiny.

As the astronauts rewired power and data connections for the arm, the backup power circuit failed to respond to commands from Station flight engineer Susan Helms, operating a workstation inside Destiny. Disconnecting and reconnecting the cables at the base of the arm resolved the situation and the redundant power path to the arm was completed.

Computer problems surfaced late on April 24 when flight controllers for the Station experienced a loss of Command and Control computer No. 1, one of three computers on board for systems management. The result was a loss of communication and data transfer between the Space Station Flight Control Room in Houston and the Station. Communication was routed through Endeavour, which enabled the Station crew and flight controllers to talk to one another. No computer problems were encountered on Endeavour. Activities involving the SSRMS were postponed.

Station flight engineer Susan Helms, using a laptop computer, was able to restore the ground's ability to monitor and send commands to the Station's U.S. systems. Through the laptop, data from the Station computers could be transmitted to the ground for analysis and investigation of the problems.

Computer restoration continued successfully, especially C&C number three. C&C number one was found to have a failed hard drive. It was replaced by a backup payload computer.

Ground controllers successfully synchronized timers on all on-board computers and investigated an error in the 9



software load that might have caused the computer problem. With one operational C&C computer in Destiny and a back-up laptop in Unity, the undocking procedure for Raffaello was given the go-ahead.

Endeavour undocked from the Space Station April 29 at 1:34 p.m. EDT. Pilot Jeff Ashby performed a three-quarter circle flyaround of the Station and at 2:28 p.m. fired a separation burn for final departure.

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## STS-104 (ISS Flight 7A)



### Atlantis Pad 39B

105th Shuttle mission  
24th flight OV-103  
50th KSC landing

### Crew:

Steven W. Lindsey, Commander (3rd Shuttle flight)  
Charles O. Hobaugh, Pilot (1st)  
Janet Lynn Kavandi, Mission Specialist (3rd)  
Michael L. Gernhardt, Mission Specialist (4th)  
James F. Reilly, Mission Specialist (2nd)

### Orbiter Preps (move to):

OPF bay 2 ñ March 6, 2001  
VAB ñ May 29, 2001  
Pad 39B ñ June 21, 2001

### Launch:

**July 12, 2001 at 5:03:59 a.m. EDT.** Lifted off on time to deliver the joint airlock module to the International Space Station. This mission marked the end of the second phase of Station assembly.

### Landing:

**July 24, 2001, at 11:39 p.m. EDT.** Runway 15, Kennedy Space Center, Fla. Rollout distance: 10,858 feet. Rollout time: 01:41. Mission duration: 12 days, 18 hours, 36 minutes. Landed on orbit 200. Logged about 5.3 million statute miles. After a 24-hour wave-off due to weather concerns, Atlantis landed on the first of two Florida landing opportunities. The landing marked the 50th landing at KSC, and the 18th nighttime landing.

### Mission Highlights:

After docking with the ISS on July 13, both Atlantis and ISS crews reviewed EVA procedures. In a series of three spacewalks, the joint airlock module was attached to the Unity Node and high-pressure gas tanks attached to the airlock, christened 'Quest.' The crews tested nitrogen

and oxygen lines for use on future Shuttle missions and installed valves to connect Quest to the ISS environmental control system. They also installed a computer to run the airlock's systems. Air bubbles in a coolant line caused a water spill ñ cleanup caused a task to be postponed to another day. Astronauts replaced a leaky air circulation valve and moved the hatch for the airlock into position between the Equipment Lock and Crew Lock.

Kavandi, Gernhardt and Reilly transferred items between the Shuttle and Station, storing equipment and space suits in the airlock.

Both Station and Shuttle crews checked out and activated the new Quest airlock, conducting a dry run before the inaugural event.

### EVA No. 1 ñ 5 hours, 59 minutes:

On July 15 Spacewalkers Michael Gernhardt and James Reilly removed an insulating cover from the airlock's berthing mechanism and covers from its seals plus installed bars on the airlock that are attachment points for four high-pressure gas tanks. Expedition 2 crew member Susan Helms then lifted the airlock out of Atlantis's payload bay using the Canadarm2 and maneuvered it to the berthing port on the Unity Node. Gernhardt and Reilly provided additional guidance from outside the ISS.

Gernhardt then attached heating cables from the ISS to the airlock and Reilly positioned foot restraints needed for the second EVA.

### EVA No. 2 ñ 6 hours, 29 minutes: *(the 66th spacewalk in Shuttle history and 23rd for ISS assembly)*

On July 18, Gernhardt and Reilly installed three tank assemblies for the joint airlock with the help from both the Shuttle's Canadarm and the Station's Canadarm2.

### EVA No. 3 ñ 4 hours, 2 minutes: *(the 24th spacewalk devoted to ISS assembly, totaling 155 hours, 39 minutes).*

On July 21, Gernhardt and Reilly exited the new airlock and, with support from the Station and Shuttle robotic arms, attached a nitrogen supply tank to the airlock's shell. This completed installation of two nitrogen and two oxygen tanks that will be used to pressurize the airlock and resupply space suits. The astronauts also moved hand-over-hand up the Station's solar array truss to take a look at a gimbal assembly mechanism that allows the arrays to swivel with the Sun.

# STS-105

## (ISS Flight 7A.1)



### Discovery Pad 39A

106th Shuttle mission  
30th flight OV-103  
56th KSC landing

### Crew:

Scott "Doc" Horowitz, Commander (4th Shuttle flight)  
Rick Sturckow, Pilot (2nd)  
Daniel Barry, Mission Specialist (3rd)  
Patrick Forrester, Mission Specialist (1st)

#### *ISS Resident Crew, Expedition 3:*

Frank Culbertson, Commander  
Vladimir Dezhurov, Cosmonaut  
Mikhail Tyurin, Cosmonaut

#### *Returning Crew, Expedition 2:*

Yuri Usachev, Cosmonaut, Commander  
Susan Helms  
James Voss

### Orbiter Preps (move to):

**OPF bay 2** ñ March 21, 2001  
**VAB** ñ June 13, 2001  
**Pad 39A** ñ July 2, 2001

### Launch:

**Aug. 10, 2001 at 5:10 p.m. EDT.** The scheduled launch on Aug. 9, 2001, was scrubbed due to lightning, thick cloud cover and potential showers. Launch proceeded the following day; however, due to expected bad weather, the launch occurred at the opening of the planer window, 5 minutes earlier than the planned 5:15 p.m. preferred launch time.

### Landing:

**Aug. 22, 2001, at 2:23 p.m. EDT.** Runway 15, Kennedy Space Center, Fla. Main gear touchdown was at 2:22:58 p.m. EDT, wheel stop at 2:24:06 p.m. EDT. Rollout distance: 10,036 feet. Rollout time: one minute, 8 seconds. Mission duration: 11 days, 19 hours, 38 minutes. Landed on orbit 186. Logged about 4.3 million statute miles. Landed on the second of two Florida opportunities. The landing marked the 56th landing at KSC.

### Mission Highlights:

After linkup of Shuttle Discovery to the International Space Station, hatches were opened and crews greeted one another. Part of the mission was to bring the next resident crew, Expedition 3, to the ISS and return Expedition 2 to Earth. The payload included the Early Ammonia Servicer (EAS), to be installed on the outside of the ISS, and MPLM Leonardo.

On the fifth day of the mission, Aug. 16, Discovery maintained control of the Space Station while Russian flight controllers completed loading upgraded software commands to the Zvezda module. After completion of the upgrade, the Zvezda module again assumed control of the station's attitude, or position in space.

During the time docked with the ISS, crews unloaded 7,000 pounds of supplies, equipment and science racks from the MPLM Leonardo, storing it on the Space Station. This was the second flight of the Leonardo to the ISS.

### EVA No. 1 ñ 6 hours, 16 minutes:

Mission Specialists Forrester and Barry completed the first of two Extra-Vehicular Activities to install the EAS on Aug. 16, 2001. The EAS contains spare ammonia that can be used in the Space Station's cooling systems if needed. During the EVA, Discovery Commander Horowitz operated the Shuttle robot arm and Pilot Sturckow choreographed the spacewalk from the orbiter's flight deck.

On Aug. 17, in a special ceremony, the Expedition 2 crew handed over command of the ISS to Expedition 3. Briefings followed as well as stowing equipment, discarded items and belongings of Expedition 2 into the MPLM Leonardo.

### EVA No. 2 ñ 5 hours, 29 minutes:

Barry and Forrester completed their second EVA on Aug. 18, 2001, setting the stage for delivery of the S0 Integrated Truss Structure that is planned for 2002. They strung heater cables and installed hand rails on both sides of the U.S. Lab Destiny.

This EVA was the 26th devoted to assembly of the ISS, and the 68th spacewalk in Shuttle program history. It also marked 431 hours, 39 minutes of total spacewalk time in Shuttle history.

On Aug. 20, the Discovery crew undocked from the ISS and performed a fly-around. They later deployed a small science satellite, Simplesat, via a spring ejection from a canister at the rear of the cargo bay.

# STS-108

## (ISS Flight UF-1)

### Endeavour Pad 39B

107th Shuttle mission  
17th flight OV-105  
57th KSC landing

### Crew:

Dominic L. Gorie, Commander (3rd Shuttle flight)  
Mark E. Kelly, Pilot (1st)  
Linda A. Godwin, Mission Specialist (4th)  
Daniel M. Tani, Mission Specialist (1st)

#### *ISS Resident Crew, Expedition 4:*

Yuri Onufrienko, Commander  
Daniel W. Bursch, Flight Engineer  
Carl E. Walz, Flight Engineer

#### *Returning Crew, Expedition 3:*

Frank Culbertson, Commander  
Vladimir Dezhurov, Pilot  
Mikhail Tyurin, Flight Engineer

### Orbiter Preps (move to):

**OPF bay 2** ñ May 10, 2001  
**VAB** ñ Oct. 24, 2001  
**Pad 39B** ñ Oct. 31, 2001

### Launch:

**Dec. 5, 2001, at 5:19 p.m. EST.** The launch of Space Shuttle Endeavour on Nov. 29 was rescheduled for Tuesday, Dec. 4, to allow sufficient time for the Expedition 3 crew on the Space Station to successfully complete a spacewalk to clear an obstruction on the latching mechanism on the Russian Progress supply vehicle.

The launch Dec. 4 was postponed due to unsatisfactory weather conditions in the KSC area. Launch controllers counted down to the T-5 minute point and held until the remainder of the window expired. The scrub had to be called after Astronaut Office Chief Charles Precourt, flying the Shuttle Training Aircraft, detected precipitation in a cloud mass that moved into the Complex 39 area shortly before launch.

Endeavour lifted off Dec. 5 on the final space Shuttle mission of 2001 to deliver three tons of supplies and a fresh crew to the International Space Station, and return home a crew that spent four months in space

In addition to a new Station crew and supplies, Endeavour carried a host of scientific investigations, including experiments from space agencies, schools and universities across the United States, Europe and South America, as well as a small satellite that involved more than 25,000 students in 26 countries.



### Landing:

**Dec. 17, 2001, at 12:55 p.m. EST.** Runway 15, Kennedy Space Center, Fla. Main gear touchdown was at 12:55:11 p.m. EST; nose gear touchdown at 12:55:23 p.m.; wheel stop at 12:56:18 p.m. EST. Rollout distance: 8,941 feet. Mission duration: 11 days, 19 hours, 55 minutes. Landed on orbit 186. Logged about 4.8 million statute miles. Landed on the first of two Florida landing opportunities. The landing marked the 57th landing at KSC.

### Mission Highlights:

Shuttle Commander Dom Gorie brought Endeavour to a gentle linkup with the ISS at 3:03 p.m. EST as the two craft sailed over England. Within minutes, Pilot Mark Kelly and Mission Specialists Linda Godwin and Dan Tani began to conduct post-docking checks of the mechanical interface between Endeavour and the Station's Destiny Laboratory prior to the opening of the hatches on the two vehicles. At first, the Shuttle's docking ring and the docking mechanism on the ISS did not align properly, but after allowing the two craft to dampen their relative motion against one another, the vehicles were hard mated for a week of joint operations by the 10 crew members.

The hatches were opened between Endeavour and the ISS Destiny Laboratory at 5:42 p.m. EST Dec. 7, enabling the 10 crew members to greet one another. The Expedition 3 crew officially ended their 117-day residency on board the ISS Dec. 8 as their custom Soyuz seatliners were transferred to Endeavour for the return trip home. The transfer of the Expedition 4 seatliners to the Soyuz return vehicle attached to the Station marked the official exchange of crews.

Endeavour Pilot Mark Kelly and Mission Specialist Linda Godwin used the Shuttle's robotic arm to lift the MPLM Raffaello from the Shuttle payload bay and attach it to a berth on the Station's Unity node. The crews began unloading supplies the same day.

The 10 astronauts and cosmonauts in orbit took a break from the transfer of supplies, experiments and equipment to and from the Space Shuttle Endeavour and the Space Station to pay tribute to the heroes of the Sept. 11 attacks on New York and the Pentagon. Joined by flight controllers in Mission Control, the crews observed the playing of the U.S. and Russian national anthems at 8:46 a.m. EST, the three-month anniversary of the first impact at the World Trade Center.

Also, aboard Endeavour were 6,000 small United States flags that would be distributed to heroes and families of the victims of the attacks after the Shuttle returned to Earth; a U.S. flag that was found at the World Trade Center site after the attacks; a U.S. flag that had flown above the Pennsylvania state capitol; a U.S. Marine Corps Colors flag from the Pentagon; a New York Fire Department flag; and a poster that included photographs of firefighters lost in the attacks.



## **EVA ñ 4 hours, 12 minutes:**

Endeavour astronauts Godwin and Tani completed the spacewalk to install insulation on mechanisms that rotate the Space Station's main solar arrays. The two spacewalkers stopped at a stowage bin to retrieve a cover that had been removed from a Station antenna during an earlier flight, and after its return to Earth, may be reused. Godwin and Tani also performed a 'get-ahead' task, positioning two switches on the Station's exterior to be installed on a future Shuttle mission, STS-110. The spacewalk completed a record year with 18 spacewalks conducted: 12 originating from the Shuttle and six from the Station.

Mission managers extended Endeavour's flight to a duration of 12 days to allow Endeavour's crew to assist with additional maintenance tasks on the Station, including work on a treadmill and replacing a failed compressor in one of the air conditioners in the Zvezda Service Module.

The astronauts and cosmonauts completed the transfer of more than 5,000 pounds of supplies and material from Endeavour's mid-deck and the MPLM Raffaello to the Station. The transferred items included more than 850 pounds of food, 1,000 pounds of clothing and other crew provisions, 300 pounds of experiments and associated equipment, 800 pounds of spacewalking gear, and 600 pounds of medical equipment. In turn, the crew packed up the Raffaello module with items bound for a return trip to Earth.

On Dec. 12, the crew and Mission Control noted a transient problem with one of the Shuttle's three inertial measurement units (IMUs), the primary navigation units for the Shuttle. Only two of the three IMUs were on line at the time, with the third unit off line to save electricity. The IMU that experienced a problem, designated IMU 2, was immediately taken off line and the third IMU brought on line. IMU 2 operated well after that, but it remained off line and was considered failed by flight controllers. The loss of one IMU had no impact on Endeavour's mission, and the other two units operated in excellent condition.

A formal change of command ceremony took place Dec. 13 as Expedition 3 ended their residence and Expedition 4 began theirs.

Flight controllers planned slight changes to Endeavour's departure from the Station Dec. 15, allowing time for a small jet firing by the Shuttle to boost the Station's future path away from a piece of space debris that could pass near the complex. Mission Control was notified that a spent Russian rocket upper stage launched in the 1970s could pass within three miles of the Station if Endeavour did not perform the engine firing. With the Shuttle reboost, the Station was predicted to pass more than 40 miles away from the debris.

Because the scheduled reboost used additional propellant, Endeavour did not perform a full-circle flyaround of

the Station after undocking. Instead, the Shuttle undocked from the Station, performed a quarter circle flyaround of the complex to a point about 400 feet directly above the Station where it fired its engines in a final separation burn at 12:20 a.m. EST, beginning its departure from the orbiting outpost.

Endeavour's middeck carried home the results of several experiments completed during Expedition 3's stay on the Station. These included the Advanced Protein Crystallization Facility, the Dynamically Controlled Protein Crystal Growth experiment and cells from the Cellular Biotechnology Operations Support System (CBOSS).

The CBOSS equipment aboard the Space Station will remain active during Expedition 4, growing ovarian and colon cancer cells, as well as kidney cells in microgravity.

Experiments in Endeavour's payload bay were returned for investigators around the world. The Multiple Application Customized Hitchhiker-1 (MACH-1) carried a wide array of experiments, including the Prototype Synchrotron Radiation Detector, the Collisions Into Dust Experiment-2, the Capillary Pump Loop, and the Space Experiment Module (SEM). The SEM carried experiments from Argentina, Portugal, Morocco and Australia, as well as experiments from U.S. schoolchildren. Several other canisters in Endeavour's payload bay also carried student experiments.

On its return to Earth, Endeavour's crew deployed a small satellite called STARSHINE 2 from a canister located in the payload bay. More than 30,000 students from 660 schools in 26 countries will be tracking STARSHINE 2 as it orbits the Earth for eight months. The students, who helped polish STARSHINE's 845 mirrors, will use the information they collect to calculate the density of the Earth's upper atmosphere.

**2 0 0 2**

## **STS-109 (Hubble Space Telescope Servicing Mission 3B)**



### **Columbia Pad 39A**

108th Shuttle mission  
27th flight OV-102  
58th KSC landing

**Crew:**

Scott D. Altman, Commander (3rd Shuttle flight)  
Duane G. Carey, Pilot (1st)  
John M. Grunsfeld, Payload Commander (4th)  
Nancy Jane Currie, Mission Specialist (4th)  
Richard M. Linnehan, Mission Specialist (3rd)  
James H. Newman, Mission Specialist (4th)  
Michael J. Massimino, Mission Specialist (1st)

**Orbiter Preps (move to):**

**OPF bay 3** ñ May 29, 2001  
**VAB** ñ Jan. 16, 2002  
**Pad 39A** ñ Jan. 28, 2002

**Launch:**

**March 1, 2002 at 6:22:02 a.m. EST.** Prior to tanking activities, the scheduled launch on Feb. 28 was postponed 24 hours to March 1 when the launch weather forecast projected 38-degree temperature at the launch pad, which was at the margin of the acceptable limit in combination with the predicted wind speed and relative humidity. The forecast for a launch attempt on Friday called for a temperature approximately 10 degrees warmer. Waiting an additional 24 hours protected the option for two possible back-to-back launch opportunities for the launch team. Launch occurred without delay on March 1.

**Landing:**

**March 12, 2002 at 4:33:05 a.m. EST.** Runway 33, Kennedy Space Center, Fla. Main landing gear touchdown: 4:31:53 a.m. Nose gear touchdown: 4:32:04 a.m. Wheelstop: 4:33:05 a.m. Rollout distance: 10,119 feet. Rollout time: 1 minute, 17 seconds. Mission elapsed time: 10 days, 22 hours, 11 minutes, 9 seconds. Landed on orbit 165. Logged about 3.9 million statute miles. Landed on the first of two Florida landing opportunities. The landing marked the 58th landing at KSC in the history of the Shuttle program.

**Mission Highlights:**

The 11-day mission rejuvenated the Hubble Space Telescope in a series of five spacewalks. After grasping the telescope and pulling it into the payload bay, the spacewalkers, assisted by Mission Specialist Nancy Jane Currie operating the Shuttle's robotic arm, installed new and improved equipment that gave the telescope more power, a new module to dispense the power, and a camera able to see twice as much area, with more speed and clarity. They also installed an experimental cooling system in hope of restoring life to the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS). Columbia performed perfectly.

**EVA No. 1 ñ 7 hours, 1 minute:**

Mission Specialists John Grunsfeld and Rick Linnehan removed the old starboard solar array from Hubble and installed in its place a new third-generation solar array. The two spacewalkers were maneuvered around Columbia's payload bay and Hubble telescope by the Shuttle's robotic arm, manipulated by Mission

Specialist Nancy Currie. From the aft flight deck of Columbia, astronauts Michael Massimino and James Newman assisted the spacewalkers throughout their tasks. The old solar array was stored in Columbia's payload bay for return to Earth and evaluation of its nine-year performance.

**EVA No. 2 ñ 7 hours, 16 minutes:**

Mission Specialists Newman and Massimino installed a new port solar array and a new Reaction Wheel Assembly on Hubble after removing the old solar array. Again, the spacewalkers used the robotic arm to get to and from the worksite. Newman and Massimino also had time to install a thermal blanket on Bay 6, door stop extensions on Bay 5, and foot restraints to prepare for the third spacewalk by Grunsfeld and Linnehan. Testing two bolts on the telescope's aft shroud doors, they determined that the bottom two bolts required replacement and they completed that task.

During the spacewalk Commander Altman and Pilot Carey documented the activity using television and still-photo cameras.

**EVA No. 3 ñ 6 hours, 48 minutes:**

A water leak in Grunsfeld's spacesuit delayed the start of the third EVA. After swapping the upper portion of the suit, he and Linnehan began work to replace the original, 12-year-old Power Control Unit with a new one capable of handling the extra 20 percent of power output being generated from the newly installed solar panels.

For the first time since its launch, Hubble was powered down, by controllers at the Space Telescope Operations Control Center, Greenbelt, Md. Linnehan first removed 30 of 36 connectors on the old PCU then switched places with Grunsfeld to prepare the new PCU. Grunsfeld unhooked the remaining six connectors and eased the PCU from the telescope, carrying it to the payload bay. Mission Specialist Currie again worked the robotic arm to maneuver the spacewalkers. Grunsfeld then installed the new PCU on the telescope and connectors were mated an hour and a half later. An hour later the new PCU passed its aliveness test.

**EVA No. 4 ñ 7 hours, 18 minutes:**

Mission Specialists James Newman and Michael Massimino completed the first science instrument upgrade of the servicing mission by installing the Advanced Camera for Surveys ñ it replaced the original Faint Object Camera. Afterward, Massimino installed the Electronic Support Module, the first part of an experimental cooling system to be installed on EVA five.

**EVA No. 5 ñ 7 hours, 32 minutes:**

On the final spacewalk, Mission Specialists Grunsfeld and Linnehan removed the NICMOS cryocooler from its carrier in the payload bay and installed it inside the aft shroud, connecting cables from the Electronics Support Module. They retrieved the



Cooling System Radiator from the payload bay and installed it on the outside of Hubble. Linnehan fed the radiator wires through the bottom of the telescope to Grunsfeld, who connected them to NICMOS.

The Hubble Space Telescope was released from the grasp of Columbia's robotic arm at 5:04 a.m. EST March 9. The series of spacewalks to install the new and upgraded equipment set a new record for a single Shuttle mission with a total time of 35 hours, 55 minutes. The previous record was 35 hours, 28 minutes, set by STS-61, the first Hubble servicing mission.

### Concerns

After a successful launch, flight controllers in Mission Control noticed a degraded flow rate in one of two freon cooling loops that help to dissipate heat from the orbiter. After reviewing the loop's performance, mission managers gave the crew a go-for to proceed with normal operations. The problem had no impact on any of the crew's activities. Both cooling loops performed normally on de-orbit and on landing.

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# STS-110

## (8A/13th flight to the ISS)



### Atlantis Pad 39B

109th Shuttle mission  
25th flight OV-104  
59th KSC landing

### Crew:

Michael Bloomfield, Commander (3rd Shuttle flight)  
Stephen Frick, Pilot (1st)  
Jerry Ross, Mission Specialist (7th)  
Steven Smith, Mission Specialist (4th)  
Ellen Ochoa, Mission Specialist (4th)  
Lee Morin, Mission Specialist (1st)  
Rex Walheim, Mission Specialist (1st)

### Orbiter Preps (move to):

**OPF bay 2** ñ July 24, 2001  
**VAB** ñ March 6, 2002  
**Pad 39B** ñ March 12, 2002

### Launch:

**April 8, 2002, at 4:44:19 p.m. EDT.** The original April 4 launch was terminated about an hour into tanking operations due to a leak in a liquid hydrogen vent line of the Mobile Launcher Platform at Pad B. The launch was rescheduled for April 8. The repair work involved welding a 10-inch wide, two-piece aluminum clam shell sleeve around

the 16-inch diameter line.

The countdown on April 8 went into an unscheduled hold at the 5-minute mark due to data dropouts in a backup Launch Processing System. The Launch Processing System team reloaded the required data and the countdown resumed. Liftoff occurred with 11 seconds remaining in the launch window.

### Landing:

**April 19, 2002 at 12:28:08 p.m. EDT.** Runway 33, Kennedy Space Center, Fla. Main gear touchdown: 12:26:58 p.m. EDT. Nose gear touchdown: 12:27:08. Wheel stop: 12:28:08. Rollout distance: 9576 feet. Rollout time: 1 minute, 10 seconds. Mission duration: 10 days, 19 hours, 42 minutes, 44 seconds. Landed on orbit 171. Logged about 4.5 million statute miles. Landed on the first of two Florida landing opportunities. The landing marked the 59th landing at KSC overall.

### Mission Highlights:

The launch marked a milestone as Mission Specialist Jerry Ross became the first human to fly in space seven times, breaking his own and other astronaut's records of six space flights. His two spacewalks gave him a total of 58 hours and 18 minutes, surpassed only by Russian cosmonaut Anatoly Solovyev in human space flight history.

Installation of the S0 truss was the primary objective and began with removal of the truss from Atlantis' payload bay. Mission Specialist Ellen Ochoa lifted it out with the Station's robotic arm and maneuvered it onto a clamp at the top of the Destiny Lab. The truss contains navigational devices, computers, cooling and power systems needed to attach additional laboratories to the complex. Four spacewalks were required for the task. The truss will serve as a platform on which other trusses will be attached and additional solar arrays will be mounted to form a 356-foot-long Space Station.

Between and during spacewalks, Shuttle and ISS crew members transferred experiments and supplies between the Shuttle and the Station. They also transferred oxygen from the Shuttle to one of four high-pressure gas tanks, used on the Quest Airlock to repressurize the module after spacewalks. Overall, 100 pounds of oxygen and 50 pounds of nitrogen were transferred.

Initial tests of the movement of the Mobile Transporter were successful. ISS Flight Engineer Walz commanded the transporter, via a laptop computer, to move to a work site 17 feet down a rail spanning the 44-foot-length of the girder, then to a second site and back to the first. Automatic latching did not occur due to minute lifting of the rail car but was accomplished by manual commands. Other transporter systems functioned perfectly.

Tasks not accomplished on the mission were removal of the balky bolt from the backup cable on the Mobile Transporter and installation of a gas analyzer on the truss. The gas analyzer, considered low priority on the flight, proved to be faulty.

### **EVA No. 1 ñ 7 hours, 48 minutes:**

After the temporary latching, Mission Specialists Rex Walheim and Steven Smith began the first of four spacewalks to electrically and structurally mate the truss to the Station. The spacewalking pair attached two of four mounting struts onto Destiny, deployed trays of avionics equipment and cables connecting Destiny to the truss, attached an umbilical system from the truss to the Mobile Transporter, and secured critical power connections. Walheim was the first spacewalker to use the Stationís Canadarm 2 as a cherrypicker, maneuvering to different areas for the assembly work. Smith operated as a ifree-floater,î tethered to the Station and other work sites around the truss. From the aft flight deck of the Shuttle, Ross and ISS Flight Engineer Carl Walz helped choreograph the spacewalk.

### **EVA No. 2 ñ 7 hours, 30 minutes:**

Ross and Mission Specialist Lee Morin bolted the final two struts of the S0 truss to the Destiny Lab. Morin used Canadarm 2 to work while Ross was tethered to the Station. The two removed support panels and clamps from the truss, used during launch, then installed a backup device with an umbilical reel for the Mobile Transporter railcar. A restraining bolt that needed to be removed did not perform as expected and was left for a later spacewalk.

### **EVA No. 3 ñ 6 hours, 27 minutes:**

Smith and Walheim released the claw that initially held the truss to the Lab. They also reconfigured Canadarm 2 connectors for electricity from the Lab to be powered by the truss. Smith worked from the end of the Shuttleís robotic arm while Walheim was the free-floater, tethered to the Station. This was Smithís seventh spacewalk, second to Ross. Smith and Walheim also released clamps that secured the Mobile Transporter to the truss. A task to attach the Airlock Spur, a 14-foot ladder, from the truss to the Quest Airlock was delayed to the fourth EVA.

### **EVA No. 4 ñ 6 hours, 37 minutes:**

Ross and Morin installed the 14-foot beam, the Airlock Spur, from the S0 truss to the Quest Airlock. The beam will provide a quick pathway for future spacewalkers working on truss assembly. Ross tested switches on both sides of the truss for future truss assembly. He and Morin installed floodlights on the Unity connecting Module and Destiny Lab to provide illumination for future spacewalks. Other activities included attaching a work platform on the Station for future construction work, installing electrical converters and circuit breakers, and attaching shock absorbers to the Mobile Transporter railcar. Ross used the Canadarm2 for his work while Morin was the free-floater, tethered to the Station.

# STS-111

## (UF2/14th ISS flight)



### **Endeavour**

#### **Pad 39A**

110th Shuttle mission  
18th flight OV-105  
49th EAFB landing

### **Crew:**

Kenneth Cockrell, Commander (5th Shuttle flight)  
Paul Lockhart, Pilot (1st)  
Franklin Chang-Diaz, Mission Specialist (7th)  
Philippe Perrin, Mission Specialist (1st), CNES

#### *ISS Resident Crew, Expedition 5:*

Valery Korzun, RSA, Commander (2nd)  
Peggy Whitson, Flight Engineer (1st)  
Sergei Treschev, RSA, Flight Engineer (1st)

#### *Returning crew, Expedition 4:*

Yuri Onufriyenko, RSA, Commander (1st)  
Daniel Bursch, Flight Engineer (4th)  
Carl Walz, Flight Engineer (4th)

### **Orbiter Preps (move to):**

**OPF bay 2 ñ Dec. 17, 2001**  
**VAB ñ April 22, 2002**  
**Pad 39A ñ April 29, 2002**

### **Launch:**

**June 5, 2002, at 5:22:49 p.m. EDT.** The launch originally set for May 30 was scrubbed due to weather concerns. It was rescheduled for May 31; technicians, however, had detected pressure differentials in the gaseous nitrogen pressure on the left Orbital Maneuvering System pod aboard Endeavour during the launch count on May 30. Managers elected to replace the component and moved the launch of STS-111 to no earlier than June 4. Due to the uniqueness of the change-out and the work required to build a test fixture, launch of Endeavour was again postponed until June 5.

### **Landing:**

**June 19, 2002 at 1:58:45 p.m. EDT.** Runway 22, Edwards Air Force Base, Calif. Main gear touchdown: 1:57:41 p.m. EDT. Nose gear touchdown: 1:57:53 p.m. EDT. Wheel stop: 1:58:45 p.m. EDT. Rollout time: 1 minute, 4 seconds. Mission elapsed time: 13 days, 20 hours, 35 minutes, 56 seconds. Landed on orbit 217. Logged 5.8 million statute miles. Landed on the first of two California landing opportunities, after two days of wave-offs at KSC due to weather concerns.

Endeavour was flown back to KSC June 29, 2002, atop a Boeing modified 747 aircraft.

### **Mission Highlights:**

June 7, Mission Specialist Franklin Chang-Diaz equaled a space flight record with his seventh Shuttle flight, tying astronaut Jerry Ross. After docking with the ISS, linking to the Destiny Lab's forward docking port, the Endeavour and ISS crews transferred equipment, supplies and experiments.

The Expedition 4 crew ñ Yuri Onufriyenko, Daniel Bursch and Carl Walz ñ unofficially ended their 182-day residence aboard ISS, and the Expedition 5 crew ñ Commander Valery Korzun, Flight Engineer Peggy Whitson and Sergei Treschev ñ began their tenure.

June 8, using the Shuttle's robotic arm, Commander Kenneth Cockrell moved the Multi-Purpose Logistics Module Leonardo from Endeavour's payload bay to the Unity module. Transfer began of more than 5,600 pounds of cargo to the ISS.

Leonardo carried a total of 8,062 pounds of supplies and equipment to the Space Station, including a new science rack to house microgravity experiments and a glovebox that will allow Station crews to conduct experiments requiring isolation.

June 10, Whitson and Walz used the Canadarm2 to move the Mobile Remote Service Base System (MBS) from Endeavour to the Mobile Transporter on the Destiny Lab. The MBS, part of the Station's Mobile Servicing System, will allow the Canadarm2 to travel the length of the Station for construction tasks. The official change of command ceremony between the two Expedition crews followed.

June 12, the crews stowed 4,500 pounds of supplies and hardware in the MPLM Leonardo for return to Earth. Payload bay cameras captured views of the Colorado wildfires, visible from the 240-mile-high orbit of Endeavour/ISS.

Perrin returned the MPLM Leonardo to the Shuttle's payload bay June 14. The MPLM was filled with 4,667 pounds of equipment and supplies no longer needed on the Station.

June 15 Endeavour undocked from the ISS, flying one and a quarter laps around the Station before final separation.

Landing opportunities at Kennedy Space Center June 17-19 were waived due to low cloud cover, rain and thundershowers in the landing area.

### **EVA No. 1 ñ 7 hours, 14 minutes:**

In their first ever spacewalk, Mission Specialists Franklin Chang-Diaz and Philippe Perrin installed a Power and Data Grapple Fixture to the Station's P6 truss. The fixture will be used to relocate the P6 truss to its final site on the Station.

They retrieved six micrometeoroid debris shields from Endeavour's cargo bay and temporarily stored them on PMA-1. They will ultimately be installed on the Zvezda Service Module.

A newly added task required the two astronauts to inspect and photograph the failed control moment gyroscope on the Z1 truss. The photos may help ground controllers understand why the gyroscope failed. Next Chang-Diaz and Perrin removed thermal blankets from the MBS and positioned it above the Mobile Transporter to thermally condition it before mating it on EVA No. 2.

### **EVA No. 2 ñ 5 hours:**

Chang-Diaz and Perrin connected primary and backup video and data cables and primary power cables between the Mobile Transporter rail car and the MBS. They deployed an auxiliary grapple fixture, the Payload Orbital Replacement Unit Accommodation (POA), on the MBS. The POA will be able to grapple payloads and hold them as they are moved along the Station's truss atop the MBS.

The two astronauts secured four bolts to complete installation of the MBS platform. They also relocated a TV camera on top of the MBS to provide views of Station assembly and maintenance operations.

### **EVA No. 3 ñ 7 hours, 17 minutes:**

Chang-Diaz and Perrin replaced the wrist-roll joint on Canadarm2, restoring it to full use. The faulty joint was secured in a flight support structure in Endeavour's cargo bay. Perrin removed the new joint from its launch carrier and brought it up to Chang-Diaz and the Canadarm2. The duo aligned the new component with the wrist yaw joint, tightened six bolts to secure the joint to the arm and turned the final bolt to connect power, data and video lines.

After reinstalling the latching end effector, power to the arm was turned back on. The arm returned to full operational status at 4:43 p.m. EDT.

This was the 41st spacewalk supporting ISS assembly, bringing the total mission EVA time to 19 hours, 31 minutes.

## **STS-112 (9A/15th assembly flight to the ISS)**



### **Atlantis Pad 39B**

111th Shuttle mission  
26th flight OV-104  
60th KSC landing



### Crew:

Jeffrey Ashby, Commander (3rd Shuttle flight)  
Pamela Melroy, Pilot (2nd)  
David Wolf, Mission Specialist, (3rd)  
Piers Sellers, Mission Specialist, (1st)  
Sandra Magnus, Mission Specialist (1st)  
Fyodor Yurchikhin, Mission Specialist (1st)  
(Russian Space Agency)

### Orbiter Preps (move to):

**OPF bay 2** ñ April 19, 2002  
**VAB** ñ Sept. 4, 2002  
**Pad 39B** ñ Sept. 10, 2002

### Launch:

**Oct. 7, 2002, at 3:45:51 p.m. EDT.** The STS-112 mission was originally scheduled to launch Oct. 2; however, Hurricane Lili, in the Gulf of Mexico, threatened Mission Control at Johnson Space Center, Houston. Since the exact path was not determined until late in its forward movement, a decision was made to power down the JSC Mission Control Center and the launch was rescheduled for Oct. 7. Atlantis then lifted off on time to deliver the 28,000 pound Starboard 1 (S1) truss segment to the International Space Station.

A problem prevented the detonation of one of two sets of small explosives that release bolts that hold the Shuttle's solid rocket boosters to the launch platform and release ground connections to the external tank. A second redundant system fired normally and all pyrotechnic bolts were safely released.

### Landing:

**Oct. 18, 2002, at 11:44:35 a.m. EDT.** Main gear touch-down occurred at 11:43:40 a.m. EDT; nose gear touch-down at 11:43:48 a.m.; and wheel stop at 11:44:35 a.m. Mission elapsed time was 10:19:58:44. Logged 4.5 million statute miles. Rollout: 8,305 feet. This was the 60th landing at KSC in Shuttle program history.

### Mission Highlights:

Primary payloads were the S1 integrated truss segment and the Crew and Equipment Translation Aid (CETA) Cart A. The CETA is the first of two human-powered carts that will ride along the ISS railway, providing mobile work platforms for future spacewalking astronauts.

Activities included three spacewalks to attach the S1 truss to the Space Station. Mission Specialist Sandra Magnus and ISS Science Officer Peggy Whitson lifted the 14-ton, 45-foot S1 truss from Atlantis' payload bay using the Station's Canadarm2. They then attached it to the Station with four remotely operated bolts.

Other chores were repairing the Station's exercise treadmill; adjusting protective circuits that measure current in the S1 truss radiator assembly to greater tolerance levels for space; removing and replacing a humidity separator in the Quest airlock.

Three spacewalks, totalling 19 hours, 41 minutes, accomplished the following:

### EVA No. 1 ñ 7 hours, 1 minute:

Mission Specialists Wolf and Sellers hooked up power, data and fluid lines, released locks on a beam allowing the S1 radiators to be oriented for optimal cooling, deployed an antenna and released restraints on the CETA cart.

### EVA No. 2 ñ 6 hours, 4 minutes:

Wolf and Sellers prepared CETA cart A for future use, installed 22 Spool Positioning Devices (SPD) on the Space Station ammonia-cooling line connections, installed an exterior TV camera outside Destiny, hooked up an ammonia supply for lines to the S1 radiator, and checked equipment to be used to install the next starboard truss. Two additional SPDs would not fit and were left unattached.

### EVA No. 3 ñ 6 hours, 36 minutes:

After completing their first task, removing a bolt that prevented activation of a cable cutter on the mobile transporter, Wolf and Sellers then connected ammonia lines and removed structural support clamps that held the truss in place during launch. Working ahead of schedule, they then added a task ñ installing SPDs on a pump motor assembly that helps circulate ammonia through the Station's cooling system. The Station's robotic arm, used as a work platform by the two spacewalkers, was operated by Whitson and Magnus.

Final activities on the Space Station included transferring the last of the equipment and supplies from Atlantis, and packing items for return on the orbiter. In all, 1,800 pounds were transferred and an equivalent amount stored for the journey back.

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## STS-113 (11A/16th ISS assembly flight)



### Endeavour Pad 39A

112th Shuttle mission  
19th flight OV-105  
61st KSC landing

### Crew:

James Wetherbee, Commander (6th Shuttle flight)  
Paul Lockhart, Pilot (2nd)  
Michael Lopez-Alegria, Mission Specialist (3rd)  
John Herrington, Mission Specialist (1st)

*ISS Resident crew, Expedition 6:*  
Ken Bowersox, Commander  
Nikolai Budarin, flight engineer, RSA  
Donald Pettit, flight engineer

*Returning crew, Expedition 5:*  
Valery Korzun, Commander, RSA  
Peggy Whitson, Science Officer  
Sergei Treschev, flight engineer, RSA

### **Orbiter Preps (move to):**

**OPF bay 1** ñ June 29, 2002  
**VAB** ñ Sept. 30, 2002  
**Pad 39A** ñ Oct. 12, 2002

### **Launch:**

**Nov. 23, 2002, at 7:49:47 p.m EST.** The earlier planned launch on Nov. 11 was postponed when higher than allowable oxygen levels were detected in the orbiter's mid-body. Launch was tentatively set for no earlier than Nov. 18 so that technicians could troubleshoot and repair the leak. A fatigued flexible hose was found to be the cause and was replaced, along with another similar hose.

Another problem surfaced when a platform used to access the oxygen line bumped the robotic arm in the payload bay. Inspections of the arm for damage postponed launch until Nov. 22.

The launch was again postponed 24 hours to Nov. 23 due to poor weather conditions at Transoceanic Abort Landing sites.

### **Landing:**

**Dec. 7, 2002, at 2:37 p.m. EST.** After four days of landing attempts thwarted by bad weather, Endeavour and crew made a flawless landing on the first of two opportunities on Runway 33 at the KSC Shuttle Landing Facility, completing a 5.74-million-mile journey. The delays marked the first time landing had been waived off three consecutive days. Main gear touchdown was 2:37:12 p.m. EST, nose gear touchdown at 2:37:23 p.m., wheel stop at 2:38:25 p.m. Mission elapsed time was 13 days, 18 hours, 48 minutes, 38 seconds. Rollout distance averaged 10,563 feet.

### **Mission Highlights:**

Over the course of the 14-day mission, the STS-113 crew and the Expedition Six crew combined to install the new P1 truss to the International Space Station, perform three spacewalks to outfit and activate the truss, and transfer supplies and equipment between the two spacecraft. Endeavour brought more than 2,500 pounds of material to the Station.

Among the transfer were science experiments, the PCG-STES and PGBA returning to Earth and the PCG-STES Unit 10 moving onto the Station.

While Endeavour was docked to the Space Station, Expedition 5 NASA Science Officer Peggy Whitson and Expedition 6 Commander Ken Bowersox replaced two valves and cleared debris from vent lines of the Carbon

Dioxide Removal Assembly (CDRA) in the Station's U.S. Destiny Laboratory.

Prior to the first spacewalk, Commander Jim Wetherbee removed the P1 truss from Endeavour's payload bay, using the Shuttle's robotic arm, and handed it off to the Station's Canadarm2. Whitson and Bowersox maneuvered the P1 to its installation position.

### **EVA No. 1 ñ 6 hours, 45 minutes:**

Mission Specialists Michael Lopez-Alegria and John Herrington hooked up electrical connections between the P1 truss and Station, installed spool positioning devices that will ensure quick disconnect devices in fluid lines function properly, and released launch locks on the Crew and Equipment Translation Aid (CETA) cart. They also installed Node Wireless video system External Transceiver Assembly (WETA) antennas allowing reception from spacewalkers' helmet cameras without a Shuttle present.

### **EVA No. 2 ñ 6 hours, 10 minutes:**

On Thanksgiving Day, Lopez-Alegria and Herrington connected two fluid jumpers between the P1 and S0 trusses, linking plumbing for ammonia in the Station's cooling system. They removed the starboard keel pin, moving it to the proper location and stowing it in the P1 truss. They also installed a second WETA, this one on the P1 truss. They released launch locks on the P1 radiator beams.

Working from the Canadarm2, Herrington lifted the CETA cart to the S1 truss where he attached it to the tracks and secured it to its sister CETA, delivered on STS-112. The move cleared the P1 tracks so the Canadarm 2 can move on them via the Mobile Transporter and Mobile Base System.

A final task was reconnecting a cable on the WETA installed 2 days earlier.

### **EVA No. 3 ñ 7 hours:**

Herrington and Lopez-Alegria successfully completed installation of 33 spool positioning devices around the outside of the Station.

Herrington also troubleshooted the stalled railcar (Mobile Transporter). He freed and deployed a UHF communications antenna that had snagged a trailing umbilical mechanism on the MT. The MT was able to reach its destination, Worksite 7. Herrington completed his assigned tasks without using the Canadarm2, which was to have transferred from the U.S. Lab to the MT to maneuver Herrington through some of his tasks.

During the mission, Whitson and Flight Engineer Donald Pettit did troubleshooting on the Microgravity Science Glovebox (MSG) on the Station. The device, which provides electrical power to the facility, had failed Nov. 20. The MSG allows experiments with fluids, flame, particles or fumes to be performed in an enclosed environment. The box was returned to Earth for further study.



# 2003

## STS-107 (research mission)



### Columbia Pad 39A

113th Shuttle mission  
28th flight OV-102

### Crew:

Rick Husband, Commander (2nd Shuttle flight)  
William iWillieî McCool, Pilot (1st)  
Michael Anderson, Payload Commander (2nd)  
Kalpana Chawla, Mission Specialist (2nd)  
David Brown, Mission Specialist (1st)  
Laurel Clark, Mission Specialist (1st)  
Ilan Ramon, Payload Specialist (1st),  
Israel Space Agency

### Orbiter Preps (move to):

OPF bay 3 ñ March 12, 2002  
VAB ñ Nov. 20, 2002  
Pad 39A ñ Dec. 9, 2002

### Launch:

**Jan. 16, 2003, at 10:39 a.m. EST.** Columbia lifted off on time on the first Shuttle mission of the year. It carried seven crew members, including the first Israeli astronaut, on a marathon international scientific research flight.

### Landing:

KSC landing planned for Feb. 1 after a 16-day mission, but Columbia and crew were lost during re-entry over East Texas at about 9 a.m. EST, 16 minutes prior to the scheduled touchdown at KSC. A seven-month investigation followed, including a four-month search across Texas to recover debris. The search headquarters were at Barksdale Air Force Base in Shreveport, La. Nearly 85,000 pieces of orbiter debris were shipped to KSC and housed in the Columbia Debris Hangar near the Shuttle Landing Facility. The KSC debris reconstruction team identified pieces as to location on the orbiter, and determined damaged areas. About 38 percent of the dry weight of the orbiter Columbia was eventually recovered.

### Mission Highlights:

As a research mission, the crew was kept busy 24 hours a day performing various chores involved with science experiments.

Experiments in the SPACEHAB Research Double Module included nine commercial payloads involving 21 separate investigations, four payloads for the European Space Agency with 14 investigations, one payload/investigation for ISS Risk Mitigation and 18 payloads supporting 23 investigations for NASA's Office of Biological and Physical Research (OBPR).

In the physical sciences, three studies inside a large, rugged chamber examined the physics of combustion, soot production and fire quenching processes in microgravity. These experiments provided new insights into combustion and fire-suppression that cannot be gained on Earth.

An experiment that compresses granular materials in the absence of gravity furthered our understanding of construction techniques. This information can help engineers provide stronger foundations for structures in areas where earthquakes, floods and landslides are common.

Another experiment evaluated the formation of zeolite crystals, which can speed the chemical reactions that are the basis for chemical processes used in refining, biomedical and other areas. Yet another experiment used pressurized liquid xenon to mimic the behaviors of more complex fluids such as blood flowing through capillaries.

In the area of biological applications, two separate OBPR experiments allowed different types of cell cultures to grow together in weightlessness to elevate their development of enhanced genetic characteristics ñ one use was to combat prostate cancer, the other to improve crop yield. Another experiment evaluated the commercial usefulness of plant products grown in space.

A facility for forming protein crystals more purely and with fewer flaws than is possible on Earth may lead to a drug designed for specific diseases with fewer side effects.

A commercially sponsored facility housed two experiments to grow protein crystals to study possible therapies against the factors that cause cancers to spread and bone cancer to inflict intense pain on its sufferers.

A third experiment looked at developing a new technique of encapsulating anti-cancer drugs to improve their efficiency.

Other studies focused on changes, due to space flight, in the cardiovascular and musculoskeletal systems; in the systems which sense and respond to gravity; and in the capability of organisms to respond to stress and maintain normal function.

NASA also tested a new technology to recycle water prior to installing a device to recycle water permanently aboard the International Space Station.

The European Space Agency (ESA), through a contract with SPACEHAB, flew an important payload focused on astronaut health, biological function and basic physical phenomena in space. These experiments addressed different aspects of many of the same phenomena that NASA is interested in, providing a more thorough description of the effects of space flight, often in the same subjects or specimens.

ESA performed seven in-flight experiments, and one ground-based, on the cardiopulmonary changes that occur in astronauts.

Additional ESA biological investigations examined bone formation and maintenance; immune system functioning; connective tissue growth and repair; and bacterial and yeast cell responses to the stresses of space flight.

A special facility grew large, well-ordered protein and virus crystals that were expected to lead to improved drug designs. Another studied the physical characteristics of bubbles and droplets in the absence of the effects of Earth's gravity.

SPACEHAB was also making it possible for universities, companies and other government agencies to do important research in space without having to provide their own spacecraft.

The Canadian Space Agency sponsored three bone-growth experiments, and was collaborating with ESA on two others.

The German Space Agency measured the development of the gravity-sensing organs of fish in the absence of gravity.

A university was growing ultra-pure protein crystals for drug research. And another university was testing a navigation system for future satellites.

The U.S. Air Force was conducting a communications experiment. Students from six schools in Australia, China, Israel, Japan, Liechtenstein and the United States were probing the effects of space flight on spiders, silkworms, inorganic crystals, fish, bees and ants, respectively.

There were also experiments in Columbia's payload bay, including three attached to the top of the RDM: the Combined Two-Phase Loop Experiment (COM2PLEX), Miniature Satellite Threat Reporting System (MSTRS) and Star Navigation (STARNAV).

There were six payloads/experiments on the Hitchhiker pallet — the Fast Reaction Experiments Enabling Science, Technology, Applications and Research (FREESTAR), which was mounted on a bridge-like structure spanning the width of the payload bay. These six investigations looked outward to the Sun, downward at Earth's atmosphere and inward into the physics of fluid phenomena, as well as tested technology for space communications.

FREESTAR held the Critical Viscosity of Xenon-2 (CVX-2), Low Power Transceiver (LPT), Mediterranean Israeli Dust Experiment (MEIDEX), Space Experiment Module (SEM- 14), Solar Constant Experiment-3 (SOLCON-3) and Shuttle Ozone Limb Sounding Experiment (SOLSE-2). The SEM comprised 11 separate student experiments from schools across the U.S. and was the 14th flight of a SEM on the space shuttle.

Additional secondary payloads were the Shuttle Ionospheric Modification with Pulsed Local Exhaust Experiment (SIMPLEX) and Ram Burn Observation (RAMBO).

During the debris recovery activities, some of the Columbia experiments were found. Scientists have indicated valuable science will still be produced. Much of the scientific data was transmitted to experimenters on the ground during the flight.

## **For More Information**

**Reports about the Columbia investigation and return to flight efforts can be found online at these sites:**

**<http://www.nasa.gov/columbia/home/index.html>**

**<http://spaceflight.nasa.gov/shuttle/investigation/index.html>**



Flagship of the Shuttle fleet, Columbia lifts off on its final mission to space, Jan. 16, 2003, at 10:39 a.m. EST, with a crew of seven.

# NOTES



National Aeronautics and  
Space Administration