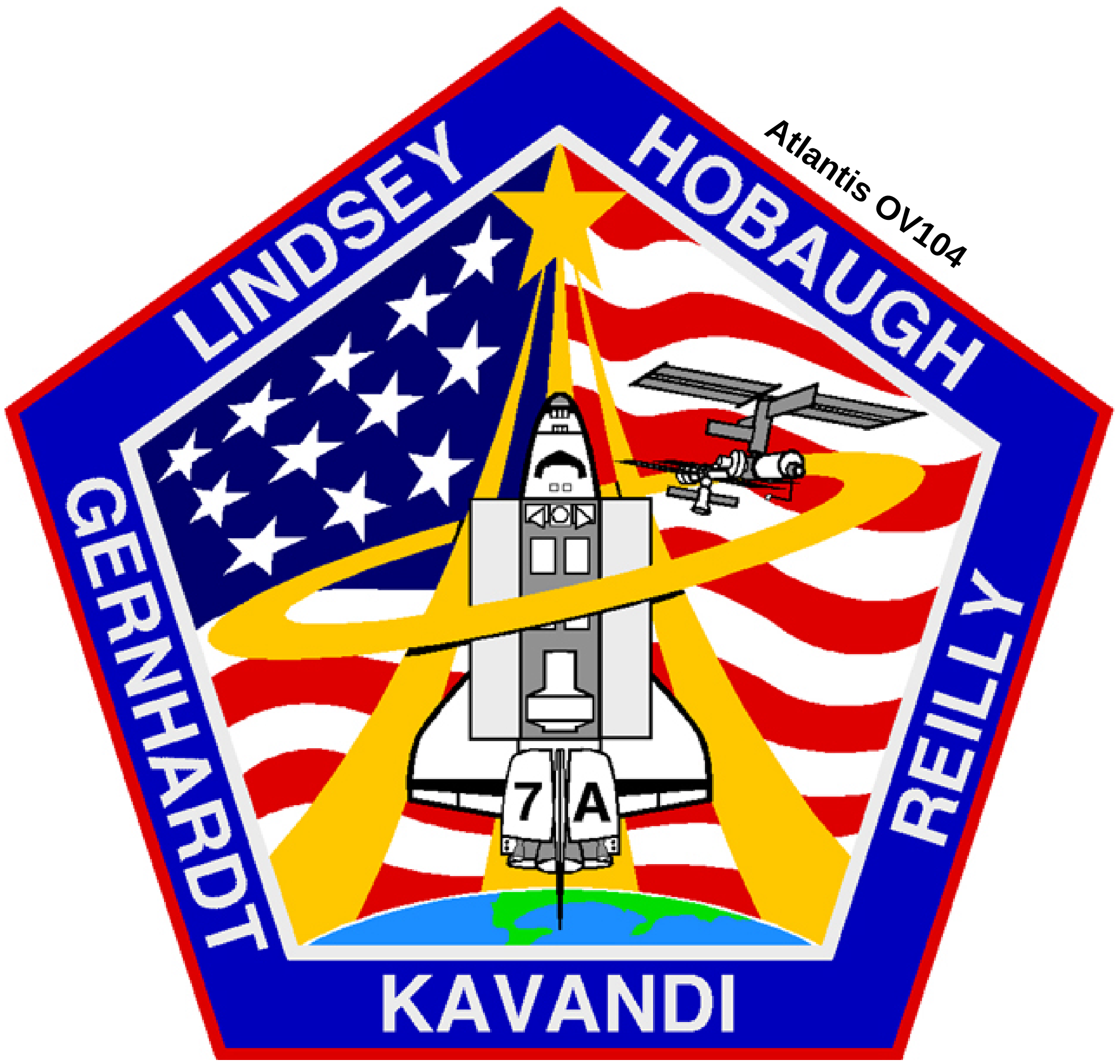
Giving the ISS a Doorway to Space

Three Spacewalks Set for Airlock Installation



STS-104

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USA
United Space Alliance

Updated June 22, 2001

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Mission Overview

Giving the ISS a Doorway to Space

Another International Space Station phase reaches completion during the STS-104 (ISS Assembly Flight 7A) mission aboard Atlantis, the fourth shuttle mission of the year, the 10th shuttle flight to the expanding station and the 105th flight in Space Shuttle Program history.

Five astronauts, commanded by veteran shuttle flier Steve Lindsey, an Air Force lieutenant colonel, with help from ISS Expedition Two Flight Engineers Susan Helms and Jim Voss, will install a 6½-ton Joint Airlock to the starboard berthing mechanism of the station's Unity module. It will be used by resident crewmembers and visiting shuttle crews to conduct spacewalks, using either American or Russian spacesuits. Expedition Two Commander Yury Usachev will monitor ISS systems during the delicate airlock installation procedure and the initial testing of the airlock itself.

Once it is installed and activated, the airlock will symbolize the completion of the ISS Phase Two, giving the station a capability for spacewalks with no shuttle present.

Scheduled for launch from Launch Pad 39B at Kennedy Space Center (KSC), Atlantis will reach the ISS for a docking two days after liftoff. Its arrival will set the stage for three spacewalks by veterans Mike Gernhardt and Jim Reilly to install the massive chamber and four high-pressure tanks, two oxygen and two nitrogen.

The tanks will be used to pressurize and depressurize the new airlock. The third spacewalk will be the first to be conducted from the new ISS airlock.

Lindsey is joined on Atlantis by Pilot Charlie Hobaugh, a Marine Corps captain and first-time flier, and Janet Kavandi, a shuttle veteran. She will be responsible for shuttle robot arm operations in support of the spacewalks.

Helms and Voss will use the station's Canadarm2 robot arm to grapple and install the airlock on Unity on the first spacewalk by Gernhardt and Reilly.

Built at a cost of $164 million (including associated tanks), the airlock consists of two separate chambers. The equipment lock, the larger of the two, has room for spacesuits and environment equipment, which will be used by spacewalkers to suit up and prepare for their excursion outside the station. The crew lock, which is separated from the equipment lock by a hatch, is the portal from which the spacewalkers will open the outer hatch to begin their excursions. The crew lock contains lighting, handrails and internal umbilical assemblies to provide power and communications for the spacewalkers until they put their suits on internal battery power. It is similar in size to the shuttle's airlock.

Once installed, the airlock will undergo a series of tests by ground controllers and station crewmembers to verify that its environmental, communications and telemetry systems work before Gernhardt and Reilly venture out of it for the first time on the ninth day of the mission.

During the second and third spacewalks, Helms will use the Canadarm2 to grapple and unberth two pressurized oxygen tanks and two pressurized nitrogen tanks from the Spacelab double pallet in Atlantis' cargo bay. She will hand them off, one by one, to Gernhardt and Reilly for installation on the new airlock.

Kavandi will operate the shuttle's smaller Canadian-built robot arm from Atlantis' aft flight deck to maneuver the spacewalkers. It will be the second time robotics from two spacecraft will be employed in ISS assembly.

The hatches between Atlantis and the ISS will be closed and opened twice for the first two spacewalks to maintain the proper cabin pressure for each vehicle. But once the new airlock is installed and activated, hatches can stay open between visiting shuttles and the station during future flights during docked operations.

Most of Atlantis' mission will be devoted to installing and outfitting the airlock, but the shuttle crewmembers also will transfer cargo and water to the station. Kavandi will be in charge of cargo transfer operations, helped by Lindsey, Hobaugh and Reilly.

In addition, during a week of joint activity between the shuttle and station crews, Atlantis' astronauts will conduct an experiment called SIMPLEX, an acronym for Shuttle Ionospheric Modification with Pulsed Local Exhaust. It studies the sources of high frequency radar echoes created by shuttle engine firings in space. The crew will also shoot scenes of its visit to the ISS on the large format IMAX camera, a 65mm color movie camera system. More than a mile of film will be shot during the mission.

The 11-day flight will end with Atlantis' landing on the 3-mile-long runway at KSC.

Day 1 - Launch

Atlantis' crew will launch at the end of its day during a precisely timed, few-minutes-long launch window that begins the process of rendezvous with the International Space Station. Once in orbit, they will power up and activate heaters on the airlock in the cargo bay to keep it from being damaged by the cold of space. Crewmembers will go to sleep about five hours after launch.

Day 2 - Equipment Checkouts, Rendezvous Preparations

Atlantis' crew will spend its first full day in space checking out equipment that will be used for upcoming major activities -- spacesuits and spacewalking gear; the shuttle's robotic arm; and the controls and tools used for the final rendezvous and docking with the station. The crew also will power up and prepare the shuttle's docking system and perform several engine firings to optimize the rate at which Atlantis closes in on the station.

Day 3 - Rendezvous and Docking

Plans call for Atlantis to dock with the International Space Station on Flight Day 3. The shuttle and station crews will open hatches and transfer some equipment and supplies, including water bags. They will then close the hatches and Atlantis' cabin pressure will be lowered to 10.2 pounds per square inch in preparation for the next day's spacewalk.

Day 4 - First Spacewalk; Joint Airlock Installation

The first spacewalk focuses on airlock installation. The spacewalkers will help as Helms, using the station's robotic arm, lifts the new station airlock from Atlantis' payload bay and moves it to the station's Unity module. During much of the almost seven-hour spacewalk, Reilly will work from a foot platform attached to the end of the shuttle's robotic arm, operated by Kavandi. After the spacewalk, crewmembers inside the station will attach connections to the airlock to prevent thermal damage.

Day 5 - Airlock Activation

After an overnight Airlock leak check, the day's activities will be largely devoted to airlock activation. Tasks include removing Common Berthing Mechanism motor controllers and connecting remaining utilities in the vestibule linking Unity with the airlock. Crewmembers will enter the airlock to do more activation tasks, stow some equipment and check out the oxygen and nitrogen activities.

Day 6 - Spacewalk Preparation, Additional Airlock Activities

Astronauts will check out spacesuits and other spacewalking equipment and install a hatch between the equipment lock and the crew lock of the new airlock. The hatch was launched in the endcone of the airlock. The airlock's depressurization pump will be checked out and the newly installed hatch's seal will be verified. The station and shuttle arms will be prepared for the next day's activities.

Day 7 - Second Spacewalk

The second spacewalk is to last about 5½ hours. The internal hatches between the shuttle and station will be closed at the end of Flight Day 6 so Atlantis' cabin pressure can be lowered in preparation for the second spacewalk. The major objective is to attach and connect an oxygen and a nitrogen tank. Helms will operate the station arm to lift the tanks from the shuttle's payload bay and maneuver them to the new airlock. At the airlock, Gernhardt and Reilly will latch the tanks in place and connect cables and hoses.

Day 8 - Rest and Spacewalk Preparation

Shuttle and station crews are to get the first half of the day off. The second half will be used to prepare for the third spacewalk. Some equipment and supplies will be transferred, including the Protein Crystal Growth - Enhanced GN2 Nitrogen Deware experiment.

Day 9 - The Third Spacewalk

The third spacewalk will be the first conducted from the new space station airlock. It may include a new protocol, developed by former commercial diver Gernhardt, to purge nitrogen from the spacewalkers' bodies -- essentially exercising while breathing oxygen. Primary objective is to install the final two tanks -- one oxygen and one nitrogen -- outside the airlock.

Day 10 - Shuttle-Station Hatch Closing, Undocking, Flyaround

The shuttle and station crews will close hatches between the spacecraft. Lindsey and Hobaugh will undock Atlantis from the station. With Hobaugh at the controls, Atlantis will do a flyaround of the complex before departing.

Day 11 - Pre-Landing Checkouts, Cabin Stow

Activities include the standard day-before-landing flight control checks of Atlantis by Lindsey and Hobaugh as well as the normal steering jet test firing. The crew will spend most of the day stowing away gear on board the shuttle and preparing for the return home.

Day 12 - Entry and Landing

The Kennedy Space Center, Fla., is the preferred landing site.

Updated: 06/21/2001

Mission Objectives

Top priority of the STS-104 mission of Atlantis is installation on the International Space Station of the Joint Airlock. This will give station crewmembers the capability of conducting spacewalks from the orbiting laboratory using either the Russian Orlan spacesuits or U.S. spacesuits.

The airlock will be attached to the station's Unity Node, on the module's starboard Common Berthing Mechanism, and its "survival heaters" activated. The installation will use the station's new Canadarm2 robotic arm during the mission's first spacewalk.

Again helped by the station's robotic arm, astronauts performing a second spacewalk from Atlantis will install an oxygen and a nitrogen tank on the airlock. The tanks, called high-pressure gas tanks or oxygen/nitrogen tank orbital replacement units, must be installed before a spacewalk can be performed from the airlock without a shuttle present.

A third spacewalk will be performed to attach an additional oxygen and an additional nitrogen tank on the airlock. This spacewalk, by shuttle crewmembers, will be from the airlock itself. All four tanks, two oxygen and two nitrogen, must be installed to give station crewmembers the capability to do spacewalks without oxygen- or nitrogen-related constraints.

Crewmembers and flight controllers on the ground will activate airlock core systems. Those systems must be checked out to be ready for extended work in the airlock and to confirm that it is ready to serve as the base for future spacewalks.

They will connect oxygen and nitrogen lines and check the lines for leaks. If the tank lines leaked into the airlock, it would require isolation and perhaps repair before it could be used for normal spacewalks. The checks are performed both by spacewalkers and by crewmembers inside the space station.

Astronauts will transfer spacewalk and airlock outfitting equipment from Atlantis' middeck to the ISS. They also will install a spacewalk work site on the airlock and other equipment for use by spacewalkers on subsequent missions.

Another priority is to transfer water for the Expedition Two crew. Water bags to last the crew until the next resupply opportunity will be transferred from Atlantis to the ISS through the course of the shuttle's stay at the space station.

Supplies will be transferred from Atlantis to the station, and unused cargo will be transferred from the station to Atlantis to be returned to Earth.
Additional priorities include:

--Transfer of science payloads from Atlantis to the ISS.

--IMAX 3D filming.

--The SIMPLEX experiment, using ground sites to track shuttle thruster firings. The acronym is for Shuttle Ionospheric Modification with Pulsed Local Exhaust.

--Installation of airlock trunnion pin covers and oxygen/nitrogen gas tank quick disconnect thermal covers for long-term protection against condensation and heat loss.

Crew

Commander:	Steven W. Lindsey
Pilot:	Charles O. Hobaugh
Mission Specialist 1:	Michael L. Gernhardt
Mission Specialist 2:	Janet L. Kavandi
Mission Specialist 3:	James F. Reilly

Launch

Orbiter:	Atlantis OV104
Launch Site:	Kennedy Space Center Launch Pad 39B
Launch Window:	2.5 to 5 Minutes
Altitude:	122 Nautical Miles
Rendezvous:	240 Nautical Miles
Inclination:	51.6 Degrees
Duration:	10 Days 19 Hrs. 40 Min.

Vehicle Data

Shuttle Liftoff Weight:	4520042 lbs.
Orbiter/Payload Liftoff Weight:	258222 lbs.
Orbiter/Payload Landing Weight:	207251 lbs.

Software Version: OI-28

Space Shuttle Main Engines

SSME 1: 2056 **SSME 2:** 2051 **SSME 3:** 2047

External Tank: ET-109A (Super Light Weight Tank)

SRB Set: BI-108/RSRM-80

Shuttle Aborts

Abort Landing Sites

RTLS: Kennedy Space Center Shuttle Landing Facility
TAL: Zaragoza primary; Ben Guerir, Moron alternates
AOA: Kennedy Space Center Shuttle Landing Facility

Landing

Landing Date:	07/23/01
Landing Time:	1:02 AM (eastern time)
Primary Landing Site:	Kennedy Space Center Shuttle Landing Facility

Updated: 05/25/2001

Crew Profile Menu

Commander: Steven W. Lindsey

Steven W. Lindsey, 40, an Air Force lieutenant colonel and former test pilot, will be responsible for the overall safety and success of the STS-104 mission. He will be responsible for the rendezvous and docking of Atlantis to the International Space Station on the fourth shuttle mission of the year. He will serve as backup operator of the shuttle's robotic arm. He will play a primary or backup role in Joint Airlock /vestibule outfitting, pressure leak checks and activation. He will serve as backup in water transfer from Atlantis to the space station. Lindsey also will assist pilot Charles Hobaugh at the controls for Atlantis' flyaround of the space station after undocking, and will be at the controls for the shuttle's landing at the end of the mission.

Lindsey flew as pilot on STS-87, the fourth U.S. Microgravity Payload flight, in November and December of 1997 and pilot on STS-95, a research flight in October and November of 1998.

Ascent Seating: Flight Deck - Port Forward
Entry Seating: Flight Deck - Port Forward
RMS

Pilot: Charles O. Hobaugh

Charles O. Hobaugh, 39, a Marine Corps major and former test pilot, will be in charge of monitoring critical shuttle systems during Atlantis' ascent to orbit and its re-entry and landing. He also will be responsible for the operation of many of the shuttle's navigational tools during its rendezvous with the space station. Hobaugh will serve as the intravehicular crewmember during the three spacewalks, helping with checklists and providing direction and coordination to the astronauts outside and helping keep them on their timeline. He also is designated as the backup spacewalker. After undocking, Hobaugh will be at the controls of Atlantis during its flyaround of the station.

Hobaugh is making his first space flight.

Ascent Seating: Flight Deck - Starboard Forward
Entry Seating: Flight Deck - Starboard Forward
IV1

Mission Specialist 1: Michael L. Gernhardt

Michael L. Gernhardt, 44, a former commercial diver who holds a Ph.D. in bioengineering from the University of Pennsylvania, will perform three spacewalks while Atlantis is docked to the space station. Focus of the spacewalks is installation of the Joint Airlock and four high-pressure tanks, two oxygen and two nitrogen, outside it. Gernhardt also has primary responsibility for airlock systems and stowage within it. He also is tasked with the payload bay door opening and rendezvous photography and television. Gernhardt will assist with rendezvous as backup with a handheld laser range finder and with operating the shuttle's docking system. He also has backup responsibilities for post-insertion activities and prime responsibility for deorbit preparation. He will conduct Earth observations focusing on oceanography and meteorology.

Gernhardt was a mission specialist on STS-69, which deployed and retrieved the Spartan satellite and the Wake Shield Facility, in September 1995; STS-83, the Microgravity Science Laboratory Spacelab mission, in April 1997; and STS-94, a reflight of that Spacelab mission, in July 1997.

Ascent Seating: Flight Deck - Starboard Aft
Entry Seating: Mid Deck - Port
EV1

Mission Specialist 2: Janet L. Kavandi

Janet L. Kavandi, 40, holds a doctorate in analytical chemistry from the University of Washington-Seattle. Kavandi will serve as flight engineer on the flight deck of Atlantis during launch, landing and rendezvous. Kavandi is the mission's primary shuttle arm operator. In addition to moving spacewalking astronauts, she will use the shuttle arm cameras to provide vital views to Susan Helms as Helms uses the space station's Canadarm2 to unberth the airlock from Atlantis's cargo bay. Kavandi also will use those cameras to help provide a Space Vision System solution to help Helms berth the airlock to the space station. She will have primary responsibility in airlock/vestibule outfitting. She also will be loadmaster on the shuttle side for logistics transfer to and from the space station.

Kavandi served as a mission specialist on STS-91, the last shuttle flight to Mir, in June 1998, and on STS-99, the Shuttle Radar Topography Mission, in February 2000.

Ascent Seating: Flight Deck - Center Aft
Entry Seating: Flight Deck - Center Aft
RMS

Mission Specialist 3: James F. Reilly

James F. Reilly, 46, a former offshore oil and gas exploration geologist and holder of a Ph.D. in geosciences from the University of Texas at Dallas, will perform three spacewalks outside the space station during Atlantis' docked operations. Purpose of the spacewalks centers on installation of the Joint Airlock and the four high-pressure tanks for oxygen and nitrogen outside it. He also will have primary responsibility for post-insertion operations and for handheld laser range finder operations during rendezvous. He also is responsible for numerous shuttle computer functions, crew and equipment transfer operations and airlock activation. He will conduct Earth observations focusing on geography.

Reilly flew on STS-89, the eighth Shuttle-Mir docking mission, in January 1998.

Ascent Seating: Mid Deck - Port
Entry Seating: Flight Deck - Starboard Aft
EV2

Updated: 05/22/2001

Flight Day Summary

DATE TIME (EST)	DAY	MET	EVENT
07/12/01 5:04:00 AM	1	000/00:00	Launch
07/13/01 8:33:00 PM	3	001/15:29	TI Burn
07/13/01 10:52:00 PM	3	001/17:48	Docking
07/14/01 12:14:00 AM	3	001/19:10	ISS Ingress
07/14/01 10:09:00 PM	4	002/17:05	EVA 1 Start
07/15/01 6:49:00 AM	4	003/01:45	Ingress 2
07/17/01 10:14:00 PM	7	005/17:10	EVA 2 Start
07/18/01 5:44:00 AM	7	006/00:40	Ingress 3
07/19/01 11:44:00 PM	9	007/18:40	EVA 3 Start
07/20/01 9:49:00 PM	10	008/16:45	ISS Egress
07/21/01 12:17:00 AM	10	008/19:13	Undocking
07/23/01 12:00:00 AM	12	010/18:56	Deorbit Burn
07/23/01 1:02:00 AM	12	010/19:58	Landing

Updated: 06/22/2001

Rendezvous

Rendezvous and Docking Overview

Rendezvous and Docking

Atlantis' rendezvous and docking with the International Space Station begins with the precisely timed launch of the shuttle on a course for the station. During the first two days of the mission, periodic engine firings will gradually bring Atlantis to a point about 9 1/2 statute miles behind the station, the starting point for a final approach to the station.

About 2 ½ hours before the scheduled docking time on Flight Day 3, Atlantis will reach a point about 50,000 feet behind the ISS. At that time, Atlantis' jets will be fired in a Terminal Intercept (TI) burn to begin the final phase of the rendezvous. Atlantis will close the final miles to the station during the next orbit.

As Atlantis closes in, the shuttle's rendezvous radar system will begin tracking the station and providing range and closing rate information to the crew. During the approach toward the station, the shuttle will have an opportunity to conduct four small mid-course corrections at regular intervals. Just after the fourth correction is completed, Atlantis will reach a point about half a mile below the station. At that time, about an hour before the scheduled docking, Commander Steve Lindsey will take over manual control of the approach.

Lindsey will slow Atlantis's approach and fly to a point about 600 feet directly below the station, from which he will begin a quarter-circle of the station, slowly moving to a position in front of the complex, in line with its direction of travel. Pilot Charlie Hobaugh will assist Lindsey in controlling Atlantis' approach. Mission Specialist James Reilly also will play key roles in the rendezvous, assisting with the rendezvous navigation and operating a handheld laser ranging device. Mission Specialists Janet Kavandi and Mike Gernhardt will operate the shuttle's docking mechanism to latch the station and Atlantis together after the two spacecraft make contact.

Lindsey will fly the quarter-circle of the station, starting 600 feet below it, while slowly closing in on the complex, stopping at a point a little more than 300 feet directly in front of the station. From that point, he will begin slowly closing in on the station -- moving at a speed of about a tenth of a mile per hour. Using a view from a camera mounted in the center of Atlantis' docking mechanism as a key alignment aid, Lindsey will precisely center the docking ports of the two spacecraft. Lindsey will fly to a point where the docking mechanisms are 30 feet apart, and pause for about five minutes to check the alignment.

For Atlantis' docking, Lindsey will maintain the shuttle's speed relative to the station at about one-tenth of a foot per second, and keep the docking mechanisms aligned to within three inches of one another. When Atlantis makes contact with the station, preliminary latches will automatically attach the two spacecraft together. Immediately after Atlantis docks, the shuttle's steering jets will be deactivated to reduce the forces acting at the docking interface. Shock absorber-type springs in the docking mechanism will dampen any relative motion between the shuttle and the station.

Once relative motion between the spacecraft has been stopped, Kavandi and Gernhardt will secure the docking mechanism, sending commands for Atlantis's mechanism to retract and close a final set of latches between the shuttle and station.

Undocking, Separation and Flyaround

Once Atlantis is ready to undock, Kavandi and Gernhardt will send a command that will release the docking mechanism. The initial separation of the spacecraft will be performed by springs in the docking mechanism that will gently push the shuttle away from the station. Atlantis's steering jets will be shut off to avoid any inadvertent firings during this initial separation.

Once the docking mechanism's springs have pushed Atlantis away to a distance of about two feet, when the docking devices will be clear of one another, Hobaugh will turn the steering jets back on and fire them to begin very slowly moving away. From the aft flight deck, Hobaugh will manually control Atlantis within a tight corridor as he separates from the ISS, essentially the reverse of the task performed by Lindsey when Atlantis docked.

Atlantis will continue away to a distance of about 450 feet, where Hobaugh will begin a close flyaround of the station, circling the complex almost one and a quarter times. Hobaugh will pass a point directly above the station, then behind, then underneath, then in front and then reach a point directly above the station for a second time. At that point, passing above the station for a second time, Hobaugh will fire Atlantis's jets for final separation from the station. The flyaround is expected to be completed about an hour and 20 minutes after undocking.

Updated: 05/22/2001

EVAs

STS-104 Spacewalks: Installing a Spacewalking Portal

Overview

Astronauts Mike Gernhardt and Jim Reilly will conduct three spacewalks while Atlantis is docked to the International Space Station to install, outfit and flight test a new airlock. Called the Joint Airlock, the new station component will accommodate both Russian and U.S. spacesuits and space-walking gear for future excursions from the station.

During the Extravehicular Activities (EVAs), as the spacewalks are technically described, Gernhardt will be designated extravehicular crew member 1 (EV1), distinguishable by red stripes around the legs of his spacesuit, and Reilly will be EV2, with an all-white spacesuit. Atlantis' Pilot Charlie Hobaugh will serve as the intravehicular activity crew member (IV), coordinating the spacewalk activities from within the shuttle cabin.

Astronaut Janet Kavandi will be operating the shuttle's robotic arm during the space walk while, aboard the station, Expedition Two Flight Engineer Susan Helms, assisted by fellow Expedition Two crew member Jim Voss, will operate the station's robotic arm. The internal hatches will be closed between Atlantis and the station during the first two spacewalks, although they are planned to be open for the third spacewalk, which is planned to begin from the newly installed station airlock rather than from Atlantis' airlock.

The first spacewalk is planned for Flight Day 4 of the mission, the day after Atlantis docks to the station. During the first spacewalk, planned to last almost seven hours, the space walkers will assist as Helms, using the station's robotic arm, lifts the new station airlock from Atlantis' payload bay and attaches it to a port on the station's Unity connecting module. During much of the first spacewalk, Reilly will work from a foot platform attached to the end of the shuttle's robotic arm, operated by Kavandi.

The first major task for the spacewalkers will be for Gernhardt to remove an insulating cover, nicknamed the "shower cap," from the airlock's Common Berthing Mechanism, the mechanism that will attach to Unity, while the airlock is in the payload bay. Gernhardt also will remove protective covers from the berthing mechanism's seals. The "shower cap" and seal covers will later be stowed by the spacewalkers in a tool locker in Atlantis' payload bay for the trip back to Earth.

While Gernhardt is removing the covers, Reilly will work on the side of the airlock, installing devices, nicknamed "towel bars," that will later serve as attachment points for four high-pressure oxygen and nitrogen tanks outside the new airlock. Reilly also will temporarily affix several thermal covers to the airlock exterior, positioning them for a later full installation on the third spacewalk.

Next, Gernhardt will disconnect a cable that provided shuttle electrical power to heaters on the airlock, called Launch To Activation or LTA heaters. Then Reilly will take the disconnected power cable and the removed airlock covers to a Tool Stowage Assembly (TSA) on the starboard side of the shuttle's payload bay to stow them. With the power cable between the shuttle and new airlock disconnected, Helms will begin to latch the station's Canadarm2 onto a fixture on the new airlock.

While Helms and Voss lift the airlock from Atlantis' cargo bay and maneuver it into position to attach to the Unity module, Gernhardt and Reilly will wait inside the still-depressurized shuttle airlock, recharging their spacesuits by connecting to air and power from the shuttle. As Helms works with the station's arm, Kavandi will maneuver the shuttle's arm into positions to provide television camera views to assist Helms.

Once the station airlock is poised high above the shuttle payload bay only a few feet from its attachment point on the station, Gernhardt and Reilly will leave the shuttle's airlock. If needed, the two spacewalkers will provide on-the-spot observations for Helms to assist with aligning the airlock as it is attached to Unity. Once the new airlock has been attached to the station, Gernhardt will then connect a cable that will provide station power to the new component, the final major task planned for the spacewalk.

Second Spacewalk: Air for the Airlock

The second spacewalk, planned to last about 5½ hours, will be on Flight Day 7. The internal hatches between the shuttle and station will be closed at the end of Flight Day 6 to prepare for the second spacewalk, allowing the shuttle's cabin pressure to be reduced slightly as part of a protocol that protects spacewalkers from decompression sickness.

The major objective of the second spacewalk is to attach and connect two -- one oxygen and one nitrogen -- of four oxygen and nitrogen tanks to the exterior of the new station airlock. The remaining two tanks are planned to be installed during the mission's third spacewalk. During the second spacewalk, Gernhardt will be tethered to the end of the shuttle's robotic arm for much of the work.

Helms will be operating the station's arm to lift the tanks from the shuttle's payload bay and maneuver them to the new airlock on the station. As the spacewalk begins, Helms will latch the station arm onto the first tank, an oxygen tank, in Atlantis' payload bay. After the station arm is latched onto the tank, Gernhardt will release latches that held it in place in the shuttle for launch. Helms will then lift it from the shuttle bay and maneuver it to the new station airlock. After releasing the latches, Gernhardt will get on the shuttle's robotic arm and Kavandi will fly him up to the station airlock. Meanwhile, Reilly will install foot platforms and guideposts at the station airlock in preparation for installing the tank.

When Helms has moved the tank into position near the airlock, Gernhardt and Reilly, both working in foot platforms on the station's exterior, will take the tank from the arm as Helms releases it. The spacewalkers will then latch it into place on the airlock exterior, clamping it to some of the "towel bars" installed on the first spacewalk and using guideposts installed by Reilly to ensure that the tank is properly aligned. Gernhardt will then connect hoses from the tank to the airlock.

The same tasks will basically be repeated to lift the second tank, a nitrogen tank, from the shuttle's cargo bay and install it onto the station airlock, although some foot platforms will have to be repositioned. Then, while Reilly finishes connections for the second tank, Gernhardt will install insulating covers on several airlock fixtures, including the four pins that helped latch the airlock in place during its time in the shuttle bay and the grapple fixture held by the station's robotic arm to attach the airlock to the station.

Third Spacewalk: The First from the International Space Station Airlock

The third spacewalk will be conducted on Flight Day 9 and is planned to last about 5 1/2 hours. Although it can be conducted successfully from the shuttle airlock if needed, the third spacewalk is planned to begin from the new station airlock, both to serve as a flight test of the new station addition and to make the spacewalk and mission's work as efficient as possible.

Preparations for the third spacewalk also are planned to include a new protocol to purge nitrogen from the body before the start of a spacewalk and thus protect the spacewalkers from decompression sickness. The new protocol, which involves breathing pure oxygen while exercising vigorously, will preclude the need for spacewalkers to spend long hours at reduced cabin pressure immediately before a spacewalk. It will allow the internal hatch between the new airlock and the station to remain open longer before a spacewalk begins yet still reduce the time that spacewalkers must prebreathe pure oxygen in their spacesuits before venting air from the airlock and venturing outside.

The primary objective of the third spacewalk will be to install the final two tanks -- one oxygen and one nitrogen -- on the exterior of the new station airlock. The task will basically mirror the procedures used during the second spacewalk to remove the first two tanks from the shuttle's payload bay and install them on the airlock exterior.

In addition to installing the final two tanks, the spacewalkers will connect a cable to the airlock that will enable communications with Russian spacesuits during future station spacewalks. They also will install several handholds on the airlock exterior and install insulating covers over grapple fixtures on the newly installed air tanks.

EVA Timeline for STS-104
Spacewalks: Installing a Spacewalking Portal

Time	Event
002/17:10	EVA 1 Start
002/17:20	EVA 1 Setup
002/17:50	EVA 1 PCBM Cover Removal
002/17:50	EVA 1 Towel Bar Installation
002/18:30	EVA 1 Launch To Activation (LTA) Jumper Removal
002/18:55	EVA 1 Cleanup/Airlock Ingress
002/20:05	EVA 1 SSRMS Maneuver Airlock to Pre-Install
002/20:55	EVA 1 Airlock Egress to continue EVA
002/21:10	EVA 1 Starboard CBM Inspection
002/22:00	EVA 1 Airlock Attached to Unity
002/22:25	EVA 1 Mate Airlock-Unity Jumper
002/23:15	EVA 1 Cleanup
003/23:55	EVA 1 Ingress
005/17:05	EVA 2 Start
005/17:15	EVA 2 Setup
005/17:30	EVA 2 Oxygen-Nitrogen Tank 1 Installation
005/18:40	EVA 2 Oxygen-Nitrogen Tank 4 Installation
005/20:15	EVA 2 Grapple Fixture & Trunion Cover Installation
005/21:45	EVA 2 Cleanup
005/22:15	EVA 2 Ingress
007/18:40	EVA 3 Start
007/18:55	EVA 3 Setup
007/19:25	EVA 3 Oxygen Tank 2 Installation
007/20:35	EVA 3 Nitrogen Tank 3 Installation
007/22:25	EVA 3 Lab Launch To Activation (LTA) Cable Stow
007/22:40	EVA 3 Grapple Fixture Cover Installation
007/23:10	EVA 3 Cleanup
007/23:40	EVA 3 Ingress

Updated: 06/21/2001

Payloads

Airlock Offers New Gateway to Space

Overview

Atlantis will deliver the Joint Airlock to the International Space Station on the STS-104 mission, giving station crewmembers the ability to conduct spacewalks using either U.S. or Russian suits. The airlock also will vent less precious air into space than the shuttle airlock.

The airlock is a critical space station element because of design differences between American and Russian spacesuits. American suits will not fit through Russian-designed airlocks. During a series of integration tests, the Russian suits were connected to the airlock to assure that they worked together. The airlock is specially designed to accommodate both suits, providing a chamber where astronauts from every nation can suit up for spacewalks to conduct science experiments and perform maintenance outside the station.

Once the airlock is carried into space aboard Atlantis, the astronaut crew, using the station's newly installed robotic arm, will secure it to the starboard side of the Unity node.

The airlock serves two key purposes: to keep air from escaping when the hatch to space is opened and to regulate the air pressure before an astronaut enters or leaves the ISS. It has two compartments: the crew lock, from which astronauts will enter and leave the station; and the equipment lock, where the spacewalkers will change into and out of their suits and stow all necessary gear.

The airlock was designed and built by Boeing at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Ala. Boeing-MSFC manufactured the equipment lock pressure shell, mated the equipment lock with the crew lock, installed all subsystems, and successfully performed airlock qualification testing.

The airlock was shipped to the Kennedy Space Center last September aboard NASA's "Super Guppy" cargo aircraft. There it underwent leak testing and ground processing while multi-layer insulation and debris shields were installed on its exterior.

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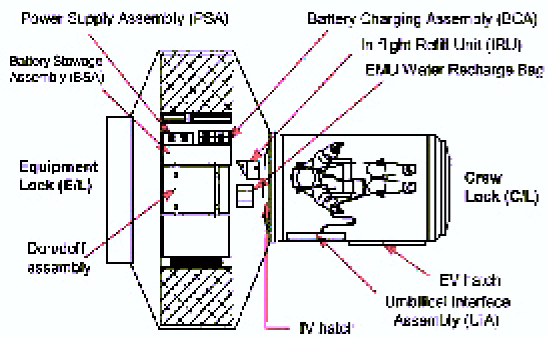


<u>Airlock Specifications</u>

Material: Aluminum

Length: 5.5 meters (18 ft.)

Diameter: 4 meters (13 ft.)

Weight: 6,064 kilograms (13,368 lbs.)

Volume: 34 cubic meters (1,200 cu ft.)

Cost: $164 million, including tanks

Updated: 06/19/2001

Payloads

High-Pressure Gas Tanks

Overview

In addition to the airlock, the High-Pressure Gas Assembly also is being delivered by Atlantis. The assembly includes four high-pressure gas tanks -- two oxygen and two nitrogen. Each tank is just over 3 feet (.9 meter) in diameter. A meteor debris shield and a multi-layer insulation blanket to protect them from the harsh elements of space cover each tank. For the STS-104 flight, the tanks are on an adaptor that is mounted on the double Spacelab pallet in the shuttle cargo bay. The tanks and adapters also were designed and built by Boeing at MSFC.

The Russian Service Module "Zvezda" has been supplying these gases for the ISS. The High-Pressure Gas Assembly will augment the Service Module gas re-supply system.

High-Pressure Gas Assembly Specifications

(Note: There are four High-Pressure Gas Assemblies on board.)

Tank Material: Carbon Fiber Wrap

Tank Diameter: .9 meter (3 ft.) each

Tank Volume: .42 cubic meter (15.1 cubic ft.) each

Weight per unit: 545.4 kilograms (1,200 lbs.) each

Updated: 05/22/2001

New Main Engine Promises Even Safer Shuttle Ride

The next space shuttle crew can expect an even safer ride into orbit, thanks to the completion of a new Space Shuttle Main Engine. Workers installed one of the new engines, called the Block II configuration, on Atlantis April 24 at NASA's Kennedy Space Center, Fla.

Atlantis' first flight using the new engine is targeted for launch no earlier than July 12 on the STS-104 mission to the International Space Station. Atlantis will use one Block II Main Engine and two Block IIA Main Engines to complete its full complement of three engines.

Improvements to the main engines, managed by NASA’s Marshall Space Flight Center in Huntsville, Ala., continue to evolve to produce the safest, most reliable and reusable space transportation system in the world.

The Block II Main Engine configuration includes a new Pratt & Whitney high-pressure fuel turbopump. The primary modification to the engine is elimination of welds by using a casting process for the housing, and an integral shaft/disk with thin-wall blades and ceramic bearings. This makes the pump stronger and should increase the number of flights between major overhauls. Although the new pump adds 300 pounds (135 kilograms) of weight to the shuttle, the results are a more reliable and safer engine because of increased pump robustness.

"With this design change, we believe we have more than doubled the reliability of the engine," said George Hopson, manager of the Space Shuttle Main Engine Project at Marshall.

Previous improvements to the Space Shuttle Main Engine include the Block I configuration, which featured an improved high-pressure liquid oxygen turbopump, two-duct engine power head and single-coil heat exchanger. The turbopump incorporated ball bearings of silicon nitride — a ceramic material 30 percent harder and 40 percent lighter than steel. The Block I engine first flew in 1995.

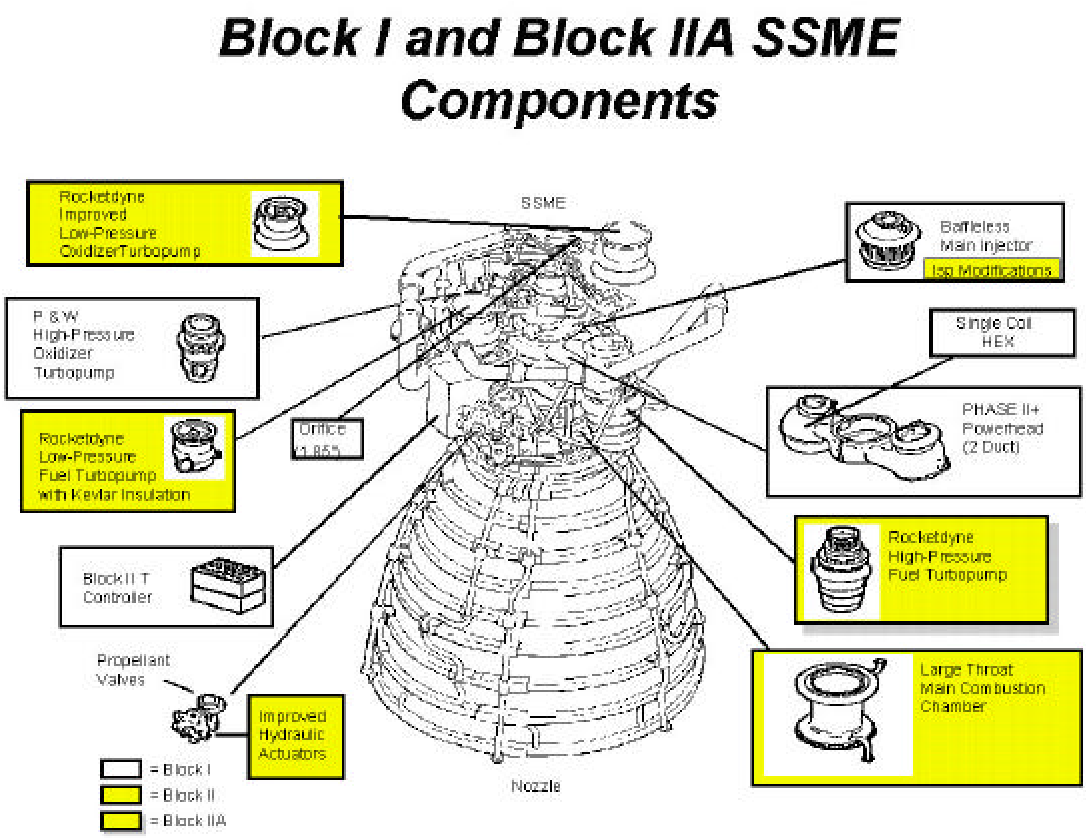
The Block IIA engine added a larger-throat main-combustion chamber to Block I improvements. The new chamber lowered the engine's operating pressures and temperatures while increasing the engine's operational safety margin. This engine first flew in 1998.

Developed in the 1970s by Marshall, the Space Shuttle Main Engine is the world's most sophisticated reusable rocket engine. Each powerful main engine is 14 feet long (4.3 meters), weighs about 7,000 pounds (3,175 kilograms) and is 7.5 feet (2.3 meters) in diameter at the end of the nozzle.

The engines operate for about 8½ minutes during liftoff and ascent and shut down just before the shuttle reaches low-Earth orbit.

The engines perform at greater temperature extremes than any mechanical system in common use today. At -423 degrees Fahrenheit (-250 degrees Celsius), the liquid hydrogen fuel is the second coldest liquid on Earth. When it and the liquid oxygen are combusted, the temperature in the main combustion chamber of the engine is 6,000 degrees Fahrenheit (3,316 degrees Celsius), hotter than the boiling point of iron.

Boeing Rocketdyne in Canoga Park, Calif., manufactures the Space Shuttle Main Engine.



Space Shuttle Main Engine Enhancements

When a space shuttle lifts off, it does so with the help of three reusable, high-performance rocket engines.

The engines operate for about 8½ minutes during liftoff and ascent -- long enough to burn more than 500,000 gallons (1.9 million liters) of super-cold liquid hydrogen and liquid oxygen propellants stored in the huge external tank attached to the underside of the shuttle. Liquid oxygen is stored at –298 degrees Fahrenheit (-183 degrees Celsius) and liquid hydrogen at -423 degrees Fahrenheit (-250 degrees Celsius). The engines shut down just before the shuttle, traveling at about 17,000 mph, reaches orbit.

NASA continues to increase the reliability and safety of shuttle flights through a series of enhancements to the Space Shuttle Main Engines. The engines were modified in 1988, again in 1995, and more improvements were under development in 2000.

The newest modifications include new high-pressure fuel and oxidizer turbopumps, a two-duct powerhead, a single-coil heat exchanger and a large-throat main combustion chamber.

Each engine has two powerful high-pressure turbopumps that supply up to 970 pounds (440 kilograms) of liquid oxygen per second and up to 162 pounds (73 kilograms) of liquid hydrogen fuel per second to the engine's main combustion chamber. In this chamber, the hydrogen propellant and oxygen oxidizer mix and burn at high pressures and at temperatures exceeding 6,000 degrees Fahrenheit (3,316 degrees Celsius) to produce thrust. This year, the first flight is expected of a redesigned hydrogen turbopump. The new design uses a unique casting process to eliminate welds, significantly increasing the number of missions between major overhauls. In July 1995, a redesigned oxygen turbopump first flew on a shuttle.

Considered the backbone of the engine, the powerhead consists of the main injector and two preburners, or small combustion chambers. Liquid oxygen and hydrogen are partially burned in the preburners, generating hot gases. The liquids continue to move through ducts into the main combustion chamber, while the gases created in these chambers drive the high-pressure turbopumps, which give the shuttle thrust. The two-duct hot gas manifold is a new powerhead design that first flew on the shuttle in July 1995. It significantly improves fluid flows in the system by decreasing pressure and turbulence, thus reducing maintenance and enhancing the overall performance of the engine.

The shuttle's engines supply pressure to the external tank, which in turn provides propellants to the engines. This pressure is produced by the engine's heat exchanger, a 40-foot-long (12-meter) piece of coiled stainless steel alloy tubing. Until mid-1995, the heat exchanger had seven welds in the 40-foot (12-meter) tube. The newly designed exchanger is a continuous piece of stainless steel alloy — thicker and with no welds. Beginning with the STS-70 mission in July 1995, a new enhanced single-coil heat exchanger has flown on each shuttle.

A shuttle engine’s main combustion chamber is where the liquid hydrogen and liquid oxygen are mixed and burned to provide thrust. In January 1998, the first large-throat main combustion chamber flew on the STS-89 mission. The throat of the new chamber, made with fewer welds, is about 10 percent larger than the previous design -- improving the engine's reliability by reducing pressure and temperature in the chamber and throughout the engine. This allows the high-pressure pumps to operate at lower turbine temperatures and pressures. It improves chamber cooling and extends the life of the hardware.

Updated: 05/25/2001

DTO/DSO/RMEs

Monitoring Latent Virus Reactivation and Shedding in Astronauts
DSO 493

Overview

The premise of this DSO is that the incidence and duration of latent virus reactivation in saliva and urine will increase during spaceflight. The objective is to determine the frequency of induced reactivation of latent viruses, latent virus shedding, and clinical disease after exposure to the physical, physiological, and psychological stressors associated with spaceflight.

History/Background

Spaceflight-induced alterations in the immune response become increasingly important on long missions, particularly the potential for reactivation and dissemination (shedding) of latent viruses. An example of a latent virus is Herpes Simplex Type 1 (HSV-1), which infects 70 to 80 percent of all adults. Its classic manifestations are cold sores, pharyngitis, and tonsillitis; and it usually is acquired through contact with the saliva, skin, or mucous membranes of an infected individual. However, many recurrences are asymptomatic, resulting in shedding of the virus. Twenty subjects have been studied for Epstein-Barr virus. Three additional viruses will be examined in an expanded subject group.

Updated: 05/22/2001

DTO/DSO/RMEs

Individual Susceptibility to Post-Spaceflight Orthostatic Intolerance DSO 496

Overview

Susceptibility to postflight orthostatic intolerance -- lightheadedness or fainting upon return to Earth -- is highly individual. Some astronauts are little affected, while others have severe symptoms. Women are more often affected than men. The goal of this DSO is to discover the mechanisms responsible for these differences in order to customize countermeasure protocols.

History/Background

It has been well documented that spaceflight significantly alters cardiovascular function. One of the most important changes from a crew safety standpoint is postflight loss of orthostatic tolerance, which causes astronauts to have difficulty walking independently and induces lightheadedness or fainting. These effects may impair their ability to leave the orbiter after it lands.

This DSO will perform a flight-related study, designed to clarify preflight and postflight differences in susceptible and nonsusceptible astronauts. There are no on-orbit activities associated with this DSO.

Updated: 05/22/2001

DTO/DSO/RMEs

Spaceflight and Immune Function
DSO 498

Overview
Astronauts face an increasing risk of contracting infectious diseases as they work and live for longer periods in the crowded conditions and closed environments of spacecraft such as the International Space Station. The effects of spaceflight on the human immune system, which plays a pivotal role in warding off infections, is not fully understood. Understanding the changes in immune functions caused by exposure to microgravity will allow researchers to develop countermeasures to minimize the risk of infection.

History/Background
The objective of this DSO is to characterize the effects of spaceflight on neutrophils, monocytes, and cytotoxic cells, which play an important role in maintaining an effective defense against infectious agents. The premise of this study is that the space environment alters the essential functions of these elements of human immune response.

Researchers will conduct a functional analysis of neutrophils and monocytes from blood samples taken from astronauts before and after the flight. They will also assess the subjects' pre- and postflight production of cytotoxic cells and cytokine.

This study will complement previous and continuing immunology studies of astronauts' adaptation to space.

Updated: 05/22/2001

DTO/DSO/RMEs

Sleep-Wake Actigraphy and Light Exposure During Spaceflight DSO 634

Overview

Disruption of sleep during spaceflight, both short and long duration, is associated with inappropriately timed (non-24 hour) or insufficiently intense light exposure. Sleep disruption and circadian misalignment can lead to subjective dissatisfaction with self-reported sleep quality and daytime alertness. Both of these conditions are associated with insomnia and associated impairment of alertness and cognitive performance, which could impair mission success.

History/Background

This experiment will use state-of-the-art ambulatory technology to monitor sleep-wake activity and light exposure patterns obtained in flight. These data should help researchers better understand the effects of spaceflight on sleep, as well as aid in the development of effective countermeasures for both short- and long-duration spaceflight.

Updated: 05/25/2001

DTO/DSO/RMEs

Spatial Reorientation Following Spaceflight
DSO 635

Overview

Spatial orientation is altered during and after spaceflight by a shift of central vestibular processing (from a gravitational frame-of-reference to an internal, head-centered frame-of-reference) that occurs during adaptation to microgravity and is reversed during the first few days after return to Earth. Discordant sensory stimuli during the postflight re-adaptive period will temporarily disorient/destabilize the subject by triggering a shift (state change) to the previously learned, internally referenced, microgravity-adapted pattern of spatial orientation and sensorimotor control.

History/Background

The purpose of this DSO is to examine both the adaptive changes in the spatial reference frame used for coding spatial orientation and sensorimotor control as well as the fragility of the adaptive process and the feasibility of driving state changes in central vestibular processing via discordant sensory stimuli using balance control tests and eye movement responses to pitch-axis rotation in a short-arm centrifuge. The findings are expected to demonstrate the degree to which challenging motion environments may affect postflight re-adaptation and lead to a better understanding of safe postflight activity regimens. The findings are also expected to demonstrate the feasibility of triggering state changes between sensorimotor control sets using a centrifuge device.

Updated: 05/22/2001

DTO/DSO/RMEs

International Space Station On-Orbit Loads Validation
DTO 261

Overview

This DTO will use the shuttle's aft primary reaction control system jets to measure the structural dynamics (natural frequencies, modal amplitudes, and structural dampening) of the ISS and use the results to validate critical areas of the on-orbit loads prediction models.

Three tests will be conducted to obtain various measurements. Test 1 will obtain photogrammetric measurements of the photovoltaic arrays. Test 2 will obtain photogrammetric measurements of the radiator. Test 3 will obtain acceleration and dynamic strain measurements in Unity, Zarya, Zvezda, and Destiny. The Internal Wireless Instrumentation System (IWIS) kit, which contains remote sensors, accelerometers, cables, and antennas for use on the shuttle or the ISS, will be used as part of Test 3.

History/Background

This is the sixth flight of DTO 261.

Updated: 05/22/2001

DTO/DSO/RMEs

On-Orbit Bicycle Ergometer Loads Measurement
DTO 262

Overview

The purpose of this DTO is to study the possibility of reducing the engineering conservatism by measuring the joined shuttle/International Space Station natural frequencies, using the bicycle ergometer as the natural frequency excitation source. Reduction of conservatism would allow more operational flexibility by reducing preflight load predictions and, thus, operational constraints.

History/Background

This is the second of seven planned flights of DTO 262.

Updated: 05/22/2001

DTO/DSO/RMEs

International Space Station Waste Collector Subsystem Refurbishment
DTO 692

Overview

The Extended Duration Orbiter (EDO) Waste Collection Subsystem was originally designed for EDO flights and used three times on shuttle missions. It is now being provided to the International Space Station and is referred to as the ISS Waste Collector Subsystem (WCS). DTO 692 will test and verify the ISS WCS zero-g specific design changes before permanent installation on the ISS.

History/Background

This is the first of two flights of DTO 692.

Updated: 05/22/2001

DTO/DSO/RMEs

Single-String Global Positioning System
DTO 700-14

Overview

The purpose of the Single-String Global Positioning System (GPS) is to demonstrate the performance and operation of the GPS during orbiter ascent, on orbit, entry, and landing phases using a modified military GPS receiver processor and the existing orbiter GPS antennas. GPS data may be downlinked during all mission phases.

History/Background

The purpose of the Single-String Global Positioning System (GPS) is to demonstrate the performance and operation of the GPS during orbiter ascent, on orbit, entry, and landing phases using a modified military GPS receiver processor and the existing orbiter GPS antennas. GPS data may be downlinked during all mission phases.

Updated: 05/22/2001

DTO/DSO/RMEs

Crosswind Landing Performance
DTO 805

Overview
The purpose of this DTO is to demonstrate the capability to perform a manually controlled landing in the presence of a crosswind. The testing is done in two steps.

1. Prelaunch: Ensure planning will allow selection of a runway with Microwave Scanning Beam Landing System support, which is a set of dual transmitters located beside the runway providing precision navigation vertically, horizontally, and longitudinally with respect to the runway. This precision navigation subsystem helps provide a higher probability of a more precise landing with a crosswind of 10 to 15 knots as late in the flight as possible.

2. Entry: This test requires that the crew perform a manually controlled landing in the presence of a 90-degree crosswind component of 10 to 15 knots steady state.

During a crosswind landing, the drag chute will be deployed after nose gear touchdown when the vehicle is stable and tracking the runway centerline.

History/Background
This DTO has been manifested on 65 previous flights.

Updated: 05/22/2001

DTO/DSO/RMEs

Micro-Wireless Instrumentation System (Micro-WIS)
DTO HTD 1403

Overview

This HTD will demonstrate the operational utility and functionality of Micro-WIS on orbit, initially in the crew cabin of the orbiter and then in the International Space Station. The Micro-WIS sensor/transmitter will provide important real-time temperature measurements. The Micro-WIS sensor/recorder will provide recorded temperature readings for postflight evaluation.

History/Background

This is the fifth flight of HTD 1403.

Updated: 05/22/2001

Shuttle Reference Data

Shuttle Abort History

RSLS Abort History:

(STS-41 D) June 26, 1984

The countdown for the second launch attempt for Discovery's maiden flight ended at T-4 seconds when the orbiter's computers detected a sluggish valve in main engine #3. The main engine was replaced and Discovery was finally launched on August 30, 1984.

(STS-51 F) July 12, 1985

The countdown for Challenger's launch was halted at T-3 seconds when on-board computers detected a problem with a coolant valve on main engine #2. The valve was replaced and Challenger was launched on July 29, 1985.

(STS-55) March 22, 1993

The countdown for Columbia's launch was halted by on-board computers at T-3 seconds following a problem with purge pressure readings in the oxidizer preburner on main engine #2 Columbia's three main engines were replaced on the launch pad, and the flight was rescheduled behind Discovery's launch on STS-56. Columbia finally launched on April 26, 1993.

(STS-51) August 12, 1993

The countdown for Discovery's third launch attempt ended at the T-3 second mark when on-board computers detected the failure of one of four sensors in main engine #2 which monitor the flow of hydrogen fuel to the engine. All of Discovery's main engines were ordered replaced on the launch pad, delaying the Shuttle's fourth launch attempt until September 12, 1993.

(STS-68) August 18, 1994

The countdown for Endeavour's first launch attempt ended 1.9 seconds before liftoff when on-board computers detected higher than acceptable readings in one channel of a sensor monitoring the discharge temperature of the high pressure oxidizer turbopump in main engine #3. A test firing of the engine at the Stennis Space Center in Mississippi on September 2nd confirmed that a slight drift in a fuel flow meter in the engine caused a slight increase in the turbopump's temperature. The test firing also confirmed a slightly slower start for main engine #3 during the pad abort, which could have contributed to the higher temperatures. After Endeavour was brought back to the Vehicle Assembly Building to be outfitted with three replacement engines, NASA managers set October 2nd as the date for Endeavour's second launch attempt.

Abort to Orbit History:

(STS-51 F) July 29, 1985

After an RSLS abort on July 12, 1985, Challenger was launched on July 29, 1985. Five minutes and 45 seconds after launch, a sensor problem resulted in the shutdown of center engine #1, resulting in a safe "abort to orbit" and successful completion of the mission.

Updated: 05/22/2001

Shuttle Reference Data

Shuttle Abort Modes

RSLS ABORTS

These occur when the onboard shuttle computers detect a problem and command a halt in the launch sequence after taking over from the Ground Launch Sequencer and before Solid Rocket Booster ignition.

ASCENT ABORTS

Selection of an ascent abort mode may become necessary if there is a failure that affects vehicle performance, such as the failure of a space shuttle main engine or an orbital maneuvering system. Other failures requiring early termination of a flight, such as a cabin leak, might also require the selection of an abort mode.

There are two basic types of ascent abort modes for space shuttle missions: intact aborts and contingency aborts. Intact aborts are designed to provide a safe return of the orbiter to a planned landing site. Contingency aborts are designed to permit flight crew survival following more severe failures when an intact abort is not possible. A contingency abort would generally result in a ditch operation.

INTACT ABORTS

There are four types of intact aborts: abort to orbit (ATO), abort once around (AOA), transoceanic abort landing (TAL) and return to launch site (RTLS).

Return to Launch Site

The RTLS abort mode is designed to allow the return of the orbiter, crew, and payload to the launch site, Kennedy Space Center, approximately 25 minutes after lift-off.

The RTLS profile is designed to accommodate the loss of thrust from one space shuttle main engine between lift-off and approximately four minutes 20 seconds, at which time not enough main propulsion system propellant remains to return to the launch site.

An RTLS can be considered to consist of three stages--a powered stage, during which the space shuttle main engines are still thrusting; an ET separation phase; and the glide phase, during which the orbiter glides to a landing at the Kennedy Space Center. The powered RTLS phase begins with the crew selection of the RTLS abort, which is done after solid rocket booster separation. The crew selects the abort mode by positioning the abort rotary switch to RTLS and depressing the abort push button. The time at which the RTLS is selected depends on the reason for the abort. For example, a three-engine RTLS is selected at the last moment, approximately three minutes 34 seconds into the mission; whereas an RTLS chosen due to an engine out at lift-off is selected at the earliest time, approximately two minutes 20 seconds into the mission (after solid rocket booster separation).

After RTLS is selected, the vehicle continues downrange to dissipate excess main propulsion system propellant. The goal is to leave only enough main propulsion system propellant to be able to turn the vehicle around, fly back towards the Kennedy Space Center and achieve the proper main engine cutoff conditions so the vehicle can glide to the Kennedy Space Center after external tank separation. During the downrange phase, a pitch-around maneuver is initiated (the time depends in part on the time of a space shuttle main engine failure) to orient the orbiter/external tank configuration to a heads up attitude, pointing toward the launch site. At this time, the vehicle is still moving away from the launch site, but the space shuttle main engines are now thrusting to null the downrange velocity. In addition, excess orbital maneuvering system and reaction control system propellants are dumped by continuous orbital maneuvering system and reaction control system engine thrustings to improve the orbiter weight and center of gravity for the glide phase and landing.

The vehicle will reach the desired main engine cutoff point with less than 2 percent excess propellant remaining in the external tank. At main engine cutoff minus 20 seconds, a pitch-down maneuver (called powered pitch-down) takes the mated vehicle to the required external tank separation attitude and pitch rate. After main engine cutoff has been commanded, the external tank separation sequence begins, including a reaction control system translation that ensures that the orbiter does not recontact the external tank and that the orbiter has achieved the necessary pitch attitude to begin the glide phase of the RTLS.

After the reaction control system translation maneuver has been completed, the glide phase of the RTLS begins. From then on, the RTLS is handled similarly to a normal entry.

Transoceanic Abort Landing

The TAL abort mode was developed to improve the options available when a space shuttle main engine fails after the last RTLS opportunity but before the first time that an AOA can be accomplished with only two space shuttle main engines or when a major orbiter system failure, for example, a large cabin pressure leak or cooling system failure, occurs after the last RTLS opportunity, making it imperative to land as quickly as possible.

In a TAL abort, the vehicle continues on a ballistic trajectory across the Atlantic Ocean to land at a predetermined runway. Landing occurs approximately 45 minutes after launch. The landing site is selected near the nominal ascent ground track of the orbiter in order to make the most efficient use of space shuttle main engine propellant. The landing site also must have the necessary runway length, weather conditions and U.S. State Department approval. Currently, the three landing sites that have been identified for a due east launch are Moron, Spain; Dakar, Senegal; and Ben Guerur, Morocco (on the west coast of Africa).

To select the TAL abort mode, the crew must place the abort rotary switch in the TAL/AOA position and depress the abort push button before main engine cutoff. (Depressing it after main engine cutoff selects the AOA abort mode.) The TAL abort mode begins sending commands to steer the vehicle toward the plane of the landing site. It also rolls the vehicle heads up before main engine cutoff and sends commands to begin an orbital maneuvering system propellant dump (by burning the propellants through the orbital maneuvering system engines and the reaction control system engines). This dump is necessary to increase vehicle performance (by decreasing weight), to place the center of gravity in the proper place for vehicle control, and to decrease the vehicle's landing weight.

TAL is handled like a nominal entry.

Abort to Orbit

An ATO is an abort mode used to boost the orbiter to a safe orbital altitude when performance has been lost and it is impossible to reach the planned orbital altitude. If a space shuttle main engine fails in a region that results in a main engine cutoff under speed, the Mission Control Center will determine that an abort mode is necessary and will inform the crew. The orbital maneuvering system engines would be used to place the orbiter in a circular orbit.

Abort Once Around

The AOA abort mode is used in cases in which vehicle performance has been lost to such an extent that either it is impossible to achieve a viable orbit or not enough orbital maneuvering system propellant is available to accomplish the orbital maneuvering system thrusting maneuver to place the orbiter on orbit and the deorbit thrusting maneuver. In addition, an AOA is used in cases in which a major systems problem (cabin leak, loss of cooling) makes it necessary to land quickly. In the AOA abort mode, one orbital maneuvering system thrusting sequence is made to adjust the post-main engine cutoff orbit so a second orbital maneuvering system thrusting sequence will result in the vehicle deorbiting and landing at the AOA landing site (White Sands, N.M.; Edwards Air Force Base; or the Kennedy Space Center). Thus, an AOA results in the orbiter circling the Earth once and landing approximately 90 minutes after lift-off.

After the deorbit thrusting sequence has been executed, the flight crew flies to a landing at the planned site much as it would for a nominal entry.

CONTINGENCY ABORTS

Contingency aborts are caused by loss of more than one main engine or failures in other systems. Loss of one main engine while another is stuck at a low thrust setting may also necessitate a contingency abort. Such an abort would maintain orbiter integrity for in-flight crew escape if a landing cannot be achieved at a suitable landing field.

Contingency aborts due to system failures other than those involving the main engines would normally result in an intact recovery of vehicle and crew. Loss of more than one main engine may, depending on engine failure times, result in a safe runway landing. However, in most three-engine-out cases during ascent, the orbiter would have to be ditched. The in-flight crew escape system would be used before ditching the orbiter.

ABORT DECISIONS

There is a definite order of preference for the various abort modes. The type of failure and the time of the failure determine which type of abort is selected. In cases where performance loss is the only factor, the preferred modes would be ATO, AOA, TAL and RTLS, in that order. The mode chosen is the highest one that can be completed with the remaining vehicle performance.

In the case of some support system failures, such as cabin leaks or vehicle cooling problems, the preferred mode might be the one that will end the mission most quickly. In these cases, TAL or RTLS might be preferable to AOA or ATO. A contingency abort is never chosen if another abort option exists.

The Mission Control Center-Houston is prime for calling these aborts because it has a more precise knowledge of the orbiter's position than the crew can obtain from onboard systems. Before main engine cutoff, Mission Control makes periodic calls to the crew to tell them which abort mode is (or is not) available. If ground communications are lost, the flight crew has onboard methods, such as cue cards, dedicated displays and display information, to determine the current abort region.

Which abort mode is selected depends on the cause and timing of the failure causing the abort and which mode is safest or improves mission success. If the problem is a space shuttle main engine failure, the flight crew and Mission Control Center select the best option available at the time a space shuttle main engine fails.

If the problem is a system failure that jeopardizes the vehicle, the fastest abort mode that results in the earliest vehicle landing is chosen. RTLS and TAL are the quickest options (35 minutes), whereas an AOA requires approximately 90 minutes. Which of these is selected depends on the time of the failure with three good space shuttle main engines.

The flight crew selects the abort mode by positioning an abort mode switch and depressing an abort push button.

Updated: 05/22/2001

Shuttle Reference Data

Space Shuttle Rendezvous Maneuvers

COMMON SHUTTLE RENDEZVOUS MANEUVERS

OMS-1 (Orbit insertion) - Rarely used ascent abort burn

OMS-2 (Orbit insertion) - Typically used to circularize the initial orbit following ascent, completing orbital insertion. For ground-up rendezvous flights, also considered a rendezvous phasing burn

NC (Rendezvous phasing) - Performed to hit a range relative to the target at a future time

NH (Rendezvous height adjust) - Performed to hit a delta-height relative to the target at a future time

NPC (Rendezvous plane change) - Performed to remove planar errors relative to the target at a future time

NCC (Rendezvous corrective combination) - First on-board targeted burn in the rendezvous sequence. Using star tracker data, it is performed to remove phasing and height errors relative to the target at Ti

Ti (Rendezvous terminal intercept) - Second on-board targeted burn in the rendezvous sequence. Using primarily rendezvous radar data, it places the Orbiter on a trajectory to intercept the target in one orbit

MC-1, MC-2, MC-3, MC-4 (Rendezvous midcourse burns) - These on-board targeted burns use star tracker and rendezvous radar data to correct the post-Ti trajectory in preparation for the final, manual proximity operations phase

Updated: 05/22/2001

Shuttle Reference Data

Space Shuttle Solid Rocket Boosters

The two SRBs provide the main thrust to lift the space shuttle off the pad and up to an altitude of about 150,000 feet, or 24 nautical miles (28 statute miles). In addition, the two SRBs carry the entire weight of the external tank and orbiter and transmit the weight load through their structure to the mobile launcher platform.

Each booster has a thrust (sea level) of approximately 3,300,000 pounds at launch. They are ignited after the three space shuttle main engines' thrust level is verified. The two SRBs provide 71.4 percent of the thrust at lift- off and during first-stage ascent. Seventy- five seconds after SRB separation, SRB apogee occurs at an altitude of approximately 220,000 feet, or 35 nautical miles (40 statute miles). SRB impact occurs in the ocean approximately 122 nautical miles (140 statute miles) downrange.

The SRBs are the largest solid-propellant motors ever flown and the first designed for reuse. Each is 149.16 feet long and 12.17 feet in diameter.

Each SRB weighs approximately 1,300,000 pounds at launch. The propellant for each solid rocket motor weighs approximately 1,100,000 pounds. The inert weight of each SRB is approximately 192,000 pounds.

Primary elements of each booster are the motor (including case, propellant, igniter and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system and range safety destruct system.

Each booster is attached to the external tank at the SRB's aft frame by two lateral sway braces and a diagonal attachment. The forward end of each SRB is attached to the external tank at the forward end of the SRB's forward skirt. On the launch pad, each booster also is attached to the mobile launcher platform at the aft skirt by four bolts and nuts that are severed by small explosives at lift-off.

During the downtime following the Challenger accident, detailed structural analyses were performed on critical structural elements of the SRB. Analyses were primarily focused in areas where anomalies had been noted during postflight inspection of recovered hardware.

One of the areas was the attach ring where the SRBs are connected to the external tank. Areas of distress were noted in some of the fasteners where the ring attaches to the SRB motor case. This situation was attributed to the high loads encountered during water impact. To correct the situation and ensure higher strength margins during ascent, the attach ring was redesigned to encircle the motor case completely (360 degrees). Previously, the attach ring formed a C and encircled the motor case 270 degrees.

Additionally, special structural tests were performed on the aft skirt. During this test program, an anomaly occurred in a critical weld between the hold-down post and skin of the skirt. A redesign was implemented to add reinforcement brackets and fittings in the aft ring of the skirt.

These two modifications added approximately 450 pounds to the weight of each SRB.

The propellant mixture in each SRB motor consists of an ammonium perchlorate (oxidizer, 69.6 percent by weight), aluminum (fuel, 16 percent), iron oxide (a catalyst, 0.4 percent), a polymer (a binder that holds the mixture together, 12.04 percent), and an epoxy curing agent (1.96 percent). The propellant is an 11-point star-shaped perforation in the forward motor segment and a double-truncated-cone perforation in each of the aft segments and aft closure. This configuration provides high thrust at ignition and then reduces the thrust by approximately a third 50 seconds after lift-off to prevent overstressing the vehicle during maximum dynamic pressure.

The SRBs are used as matched pairs and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimize any thrust imbalance. The segmented-casing design assures maximum flexibility in fabrication and ease of transportation and handling. Each segment is shipped to the launch site on a heavy-duty rail car with a specially built cover.

The nozzle expansion ratio of each booster beginning with the STS-8 mission is 7-to-79. The nozzle is gimbaled for thrust vector (direction) control. Each SRB has its own redundant auxiliary power units and hydraulic pumps. The all-axis gimbaling capability is 8 degrees. Each nozzle has a carbon cloth liner that erodes and chars during firing. The nozzle is a convergent-divergent, movable design in which an aft pivot-point flexible bearing is the gimbal mechanism.

The cone- shaped aft skirt reacts the aft loads between the SRB and the mobile launcher platform. The four aft separation motors are mounted on the skirt. The aft section contains avionics, a thrust vector control system that consists of two auxiliary power units and hydraulic pumps, hydraulic systems and a nozzle extension jettison system.

The forward section of each booster contains avionics, a sequencer, forward separation motors, a nose cone separation system, drogue and main parachutes, a recovery beacon, a recovery light, a parachute camera on selected flights and a range safety system.

Each SRB has two integrated electronic assemblies, one forward and one aft. After burnout, the forward assembly initiates the release of the nose cap and frustum and turns on the recovery aids. The aft assembly, mounted in the external tank/SRB attach ring, connects with the forward assembly and the orbiter avionics systems for SRB ignition commands and nozzle thrust vector control. Each integrated electronic assembly has a multiplexer/ demultiplexer, which sends or receives more than one message, signal or unit of information on a single communication channel.

Eight booster separation motors (four in the nose frustum and four in the aft skirt) of each SRB thrust for 1.02 seconds at SRB separation from the external tank. Each solid rocket separation motor is 31.1 inches long and 12.8 inches in diameter.

Location aids are provided for each SRB, frustum/drogue chutes and main parachutes. These include a transmitter, antenna, strobe/converter, battery and salt water switch electronics. The location aids are designed for a minimum operating life of 72 hours and when refurbished are considered usable up to 20 times. The flashing light is an exception. It has an operating life of 280 hours. The battery is used only once.

The SRB nose caps and nozzle extensions are not recovered.

The recovery crew retrieves the SRBs, frustum/drogue chutes, and main parachutes. The nozzles are plugged, the solid rocket motors are dewatered, and the SRBs are towed back to the launch site. Each booster is removed from the water, and its components are disassembled and washed with fresh and deionized water to limit salt water corrosion. The motor segments, igniter and nozzle are shipped back to Thiokol for refurbishment.

Each SRB incorporates a range safety system that includes a battery power source, receiver/ decoder, antennas and ordnance.

HOLD-DOWN POSTS

Each solid rocket booster has four hold-down posts that fit into corresponding support posts on the mobile launcher platform. Hold-down bolts hold the SRB and launcher platform posts together. Each bolt has a nut at each end, but only the top nut is frangible. The top nut contains two NASA standard detonators, which are ignited at solid rocket motor ignition commands.

When the two NSDs are ignited at each hold-down, the hold-down bolt travels downward because of the release of tension in the bolt (pretensioned before launch), NSD gas pressure and gravity. The bolt is stopped by the stud deceleration stand, which contains sand. The SRB bolt is 28 inches long and is 3.5 inches in diameter. The frangible nut is captured in a blast container.

The solid rocket motor ignition commands are issued by the orbiter''s computers through the master events controllers to the hold-down pyrotechnic initiator controllers on the mobile launcher platform. They provide the ignition to the hold-down NSDs. The launch processing system monitors the SRB hold-down PICs for low voltage during the last 16 seconds before launch. PIC low voltage will initiate a launch hold.

SRB IGNITION

SRB ignition can occur only when a manual lock pin from each SRB safe and arm device has been removed. The ground crew removes the pin during prelaunch activities. At T minus five minutes, the SRB safe and arm device is rotated to the arm position. The solid rocket motor ignition commands are issued when the three SSMEs are at or above 90-percent rated thrust, no SSME fail and/or SRB ignition PIC low voltage is indicated and there are no holds from the LPS.

The solid rocket motor ignition commands are sent by the orbiter computers through the MECs to the safe and arm device NSDs in each SRB. A PIC single-channel capacitor discharge device controls the firing of each pyrotechnic device. Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals--arm, fire 1 and fire 2--originate in the orbiter general-purpose computers and are transmitted to the MECs. The MECs reformat them to 28-volt dc signals for the PICs. The arm signal charges the PIC capacitor to 40 volts dc (minimum of 20 volts dc).

The fire 2 commands cause the redundant NSDs to fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe and arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator; and combustion products of this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The GPC launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the SSMEs. The MPS start commands are issued by the onboard computers at T minus 6.6 seconds (staggered start--engine three, engine two, engine one--all approximately within 0.25 of a second), and the sequence monitors the thrust buildup of each engine. All three SSMEs must reach the required 90-percent thrust within three seconds; otherwise, an orderly shutdown is commanded and safing functions are initiated.

Normal thrust buildup to the required 90-percent thrust level will result in the SSMEs being commanded to the lift-off position at T minus three seconds as well as the fire 1 command being issued to arm the SRBs. At T minus three seconds, the vehicle base bending load modes are allowed to initialize (movement of approximately 25.5 inches measured at the tip of the external tank, with movement towards the external tank).

At T minus zero, the two SRBs are ignited, under command of the four onboard computers; separation of the four explosive bolts on each SRB is initiated (each bolt is 28 inches long and 3.5 inches in diameter); the two T-0 umbilicals (one on each side of the spacecraft) are retracted; the onboard master timing unit, event timer and mission event timers are started; the three SSMEs are at 100 percent; and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure region.

ELECTRICAL POWER DISTRIBUTION

Electrical power distribution in each SRB consists of orbiter-supplied main dc bus power to each SRB via SRB buses A, B and C. Orbiter main dc buses A, B and C supply main dc bus power to corresponding SRB buses A, B and C. In addition, orbiter main dc bus C supplies backup power to SRB buses A and B, and orbiter bus B supplies backup power to SRB bus C. This electrical power distribution arrangement allows all SRB buses to remain powered in the event one orbiter main bus fails.

The nominal dc voltage is 28 volts dc, with an upper limit of 32 volts dc and a lower limit of 24 volts dc.

HYDRAULIC POWER UNITS

There are two self-contained, independent HPUs on each SRB. Each HPU consists of an auxiliary power unit, fuel supply module, hydraulic pump, hydraulic reservoir and hydraulic fluid manifold assembly. The APUs are fueled by hydrazine and generate mechanical shaft power to a hydraulic pump that produces hydraulic pressure for the SRB hydraulic system. The two separate HPUs and two hydraulic systems are located on the aft end of each SRB between the SRB nozzle and aft skirt. The HPU components are mounted on the aft skirt between the rock and tilt actuators. The two systems operate from T minus 28 seconds until SRB separation from the orbiter and external tank. The two independent hydraulic systems are connected to the rock and tilt servoactuators.

The APU controller electronics are located in the SRB aft integrated electronic assemblies on the aft external tank attach rings.

The APUs and their fuel systems are isolated from each other. Each fuel supply module (tank) contains 22 pounds of hydrazine. The fuel tank is pressurized with gaseous nitrogen at 400 psi, which provides the force to expel (positive expulsion) the fuel from the tank to the fuel distribution line, maintaining a positive fuel supply to the APU throughout its operation.

The fuel isolation valve is opened at APU startup to allow fuel to flow to the APU fuel pump and control valves and then to the gas generator. The gas generator's catalytic action decomposes the fuel and creates a hot gas. It feeds the hot gas exhaust product to the APU two-stage gas turbine. Fuel flows primarily through the startup bypass line until the APU speed is such that the fuel pump outlet pressure is greater than the bypass line's. Then all the fuel is supplied to the fuel pump.

The APU turbine assembly provides mechanical power to the APU gearbox. The gearbox drives the APU fuel pump, hydraulic pump and lube oil pump. The APU lube oil pump lubricates the gearbox. The turbine exhaust of each APU flows over the exterior of the gas generator, cooling it, and is then directed overboard through an exhaust duct.

When the APU speed reaches 100 percent, the APU primary control valve closes, and the APU speed is controlled by the APU controller electronics. If the primary control valve logic fails to the open state, the secondary control valve assumes control of the APU at 112-percent speed.

Each HPU on an SRB is connected to both servoactuators on that SRB. One HPU serves as the primary hydraulic source for the servoactuator, and the other HPU serves as the secondary hydraulics for the servoactuator. Each sevoactuator has a switching valve that allows the secondary hydraulics to power the actuator if the primary hydraulic pressure drops below 2,050 psi. A switch contact on the switching valve will close when the valve is in the secondary position. When the valve is closed, a signal is sent to the APU controller that inhibits the 100-percent APU speed control logic and enables the 112-percent APU speed control logic. The 100-percent APU speed enables one APU/HPU to supply sufficient operating hydraulic pressure to both servoactuators of that SRB.

The APU 100-percent speed corresponds to 72,000 rpm, 110-percent to 79,200 rpm, and 112-percent to 80,640 rpm.

The hydraulic pump speed is 3,600 rpm and supplies hydraulic pressure of 3,050, plus or minus 50, psi. A high-pressure relief valve provides overpressure protection to the hydraulic system and relieves at 3,750 psi.

The APUs/HPUs and hydraulic systems are reusable for 20 missions.

THRUST VECTOR CONTROL

Each SRB has two hydraulic gimbal servoactuators: one for rock and one for tilt. The servoactuators provide the force and control to gimbal the nozzle for thrust vector control.

The space shuttle ascent thrust vector control portion of the flight control system directs the thrust of the three shuttle main engines and the two SRB nozzles to control shuttle attitude and trajectory during lift-off and ascent. Commands from the guidance system are transmitted to the ATVC drivers, which transmit signals proportional to the commands to each servoactuator of the main engines and SRBs. Four independent flight control system channels and four ATVC channels control six main engine and four SRB ATVC drivers, with each driver controlling one hydraulic port on each main and SRB servoactuator.

Each SRB servoactuator consists of four independent, two-stage servovalves that receive signals from the drivers. Each servovalve controls one power spool in each actuator, which positions an actuator ram and the nozzle to control the direction of thrust.

The four servovalves in each actuator provide a force-summed majority voting arrangement to position the power spool. With four identical commands to the four servovalves, the actuator force-sum action prevents a single erroneous command from affecting power ram motion. If the erroneous command persists for more than a predetermined time, differential pressure sensing activates a selector valve to isolate and remove the defective servovalve hydraulic pressure, permitting the remaining channels and servovalves to control the actuator ram spool.

Failure monitors are provided for each channel to indicate which channel has been bypassed. An isolation valve on each channel provides the capability of resetting a failed or bypassed channel.

Each actuator ram is equipped with transducers for position feedback to the thrust vector control system. Within each servoactuator ram is a splashdown load relief assembly to cushion the nozzle at water splashdown and prevent damage to the nozzle flexible bearing.

SRB RATE GYRO ASSEMBLIES

Each SRB contains two RGAs, with each RGA containing one pitch and one yaw gyro. These provide an output proportional to angular rates about the pitch and yaw axes to the orbiter computers and guidance, navigation and control system during first-stage ascent flight in conjunction with the orbiter roll rate gyros until SRB separation. At SRB separation, a switchover is made from the SRB RGAs to the orbiter RGAs.

The SRB RGA rates pass through the orbiter flight aft multiplexers/ demultiplexers to the orbiter GPCs. The RGA rates are then mid-value- selected in redundancy management to provide SRB pitch and yaw rates to the user software. The RGAs are designed for 20 missions.

SRB SEPARATION

SRB separation is initiated when the three solid rocket motor chamber pressure transducers are processed in the redundancy management middle value select and the head-end chamber pressure of both SRBs is less than or equal to 50 psi. A backup cue is the time elapsed from booster ignition.

The separation sequence is initiated, commanding the thrust vector control actuators to the null position and putting the main propulsion system into a second-stage configuration (0.8 second from sequence initialization), which ensures the thrust of each SRB is less than 100,000 pounds. Orbiter yaw attitude is held for four seconds, and SRB thrust drops to less than 60,000 pounds.

The SRBs separate from the external tank within 30 milliseconds of the ordnance firing command.

The forward attachment point consists of a ball (SRB) and socket (ET) held together by one bolt. The bolt contains one NSD pressure cartridge at each end. The forward attachment point also carries the range safety system cross-strap wiring connecting each SRB RSS and the ET RSS with each other.

The aft attachment points consist of three separate struts: upper, diagonal and lower. Each strut contains one bolt with an NSD pressure cartridge at each end. The upper strut also carries the umbilical interface between its SRB and the external tank and on to the orbiter.

There are four booster separation motors on each end of each SRB. The BSMs separate the SRBs from the external tank. The solid rocket motors in each cluster of four are ignited by firing redundant NSD pressure cartridges into redundant confined detonating fuse manifolds.

The separation commands issued from the orbiter by the SRB separation sequence initiate the redundant NSD pressure cartridge in each bolt and ignite the BSMs to effect a clean separation.

Updated: 05/22/2001

Shuttle Reference Data

Space Shuttle Super Light Weight Tank (SLWT)

The super lightweight external tank (SLWT) made its first shuttle flight June 2, 1998, on mission STS-91. The SLWT is 7,500 pounds lighter than the standard external tank. The lighter weight tank will allow the shuttle to deliver International Space Station elements (such as the service module) into the proper orbit.

The SLWT is the same size as the previous design. But the liquid hydrogen tank and the liquid oxygen tank are made of aluminum lithium, a lighter, stronger material than the metal alloy used for the shuttle's current tank. The tank's structural design has also been improved, making it 30% stronger and 5% less dense.

The SLWT, like the standard tank, is manufactured at Michoud Assembly, near New Orleans, Louisiana, by Lockheed Martin.

The 154-foot-long external tank is the largest single component of the space shuttle. It stands taller than a 15-story building and has a diameter of about 27 feet. The external tank holds over 530,000 gallons of liquid hydrogen and liquid oxygen in two separate tanks. The hydrogen (fuel) and liquid oxygen (oxidizer) are used as propellants for the shuttle's three main engines.

Updated: 05/22/2001

APPENDIX A ACRONYMS AND ABBREVIATIONS

A/L	Airlock (ISS Joint Airlock)
AAP	Airlock Adapter Plate
ABC	Audio Bus Coupler
ACBM	Active Common Berthing Mechanism
ACS	Assembly Contingency System
	Atmosphere Control System
ACU	Arm Computer Unit
AL	Airlock (ISS Joint Airlock)
AOH	Assembly Operations Handbook
APAS	Androgynous Peripheral Attachment System
APCU	Assembly Power Converter Unit
APFR	Articulating Portable Foot Restraint
APS	Automated Payload Switch
ARIS	Active Rack Isolation System
ARS	Atmospheric Revitalization System
ASCR	Assured Safe Crew Return
ATCS	Active Thermal Control System
ATU	Audio Terminal Unit
AUAI	Assembly Contingency System UHF Audio Interface
AUX	Auxiliary
AVU	Artificial Vision Unit
BC	Bus Controller
BCA	Battery Charger Assembly
BCU	Backup Drive Control Unit
BSA	Battery Storage Assembly
BSP	Baseband Signal Processor
C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communications and Tracking
C&W	Caution and Warning
C/L	Crew Lock
CB	Control Bus
CBM	Common Berthing Mechanism
CCAA	Common Cabin Air Assembly
CCC	Containment Control Cartridge
CCD	Cursor Control Device
CCH	Crew Communication Headset
CCSDS	Consultative Committee on Space Data Systems
CCTV	Closed Circuit Television
CDDT	Common Display Development Team
CETA	Crew Equipment Translation Aid
CEU	Control Electronics Unit

CheCS	Crew Health Care System
Comm	Communications
CPA	Control Panel Assembly
CPC	Control Post Computer
CSA-H	Compound Specific Analyzer-Hydrazine
CTV	Crew Transfer Vehicle
CVIU	Common Video Interface Unit
CVT	Current Value Table
CWC	Contingency Water Container
CWR	Collapsible Water Reservoir (aka EMU water recharge bag)
CWU	Crew Wireless Unit
DAIU	Docked Audio Interface Unit
DAP	Digital Autopilot
DCM	Display and Control Module
DCSU	Direct Current Switching Unit
DDCU	Direct Current-to-Direct Current Converter Unit
DMCU	Docking Mechanism Control Unit
DPA	Data Processing Assembly
DSCU	Docking System Control Unit
DTO	Detailed Test Objective
E/L	Equipment Lock
EACP	EMU audio control panel
EAIU	EMU Audio Interface Unit
ECLSS	Environmental Control and Life Support System
ECS	Early Communications Subsystem
EDDA	EMU Don/Doff Assembly
EDP	Electronic Data Processing
EEATCS	Early External Active Thermal Control System
EEL	Emergency Egress Lighting
EMU	Extravehicular Maneuvering Unit
EPS	Electrical Power system
ESA	European Space Agency
ETSD	EVA Tools Stowage Device
EUE	Experiment Unique Equipment
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
FD	Flight Day
FDS	Fire Detection and Suppression
FGB	Functional Cargo Block
FRGF	Flight Releasable Grapple Fixture
GFCI	Ground Fault Interruption Circuit
GFE	Government Furnished Equipment
GFI	Ground Fault Interruption

GLA	General Luminaire Assembly
GLONASS	Global Navigational Satellite System
GNC	Guidance and Navigation Computer
GPS	Global Positioning System
GUI	Graphical User Interface
HCU	Headset Control Unit
HDR	High Data Rate
HEPA	High-Efficiency Particulate Arrestor (a filter for the CCAA)
HGA	High Gain Antenna
HPGT	High Pressure Gas Tank (see ONTO)
I/O	Input/Output
IAA	Intravehicular Antenna Assembly
IAS	Internal Audio System
ICBC3D	IMAX Cargo Bay Camera 3-Dimensional
IMV	Intermodule Ventilation
IOCU	Input/Output Controller Unit
IP	International Partner
IRU	In-flight Refill Unit
ISA	International Sampling Adapter
ISPR	International Standard Payload Rack
ISS	International Space Station
ISSP	International Space Station Program
ISSSH	International Space Station Systems Handbook
ITCS	Internal Thermal Control System
IVA	Intervehicular Activity
JEU	Joint Electronics Unit
JSC	Johnson Space Center
LAN	Local Area Networl
LB	Local Bus
LDR	Low Data Rate
LGA	Low Gain Antenna
LTA	Launch to Activation
LEE	Latching End Effector (both SRMS and SSRMS)
Mb	Megabytes
MBM	Manual Berthing Mechanism
MCS	Motion Control System
MDM	Multiplexer/Demultiplexer
MDP	Maximum Design Pressure
METOX	Metal Oxide (for CO2 removal)
MIP	Mission Integration Plan
MLE	Middeck Locker Equipment
MLI	Multilayer Insulation

MM/OD	Micrometeoroid/Orbital Debris
MOD	Mission Operations Directorate
MPEV	Manual Pressure Equalization Valve
MSD	Mass Storage Device
MSFC	Marshall Space Flight Center
MSS	Mobile Servicing System
MT	Mobile Transporter
N_2	Nitrogen (DI-molecular)
NPRV	Negative Pressure Relief Valve
O_2	Oxygen (DI-molecular)
OCA	Orbital Communication Adapter
OCAD	Operational Control Agreement Document
OCJM	Operator Commanded Joint Position Mode
OCPM	Operator Commanded POR Mode
ODS	Orbiter Docking System
OIU	Orbiter Interface Unit
ONTO	Oxygen Nitrogen Tank ORU (see HPGT)
OPS	Operations (Operational)
ORCA	Oxygen Recharge Compressor Assembly
ORU	Orbital Replacement Unit
OSVS	Orbiter Space Vision System
OSVU	Orbiter Space Vision Unit
PBA	Portable Breathing Apparatus (mask)
PCA	Pressure Control Assembly
PCBM	Passive Common Berthing Mechanism
PCR	Portable Computer Receptacles
PCS	Portable Computer System
PDGF	Power and Data Grapple Fixture
PEHG	Payload Ethernet Hub Gateway
PEP	Portable Emergency Provision
PEV	Pressure Equalization Valve
PG	Product Group
PL	Payload
PMA	Pressurized Mating Adapter
PPAM	Pre-stored POR Auto-sequence Mode
PPP	Power Patch Panel
PPRV	Positive Pressure Relief Valve
PRLA	Payload Retention Latch Assembly
PSA	Power Supply Assembly
psia	pounds per square inch – absolute
Psid	pounds per square inch – differential
PTT	Push To Talk
PTU	Pan/Tilt Units

QD	Quick Disconnect
RAIU	Russian Audio Interface Unit
RAM	Random Access Memory
RF	Radio Frequency
RFG	Radio Frequency Group
RHC	Rotational Hand Controller
ROEU	Remote Operated Electrical Umbilical
ROS	Russian Orbital Segment
RPCM	Remote Power Controller Module
RSC-E	Rocket Space Corporation - Energia
RWS	Robotic Workstation
RS	Russian Segment
RSA	Russian Space Agency
RT	Remote Terminal
SASA	S-Band Antenna Support Assembly
SCU	Servicing and Cooling Umbilical
	Sync and Control Unit
SLDP	Spacelab Logistics Double Pallet
SPCE	Servicing and Performance Checkout Equipment
SPDA	Secondary Power Distribution Assembly
SPDM	Special Purpose Dextrous Manipulator
SPDU	Secondary Power Distribution Unit
SRMS	Shuttle Remote Manipulator System
SSC	Station Support Computer
	Subsystem Computer
SSP	Space Shuttle Program
	Standard Switch Panel
SSRMS	Space Station Remote Manipulator System
SSSR	Space to Space Station Radio
STS	Space Transportation System
SW	Software
TCS	Thermal Conditioning System
	Thermal Control System
TDRSS	Tracking and Data Relay Satellite System
THC	Temperature and Humidity Control
	Translational Hand controller
UB	User Bus
UIA	Umbilical Interface Assembly
UHF	Ultrahigh Frequency
UOP	Utility Outlet Panel
USOS	United States Orbital Segment

VAJ	Vacuum Access Jumper
Vdc	Volts (direct current)
VDU	Video Distribution Unit
VOX	Voice Operated Transmission
VSU	Video Switch Unit
VTR	Video Tape Recorder
WAA	Wireless Antenna Assembly
WHS	Workstation Host Software
WIU	Wireless Interface Unit
WRM	Water Recovery and Management

Media Assistance

NASA Television Transmission

NASA Television is available through the GE2 satellite system which is located on Transponder 9C, at 85 degrees west longitude, frequency 3880.0 MHz, audio 6.8 MHz.

The schedule for television transmissions from the orbiter and for mission briefings will be available during the mission at Kennedy Space Center, FL; Marshall Space Flight Center, Huntsville, AL; Dryden Flight Research Center, Edwards, CA; Johnson Space Center, Houston, TX; and NASA Headquarters, Washington, DC. The television schedule will be updated to reflect changes dictated by mission operations.

Status Reports

Status reports on countdown and mission progress, on-orbit activities and landing operations will be produced by the appropriate NASA newscenter

Briefings

A mission press briefing schedule will be issued before launch. During the mission, status briefings by a flight director or mission operations representative and when appropriate, representatives from the payload team, will occur at least once each day. The updated NASA television schedule will indicate when mission briefings are planned.

Internet Information

Information is available through several sources on the Internet. The primary source for mission information is the NASA Human Space Flight Web, part of the World Wide Web. This site contains information on the crew and its mission and will be updated regularly with status reports, photos and video clips throughout the flight. The NASA Shuttle Web's address is:

http://spaceflight.nasa.gov

General information on NASA and its programs is available through the NASA Home Page and the NASA Public Affairs Home Page:

http://www.nasa.gov

or

http://www.nasa.gov/newsinfo/index.html

Shuttle Pre-Launch Status Reports

http://www-pao.ksc.nasa.gov/kscpao/status/stsstat/current.htm

Information on other current NASA activities is available through the Today@NASA page:

http://www.nasa.gov/today/index.html

The NASA TV schedule is available from the NTV Home Page:

http://spaceflight.nasa.gov/realdata/nasatv/schedule.html

Resources for educators can be found at the following address:

http://education.nasa.gov

Access by Compuserve

Users with Compuserve accounts can access NASA press releases by typing "GO NASA" (no quotes) and making a selection from the categories offered.

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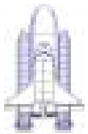
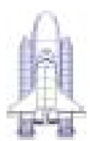
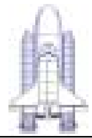
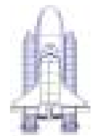
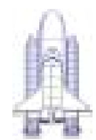
SHUTTLE FLIGHTS AS JULY 2001

104 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 79 SINCE RETURN TO FLIGHT

OV-102 **Columbia** **(26 flights)**	**OV-099** **Challenger** **(10 flights)**	**OV-103** **Discovery** **(29 flights)**	**OV-104** **Atlantis** **(23 flights)**	**OV-105** **Endeavour** **(16 flights)**
		STS-102 03/08/01 – 03/21/01		
		STS-92 10/11/00 - 10/24/00		
		STS-103 12/19/99 - 12/27/99		
STS-93 07/23/99 - 07/27/99		STS-96 05/27/99 - 06/06/99		
STS-90 04/17/98 - 05/03/98		STS-95 10/29/98 - 11/07/98		
STS-87 11/19/97 - 12/05/97		STS-91 06/02/09 - 06/12/98		
STS-94 07/01/97 - 07/17/97		STS-85 08/07/97 - 08/19/97	STS-98 02/07/01 - 02/20/01	
STS-83 04/04/97 - 04/08/97		STS-82 02/11//97 - 02/21/97	STS-106 09/08/00 - 09/20/00	
STS-80 11/19/96 - 12/07/96		STS-70 07/13/95 - 07/22/95	STS-101 05/19/00 - 05/29/00	
STS-78 06/20/96 - 07/07/96		STS-63 02/03/95 - 02/11/95	STS-86 09/25/97 - 10/06/97	
STS-75 02/22/96 - 03/09/96		STS-64 09/09/94 - 09/20/94	STS-84 05/15/97 - 05/24/97	
STS-73 10/20/95 - 11/05/95		STS-60 02/03/94 - 02/11/94	STS-81 01/12/97 - 01/22/97	
STS-65 07/08/94 - 07/23/94		STS-51 09/12/93 - 09/22/93	STS-79 09/16/96 - 09/26/96	
STS-62 03/04/94 - 03/18/94		STS-56 04/08/83 - 04/17/93	STS-76 03/22/96 - 03/31/96	STS-100 04/19/01 – 05/01/01
STS-58 10/18/93 - 11/01/93		STS-53 12/02/92 - 12/09/92	STS-74 11/12/95 - 11/20/95	STS-97 11/30/00 - 12/11/00
STS-55 04/26/93 - 05/06/93		STS-42 01/22/92 - 01/30/92	STS-71 06/27/95 - 07/07/95	STS-99 02/11/00 - 02/22/00
STS-52 10/22/92 - 11/01/92		STS-48 09/12/91 - 09/18/91	STS-66 11/03/94 - 11/14/94	STS-88 12/04/98 - 12/15/98
STS-50 06/25/92 - 07/09/92		STS-39 04/28/91 - 05/06/91	STS-46 07/31/92 - 08/08/92	STS-89 01/22/98 - 01/31/98
STS-40 06/05/91 - 06/14/91		STS-41 10/06/90 - 10/10/90	STS-45 03/24/92 - 04/02/92	STS-77 05/19/96 - 05/29/96
STS-35 12/02/90 - 12/10/90	STS-51L 01/28/86	STS-31 04/24/90 - 04/29/90	STS-44 11/24/91 - 12/01/91	STS-72 01/11/96 - 11/20/96
STS-32 01/09/90 - 01/20/90	STS-61A 10/30/85 - 11/06/85	STS-33 11/22/89 - 11/27/89	STS-43 08/02/91 - 08/11/91	STS-69 09/07/95 - 09/18/95
STS-28 08/08/89 - 08/13/89	STS-51F 07/29/85 - 08/06/85	STS-29 03/13/89 - 03/18/89	STS-37 04/05/91 - 04/11/91	STS-67 03/02/95 - 03/18/95
STS-61C 01/12/86 - 01/18/86	STS-51B 04/29/85 - 05/06/85	STS-26 09/29/88 - 10/03/88	STS-38 11/15/90 - 11/20/90	STS-68 09/30/94 - 10/11/94
STS-9 11/28/83 - 12/08/83	STS-41G 10/05/84 - 10/13/84	STS-51-I 08/27/85 - 09/03/85	STS-36 02/28/90 - 03/04/90	STS-59 04/09/94 – 04/20/94
STS-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	STS-51G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89	STS-61 12/02/93 - 12/13/93
STS-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89	STS-57 06/21/93 - 07/01/93
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88	STS-54 01/13/93 - 01/19/93
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51A 11/08/84 - 11/16/84	STS-61B 11/26/85 - 12/03/85	STS-47 09/12/92 - 09/20/92
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	STS-41D 08/30/84 - 09/05/84	STS-51J 10/03/85 - 10/07/85	STS-49 05/07/92 - 05/16/92

Table prepared by Richard W. Orloff, 06/02/2002