Science Moves to the Forefront

WWW.SHUTTLEPRESSKIT.COM

BOEING

NASA

USA
United Space Alliance

Updated July 24, 2001

Table of Contents

Mission Overview

New Crew, New Lab Racks to be Launched to ISS

Rotation of the International Space Station crew, the third flight of an Italian-built Multipurpose Logistics Module delivering additional scientific racks, equipment and supplies for the space station, and two spacewalks highlight the STS-105 mission of Discovery, scheduled for launch from Kennedy Space Center in Florida.

The crew changeout is the second for the ISS, and the logistical module, named Leonardo, is making its second flight to the space station. An identical module named Raffaello has flown once.

The STS-105 mission will involve three crews. They are the four-member crew of Discovery, the three members of the Expedition Three crew to be launched to the space station, and the three members of the Expedition Two crew returning to Earth aboard the shuttle.

Commanding the Discovery crew will be Scott Horowitz, an Air Force colonel with a Ph.D. in aerospace engineering, making his fourth flight into space. Pilot will be Frederick W. "Rick" Sturckow, a Marine major, former test pilot and veteran of a previous flight to the space station. Patrick G. Forrester, an Army lieutenant colonel and former test pilot, is making his first flight to space as mission specialist 1. Daniel T. Barry, who holds a doctorate in electrical engineering/computer science and an M.D. degree, is mission specialist 2. This is his third mission to space.

The Expedition Three crew of the space station launching aboard Discovery is made up of an astronaut and two cosmonauts. Its commander is Frank Culbertson, 52, a retired Navy captain and former test pilot making his third flight into space. Cosmonaut Vladimir Dezhurov, 39, a Russian Air Force lieutenant colonel who served as commander of a 115-day mission aboard Mir in 1995, will be Soyuz pilot. Cosmonaut Mikhail Tyurin, 41, from RSC Energia and on his first space mission, will serve as a researcher and flight engineer.

The Expedition Two crew returning to Earth aboard Discovery is cosmonaut Yury Usachev, its commander, and astronauts Jim Voss and Susan Helms. They were taken to the station aboard Discovery on a flight that launched March 8. Expedition Two began the major scientific investigations aboard Destiny that are the purpose of the orbiting laboratory, and paved the way for more to come.

About 46 hours after its launch Discovery is scheduled to dock with the International Space Station. The shuttle will spend almost eight days attached to the ISS. Transfer of equipment from the orbiter's middeck begins less than three hours after docking, which occurs during the crew's flight day three.

Leonardo will be lifted out of Discovery's payload bay on flight day four and attached directly to the station's Unity node for the unloading of its cargo. Once Leonardo is attached to Unity, half a dozen power, data and fluid connecters will be hooked up. The following day the ISS crew will begin transferring equipment and supplies to the station.

The pressurized moving van first flew on Discovery on the STS-102 mission to the space station in March 2001. Among items in Leonardo will be two EXPRESS Racks to be installed in the station's U.S. laboratory Destiny. EXPRESS stands for Expedite the Processing of Experiments to the Space Station. The racks will house a variety of scientific experiments, which can be changed out in space.

Destiny is the scientific focus of the ISS, and the most advanced and most versatile scientific research facility ever launched into orbit. The space station eventually will have six laboratories. Destiny, installed on the STS-98 mission of Atlantis in February 2001, has slots for 24 of the interchangeable racks (six on the top, six on the bottom and six on each side). Eleven are systems racks, and one slot has Destiny's 20-inch-diameter, optical-quality window. Remaining slots are for scientific racks.

Two spacewalks are planned while Discovery is docked to the International Space Station to deliver and install equipment and make repairs. The first spacewalk, to last about 6½ hours on flight day seven, will see Barry and Forrester install the Early Ammonia Servicer to the space station's P6 truss and the Materials ISS Experiment (MISSE) on handrails of the ISS airlock. The Early Ammonia Servicer and MISSE will be taken into space in two Passive Experiment Carriers on the Integrated Cargo Carrier in Discovery's cargo bay.

During the second spacewalk, to last about 5½ hours on Flight Day Nine, Barry and Forrester will install handrails and lay cables to provide temporary power to the S0 truss, to be launched on a future mission.

Space station crew transfer is a carefully thought out process. As a member of the Expedition Three crew transfers from the shuttle to the ISS, that crewmember's custom-designed seat liner, called an Individual Equipment Liner Kit, is installed in the Soyuz spacecraft docked to the station. The seat liner of the replaced crewmember is removed from the Soyuz, and that individual then becomes a member of the shuttle crew.

All three Expedition Three crewmembers complete the liner changeout with members of the Expedition Two crew on Discovery's Flight Day Four, though the formal beginning of Expedition Three occurs at final closing of the hatches between Discovery and the space station.

Equipment and supply transfer operations are scheduled during flight days five through eight.

The crew will leave Leonardo and deactivate the MPLM on flight day nine. Loaded with unneeded equipment and refuse from the ISS, it will be returned to Discovery's cargo bay to be taken back to Kennedy Space Center.

Discovery also will carry a number of small scientific payloads. Among them is Simplesat, a satellite which uses inexpensive commercial hardware to demonstrate Global Positioning System attitude control and payload-assisted fine pointing while free flying in low Earth orbit. It will be deployed from a Hitchhiker canister on Discovery.

Discovery departs the space station on the crew's Flight Day 11.

STS-105 is the 11th shuttle flight to the International Space Station. It is the fifth shuttle mission of the year and the 106th shuttle flight. The 11-day flight will end with Discovery's landing on the 3-mile runway at Kennedy Space Center.

Here is a day-by-day summary of the mission:

Day 1 - Launch

Discovery's 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. Crewmembers begin a sleep period about seven hours after launch.

Day 2 - Equipment Checkouts, Rendezvous Preparations

Discovery's crew will spend its first full day in space checking out equipment that will be used for upcoming major activities -- 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 Discovery closes in on the station.

Day 3 - Rendezvous and Docking

Plans call for Discovery to dock with the International Space Station on Flight Day 3.

Day 4 - Berthing of the MPLM Leonardo

Leonardo will be attached to the station's Unity node, powered up and activated. The three Expedition Three crewmembers will install their Individual Equipment Liner Kits in the Soyuz capsule docked to the station.

Day 5 - Equipment, Supplies Transfer

Both station and shuttle crewmembers will work at transferring equipment and supplies from Leonardo to the space station. Expedition Two and Expedition Three crewmembers will take some time for handover activities.

Day 6 - Spacewalk Preparation

Astronauts will continue transfers from Leonardo, including moving the EXPRESS racks into the Destiny laboratory. They also will check out spacesuits and other spacewalking equipment. The station and shuttle arms will be prepared for the next day's activities.

Day 7 - The First Spacewalk

Barry and Forrester will install the Early Ammonia Servicer to the space station's P6 truss and the Materials ISS Experiment (MISSE) on handrails of the ISS airlock during a spacewalk of about 6½ hours.

Day 8 - Equipment, Supplies Transfer

Again station and shuttle crewmembers will transfer equipment and supplies from Leonardo to the space station. Shuttle crewmembers also will prepare for the subsequent day's spacewalk, while station crewmembers will continue handover activities.

Day 9 - The Second Spacewalk

Barry and Forrester, in another spacewalk of about 5½ hours, will install handrails and lay cables they will install to provide temporary power to the S0 truss, to be launched later.

Day 10 – Unberthing of Leonardo

Leonardo will be unberthed from the space station and, loaded with unneeded equipment and trash from the station, returned to Discovery's cargo bay. Station crewmembers will continue their handover.

Day 11 Shuttle-Station Hatch Closing, Undocking, Flyaround

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

Day 12- Pre-Landing Checkouts, Cabin Stow

Activities include the standard day-before-landing flight control checks of Discovery by Horowitz and Sturckow 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 13 - Entry and Landing

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

Mission Objectives

Top priorities for the STS-105 (7A.1) mission of Discovery are rotation of the International Space Station crew, bringing water, equipment and supplies to the station and completion of a series of spacewalks and robotics tasks.

International Space Station Program priorities include the following tasks to be accomplished.

--Water transfer from the shuttle to the station. The quantity will be determined during the mission.

--Rotation of the Expedition Two and Expedition Three crews.

--Transfer critical cargo from the shuttle middeck to the station.

--Berth the Multipurpose Logistics Module to the station, check it out and transfer critical cargo to the space station, transfer and stow return cargo in the module and return the module to the cargo bay.

--Spacewalk and robotics activities, including installation of the Early Ammonia Servicer and preparation for future station assembly. Among the preparation activities are laying heater cables for a future station truss segment.

Crew

Commander:	Scott J. Horowitz
Pilot:	Frederick (Rick) W. Sturckow
Mission Specialist 1:	Patrick G. Forrester
Mission Specialist 2:	Daniel T. Barry
E3 Up:	Frank L. Culbertson, Jr.
E3 Up:	Vladimir N. Dezhurov
E3 Up:	Mikhail Tyurin
E2 Down:	Yury V. Usachev
E2 Down:	James S. Voss
E2 Down:	Susan J. Helms

Launch

Orbiter:	Discovery OV103
Launch Site:	Kennedy Space Center Launch Pad 39A
Launch Window:	2.5 to 5 minutes
Altitude:	Insertion 122 Nautical Miles; Rendezvous 240 Nautical Miles
Inclination:	51.6 Degrees
Duration:	11 Days 19 Hrs. 39 Min.

Vehicle Data

Shuttle Liftoff Weight:	4517989 lbs.
Orbiter/Payload Liftoff Weight:	257748 lbs.
Orbiter/Payload Landing Weight:	222275 lbs.

Software Version: OI-28

Space Shuttle Main Engines: *(1 MB pdf)*

SSME 1: 2052 **SSME 2:** 2044 **SSME 3:** 2045

External Tank: ET-110A (Super Light Weight Tank)

SRB Set: BI109PF

Landing

Primary Landing Site: Kennedy Space Center Shuttle Landing Facility

Crew Members

Commander: Scott J. Horowitz

Scott Horowitz, 44, an Air Force colonel and former test pilot with a Ph.D. in aerospace engineering, will command Discovery's STS-105 mission and be responsible for its safety and success. He will fly Discovery through its rendezvous and docking with the International Space Station on the fifth shuttle flight of the year. He will operate the shuttle's robotic arm during the mission's two spacewalks and act as backup arm operator during the berthing and unberthing of the Multipurpose Logistics Module. He will assist pilot Rick Sturckow in Discovery's flyaround of the station after undocking. Finally, he will land Discovery at mission's end.

Previous Space Flights:
Horowitz flew as pilot on STS-75, the Tethered Satellite reflight launched in February 1996; on STS-82, the second Hubble Space Telescope maintenance mission in February 1997, and on STS-101, the third shuttle mission to the space station.

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

Pilot: Frederick (Rick) W. Sturckow

A Marine major, a veteran of 41 Desert Storm combat missions and former test pilot, Rick Sturckow, 39, [40 on Aug. 11] will be responsible for monitoring critical shuttle systems during ascent and entry. He also will play a major role during rendezvous and docking operations, responsible for many of the shuttle's navigational tools. He will be responsible for operating still and video cameras. He will serve as the intravehicular crewmember during the mission's two spacewalks, monitoring and coordinating activities of the spacewalkers. Sturckow himself is the backup spacewalker. After participating in Discovery's undocking from the station, he will perform the flyaround of the orbiting laboratory.

Previous Space Flights:
Sturckow was pilot on STS-88 launched in December 1998, the first space station assembly mission.

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

Mission Specialist 1: Patrick G. Forrester

Patrick Forrester, 44, is an Army lieutenant colonel, former test pilot and Army Ranger with a master's in mechanical and aerospace engineering. He will do two spacewalks during STS-105. He also will be primary operator of the shuttle's robotic arm during berthing and unberthing of the Multipurpose Logistics Module. Among his other responsibilities will be opening and closing of Discovery's payload bay doors and the shuttle's communications equipment and instruments, as well as flight data file. He will serve as a backup in still photography and video.

Previous Space Flights:
Forrester is making his first spaceflight.

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

Mission Specialist 2: Daniel T. Barry

Daniel Barry, 47, a veteran of two space flights, earned a Ph.D. in electrical engineering/computer science and an M.D. degree. As EV1 he will be the lead for the two spacewalks during Discovery's flight to the space station. Barry will serve as Discovery's flight engineer during ascent and entry. He will have primary responsibility in post-insertion activities, converting the shuttle from a launch vehicle to an orbiting spacecraft, and in deorbit preparations. He will provide information to the commander and pilot during rendezvous with the station and after undocking. He will serve as loadmaster on the shuttle side for transfer of equipment and supplies to the space station and for items being returned to Earth from the station.

Previous Space Flights:
Barry was a mission specialist on STS-72, the Space Flyer Unit retrieval flight, launched in January 1996, and on STS-96, a logistics flight to the space station, launched in May 1999.

Ascent Seating: Flight Deck - Center Aft
Entry Seating: Flight Deck - Center Aft
EV1

E3 UP: Frank L. Culbertson, Jr.

Frank Culbertson, 52, a retired Navy captain, former test pilot, and former manager of the ISS Phase One (Shuttle-Mir) Program, will command the Expedition Three mission to the space station. As commander, he will have overall responsibility for expedition safety and success as the station's size and scientific capabilities continue to increase. Culbertson also will have a number of responsibilities aboard Discovery during STS-105. Among them will be primary responsibility for shuttle communication with the station and with Mission Control Moscow during rendezvous and docking and for pressure and leak checks once docking is complete. He also will be responsible for water transfer from Discovery to the station and for MPLM commanding and vestibule preparation.

Previous Space Flights:
Culbertson was pilot on STS-38, a five-day Defense Department mission in November 1990. He commanded STS-51, which launched the Advanced Communications Technology Satellite and the Shuttle Pallet Satellite in September 1993.

Ascent Seating: Mid Deck - Port

E3 UP: Vladimir N. Dezhurov

Vladimir Nikolaevich Dezhurov is a veteran of one long-duration spaceflight, having served as commander of a mission aboard the Russian space station Mir in 1995. That crew returned to Earth aboard the shuttle Atlantis July 7, 1995, after 115 days in orbit. Dezhurov is a lieutenant colonel in his country's air force and served as a pilot and senior pilot, earning three Armed Forces Medals. He was first assigned to the Cosmonaut Training Center in 1987. Since 1989 he has trained with a group of test cosmonauts. He served as a backup member of the Expedition One crew to the International Space Station.

Previous Space Flights:
Dezhurov commanded the Mir-18 mission, a 115-day flight in 1995.

Ascent Seating: Mid Deck - Center

E3 UP: Mikhail Tyurin

Mikhail Tyurin, 41, worked as an engineer at the RSC-Energia Corp. after his graduation from the Moscow Aviation Institute in 1984. At Energia he worked in dynamics, ballistics and software development. He continues graduate studies, and his personal scientific research relating to psychological aspects of cosmonauts' training for manual control of spacecraft. Tyurin himself was selected to begin cosmonaut training in 1993. Since 1998 he has trained as an ISS flight engineer. He was a backup crewmember for Expedition One before being named an Expedition Three crewmember.

Previous Space Flights:
Tyurin is making his first spaceflight.

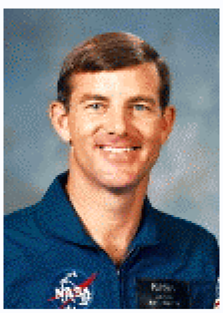
Ascent Seating: Mid Deck - Starboard

E2 DOWN: Yury V. Usachev

Yury Usachev, 43, is ending his fourth flight into space with his return to Earth on Discovery. He is the first Russian to command the International Space Station. During his Discovery flight, Usachev will be designated Mission Specialist 5. During his months on the ISS, Usachev was responsible for the safety of his crew and the success of the mission, which saw the beginning of substantial science aboard the International Space Station. He did a spacewalk with Voss in the Zvezda module and helped Voss and Helms in the checkout and troubleshooting of Canadarm2.

Previous Space Flights:
Usachev flew as a flight engineer during two long-duration missions to the Mir space station in 1994 and 1996. He was a mission specialist during the STS-101 mission of Atlantis to the space station in May 2000 along with crewmates Jim Voss and Susan Helms. Usachev has logged 386 days in space and six spacewalks.

Entry Seating: Mid Deck - Starboard



E2 DOWN: James S. Voss

Jim Voss, 52, a retired Army colonel, will return from his second visit to the space station after his months aboard the orbiting laboratory as part of the Expedition Two crew. Voss and commander Yury Usachev did an internal spacewalk, the first from the space station. They repositioned a docking cone in preparation for the arrival later this year of the Russian docking compartment. Voss was instrumental in the successful effort to recover from station computer problems that began during the STS-100 mission in April 2001. Voss worked with Helms in the checkout and troubleshooting for the station's robotic arm, Canadarm2.

Previous Space Flights:
Voss flew on STS-44 that launched a military satellite in 1991, STS-53 with a classified military payload in 1992, STS-69, the second Wake Shield Facility flight, in 1995, and STS-101 to the space station in 2000.

Entry Seating: Mid Deck - Port

E2 DOWN: Susan J. Helms

Susan Helms, 43, is an Air Force colonel returning from her fifth spaceflight. She operated the station's Canadarm2 during checkout and troubleshooting operations. She and fellow Expedition Two crewmember Voss performed a spacewalk from Discovery after Expedition Two arrived at the space station in March 2000. She was choreographer for the second spacewalk, performed by Andy Thomas and Paul Richards, operating from Discovery's aft flight deck. She also was responsible for transfer of vital racks from the Multipurpose Logistics Module to the U.S. laboratory Destiny. With Usachev and Voss, she conducted and participated in a number of scientific experiments during the Expedition Two mission.

Previous Space Flights:
Helms flew on STS-54, which launched a Tracking and Data Relay Satellite in 1993; STS-64, the Lidar In-Space Technology Experiment flight, in 1994; STS-78, a Spacelab flight, in 1996, and STS-101 to the space station in 2000.

Entry Seating: Mid Deck - Center

Flight Day Summary Timeline

DATE TIME (EST)	DAY	MET	EVENT
08/09/01 5:32:00 PM	1	000/00:00	Launch
08/11/01 1:08:00 PM	3	001/19:36	TI Burn
08/11/01 3:27:00 PM	3	001/21:55	Docking
08/11/01 5:17:00 PM	3	001/23:45	ISS Ingress
08/12/01 10:52:00 AM	4	002/17:20	MPLM Installation
08/15/01 10:37:00 AM	7	005/17:05	EVA 1 Start
08/17/01 10:37:00 AM	9	007/17:05	EVA 2 Start
08/18/01 4:22:00 PM	10	008/22:50	MPLM Berth
08/19/01 11:48:00 AM	11	009/18:16	Undocking
08/21/01 12:09:00 PM	13	011/18:37	Deorbit Burn
08/21/01 1:11:00 PM	13	011/19:39	Landing

Rendezvous and Docking

Overview

Discovery's 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 Discovery to the starting point for a final approach.

About 2½ hours before the scheduled docking on Flight Day Three, Discovery will reach that point about 50,000 feet -- 9½ miles -- behind the ISS. There Discovery's jets will be fired in a Terminal Intercept (TI) burn to begin the final phase of the rendezvous. Discovery will close the final miles to the station during the next orbit of the Earth.

As Discovery 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, the shuttle can make as many as four, small course corrections at regular intervals. Just after the last correction is completed, Discovery will reach a point about half a mile below the station. At that time, about an hour before the scheduled docking, Commander Scott Horowitz will take manual control of Discovery.

Horowitz will slow Discovery's approach and fly to a point about 600 feet directly below the station. There 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.

During the rendezvous, Horowitz will be assisted by Pilot Rick Sturckow. Mission Specialists Dan Barry and Patrick Forrester also will play key roles in the rendezvous, with Barry operating a handheld laser-ranging device and a laptop computer navigation aid assisted by Forrester. Barry also will operate the shuttle's docking mechanism to latch the station and Discovery together after the two spacecraft make contact.

Horowitz will slowly close 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 Discovery's docking mechanism as a key alignment aid, Horowitz will precisely center the docking ports of the two spacecraft. Horowitz will fly to a point where the docking mechanisms are 30 feet apart, and pause for about five minutes to check the alignment.

For Discovery's docking, Horowitz 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 Discovery makes contact with the station, preliminary latches will automatically attach the two spacecraft together. Immediately after Discovery 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, Barry will secure the docking mechanism, sending commands for Discovery's mechanism to retract and close a final set of latches between the shuttle and station.

Undocking, Separation and Flyaround

Once Discovery is ready to undock, Barry 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. Discovery's steering jets will be shut off to avoid any inadvertent firings during this initial separation.

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

Discovery will continue away to a distance of about 450 feet, where Sturckow will begin a close flyaround of the station, circling the complex 1¼ times.

Sturckow will pass directly above the station, then behind, then underneath, then in front and then reach a point directly above it for a second time. At that point, passing above the station for a second time, Sturckow will fire Discovery's jets to separate from the area of the station. The flyaround is expected to be completed a little over an hour after undocking.

EVA

Two Spacewalks to Lay Groundwork for Future ISS Construction

Overview

Astronauts Dan Barry and Patrick Forrester are to perform two spacewalks while Discovery is docked to the International Space Station during STS-105.

Barry will be designated Extravehicular crewmember 1 (EV1) and wear red stripes on his spacesuit. Forrester, designated EV2, will wear an all-white spacesuit.

Discovery Pilot Rick Sturckow will be the Intravehicular crewmember (IV), coordinating the spacewalk activities from within the shuttle's cabin. Discovery Commander Scott Horowitz will control the shuttle's robotic arm during the spacewalk.

The spacewalkers will install equipment on the exterior of the station for future maintenance and construction work on the outpost. Both spacewalks will originate from Discovery's airlock, and the two astronauts will be tethered to the shuttle's robotic arm for much of the work.

The primary objective of the first spacewalk, planned for Flight Day Seven and to last about 6½ hours, is to install an Early Ammonia Servicer on the station, a system that contains spare ammonia for the station's cooling system. Ammonia is the fluid used in the radiators that cool the station's electronics. The EAS will be installed on the truss, called the P6 truss that holds the station's giant U.S. solar arrays, associated batteries and the cooling radiators.

During the first spacewalk, Barry and Forrester also will attach an experiment to the outside of the station's airlock that will collect information on how various materials weather the space environment. The experiment, called the Materials International Space Station Experiment (MISSE), is housed in two carriers that will be attached to the station's exterior for an extended duration.

As Barry and Forrester exit Discovery's airlock, Horowitz will maneuver the shuttle's robotic arm into position to latch onto a grapple fixture on the EAS, bolted to a carrier in the shuttle's payload bay for launch. After Horowitz has latched the arm onto the EAS, Barry and Forrester will go to the pallet, called an Integrated Cargo Carrier, and begin loosening the six bolts that hold the unit in place. In addition, Barry will translate hand-over-hand up to the station's Destiny Lab, where he will pick up a foot platform to be used during installation of the EAS. With the bolts free, Horowitz will begin lifting the EAS, with Barry and Forrester holding on to handrails on the EAS as well, up to the station.

Horowitz will maneuver the spacewalkers and EAS up to the position on the station's P6 truss where the EAS will be installed.

There, Barry will attach the foot platform and secure himself to it. Horowitz will release the arm's grip on the EAS, basically handing off the unit to Barry. Forrester will then help Barry align the unit over its attachment position and move it to a "soft dock," where it will be preliminarily held in place by a hook mechanism closed and locked with a pip pin inserted by Forrester. Forrester will then tighten a bolt to firmly attach the EAS in position on the truss. The two spacewalkers will then unfurl and attach cables to supply station electrical power to heaters on the EAS, completing the installation.

That done, the spacewalkers will hold on to the station arm again as Horowitz lowers them back to Discovery's payload bay, pausing at the station's Z1 truss to allow Barry to put the foot restraint in a stowed location needed for upcoming mission STS-110/8a. In Discovery's cargo bay, Barry and Forrester will move to the carrier platform and release the two Passive Experiment Containers containing the MISSE investigations from their launch restraints. With each of the spacewalkers holding an experiment container, they will hold onto the arm while Horowitz maneuvers them up to the station's airlock. There they will let go of the arm and clamp the MISSE carriers to two separate airlock handrails.

The second spacewalk, planned to last up to 5½ hours, will be performed on Flight Day Nine of the mission and will focus on preparations for future station assembly, installing handrails on the Destiny lab and laying heater cables for a future station truss segment.

Horowitz will again be operating the shuttle robotic arm to maneuver the spacewalkers, who will be hanging on to the arm at times. As the spacewalk begins, Barry and Forrester will take with them from Discovery's airlock two bags containing the heater cables they will install on the station. Called Launch to Activation heater cables, they will be used on shuttle mission STS-110 to power heaters on the station's S0 truss segment, the center segment of the station's truss structure, more than 300 feet long. In addition, they will take with them two bags holding 11 new handrails they will install on the Destiny Lab, called Orbit-Installed Handrails.

Barry and Forrester will hold on to the shuttle arm, carrying the heater cable bags, as Horowitz lifts them to the station's Destiny lab. There, they will temporarily attach the bags to handrails, one on the port side of the lab and another on the starboard side.

Barry will install six handrails on the lab's starboard side while Forrester installs five handrails on the port side. The spacewalkers also will relocate two existing lab handrails. With the handrails installed, the spacewalkers will then feed the heater cables along the rails on either side of the lab, connecting one end to the station and placing the other end in position for use when the S0 truss segment is delivered on STS-110.

EVA Timeline for
Two Spacewalks to Lay Groundwork for Future ISS Construction

Time	Event
005/17:05	EVA 1 Start
005/17:35	EVA1 Early Ammonia Servicer Install PT 1
005/18:35	EVA 1 Early Ammonia Servicer Install PT 2
005/21:35	EVA 1 Materials International Space Station Experiment Install
005/22:50	EVA 1 Clean Up
005:23:20	EVA 1 Ingress
005/23:35	EVA 1 End
007/17:05	EVA 2 Start
007/17:35	EVA 2 S0 Launch To Activation Cable Install
007/21:05	EVA 2 Clean Up
007/23:20	EVA 2 Ingress
007/23:35	EVA 2 End

Payloads

Leonardo - An Italian Space Veteran

Overview

The Leonardo Multi-Purpose Logistics Module (MPLM) acts as a moving van for the International Space Station Program, carrying laboratory racks with science equipment as well as racks and platforms filled with bags of experiments and supplies to and from the orbiting laboratory.

Leonardo is mounted in Discovery's payload bay for launch and remains there until after the shuttle docks with the space station. Discovery's astronauts will use the shuttle's robotic arm to remove Leonardo from the payload bay and attach it to the space station's Unity Node for unloading.

Aboard Leonardo are six Resupply Stowage Racks, four Resupply Stowage Platforms, and two new scientific experiment racks for the station's U.S. laboratory Destiny. The two new science racks (EXPRESS Racks 4 and 5) will add science capability to the station. EXPRESS stands for Expedite the Processing of Experiments to the Space Station.

EXPRESS Rack 4 weighs 1,175 pounds and EXPRESS Rack 5 weighs 1,200 pounds. The empty weight of each EXPRESS rack is about 785 pounds. EXPRESS Racks 1 and 2A were delivered aboard the Raffaello cargo module during STS-100/6A in April 2001. EXPRESS Rack 3 is scheduled to be brought to the station during STS-111/UF-2 in 2002.

The Resuppy Stowage Racks and Resupply Stowage Platforms are filled with Cargo Transfer Bags that contain equipment and supplies for the station. The six Resuppply Stowage Racks contain almost 3,200 pounds of cargo and the four Resupply Stowage Platforms contain about 1,200 pounds of cargo, not including the weight of the Cargo Transfer Bags, the foam packing around the cargo or the straps and fences that hold the bags in place.

The total weight of cargo, racks and packing material aboard Leonardo is just over 11,000 pounds. Total cargo weight is about 6,775 pounds.

Leonardo's cargo includes equipment required for activation of the two new science racks, a variety of spare parts for station systems, and food and other supplies to support the Expedition Three crew. After the cargo is removed, the Resupply Stowage Racks and Resupply Stowage Platforms, which remain aboard Leonardo, will be filled with any unneeded station equipment and trash. Empty Cargo Transfer Bags and packing foam also will be loaded. Once filled, Leonardo will be detached from the station and put back into the shuttle's payload bay for the trip home.

History/Background

Construction of Leonardo began in April 1996 at the Alenia Aerospazio factory in Turin, Italy. Leonardo was flown from Italy to the Kennedy Space Center in Florida in August 1998 aboard a special Beluga cargo aircraft. Although built in Italy, Leonardo and two additional MPLMs are owned by the U.S. The MPLMs were provided in exchange for Italian access to U.S. research time on the space station.

The cylindrical Leonardo module is about 21 feet (6.4 meters) long and 15 feet (4.6 meters) in diameter. It weighs a little over 9,000 pounds (4.1 metric tons) empty and can carry up to 20,000 pounds (9.1 metric tons) of cargo packed into 16 standard space station equipment racks or platforms. The reusable MPLM functions as both a cargo carrier and a space station module.

Leonardo contains components that provide some life support, fire detection and suppression, electrical distribution and computer functions. When in the payload bay, Leonardo is independent of the space shuttle and there is no passageway for shuttle crewmembers to travel to and from the module. Eventually, the MPLMs also will carry refrigerator freezers for transporting experiment samples and food to and from the station.

Leonardo first flew to the space station aboard Discovery on STS-102/5A.1 in March 2001. The second MPLM, Raffaello, flew to the station aboard Endeavour on STS-100/6A in April 2001.

Payloads

Materials International Space Station Experiments

Overview

The Materials International Space Station Experiments (MISSE) Project is a NASA/Langley Research Center-managed cooperative endeavor to fly materials and other types of space exposure experiments on the space station. The objective is to develop early, low-cost, non-intrusive opportunities to conduct critical space exposure tests of space materials and components planned for use on future spacecraft.

Johnson Space Center, Marshall Space Flight Center, Glenn Research Center, the Materials Laboratory at the Air Force Research Laboratory and Boeing Phantom Works are participants with Langley in the project.

The MISSE experiments will be the first externally mounted experiments conducted on the ISS. The experiments are in four Passive Experiment Containers (PECs) that were initially developed and used for an experiment on Mir in 1996 during the Shuttle-Mir Program. The PECs were transported to Mir on STS-76. After an 18-month exposure in space, they were retrieved on STS-86.

PECs are suitcase-like containers for transporting experiments via the space shuttle to and from an orbiting spacecraft. Once on orbit and clamped to the host spacecraft, the PECs are opened and serve as racks to expose experiments to the space environment.

The first two MISSE PECs will be launched to the ISS on STS-105. Two more will be launched to the ISS about 18 months later.

Examples of tests to be performed in MISSE include: New generations of solar cells with longer expected lifetimes to power satellites; advanced optical components planned for future Earth observational satellites; new, longer-lasting coatings that better control heat absorption and emissions and thereby the temperature of satellites; new concepts for lightweight shields to protect crews from energetic cosmic rays found in interplanetary space; and the effects of micrometeoroid impacts on materials planned for use in the development of ultra-light membrane structures for solar sails, large inflatable mirrors and lenses.

New affordable materials will enable the development of advanced reusable launch systems and advanced spacecraft systems.

Payloads

Small Payloads Take Youth Science into Orbit

Overview

Goddard Space Flight Center's Wallops Flight Facility manages NASA's Shuttle Small Payloads Project. The SSPP designs, develops, tests, integrates and flies a group of small payload carrier systems aboard the space shuttle. These carriers -- the Hitchhiker, Getaway Specials, Space Experiment Module -- support payloads supplied by NASA, other U.S. government agencies, universities, high schools, domestic commercial customers and foreign nationals and governments. The following small payloads will be flown aboard Discovery during the STS-105 mission:

Simplesat

Simplesat, a deployable satellite, is being developed as a prototype for a satellite that could be constructed at a college or university. It is designed to evaluate the use of inexpensive commercial hardware on spacecraft. Simplesat is expected to demonstrate Global Positioning System attitude control and payload-assisted fine pointing while free flying in low Earth orbit. It will be ejected from a Hitchhiker canister on the shuttle and deployed away from the sun to protect its optical equipment. It will not be retrieved.

The shuttle crew will deploy Simplesat using switches to arm and activate pyrotechnic devices that release the satellite from the canister. Once the satellite leaves the shuttle, Simplesat's batteries will begin to charge and scientists will monitor Simplesat via radio frequency transmission. Simplesat GPS operates as a navigational tool that has both earthbound and spacebound applications because it provides scientists with a very precise reading of one's location in space.

G-780 Cell Growth in Microgravity

The Get-Away Special canister G-780, Cell Growth in Microgravity experiment, is an educational project that encourages Minnesota high school students to observe root cell growth in microgravity by germinating Vicia Faba bean seeds in space. The primary objective of the experiment is to engage some 200 Mayo High School (Rochester, Minn.) students in an authentic investigation that requires collaboration with scientific professionals from the community. The students designed and prepared the experiment. For additional information about this experiment see stbrehmer@rochester.k12.mn.us.

Microgravity Smoldering Combustion

The Microgravity Smoldering Combustion experiments are designed to study smoldering combustion in an extremely low gravity (microgravity) environment and in normal gravity. The microgravity setting is essential because it permits scientists to study smoldering combustion mechanisms without the complications introduced by gravity and it provides insight into how smoldering combustion behaves in space.

Smoldering combustion is a complex, nonflaming form of burning that occurs in the interior of porous, combustible materials, both natural (piles of leaves and pine needles) and manmade (furniture stuffing and cable insulation). Smolder is a serious problem: 40 percent of all deaths caused by fire in the U.S. can be attributed to the smoldering of household furniture, which releases toxic byproducts. In space, the threat of smoldering combustion becomes an even greater risk.

An earlier version of this experiment flew on USML-1 in 1992. The present version was first tested on Earth and flown aboard STS-69 and STS-77 in 1995-1996.

Hitchhiker Experiments Advancing Technology

The Hitchhiker Experiments Advancing Technology payload contains two experiments, Simplesat and Space Experiment Module-10. NASA's Goddard Space Flight Center, Greenbelt, Md., sponsors both experiments.

Space Experiment Module-10

The Space Experiment Module-10 contains 11 experiments and flies in the space shuttle's payload bay. Experiments flying aboard the SEM-10 module are:

· *Space Travel's Affect on Roots (STARS):* The STARS experiment examines the growing characteristics of roots subjected to the space environment. Once the roots return to Earth, they will be planted alongside control roots that were purchased at the same time. A difference in crop yield could aid in realizing the potential for growing food in space for long-term exploration. (Arizona State University, Tempe, Ariz.)

· *Flowers in Space:* Students will examine the effects of space travel on two types of perennial flowers (coreopsis and columbine) and two types of vegetables (lettuce and cucumbers). Half of the seeds will fly aboard the mission and the other half will be held at Wallops. Upon return, the flower and lettuce seeds will be planted in the fall. The lettuce will mature in the fall, the perennial flowers will mature in the following spring, and the cucumber seeds will be started indoors during the spring and planted outdoors. Students will compare growth rates at different geographic locations to determine if the seeds that traveled in space grow differently. (GSFC/Wallops New 2000, Media, Pa.)

· *Food for Earth and Space:* Students will determine whether the environment of space influences the growth of edible sprouts. Mass, volume and mean growth length will be compared for both the control and variable groups. This experiment should reveal if the environment of space could produce more or less food on the space station. (Corpus Christi School, Chambersburg, Pa.)

· *Corn: Tomorrow's Food on Earth and in Space and Rusting in Space:* The first student experiment will explore if the environment of space impacts the embryo of the corn seed or affects its ability to grow and produce once planted on Earth. Preflight, control and variable seed groups will be measured for mass, volume and density and will be stored in similar environments. Upon return, all growing conditions (time, light, temperature and watering amounts) will be the same. The "Rusting in Space" experiment will observe if rust develops differently on a variety of metals after exposure to the environment of space. The control and variable groups will be stored in similar environments and then they will be placed in a rust-promoting environment. Students will record data regarding mass and density changes, oxidation time and other physical changes. (Chambersburg Area Middle School, Chambersburg, Pa.)

· *Shirt and Shoes Required:* The experiment will determine the effect of high-frequency radiation and microgravity on fabrics, both natural and synthetic. Results from this experiment may influence clothing manufacturing on Earth's changing environment. (Great Bridge Middle School, Chesapeake, Va.)

· *Agrilaser:* This experiment will examine the effects of lasering various seeds and sending them into space. In space, outside the protective atmosphere, the molecules are subjected to cosmic particles. This may affect the seeds' growth cycle, germination period, growth timeline, edible plant taste, look and texture. A variety of seeds will be used and proper controls will be used for each seed group. (Arrowhead Union High School, Port Washington, Wis.)

· *Space Laser Comm 2001:* This experiment will test the feasibility of using a laser to communicate in space. A semiconductor laser module will be carried into space to see if it can withstand a space environment of microgravity and radiation. The peak wavelength of the laser module will be characterized, along with the optical output power of the laser module and various electrical inputs before it goes into space and after it returns. Students will be looking for changes in the peak wavelength and optical output along with any differences in the transmissivity of the laser lens. (Mills Lawn Elementary School, Yellow Springs, Ohio)

· *Different Types of Seeds:* Students will pack tubes with different types of seeds. Some of the seeds will be from the Cahokia Mounds Historical Site in Cahokia Mounds, Ill. Other types of seeds will include tomatoes, lettuce, beans, cucumbers, pumpkins and corn, some of them native to the Midwest area. The students will place the seeds in soil to see if they grow. They will also place them in the hydroponics lab to see if they will grow. They will also grow a control group of seeds that have not been up in space in soil and in the hydroponics lab. (Ellis School, Belleville, Ill.)

· *Stuck on Space:* This team of experimenters consists of students in grades seven through nine from schools in three states. This experiment will explore how temperature extremes, radiation and microgravity will affect adhesives. Commonly used adhesive-backed materials will be used to determine how these items will react in a microgravity environment. Materials that may possibly be used on the International Space Station and on future space exploration missions will be used. (Suffield High School, Suffield, Conn.)

· *SCI-FIVE:* Students from five schools will study the effects of the space environment on a variety of materials. Balls, Playdough©, gum, seeds, Alka-Seltzer©, exposed film, ink and teeth/braces will be tested after they have traveled in space to determine how radiation, temperature and microgravity may have affected them. (Anne Arundel County Schools, Anne Arundel County, Md.)

· *Imaging Media and Radiation Shielding Experiment:* Regina Science Club will conduct both of these experiments, which will be housed in one SEM module. The "Imaging Media" experiment will compare the ability of various consumer grade image storage media to withstand degradation due the SEM space flight environment. Several popular image storage media will be compared side-by-side, image-by-image comparisons with unflown control media and with each other. The "Radiation Shielding Experiment" will test the effectiveness of several radiation shielding strategies. At least 15 radiation dosimeters will be placed in the SEM module. A duplicate control set of dosimeters, both shielded and unshielded, will be kept on the ground for the duration of the experiment to allow for comparison of the levels of radiation in space to those on the ground. After the flight, all experiment dosimeters will be returned to the manufacturer for developing. The manufacturer will provide radiation exposure levels for each type of radiation measured for each dosimeter. (Regina Catholic Education Center, Iowa City, Iowa)

DTO/DSO/RME

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 readaptive 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 readaptation 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.

DTO/DSO/RME

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.

DTO/DSO/RME

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

This is the 18th flight of DTO 700-14.

DTO/DSO/RME

Space Vision Laser Camera System
DTO 701

Overview

DTO 701 will demonstrate the capability of the Space Vision Laser Camera System (SVLCS) to accurately measure the position and attitude of objects in harsh lighting conditions and the ability of the SVLCS to act as an input sensor to the Orbiter Space Vision System (OSVS).

The SVLCS consists of the Laser Camera Head (LCH), which will be mounted in the payload bay, and the Laser Camera Controller (LCC), which will be in the aft flight deck. The LCH contains an eye-safe laser, projection and receiving optics, scanning optics, detectors and driver electronics. The scanning electronics in the LCH scan a 30- by 40-degree field of view. It detects and tracks objects (satellites, payloads and structures) and provides position and attitude information to the OSVS. The LCC is based on a standard payload and general support computer. The LCH and LCC will be connected via Ethernet.

DTO/DSO/RME

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 66 previous flights.

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

ACRONYMS AND ABBREVIATIONS

A/L	Airlock (ISS Joint Airlock)
AAA	Avionics Air Assembly
AAC	Aft Access Cone
ABC	Audio Bus Coupler
ABOLT	Acquire BOLT
ACBM	Active Common Berthing Mechanism
ACLS	Advanced Cardiac Life Support System
ACO	Assembly Checkout Officer
ACS	Assembly Contingency System
	Atmosphere Control and Supply
	Attitude Control System
ACU	Arm Computer Unit
ADM	Antenna Distribution Module
AIO	Analog Input/Output
AL	Airlock (ISS Joint Airlock)
ALSP	Advanced Life Support Pack
AO	Atomic Oxygen
AOB	Assembly Operations Book
AOH	Assembly Operations Handbook
APAS	Androgynous Peripheral Attachment System
APCF	Advanced Protein Crystallization
APCU	Assembly Power Converter Unit
APDS	Androgynous Peripheral Docking System
APFR	Articulating Portable Foot Restraint
APM	Attached Pressurized Module
APPCM	Arm Pitch Plane Change Mode
APS	Automated Payload Switch
ARIS	Active Rack Isolation System
AR	Atmosphere Revitalization
ARS	Atmospheric Revitalization System
ASCR	Assured Safe Crew Return
ASL	Atmosphere Sampling Line
ASV	Air Selector Valve
ATCS	Active Thermal Control System
	Advanced Television Systems Committee
ATU	Audio Terminal Unit
AUAI	Assembly Contingency System UHF Audio Interface
AVV	Air Vent Valve
BC	Bus Controller
BCDU	Battery Charge/Discharge Units
BCSS	Biotechnology Cell Science Stowage
BCU	Backup Drive Control Unit
BDU	Backup Drive Unit

BGA	Beta Gimbal Assembly
BMRRM	Bearing Motor Roll Ring Module
BMS	Bristol Meyers Squibb Science Insert
BP/ECG	Blood Pressure/Electrocardiogram
BSP	Baseband Signal Processor
BSTC	Biotechnology Specimen Temperature Controller
BTLS	Basic Trauma Life Support System
BTR	Biotechnology Refrigerator
BUS	Bus Controller Unit
C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communication and Tracking
C&W	Caution and Warning
C/L	Crew Lock
CA	Control Attitude
CB	Control Bus
CBM	Common Berthing Mechanism
CCAA	Common Cabin Air Assembly
CCD	Cursor Control Device
CCTV	Closed Circuit Television
CDDT	Common Display Development Team
CDRA	Carbon Dioxide Removal System
CDS	Command and Data Software
CETA	Crew Equipment Translation Aid
CEU	Control Electronics Unit
CFA	Cabin Fan Assembly
CheCS	Crew Health Care System
CHX	Condensing Heat Exchanger
CMO	Crew Medical Officer
CMRS	Crew Medical Restraint System
Comm	Communications
COTS	Commercial-Off-The-Shelf
CPCG-H	Commercial Protein Crystal Growth-High Density
CPFSK	Continuous Phase Frequency Shift Keying
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSA-CP	Compound Specific Analyzer-Combustion Products
CSA-H	CSA-Hydrazine
CSCI	Computer S/W Configuration Item
CSM	Cargo Systems Manual
CSV CO_2	Selector Valve
CTB	Cargo Transfer Bag
CTV	Crew Transfer Vehicle
CVIU	Common Video Interface Unit
CVT	Current Valve Table

CVV	Carbon dioxide Vent Valve
CWC	Contingency Water Container
CWR	Collapsible Water Reservoir
DA	Depressurization Assembly
DAIU	Docked Audio Interface Unit
DAK	Double-Aluminized Kapton
DCP	Display and Control Panel
DCPCG-V	Dynamically Controlled Protein Crystal Growth-Vapor
DCSU	Direct Current Switching Unit
DIO	Discrete input/output
DMCU	Docking Mechanism Control Unit
DOF	Degrees-of-Freedom
DPA	Data Processing Assembly
DPS	Data Processing System
E/L	Equipment Lock
EACP	EMU Audio Control Panel
EAIU	EMU Audio Interface Unit
EAS	Early Ammonia Servicer
ECB	Electronics Control Board
ECG	Electrocardiogram
ECLSS	Environmental Control and Life Support System
ECS	Early Communications Subsystem
ECU	Electronic Control Unit
EDDA	EMU Don/Doff Assembly
EEATCS	Early External Active Thermal Control System
EELS	Emergency Egress Lighting System
EET	Experiment Elapsed Time
EETCS	Early External Thermal Control System
EFGF	electrical flight grapple fixture
ELPS	Emergency Lighting Power Supply
ELS	Emergency Lighting Strip
EMA	Engagement Mechanism Assembly
EMU	Extravehicular Maneuvering Unit
	EXPRESS Memory Unit
EPLS	Emergency Lighting Power Supply
EPS	Electrical Power System
EV-CPDS	Extravehicular-Charged Particle Directional Spectrometer
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
EXPRESS	Expedite the Processing of Experiments to the Space Station
FC	Firmware Controller
FCC	Flat Collector Circuit
	Federal Communications Commission
FCV	Flow Control Valve

FD	Flight Day
FDA	Fault Detection Annunciation
FDI	Failure Detection and Isolation
FDS	Fire Detection and Suppression
FGB	Functional Cargo Block
FPU	Fluid Pumping Unit
FRGF	Flight Releasable Grapple Fixture
FSE	Flight Support Equipment
FSEGF	FSE Grapple Fixture
GC	Growth Cell
GFE	Government Furnished Equipment
GLA	General Lighting Assembly
GLONASS	Global Navigational Satellite System
GMT	Greenwich Mean Time
GNC	Guidance and Navigation Computer
GPC	General Purpose Computer
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSM	Gas Supply Module
GUI	Graphical User Interface
HCU	Headset Control Unit
HDR	High Data Rate
HDPCG	High Density Protein Crystal Growth
HDTV	High Definition Television
HEAT	Hitchhiker Experiment Advancing Technology
HEC	Headset Extension Cable
HEPA	High-Efficiency Particulate Arrestor (a filter for the CCAA)
HESE	Hitchhiker Eject System Electronics
HGA	High Gain Antenna
HLA	High Level Analog
HPGT	High Pressure Gas Tank (see ONTO)
HRF	Human Research Facility
HRFM	High Rate Frame Multiplexer
HRM	High Rate Modem
	Heart Rate Monitor
I/O	Input/Output
IAA	Internal Antenna Assembly
IAC	Internal Audio Controller
IAS	Internal Audio System
ICC	Integrated Cargo Carrier
ICM	Isothermal Containment Module
IEA	Integrated Equipment Assembly
IELK	Individual Equipment Liner Kit

I/F	Interface
IFHX	Interface Heat Exchanger
IMS	Inventory Management System
IMV	Intermodule Ventilation
IOCU	Input/Output Controller Unit
IP	International Partner
IRU	In-flight Refill Unit
ISA	International Sampling Adapter
ISIS	International Subrack Interface Standard
ISPR	International Standard Payload Rack
ISS	International Space Station
ISSIS	International Space Station Interface Standard
ISSP	International Space Station Program
ISSSH	International Space Station Systems Handbook
ITCS	Internal Thermal Control System
IV-CPDS	Intravehicular-Charged Particle Directional Spectrometer
IVA	Intervehicular Activity
JEU	Joint Electronics Unit
JEUS	Joint Expedited Undocking and Separation
JSC	Johnson Space Center
KBAR	Knee-Brace Assembly Replacement
KSSL	Krug Single-Stowage Lock
KYA	Keel Yoke Assembly
LAN	Local Area Network
LaRC	Langley Research Center
LB	Local Bus
LCA	Lab Cradle Assembly
LCD	Liquid Crystal Display
LCP	Lower Connector Panel
LDA	Launch Deployment Assembly
LDR	Low Data Rate
LEE	Latching End Effector (both SRMS and SSRMS)
LED	Light Emitting Diode
LFDP	Load Fault Detect/Protect
LGA	Low Gain Antenna
LLA	Low Level Analog
LRU	Line Replaceable Unit
LTA	Launch to Activiation
LTL	Low Temperature Loop
MA	Mechanical Assembly
MAM	Manual Augmented Mode
Mb	Megabytes
MBM	Manual Berthing Mechanism

MBSU	Main Bus Switching Unit
MCA	Major Constituent Analyzer
MCC	Mission Control Center
MCC-H	MCC-Houston
MCC-M	MCC-Moscow
MCDS	Multifunction CRT Display System
MCS	Motion Control System
MDM	Multiplexer/Demultiplexer
MDPS	Meteoroid and Debris Protection System
MEEP	Mir Environment Effects Payload
METOX	Metal Oxide (for CO2 removal)
MIP	Mission Integration Plan
MISSE	Materials ISS Experiment
MLE	Middeck Locker Equivalent
MLI	Multilayer Insulation
MMOD	Micrometeoroid Orbital Debris
MOD	Mission Operations Directorate
MPEV	Manual Pressure Equalization Valve
MPLM	Multi-Purpose Logistics Module
MPMs/MRLs	Manipulator Positioning Mechanisms/ Manipulator Retention Latches
MPR	Manual Pulmonary Resuscitator
MR	Medium Rate
MSD	Mass Storage Device
MSFC	Marshall Space Flight Center
MSS	Mobile Servicing System
MT	Mobile Transporter
MTL	Moderate Temperature Loop
MUP	Mission Unique Process
N_2	Nitrogen (DI-molecular)
NCS	Node Control Software
NET	No Earlier Than
NiCD	Nickel Cadmium
NGTC	Next Generation Thermal Control
NIV	Nitrogen Isolation Valve
NMS	Nitrogen Management System
NPRA	Negative Pressure Relief Assembly
NST	Near Saturation Threshold
NPRV	Negative Pressure Relief Valve
NSTC	National Television Systems Committee
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

ODA	Orbiter Disconnect Assembly
ODS	Orbiter Docking System
OIU	Orbiter Interface Unit
OIV	Oxygen Isolation Valve
ONS	Off Nominal
ONTO	Oxygen Nitrogen Tank ORU (see HPGT)
OPP	OSVS Patch Panel
OPS	Operations (Operational)
OPS LAN	Operations Local Area Network
ORCA	Oxygen Recharge Compressor Assembly
ORU	Orbital Replacement Unit
OSE	Orbital Support Equipment
OSVS	Orbiter Space Vision System
OSVU	Orbiter Space Vision Unit
PAV	Process Air Valve
PB	Power Bus
PBA	Portable Breathing Apparatus (mask)
PCA	Pressure Control Assembly
PCBA	Portable Clinical Blood Analyzer
PCBM	Passive Common Berthing Mechanism
PCMCIA	Personal Computer Memory Card International Adapter
PCMMM	Pulse Code Master Modulation Unit
PCP	Pressure Control Panel
PCR	Portable Computer Receptacle
PCS	Portable Computer System
PDB	Power Distribution Box
PDGF	Power and Data Grapple Fixture
PDI	Payload Data Interface
PDIP	Payload Data Interface Panel
PDRS	Payload Deployment and Retrieval System
PEC	Passive Experiment Container
PEHB	Payload Ethernet Hub Bridge
PEHG	Payload Ethernet Hub Gateway
PEP	Portable Emergency Provision
PES	Pallet Ejection System
	Payload Ejection System
PEV	Pressure Equalization Valve
PFCS	Pump Flow Control Subassembly
PFE	Portable Fire Extinguisher
PG	Product Group
PIHPC	Permanent International Human Presence Capability
PJAM	Pre-Stored Joint Position Auto-sequence Mode
PL	Payload
PMA	Pressurized Mounting Panel
	Pressurized Mating Adapter

PMP	Payload Mounting Panel
ppO_2	partial pressure of Oxygen
POIC	Payload Operations Integration Center
POR	Points of Reference
PPA	Pump Package Assembly
PPAM	Pre-stored POR Auto-sequence Mode
PPP	Power Patch Panel
PPRA	Positive Pressure Relief Assembly
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
PSP	Payload Signal Processor
PTCS	Passive Thermal Control System
PTT	Push To Talk
PTU	Pan/Tilt Units
PUNT	Peremptory Unilateral Network Tracking
PV	Photovoltaic
PVM	Photovoltaic Module
PWP	Power Work Platform
QD	Quick Disconnect
QTCM	Quad Tissue Culture Module
QTCMA	QTCM Assembly
R&MA	Restraint and Mobility Aids
R-S	Reed-Solomon
R/F	refrigerator/freezer
RAIU	Russian Audio Interface Unit
RAM	Random Access Memory
RAMV	Rheostat Air Mix Valve
RAB	Rack Attachment Block
RCU	Remote Control Unit
RED	Resistive Exercise Device
RF	Radio Frequency
RFCA	Rack Flow Control Assembly
RFG	Radio Frequency Group
RGS	Russian Ground Site
RHC	Rotational Hand Controller
RHX	Regenerative Heat Exchanger
RIC	Rack Interface Controller
ROEU	Remote Operated Electrical Umbilical
ROFU	Remote Operated Fluid Umbilical
ROS	Russian Orbital Segment
RPC	Remote Power Controller

RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
RS	Russian Segment
RSA	Russian Space Agency
RSC-E	Rocket Space Corporation – Energia
RSP	Resupply Support Platform
RSR	Resupply Stowage Rack
RT	Remote Terminal
RTL	Ready to Launch
RWS	Robotic Workstation
SASA	S-Band Antenna Support Assembly
SAW	Solar Array Wing
SCA	Switchgear Controller Assembly
SCSI	Serial Command and Monitoring Interface
SCU	Servicing and Cooling Umbilical
	Sync and Control Unit
SD	Smoke Detector
SDO	Solenoid Driver Output
SDS	Sample Delivery System
SEM	Space Experiment Module
SGANT	Space-to-Ground Antenna
SJRM	Single Joint Rate Mode
SLDP	Spacelab Logistics Double Pallet
SOC	State of Charge
SM	Service Module
SPCE	Servicing and Performance Checkout Equipment
SPDA	Secondary Power Distribution Assembly
SPDM	Special Purpose Dextrous Manipulator
SPDU	Secondary Power Distribution Unit
SPP	Science Power Platform
SRMS	Shuttle Remote Manipulator System
SSC	Station Support Computer
	Subsystem Computer
SSCS	Space-to-Space Communication System
SSE	Space Station Eyewash
SSER	Space-to-Space EMU Radio
SSOR	Space-to-Space Orbiter Radio
SSOV	Sample line Shut-off Valve
SSP	Space Shuttle Program
	Standard Switch Panel
SSPC	Solid State Power Controller
SSPCM	Solid State Power Control Module
SSRMS	Space Station Remote Manipulator System
SSSR	Space-to-Space Station Radio
SSU	Sequential Shunt Unit

STIPL	Standard Interface Plate
STS	Space Transportation System
SW	Software
TA	Thruster Assist
TCCS	Trace Contaminant Control Subassembly
TCCV	Temperature Control and Check Valve
TCS	Thermal Conditioning System
	Thermal Control System
TDMA	Time Division Multiple Access
TDRSS	Tracking and Data Relay Satellite System
TEA	Torque Equilibrium Attitude
TEPC	Tissue Equivalent Proportional Counter
TFL	Telemetry Format Load
THC	Temperature and Humidity Control
	Translationall Hand Controller
TOCA	Total Organic Carbon Analyzer
TRC	Transmitter Receiver Controller
TVIS	Treadmill Vibration Isolation System
UB	User Bus
UCP	Unpressurized Cargo Pallet
UIA	Umbilical Interface Assembly
UIP	Utility Interface Panel
UHF	Ultrahigh Frequency
UOP	Utility Outlet Panel
USOS	United States Orbital Segment
VAJ	Vacuum Access Jumper
VBSP	Video Baseband Signal Processor
Vdc	Volts (direct current)
VDS	Video Distribution System
VDU	Video Distribution Unit
VES	Vacuum Exhaust System
VES/VRS	Vacuum Exhaust/Resource System
VGS	Video Graphics Software
VMDS	Valve Motor Drive Switch
VOX	Voice Operated Transmission
VPMP	Vented PMP
VRCV	Vent/Relief Control Valve
VRIV	Vent/Relief Isolation Valve
VRS	Vacuum Resource System
VRV	Vent/Relief Valve
VSC	Video Signal Converter
VSU	Video Switch Unit
VTR	Video Tape Recorder

WAA	Wireless Antenna Assembly
WHS	Workstation Host Software
WIF	Worksite Interface
WIU	Wireless Interface Unit
WMV	Water Modulating Valve
WOV	Water ON/OFF Valve
WPP	Water Pump Package
WRM	Water Recovery and Management
WS	Water Separator
WVA	Water Vent Assembly
ZSR	Zero-g Stowage Rack

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.

Media Contacts

NASA PAO CONTACTS

Carlos Fontanot NASA Johnson Space Center Houston, TX carlos.fontanot1@jsc.nasa.gov	NASA Moscow PAO	256 961-6225
Glen Golightly The Boeing Company Huntington Beach, CA robert.g.golightly@boeing.com	Space Shuttle	714 372 4742
Bruce Buckingham NASA Kennedy Space Center Kennedy Space Center, FL bruce.buckingham-1@kmail.ksc.nasa.gov	Launch Operations	321 867-2468
Dan Beck Boeing Rocketdyne Canoga Park, CA daniel.c.beck@boeing.com	Space Shuttle Main Engines	818 586-4572
Debbie Rahn NASA Headquarters Washington, DC debbie.rahn@hq.nasa.gov	International Partners	202 358-1638
Dwayne Brown NASA Headquarters Washington, DC dwayne.brown@hq.nasa.gov	Space Shuttle/Space Station Policy	202 358-1726

Eileen Hawley NASA Johnson Space Center Houston, TX eileen.hawley1@jsc.nasa.gov	Astronauts/Mission Operations	281 483-5111
Jack King United Space Alliance Kennedy Space Center, FL KingJW@usafoo.unitedspacealliance.com	Shuttle Processing	321 861-4358
Kari Kelley Allen The Boeing Company Houston, TX kari.k.allen@boeing.com	International Space Station	281 336-4844
Kyle Herring NASA Johnson Space Center Houston, TX kyle.j.herring1@jsc.nasa.gov	International Space Station Operations	281 483-5111
June Malone NASA Marshall Space Flight Center Huntsville, AL June.Malone@msfc.nasa.gov	Space Station Science	256 544-0031

SHUTTLE FLIGHTS AS AUGUST 2001

105 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 80 SINCE RETURN TO FLIGHT

		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-104 07/12/01 – 07/24/01	
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
OV-102 Columbia (26 flights)	**OV-099 Challenger (10 flights)**	**OV-103 Discovery (29 flights)**	**OV-104 Atlantis (24 flights)**	**OV-105 Endeavour (16 flights)**

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