

A T L A N T I S
V I S I T S
I N T E R N A T I O N A L S P A C E S T A T I O N

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Mission Overview

The development of the International Space Station (ISS) will continue during NASA's second shuttle flight of the year when Atlantis is launched on the STS-101 mission, the 98th flight in Shuttle program history.

Outfitted with a new "glass cockpit" and other state-of-the-art upgrades to key systems, Atlantis is scheduled to be launched from Complex 39-A at the Kennedy Space Center approximately 4:15 P.M. EDT April 24 at the start of a window of no longer than 10 minutes in duration. The precise launch time and duration of the launch opportunity will be narrowed within a week before the start of the mission to provide the best time for Atlantis to begin its two-day chase to catch up to the ISS. Atlantis last flew in space in support of the STS-86 mission in 1997. On STS-101, Atlantis will fly as the most updated Space Shuttle ever, with more than 100 new modifications incorporated during a 10-month period at Boeing's Palmdale, California Shuttle factory in 1998.

Seven astronauts, led by veteran Commander Jim Halsell (Col., USAF), will link up to the international outpost two days after launch and will spend six days docked to the ISS, four of which will be spent refurbishing and replacing components in both the Zarya and Unity modules. Two crew members will perform a six and a half hour space walk the day after docking to install a Russian "Strela" cargo boom on the outside of Zarya, as well as replace a faulty radio antenna associated with the early communications system on Unity and perform several other tasks in advance of space walks on future station assembly missions.

Halsell, who is making his fifth flight into space and third as a Commander, will be joined by veteran Pilot Scott Horowitz (Lt. Col., USAF), who is making his third flight.

Mission Specialists include Dr. Mary Ellen Weber, making her second flight, Jeff Williams (Lt. Col., USA), making his first trip into space, Jim Voss (Col., USA, ret.), embarking on his fourth flight, Susan Helms (Col., USAF), making her fourth flight, and veteran Russian cosmonaut Yuri Usachev, who is making his third flight into space and who has logged 376 days in space and six space walks during two previous missions aboard the Mir Space Station. Usachev and fellow cosmonaut Yuri Onufrienko hosted astronaut Shannon Lucid during Usachev's second flight on the Mir. Lucid went on to set a U.S. single spaceflight endurance mark of 188 days on that mission.

Usachev, Voss and Helms will return to the ISS next year as the second crew to live and work aboard the station. Permanent occupancy of the ISS is scheduled to begin in the fall by the Expedition One crew, William Shepherd, Yuri Gidzenko and Sergei Krikalev, who will be launched on a Russian Soyuz rocket from the Baikonur Cosmodrome in Kazakhstan.

Williams and Voss are the two space walkers during Atlantis' planned 10-day flight. Williams, who has no previous space walk experience, will carry the designation of EV 1 during the planned excursion outside Atlantis and will wear the suit marked with red stripes on the elbows and the knees. Voss will be designated EV 2 and will wear the pure white suit. He conducted one previous space walk during the STS-69 mission in 1995 lasting almost seven hours.

The STS-101 mission originally was designed to follow the launch of the Zvezda Service Module as the flight to outfit the Russian component as the early living quarters for crews aboard the ISS. When Zvezda's launch was delayed, Shuttle and Station managers agreed to fly Atlantis on two separate flights to the station this year, STS-101 to conduct maintenance and logistics work aboard the ISS in advance of Zvezda's arrival, and STS-106, to unload supplies onto Zvezda from both the Shuttle and a Russian Progress resupply vehicle. STS-106 is scheduled for launch in August, about five weeks after Zvezda's planned July launch on a Proton rocket from Baikonur.

The top priority of the docked phase of the mission is to replace four of six 800-ampere power-producing batteries in Zarya which are no longer operable, and its associated electronics for proper current regulation.

Zarya will receive additional new equipment including four cooling fans, three fire extinguishers, 10 smoke detectors and an on-board computer. A suspect radio frequency power distribution box (RFPDB) in Unity used as part of the early S-band communications system will be replaced during the time Atlantis is linked to the new international facility.

The crew plans to transfer almost one ton of equipment from a double Spacehab module housed at the rear of Atlantis' cargo bay into Zarya and Unity for use by the Expedition One crew later this year. Those logistical items include personal clothing and hygiene gear, medical and exercise equipment, computer equipment and printers, hardware for the eventual setup and activation of the station's Ku-band communications system and a centerline camera for Unity's common berthing mechanisms to which other ISS components will be mated. Four large bags of water will also be brought from Atlantis into the ISS for later use.

The cost for all of the hardware and logistical supplies being carried to the Station is approximately \$1.5 million. Slightly more than \$1.3 million of that total cost will be assumed by Russia for new or replacement Russian hardware, while the portion for new and or replacement U.S. hardware is \$162,000.

The next mission to expand the capacity of the International Space Station, will be the launch of the Zvezda Service Module in mid-July.

Adjustments to the official near term assembly sequence were agreed to by the International Partners and participants at a recent Space Station Control Board meeting. Representatives included the United States, Russia, Canada, Japan, the European Space Agency, Italy and Brazil.

The following is the updated near term assembly sequence through August 2001 with the no-earlier-than target launch dates. The complete assembly sequence can be viewed on NASA's Human Spaceflight Website at: <http://spaceflight.nasa.gov/station/assembly/flights/chron.html>

International Space Station Assembly Sequence March 2000 Update

Date	Flight	Launch Vehicle	Element(s)
Nov 20, 1998	1A/R	Russian Proton	'Zarya' Control Module
Dec 3, 1998	2A	Space Shuttle (STS-88)	'Unity' Connecting Module
May 27, 1999	2A.1	Space Shuttle (STS-96)	Spacehab - Logistics Flight
April 13, 2000	2A.2A	Space Shuttle (STS-101)	Spacehab - Maintenance Flt.
July 8-14, 2000	1R	Russian Proton	'Zvezda' service module
Aug 19, 2000	2A.2B	Space Shuttle (STS-106)	Spacehab - Logistics Flight
Sept 21, 2000	3A	Space Shuttle (STS-92)	Integrated Truss Structure (ITS) Z1; Pressurized Mating Adapter-3; Control Moment Gyros (CMGs)
Oct 30, 2000	2R	Russian Soyuz	Expedition 1 Crew launch
Nov 30, 2000	4A	Space Shuttle (STS-97)	Integrated Truss Structure(P6) Photovoltaic Module;Radiators
Jan 18, 2001	5A	Space Shuttle (STS-98)	'Destiny' laboratory module
Feb 9, 2001	4R	Russian Soyuz	Docking Compartment
Feb 15, 2001	5A.1	Space Shuttle (STS-102)	'Leonardo' Multi-Purpose Logistics Module (MPLM)
Apr 19, 2001	6A	Space Shuttle (STS-100)	'Rafaello' MPLM Station Remote Manipulator System
Apr 30, 2001	2S	Russian Soyuz	Soyuz spacecraft swap
May 17, 2001	7A	Space Shuttle (STS-104)	Airlock
June 21, 2001	7A.1	Space Shuttle (STS-105)	'Donatello' MPLM
Aug 23, 2001	UF-1	Space Shuttle (STS-109)	First utilization flight

If all goes as planned, Atlantis will conclude its mission at approximately 12:50 P.M. EDT on May 4 with a touchdown at the Shuttle Landing Facility at the Kennedy Space Center.

Updated: 04/06/2000



Atlantis OV104

Launch: Monday, April 24, 2000
4:15 PM (eastern time)

Mission Objectives

A categorical priority system is used to guide the ordering of key operations tasks and places the highest value on ensuring crew safety. The priorities for STS-101/2A.2a are:

1. ISS ingress/safety

- Take air samples
- Monitor carbon dioxide
- Deploy portable, personal fans
- Measure air flow
- Rework/modify ISS ducting
- Replace air filters
- Replace Zarya fire extinguishers, smoke detectors

2. Critical replacements/repairs/spares

- Replace four suspect batteries on Zarya
- Replaced failed or suspect electronics for Zarya's batteries
- Replace Radio Telemetry System memory unit
- Replace port early communications antenna
- Replace Radio Frequency Power Distribution Box
- Clear Space Vision System target

3. Incremental assembly/upgrades

- Complete assembly of Strela crane
- Install additional exterior handrails
- Set up center-line camera cable
- Install "Komparus" cable inserts
- Reseat the U.S. crane

4. Assembly parts & equipment

- Transfer U.S. hardware
- Transfer Russian hardware
- Provide EVA tools
- Supply IVA kit

5. Pre-position/stow equipment & provisions for future missions

6. Resupply

- Water and water transfer, stowage equipment
- Docking mechanism accessory kit
- Film and video tape for documentation
- Office supplies
- Personal items

7. Crew health maintenance

- Exercise equipment
- Medical support supplies
- Formaldehyde monitor kit
- Passive dosimetry system

8. Detailed test objectives

- Monitor cabin air
- SOAR

Options

If there is sufficient shuttle propellant following Atlantis' undocking from the ISS, a flyaround inspection will be performed prior to the Shuttle's final separation maneuver.

Crew

Commander:	James D. Halsell
Pilot:	Scott J. Horowitz
Mission Specialist 1:	Mary Ellen Weber
Mission Specialist 2:	Jeffrey N. Williams
Mission Specialist 3:	James S. Voss
Mission Specialist 4:	Susan J. Helms
Mission Specialist 5:	Yuri V. Usachev

Launch

Orbiter:	Atlantis OV104
Launch Site:	Kennedy Space Center Launch Pad 39A
Launch Window:	5 minutes
Altitude:	173 Nautical Miles
Inclination:	51.6 Degrees
Duration:	9 Days 20 Hrs. 36 Min.

Vehicle Data

Shuttle Liftoff Weight: 4519492 lbs.

Orbiter/Payload Liftoff Weight: 262565 lbs.

Orbiter/Payload Landing Weight: 224504 lbs.

Payload Weights

ICC 3,700 pounds

MARS 270 lb

Software Version: OI-27

Space Shuttle Main Engines

SSME 1: 2043

SSME 2: 2054

SSME 3: 2049

External Tank: ET-102

SRB Set: BI-100/RSRM-74

Shuttle Aborts

Abort Landing Sites

RTL: Kennedy Space Center Shuttle Landing Facility

TAL: Zaragoza

AOA: Edwards Air Force Base, California

Landing

Landing Date: 05/04/00

Landing Time: 12:50 PM (eastern time)

Primary Landing Site: Kennedy Space Center Shuttle Landing Facility

Payloads

Cargo Bay

BioTube Precursor Experiment

SPACEHAB

Integrated Cargo Carrier

Mission to America's Remarkable Schools

Space Experiment Module 6

In-Cabin

HTD 1403 Micro Wireless Instrumentation System (Micro WIS) HEDS Technology Demonstration

Crew Profile Menu

Commander: James D. Halsell

Jim Halsell (Col., USAF) is Commander for STS-101. Halsell will be responsible for overall mission success and safety during STS-101, as well as the rendezvous and docking of Atlantis to the International Space Station.

Halsell, 43, is making his fifth flight into space, having previously flown as Pilot on STS-65 in 1994 and STS-74 in 1995 and as Commander of STS-83 and 94 in 1997.



Ascent Seating: Flight Deck - Port Forward

Entry Seating: Flight Deck - Port Forward

Pilot: Scott J. Horowitz

Scott Horowitz (Lt. Col., USAF) is Pilot for STS-101.

Horowitz will be the intravehicular crew member during the space walk by Jeff Williams and Jim Voss during the flight, responsible for the choreography of the 6 ½ hour excursion outside Atlantis.

Horowitz will also help in the replacement of some of the equipment in the Unity module on the ISS and the inspection and installation of other systems in the Zarya module.

Horowitz, 43, is making his third flight into space after serving as Pilot on STS-75 in 1996 and STS-82 in 1997.



Ascent Seating: Flight Deck - Starboard Forward

Entry Seating: Flight Deck - Starboard Forward

IV1

Mission Specialist 1: Mary Ellen Weber

Dr. Mary Ellen Weber, 37, is Mission Specialist 1 during the STS-101 mission.

Weber will be responsible for the transfer of logistics items from

Atlantis to the International Space Station during the flight and will operate the Shuttle's robot arm during the space walk by Jeff Williams and Jim Voss.

Weber will ride upstairs on Atlantis' flight deck for both launch and landing and will be responsible for Spacehab systems for the cargo carrier housed in Atlantis' payload bay. Weber previously flew on the STS-70 mission in 1995.



Ascent Seating: Flight Deck - Starboard Aft

Entry Seating: Flight Deck - Starboard Aft

RMS

Mission Specialist 2: Jeffrey N. Williams

Jeff Williams (Lt. Col., USA) will serve as Atlantis' flight engineer during STS-101, which will be his first flight into space.

Williams, 42, who will be designated Mission Specialist 2, will be the lead space walker (EV 1) during the excursion he and Jim Voss will conduct to work on the International Space Station. He will wear the suit with the red stripes on the arms and knees of his space suit.

During the docked phase of the flight, Williams will transfer batteries and other electronics equipment into the Zarya module for installation as well as other logistics items.

Ascent Seating: Flight Deck - Center Aft

Entry Seating: Flight Deck - Center Aft

EV1



Mission Specialist 3: James S. Voss

Jim Voss (Col., USA, ret.) will make his fourth flight into space as Mission Specialist 3 during STS-101. He is also a member of the Expedition Two crew, which will be launched in 2001 for a three to four month stay aboard the International Space Station.

Voss, who conducted one space walk on STS-69, will join Jeff Williams as EV 2 for the 6 ½ hour space walk during STS-101 to work on the International Space Station. He will wear the pure white space suit.



Voss will also be responsible for air quality measures inside the ISS during docked operations and the replacement of equipment inside the Unity module. He will ride downstairs in Atlantis' middeck during launch and landing.

Voss, 51, previously flew on STS-44 in 1991, STS-53 in 1992 and STS-69 in 1995.

Ascent Seating: Mid Deck - Port

Entry Seating: Mid Deck - Port

EV2

Mission Specialist 4: Susan J. Helms

Susan Helms (Lt. Col., USAF), will make her fourth flight into space as Mission Specialist 4 during STS-101.

Helms, 42, is also a member of the Expedition Two crew, which will be launched in 2001 for a 3-4 month stay aboard the International Space Station. During STS-101, Helms will help conduct the replacement of a battery and associated electronic equipment in the Zarya module and will replace and inspect other equipment in both Zarya and the Unity module.

She will ride downstairs in Atlantis' middeck during launch and landing.

Ascent Seating: Mid Deck - Center

Entry Seating: Mid Deck - Center



Mission Specialist 5: Yuri V. Usachev

Yuri Usachev, 42, will serve as Mission Specialist 5 during STS-101. The veteran Russian cosmonaut has spent 376 days in space and has conducted six space walks during two long duration missions aboard the Mir Space Station.



Usachev will serve as the Commander of the Expedition Two crew along with Jim Voss and Susan Helms, which is scheduled for launch in 2001 for a 3-4 month stay on the International Space Station.

On STS-101, Usachev will be responsible for the replacement of a battery and associated electronic equipment in the Zarya module and will help replace and inspect other equipment in both Zarya and the Unity module. Usachev will join Helms and Voss downstairs in Atlantis' middeck for both launch and landing.

Ascent Seating: Mid Deck - Starboard

Entry Seating: Mid Deck - Starboard

Updated: 03/27/2000

Shuttle Reference and Data

Orbiter Upgrades

The 21st Century Space Shuttle: New Improvements

The space shuttle has undergone significant changes. From the inside out, thousands of advances in technology and enhanced designs have been incorporated into the shuttle since it was first launched. The result is a safer, more powerful and more efficient spacecraft. When the shuttle Atlantis launches on STS-101, it will be the most up-to-date space shuttle ever. From a new "glass cockpit" to main engines estimated to be three times safer, Atlantis is a far different vehicle from the one that first flew in 1985.

This year also will see the 100th space shuttle launch in history, a milestone for a spacecraft that has taken over 600 passengers and three million pounds of cargo to orbit. The shuttle fleet has spent almost two and a half years in space. But even the most-traveled shuttles remain young in the lifespan for which they were built. NASA is preparing for the possibility of flying the space shuttle for at least another decade, and future improvements are geared toward a goal of doubling shuttle safety by the year 2005.

The New "Glass Cockpit"

For the first time, on mission STS-101, 11 new full-color, flat-panel display screens in Atlantis's cockpit will replace 32 gauges and electromechanical displays and four cathode-ray tube displays. This new "glass cockpit," technically labeled the Multifunction Electronic Display Subsystem (MEDS), is 75 pounds lighter and uses less power than before; and its color displays facilitate pilot recognition of key functions. The new cockpit will be installed in all shuttles by 2002, setting the stage for the next cockpit improvement planned for 2005: a "smart cockpit" that reduces pilot workload during critical periods.

On STS-101, Atlantis will fly with more than 100 new modifications incorporated during a 10-month period at Boeing's Palmdale, Calif., facility in 1998. The airlock was relocated to the payload bay to prepare for International Space Station assembly flights; the communications system was updated; several weight reduction measures were installed; enhancements were made to add protection to the cooling system; and the crew cabin floor was strengthened. The shuttle Columbia is at the Palmdale factory this year receiving many of the same upgrades, including installation of the new "glass cockpit."

Future Shuttle Upgrades: Cutting Risk in Half by 2005

Enhancements now under development could double the shuttle's safety by 2005. New sensors and computer power in the main engines will "see" trouble coming a split second before it can do harm, allowing a safe engine shutdown. A new engine nozzle will eliminate the need for hundreds of welds and potential leaks. Electric generators for the shuttle's hydraulics will replace the highly volatile rocket fuel that now powers the system. And a next-generation "smart cockpit" will reduce the pilot's workload in an emergency, allowing the crew to better focus on critical tasks. Other improvements will make steering systems for the solid rocket boosters more reliable, make the manufacturing of solid propellant safer and increase the strength of external fuel tank welds.

"Smart Cockpit"--The new "glass cockpit" that will be initiated when Atlantis launches on STS-101 is the precursor of the "smart cockpit" planned for 2005. The enhanced displays of the "smart cockpit" will not fly the shuttle, but they will do much of the deductive reasoning required for a pilot to respond to a problem. By simplifying the pilot's job, this "smart cockpit" will allow astronauts to better focus on critical tasks in an emergency.

Better Main Engines--The space shuttle's main engines operate at greater extremes of temperature and pressure than any other machine. Since 1981, three overhauls of the original design have more than tripled estimates of their safety. Now, a fourth major overhaul will make them even safer by 2005. Planned improvements include a high-tech optical and vibration sensor system and computing power in the engines that detects trouble in advance. This advanced health monitoring system has sensors that will detect and track an almost microscopic flaw in an engine's performance in a split second, allowing the engine to be safely shut down before the situation can grow out of control. Also, the engine's main combustion chamber will be enlarged to reduce the pressures on internal components without reducing the thrust; and a new, simplified engine nozzle design will eliminate hundreds of welds--over 500 feet of them--and potential leaks.

Safer Hydraulic Power--Aside from the main engines and solid rocket boosters, the single highest risk shuttle subsystems are the auxiliary power units, generators that power the hydraulic systems. Today, these generators use a highly volatile and toxic rocket fuel. But recent advances in battery and electrical power technology--much of which was developed by the automotive industry--will replace that system by 2005, eliminating many hazards not only in flight but also on the ground. Electric motors, powered by a bank of lightweight batteries, will be developed to power the shuttle's hydraulic system, providing greater reliability for astronauts in flight and a safer workplace for ground crews.

Solid Rocket Boosters and External Tank Upgrades--Future improvements for the solid rocket boosters include a redesign of several valves, filters and seals in the steering system to enhance their reliability as well as studies of

the potential for an electrical system to power the booster hydraulics. In addition, changes in the solid rocket propellant manufacturing process will make the workplace safer for shuttle technicians. For the external tank, a new friction-stir welding technique will produce stronger and more durable welds throughout the structure.

Major Space Shuttle Improvements: A Brief History

April 1983, STS-6: A Lighter Fuel Tank--A redesigned lightweight external tank, 10,000 pounds lighter than the original design, flew on STS-6 in 1983, increasing the shuttle's cargo capacity by the same amount. In 1998, a super-lightweight external tank flew on STS-91, further reducing the tank's weight by 7,500 pounds and again increasing the shuttle's cargo capacity by the same amount. The super- lightweight tank is made of a Lockheed Martin-developed aluminum-lithium alloy that is not only lighter but also 30 percent stronger than the previous tank design.

September 1988, STS-26: Return to Flight--When Discovery returned the shuttle fleet to space following the Challenger accident, more than 200 safety improvements and modifications had been made. They included a major redesign of the solid rockets boosters, the addition of a crew escape and bailout system, stronger landing gear, more powerful flight control computers, updated inertial navigation equipment and several updated avionics units.

May 1992, STS-49: Endeavour's Maiden Voyage--Endeavour's first flight in 1992 was the debut of many shuttle improvements, including a drag chute to assist braking during landing, improved nosewheel steering, lighter and more reliable hydraulic power units, and updates to a variety of avionics equipment.

June 1992, STS-50: Extended-Duration Flights--Columbia was the first shuttle to be modified for allow long-duration flights and flew the first such mission in 1992. The modifications included an improved toilet, a regenerative system to remove carbon dioxide from the air, connections for a pallet of additional hydrogen and oxygen tanks to be mounted in the cargo bay, and extra stowage room in the crew cabin.

June 1995, STS-71: International Space Station Assembly--The first shuttle/Mir docking mission featured new shuttle changes that allowed it to dock with the Russian space station and prepare for assembly of the International Space Station. For the shuttle to dock with Mir and ISS, the airlock had to be moved from inside the cabin to the cargo bay on all orbiters except Columbia. Weight was also reduced through lightweight lockers, seats and other cabin equipment. Those changes, coupled with the super-lightweight external tank and performance improvements, increased the shuttle's cargo capacity by 16,000 pounds since 1992.

July 1995, STS-70: Space Shuttle Main Engines--Three major redesigns have more than tripled estimates of shuttle main engine safety. The first redesign (called the Block I engine), first flown in 1995, included changes to strengthen the oxygen turbopump and engine powerhead. The second overhaul, called the Block IIA engine, included a larger throat in main combustion chamber and first flew on STS-89 in January 1998. The third redesign, called the Block II engine, includes a stronger fuel turbopump and will fly for the first time in 2000. A fourth major overhaul is now planned to fly by 2005. Called the Block III engine, it will include further improvement of the combustion chamber and a simplified nozzle design.

Today's Space Shuttle--Since 1992, not only has the cargo capacity of the shuttle increased by 8 tons, the annual cost of operating the shuttle has decreased by 40 percent. Improvements in the main engines and other systems have reduced the estimated risks during launch by over 80 percent. And the number of all actual problems experienced by the shuttle in flight has decreased by 70 percent. Although they have flown for almost 20 years, the space shuttle orbiters have used only about a quarter of the lifetime for which they were designed. Discovery, which has flown the most missions, has completed 27 trips to space out of the 100 flights that all the shuttles were originally designed to complete.

Updated: 04/06/2000

STS-101

Flight Day Summary

DATE	TIME (EST)	DAY	MET	EVENT
04/24/00	4:14:50 PM	0	000/00:00:00	Launch
04/26/00	9:08:30 AM	3	001/16:53:40	ISS Docking
04/27/00	7:49:50 AM	4	002/15:35:00	EVA 1 Begins
04/28/00	6:14:50 AM	5	003/14:00:00	ISS Ingress Begins
04/29/00	4:44:50 AM	4	004/12:30:00	Reboost Begins
05/01/00	9:29:50 AM	8	006/17:15:00	ISS Egress Begins
05/02/00	3:59:19 AM	9	007/11:44:29	ISS Undock
05/04/00	11:46:25 AM	11	009/19:31:35	Deorbit Tig
05/04/00	12:50:50 PM	11	009/20:36:00	KSC Landing

Updated: 04/05/2000

STS-101

EVAs

STS-101 EVA

Overview

Mission Specialists James Voss and Jeffrey N. Williams will emerge from Space Shuttle Atlantis on Flight Day 4 of the second logistics mission to the International Space Station and make the last planned equipment changes prior to the arrival of the ISS's third element, Russia's Service Module Zvezda.

During the planned 6 1/2 hour space walk, they will complete the assembly of a Russian crane, test the integrity of a U.S. crane, replace a faulty communications antenna, install handrails, set up a camera cable and thus make ready for Zvezda's launch scheduled between July 8-14.

Mission Specialist Mary Ellen Weber will assist the two astronauts in maneuvering around the ISS as she operates the shuttle's robotic arm from inside Atlantis.

When Voss and Williams step from Atlantis' airlock, their first job will be to set up the foot restraints, tethers and other gear essential for safely executing activities in space. Then they can go to work.

First they will head to a workstation fixture on pressurized mating adapter (PMA) -1, the passageway connecting U.S. module Unity and Russian-built control module Zarya. The objects of their attention will be the fixture itself and a small, 209-pound U.S. space-walker-operated crane. Mission Specialists Tamara E. Jernigan and Daniel T. Barry placed it there during the first logistics mission (May 27-June 6, 1999: STS-96/2A.1).



Astronaut Tamara E. Jernigan totes part of Russian-built Strela ("Arrow") crane during first logistics mission STS-96/2A.1

The crane is not mounted to the fixture as tightly as expected. Although it poses no hazard to ISS components, Voss and Williams will inspect it and its fixture to ensure that neither is damaged or otherwise compromised. They will attempt to secure the crane in its housing, or relocate it to another, identical housing elsewhere on Zarya.

The two mission specialists will return to the airlock to get the spare Early Communications antenna and pick up a grapple fixture for the Russian crane Strela. From there they will go to the SPACEHAB Integrated Cargo Carrier (ICC) in the shuttle's cargo bay and obtain the rest of the components and tools required to complete assembly of Strela, begun by Jernigan and Barry on STS-96.

Finishing the assembly job will require about 100 different actions, steps and processes from the time Voss and Williams arrive at the ICC to get the crane's 45-ft telescoping boom to the completion of its assembly at its workstation on PMA-2. Strela, which is an updated version of the crane used on Mir, will be moved to Zarya during the August logistics mission, STS-106/2A.2b.

Next, Voss and Williams will replace an Early Communications (ECOMM) System antenna mounted on the port side of the common berthing mechanism at Unity's forward end-cone. It is one of two used for crew videoconferences, command activities and telemetry backup. The job of swapping out the device is relatively straightforward. It essentially involves

disconnecting four cable connectors, releasing the antenna from its mount, installing and reconnecting the new antenna, and checking its alignment.

Only two more tasks remain to be completed: installation of the centerline camera cable and attachment of eight handrails on Unity. The equipment is in a bag Jernigan and Barry left behind for Voss and Williams. Williams will retrieve the bag, then move to the connecting module's starboard side to meet Voss and give him the cable.



Handrails assist space-walking Astronauts in safely maneuvering around Unity

Installation of the cable will simply require that Voss secure it with wire ties to handrails already attached to Unity. Williams at the same time will use a power tool to securely bolt the new handrails to the module's forward, mid- and aft sections. When those tasks are completed, the EVA mission will be accomplished.

EVA Phase Elapsed Timeline for STS-101 EVA

Time	Event
0:00	Airlock Egress
0:15	EVA Sortie Setup
0:45	OTD Activities
1:30	EVA Sortie Setup continued
1:45	Strela Install
3:45	Early Comm Antenna
4:45	Node Handrail Install - Centerline Camera Cable
5:15	EVA Sortie Cleanup
6:15	Airlock Ingress
6:30	Repress - End of EVA

Updated: 04/04/2000

Payloads

BioTube Precursor Experiment

Payload Bay

Prime:

Principal Investigator: David Cox

Backup:

Overview

The BioTube Precursor Experiment will test newly developed technologies involved in the BioTube Magnetic Field Apparatus, a device for growing seeds in microgravity that will be flown on STS-107. This precursor experiment, which occupies half of a locker in the middeck of Atlantis, will evaluate the MFA's water delivery system and seed germination substrates.

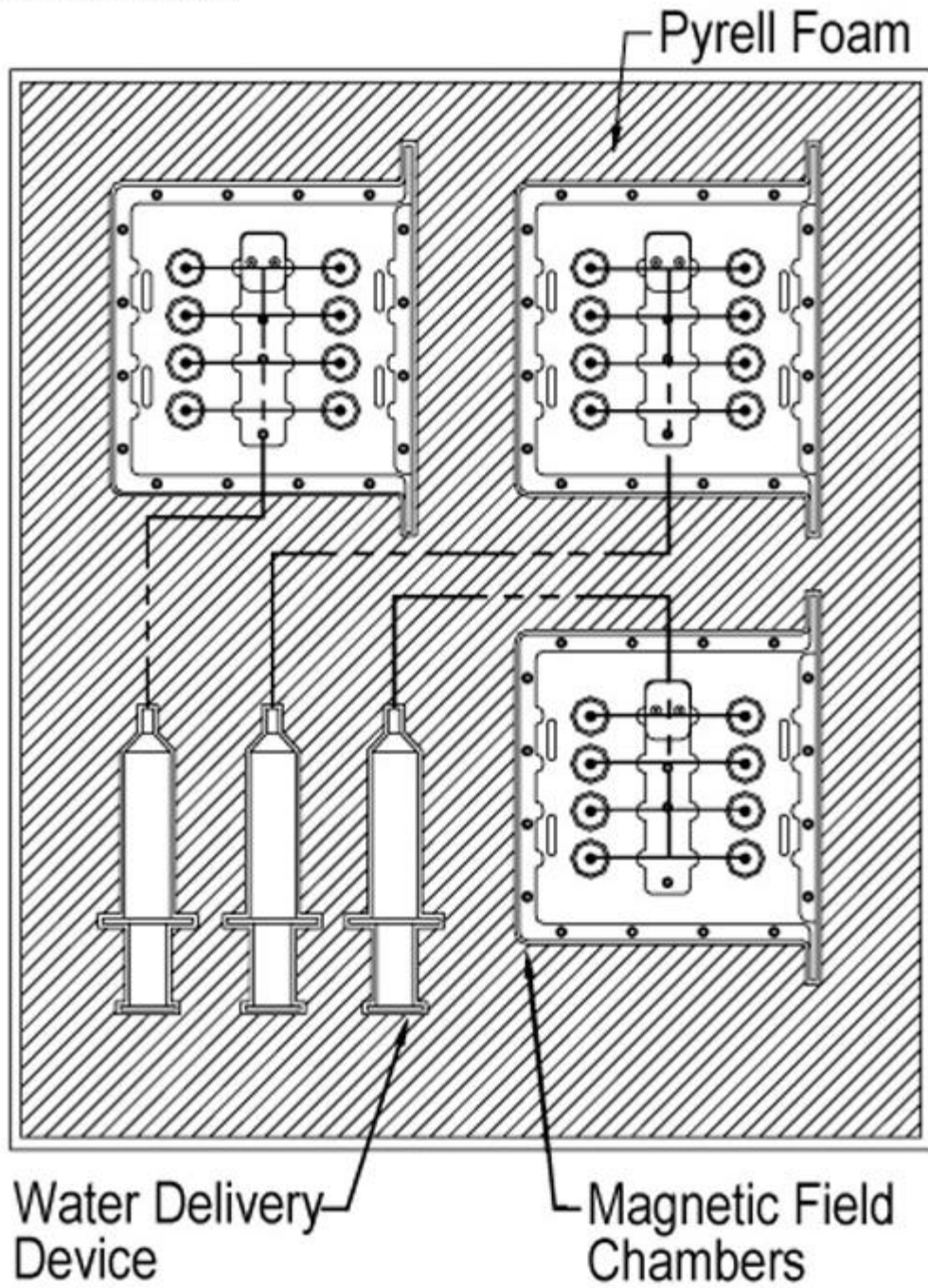
In plant growth experiments, a wicking material, such as germination paper, is sometimes used as a liquid distributor and temporary reservoir for germinating seeds. For the precursor experiment, wicking materials other than the standard germination paper will be tested for their ability to absorb, distribute, and retain water in microgravity without pooling around the seeds.

The flight will also demonstrate seedling growth as a function of temperature in the limited volume of the sealed growth chambers.

The payload consists of 24 seed cassettes housed in three Magnetic Field Chambers (MFCs), three syringe/tube mechanisms to deliver water, and three passive temperature-recording devices. The MFCs will be used on the BioTube MFA payload to expose plant materials to a magnetic field. For the precursor flight, aluminum blanks will be flown instead of magnets, so the precursor experiment will have no magnetic field.

Twice during the flight, a crew member will turn cranks on the three syringes to deliver water to the seed cassettes. The first watering will occur 30 to 36 hours before landing, the second 12 to 20 hours before landing.

BioTube



History/Background

When seeds are grown in the microgravity of space, the surface tension of water can cause excess water to pool on the surface of the seeds, which blocks oxygen transport around the seed. If the barrier forms before the seeds germinate, they will die.

Benefits

This investigation will enable researchers to develop devices for successfully growing plants in space to supply oxygen and food on long-duration space flights.

Updated: 04/06/2000

Payloads

HTD 1403 Micro Wireless Instrumentation System (Micro WIS)
HEDS Technology Demonstration
In-Cabin

Prime:

Backup:

Overview

HTD1403 will demonstrate the operational utility and functionality of the micro WIS on orbit, initially in the crew cabin of the Shuttle orbiter and then on the International Space Station.

The micro WIS consists of autonomous, tiny sensors for data acquisition. Two versions have been developed—a sensor/transmitter and a sensor/recorder. This HTD is designed to demonstrate the micro WIS transmitter and recorder.

The micro WIS sensor/recorder was first flown on STS-96 as part of the Integrated Vehicle Health Monitoring payload. This DTO will document requirements for the micro WIS sensor/recorder when it is not part of the IVHM.

One of the objectives of this HTD is to obtain meaningful real-time measurements for use in the orbiter's environmental control and life support system (ECLSS) operations. The micro WIS sensor/transmitter's simultaneous real-time measurements of air cabin temperatures in many interior compartments of the orbiter will help ECLSS operations personnel address issues encountered on STS-88 and early International Space Station flights. Currently, only one temperature reading in the aft flight deck of the orbiter is available for adjusting model predictions for real-time environments.

Micro WIS will also reduce the time it takes the crew to obtain on-orbit temperature measurements and will increase the capability to monitor temperatures over long periods. On busy Space Station assembly flights, the distances traveled and the time required to make the measurements can be prohibitive.

Micro WIS data will also be used to validate cabin air temperature models that are used for critical predictions of the dew point on early ISS missions, where orbiter cabin air exerts a significant influence on the entire station volume. Although the physical configuration of orbiter cabin air ducting has been changed significantly, the sensors have remained the same and some temperature data has never been available.

History/Background

In the past, space missions have been limited by the penalties associated with weight and integration costs. However, breakthroughs in the miniaturization of very low power radio transceivers have led to the introduction of a 1-inch-diameter micro wireless instrumentation system that can send temperature measurements to a laptop computer for five months.

Benefits

This breakthrough in miniaturization means significant cost, weight, and power savings for current and future space vehicles and ground test facilities and should revolutionize system design of future spacecraft. The micro WIS on-orbit demonstration should also increase the flexibility, reliability, and maintainability of data acquisition systems for spacecraft and lead to a reduction in vehicle turnaround time and increased reliability by eliminating cable connectors and by providing near-real-time reconfigurable data paths.

Updated: 04/06/2000

Payloads

Integrated Cargo Carrier

Payload Bay

3,700 pounds lbs.

Prime:

Backup:

Overview

Astronauts use the SPACEHAB Integrated Cargo Carrier to accommodate and support the transfer of exterior cargo from the shuttle orbiter to the International Space Station and from the station to work sites on the truss assemblies.

The ICC provides sufficient surface area in the orbiter cargo bay to carry approximately 8,000 pounds of cargo, which would otherwise have to be carried in the shuttle's cabin.

The ICC is an unpressurized flatbed pallet and keel yoke assembly housed in the orbiter's payload bay. Constructed of aluminum, it is 8 feet long, 15 feet wide and 10 inches thick, and is capable of carrying cargo on both faces of the pallet, both on top and below. There are no active interfaces (thermal, electrical or data) to the shuttle.

On Mission STS-101, the ICC will carry three cargoes: parts of the Russian Strela crane, the Space Integrated Global Positioning System/Inertial Navigation System (SIGI) Orbital Attitude Readiness (SOAR) payload, and the SPACEHAB-Oceanering Space System (SHOSS) box.

Strela is a Russian crane that will be mounted on the Zarya module to transport orbital replacement units and serve as a translational aid for extravehicular crew members on the Russian segment of the station. The Strela grapple fixture adapter and base were installed on STS-96; STS-101 will deliver the boom, ring and extension to complete the crane assembly.

SOAR is designed to be space station's primary global positioning source and the crew return vehicle's primary navigation source. (DTO 700-21 describes the SOAR test on STS-101 to demonstrate that SIGI can determine GPS attitude in space.)

The SHOSS is a trunk mounted on the ICC that can carry up to 400 pounds of tools and flight equipment. On STS-101, it will contain space-walking tools and logistics items to be transferred and stowed in the U.S. Unity module for use in future missions.

History/Background

This is the second flight of the Integrated Cargo Carrier. It last flew on STS-96.

Related Links: <http://spartans.gsfc.nasa.gov/>

Updated: 04/06/2000

Payloads

Logistics & Hardware Transfer

Prime:

Backup:

Overview

More than 3,000 pounds of hardware and supplies will accompany the Space Shuttle Atlantis when it begins its journey to the International Space Station to make final preparations for the planned addition of Russia's Service Module Zvezda this summer.



Atlantis will carry the tonnage in its mid-deck lockers and cargo bay. In addition, biotechnology and microgravity experiments will be housed in the crew compartment and the cargo bay's Space Experiment Module (SEM). The shuttle is expected to dock to the ISS on Flight Day 3 or 4, depending on the day of launch.

Mission Specialists will be preparing to move some 3,000 pounds of equipment and supplies from the shuttle into the ISS. One of the first tasks will be to test ISS air quality and to improve air circulation with the installation of new filters in the Zarya module before addressing power system issues in the Russian component.



First logistics mission astronauts Julie Payette (left) and Ellen Ochoa transfer supplies from shuttle Discovery to ISS.

The astronauts will open the hatch to the ISS on Flight Day 5 or 6 and will begin to collect air quality samples in Unity and Zarya for comparison with a sample from Atlantis. They also will measure air-circulation velocity and monitor carbon dioxide levels. Upon completion of those tasks, the crew members will break out their tools and rework some of the air ducts in Zarya to improve airflow. They will re-route some ducts, strengthen others, add new acoustic mufflers where required, and they'll swap out the contaminant filter in Zarya and the charcoal filter in Unity.

Once they determine that there has been a sufficient improvement in air circulation, the crew members will turn their attention to maintenance issues and cargo transfers.

Battery Change-Out

Problems with performance of at least one of Zarya's six "800A" storage batteries last summer during routine, ground-commanded battery maintenance led to a decision in August to take the battery off line from the ISS power system. The batteries collect energy during the daytime portion of the Station's orbit and provide power at night.

Battery current converter, left, and 800 A-1 battery with which the crew will replace failed units on Zarya during STS-101/2A.2a.

Battery No. 1 was tested a number of times during the following weeks and, in September, was removed from service with no plans for its attempted re-use. The Station can run on as few as three of the batteries with no significant impact on operations.

Battery No. 2 failed to discharge properly following routine maintenance in mid-November. It was taken off line and subsequently found to have failed altogether due to a problem with a voltage current regulator, which operates the charging and discharging function of the unit. Battery No. 1 was brought back on line in early December and operated normally at first. But after a week and a half, it once again began to discharge improperly and its use was discontinued except during short periods when necessary. In early March, it was discharged and taken off line for good until Atlantis' flight.

A problem that occurred in March during cycling of battery No. 3 led mission controllers in Moscow to disconnect the unit. They subsequently reconnected it and it appears to be operating normally, but the problem may have damaged it. Battery No. 5 is operational but is showing signs of degradation. Batteries 4 and 6 continue to operate normally.

Atlantis' crew will replace the four suspect, 163-pound batteries -Nos. 1, 2, 3 and 5 - as well as three of their 34-pound current converters and two of their 10-pound current converter controllers.



Komparus cables will provide additional control capabilities in Zarya.

The crew will complete the day's repair and replacement chores with the replacement in Zarya of one of the four Radio Telemetry System memory units, which has exceeded its design life. They will also install new "Komparus" command system cable inserts. The inserts enhance the capability of Zarya's computer to control the ISS command and measurement system flight equipment.

Other Maintenance Items

Three fire extinguishers in Zarya have reached the end of their design life. The crew will replace them, as well as 10 smoke detectors and four cooling fans. In Unity, they will replace the Radio Frequency Power Distribution Box implicated in the loss of a return link for the Early S-Band Communications System.



New fire extinguishers for Russian control module Zarya will replace three that are approaching the end of their service lives.

Cargo Transfer

The transfer of equipment and supplies between the shuttle and station will be managed by Weber and Williams. They will initiate the transfer process on Flight Day 5 or 6 and will continue through Flight Day 8 or 9.

As was the case with the first logistics flight last May, some of the cargo will be stowed aboard the ISS for use on future missions through STS-97/4A.

Among the supplies and equipment will be devices to remove humidity from the atmosphere, a cycle ergometer for the first Expedition, or resident, crew, four portable fan assemblies for STS-92/3A, and the Pressurized Mating Adapter (PMA)-3 duct extension kit for STS-97/4A.



Pressurized Mating Adapter (PMA)-3 before completion

Some of the cargo to be transferred will consist of everyday household items such as trash bags, can openers, sewing kits, bungee cords, note pads, tools and two dictionaries in both English-to-Russian and Russian-to-English language. Other items include:

US Hardware Transfer

- ISS crew health-care system elements
- Intra-vehicular activity seal kits
- Early space communications hardware
- IMAX camera
- Space walk equipment
- Printer and accessories
- Zarya enclosures (space-saving storage units)
- Treadmill assembly; resistance exercise system
- Common Berthing Mechanism Centerline Camera

Russian Hardware Transfer

- 800A Batteries
- Battery electronics
- Strela space-crane parts
- Radio telemetry unit

Updated: 04/06/2000

Payloads

Mission to America's Remarkable Schools

Payload Bay

270 lb lbs.

Prime: **Principal Investigator:** Dennis Chamberland, KSC

Backup:

Overview

This life sciences payload, sponsored by the NASA's Kennedy Space Center (KSC), contains 20 experiments from schools across the United States. The projects include seeds of various types reflight from SEEDS I and II as well as regionally important seed varieties such as lettuce and spinach. In addition, some schools submitted cellular specimens like chlorella and e.Coli (from commercial high school scientific supply houses).

Each experiment is placed in a 2-inch-diameter PVC tube inside a Complex Autonomous Payload (CAP)/Getaway Special (GAS) canister. The CAP/GAS is positioned in space shuttle cargo bay 13, port side, forward position.

MARS is a passive payload that does not require any power or crew interaction. Experiments are self-contained, back-filled with dry nitrogen at one atmosphere before launch, and sealed throughout the mission.

History/Background

The Complex Autonomous Payload project grew out of the Getaway Special program as a means to fly designated canisters as shuttle secondary payloads sponsored by NASA. These CAP experiments offer an inexpensive means for educational institutions to experiment in space. The GAS program also provides inexpensive access to space for non-NASA experiments. The GAS program allows educational institutions to develop a payload that fits in the NASA standard 5-cubic-foot GAS canister. The payload control weight is 270 pounds--100 pounds for the experiment and 170 pounds for the carrier. The Goddard Space Flight Center Wallops Island facility manages the GAS program.

The primary program objective is outreach to schools with an emphasis on NASA space life sciences, encouraging direct student participation in the space shuttle program. The program is managed by KSC and the NASA Space Life Sciences Outreach Program Intercenter Working Group.

Further information on the Getaway Special program, as well as other shuttle carrier programs managed by Goddard Space Flight Center, can be found at <http://sspp.gsfc.nasa.gov>.

Benefits

Encourages student participation and experimentation in space life sciences.

Updated: 03/27/2000

STS-101

Payloads

Space Experiment Module 6

Payload Bay

Prime:

Backup:

Overview

Ten passive experiments will fly on STS-101 as part of NASA's Space Experiment Module program, which is managed by the Goddard Space Flight Center's Wallops Flight Facility in Wallops Island, Va. The SEM program is an educational initiative to increase access to space for students in kindergarten through the university level. Since its first flight in 1995, SEM has allowed tens of thousands of students in the United States and other countries to fly their experiments in space. SEM-06 is a mixture of experiments from the United States and Argentina.

Idaho Tubers in Space: Shoshone-Bannock High School, Fort Hall, Idaho
Students will study the effect of space on Idaho tubers. The "Spuds in Space" experiment was developed by students from the Fort Hall Indian Reservation.

Seeds/CREPLD II: Purdue University, West Lafayette, Indiana
This experiment will study the effects of the space environment on seeds and on programmable logic devices.

Effects of Microgravity on Samples/GADGET: Glenbrook High School, Northbrook, Illinois
Students will determine the effects of the space environment on different types and colors of paint. Secondary experiment samples from other Illinois schools consist of dried shrimp, sand, hair, and feathers.

Yeast in Space: Brock Bridge Elementary, Laurel, Maryland
Students will study the effects of microgravity and temperature on yeast.

Effects of Cosmic Radiation: Benfield Elementary, Severna Park, Maryland
Students will study the effects of the space environment (cosmic radiation and microgravity) on various items, such as film, seeds, bulbs, yeast, beans, and popcorn.

Effects of Space on Fluids and Seeds: Technical School No. 469, Rosario, Argentina

Students will investigate the effects of the space environment on seeds and liquids such as colored fluids, oil, and water.

GERMINAR-2: National University of Patagonia, Argentina

This experiment will study the effects of the space environment on bee glue and various seeds.

Seeds and Sea Monkeys in Space: Rosario National University, Argentina

This experiment will study the effects of the space environment on Patagonic seeds (trees), humus, and Artemias Salina (sea monkeys).

Electronics and Magnetic Recording Devices: Rosario National University/St. Hilda's School, Argentina

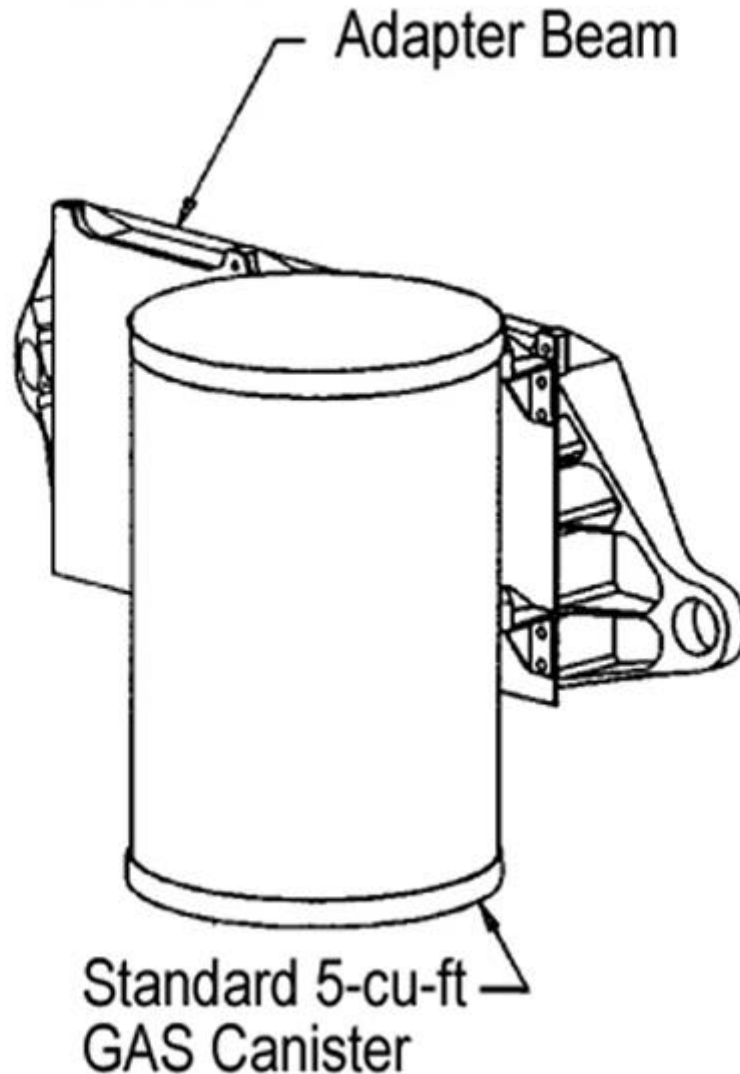
Students will study the effects of the space environment on electronics and magnetic chips such as those used in diskettes, CD ROMs, PC boards, and phone cards.

Cosmic Ray Detectors: Buenos Aires National School/Rosario National University, Argentina

This experiment will use thermoluminescent detectors to study the effect of cosmic rays.

SEM-06 uses a standard 5-cubic-foot Getaway Special (GAS) canister, mounted on an SSP/JSC-provided adapter beam in bay 13, port side, forward position in the orbiter payload bay. SEM-06 is passive: no batteries or power utilities are supplied by the orbiter.

SEM GAS Can



NASA began the Space Experiment Module (SEM) program in 1995 as an offshoot of the Getaway Special program, managed by the Shuttle Small Payloads Project at Goddard Space Flight Center in Greenbelt, Md., and the Wallops Flight Facility, Wallops Island, Va. Since 1982, GAS canisters have flown on the shuttle, offering economic access to space to a broader array of experimenters, particularly students. But participation was still somewhat limited by the high-level engineering skills required to design GAS experiments.

In 1995, the program directors started SEM to relieve students of the engineering burden and let them concentrate on creating their experiments. Since the module is equipped with electrical power, there is no need to engineer and build battery boxes, etc. Students of all ages can create, design, and build experiments with a little help from teachers or mentors. The experiments--which can be simple or complicated, active or passive--are placed in half-moon-shaped SEMs, ten of which are then stacked in a GAS canister.

This is the fourth flight of SEM.

More information about the Space Experiment Module program can be found at <http://www.wff.nasa.gov/~sspp/sem.html>.

Benefits

Economical and simplified access for space experimenters, especially students.

Interests young students in science and math.

Updated: 03/27/2000

Payloads

SPACEHAB

Payload Bay

Prime:

Backup:

Overview

U.S. and Russian hardware for the International Space Station will be carried in the SPACEHAB logistics double module, a pressurized laboratory in the shuttle's cargo bay that is connected to the middeck area of the orbiter. The seven-member crew will transfer more than 2,700 pounds of U.S. supplies and more than 2,200 pounds of Russian supplies from the module to the Unity and Zarya modules of the ISS.

The logistics include clothing and personal hygiene articles, health care supplies, exercise equipment, food, TV and movie equipment, a fire detection and suppression system, computers, and sensors. The hardware is stowed in SPACEHAB's numerous lockers and Soft Stowage bags and is mounted to the fronts of stowage racks and the module floor.

In addition to the logistics and maintenance cargo, SPACEHAB is carrying a commercial payload, the Self-Standing Drawer--Morphological Transition and Model Substances.

Designed to augment the shuttle orbiter's middeck, the SPACEHAB double module has a total cargo capacity of up to 10,000 pounds and contains systems necessary to support astronauts, such as ventilation, lighting, and limited power. Crew access to SPACEHAB is through a tunnel system located between the orbiter middeck and the SPACEHAB module.

Generally, two crew members are required for SPACEHAB operations. The SPACEHAB environmental control system is designed to nominally accommodate two crew members on a continuous basis. Additional crew members can be accommodated for brief periods at the expense of reduced cabin air heat rejection capability.

Microgravity Research Program

Working in partnership with the scientific community and commercial industry, NASA's Microgravity Research Program strives to increase understanding of the effects of gravity on biological, chemical, and physical systems.

Using both space flight- and ground-based experiments, researchers throughout the nation, as well as international partners, are working together to benefit economic, social, and industrial aspects of life for the United States and the entire Earth. U.S. universities, designated by NASA as commercial space centers, share these space advancements with U.S. industry to create new commercial products, applications, and processes.

Under the NASA Headquarters' Office of Life and Microgravity Sciences and Application, the Microgravity Research Program supports NASA's strategic plan in the Human Exploration and Development of Space Enterprise.

Microgravity research has been performed by NASA for more than 25 years. The term *microgravity* means a state of very little gravity. The prefix micro comes from the Greek word *mikros* ("small"). In metric terms, the prefix means one part in a million (0.000001).

Gravity dominates everything on Earth, from the way life has developed to the way materials interact. But aboard a spacecraft orbiting the Earth, the effects of gravity are barely felt. In this microgravity environment, scientists can conduct experiments that are all but impossible to perform on Earth. In this virtual absence of gravity as we know it, space flight gives scientists a unique opportunity to study the states of matter (solids, liquids, and gases) and the forces and processes that affect them.

Marshall Space Flight Center in Huntsville, Ala., is the lead center for NASA's Microgravity Research Program. The program manages Microgravity Science and Applications Project Offices at the Lewis Research Center in Cleveland, Ohio, and the Jet Propulsion Laboratory in Pasadena, Calif., and project offices at Marshall.

Under the project offices, the Microgravity Research Program is divided into nine major areas: five science disciplines, three research infrastructure programs, and the Space Products Development Office.

The science disciplines include biotechnology, fluid physics, materials science, combustion science and fundamental physics. The infrastructure activities include acceleration measurement, advanced technology, and the Glovebox Flight Program.

Marshall manages the Biotechnology Program and Material Science Program as well as the Glovebox Flight Program and the Space Products Development Office. Lewis Research Center manages the Fluid Physics, Combustion Science and Acceleration Measurement programs, while the Jet Propulsion Laboratory manages the Fundamental Physics and the Advanced Technology Development Program. As an element of the Biotechnology Program, Johnson Space Center manages bioreactor research in cell tissue growth.

In addition to the U.S. and Russian hardware for the International Space Station carried within the SPACEHAB module, additional unpressurized equipment for transfer to the space station will be carried on the new SPACEHAB integrated cargo carrier. The ICC, a cross-bay carrier that can accommodate 6,000 pounds of cargo, will be carrying parts of the Russian cargo crane known as Strela, the SPACEHAB Oceanering Space System box, and DTO 700-21.

History/Background

Early in the shuttle program, it became evident that the orbiter middeck is the best place to conduct crew-tended experiments in space. Each shuttle orbiter has 42 middeck lockers, but most are used to stow crew gear for a typical seven-day mission, leaving only seven or eight for scientific studies. But SPACEHAB, the first crew-tended commercial payload carrier, has initiated a new era of space experimentation.

The basic SPACEHAB module, which takes up a quarter of the orbiter's payload bay, is like a second middeck. The 10-foot-long pressurized module adds 1,100 cubic feet of pressurized work space that can hold 61 lockers or experiment racks or a combination of the two. The lockers are sized and equipped like those in the shuttle middeck so that experiments can be moved from one location to the other. The lockers accommodate up to 60 pounds of experiment hardware in about 2 cubic feet. A rack, which can be single or double, takes the space of ten lockers. Double racks are similar in size and design to those planned for the space station so that they can serve as test beds for future projects. A single rack can carry 655 pounds of hardware in 22.5 cubic feet.

A new double module, developed specifically for shuttle missions to Mir, will be used on STS-96. The double module, which can accommodate nearly 10,000 pounds of cargo, was created by joining two single modules.

The astronauts enter the module through a modified Spacelab tunnel adapter. SPACEHAB can accommodate two crew members on a continuous basis, but additional crew members can work in the module for brief periods. Power, command and data services, cooling, vacuum, and other utilities are supplied by orbiter crew cabin and payload bay resources.

SPACEHAB was privately developed and is privately operated by SPACEHAB, Inc., of Arlington, Va. STS-101 is the 14th flight of SPACEHAB.

Benefits

Using both space- and ground-based experiments, researchers throughout the nation, as well as international partners, are working together to develop economic, social, and industrial benefits for the United States and the entire Earth. U.S. universities, designated by NASA as commercial space centers, share these space advancements with U.S. industry to create new commercial products, applications, and processes.

Updated: 04/06/2000

Experiments

Biotechnology Ambient Generic (PCG-BAG)

Prime: **Principal Investigator:** Dr. Daniel Carter of New Century Pharmaceuticals Inc., Huntsville, Ala.
Backup: **Project Scientist:** Todd Holloway of NASA's Marshall Space Flight Center in Huntsville, Ala.

Overview

Objective:

The Protein Crystal Growth Biotechnology Ambient Generic payloads are designed to provide opportunities to grow high-quality protein crystals in microgravity.

Researchers use these crystals to understand the molecular structure of the proteins. This information can be used to develop drugs that someday may battle the effects of aging, and treat cancer, rheumatoid arthritis, periodontal disease, influenza, septic shock, emphysema and AIDS.

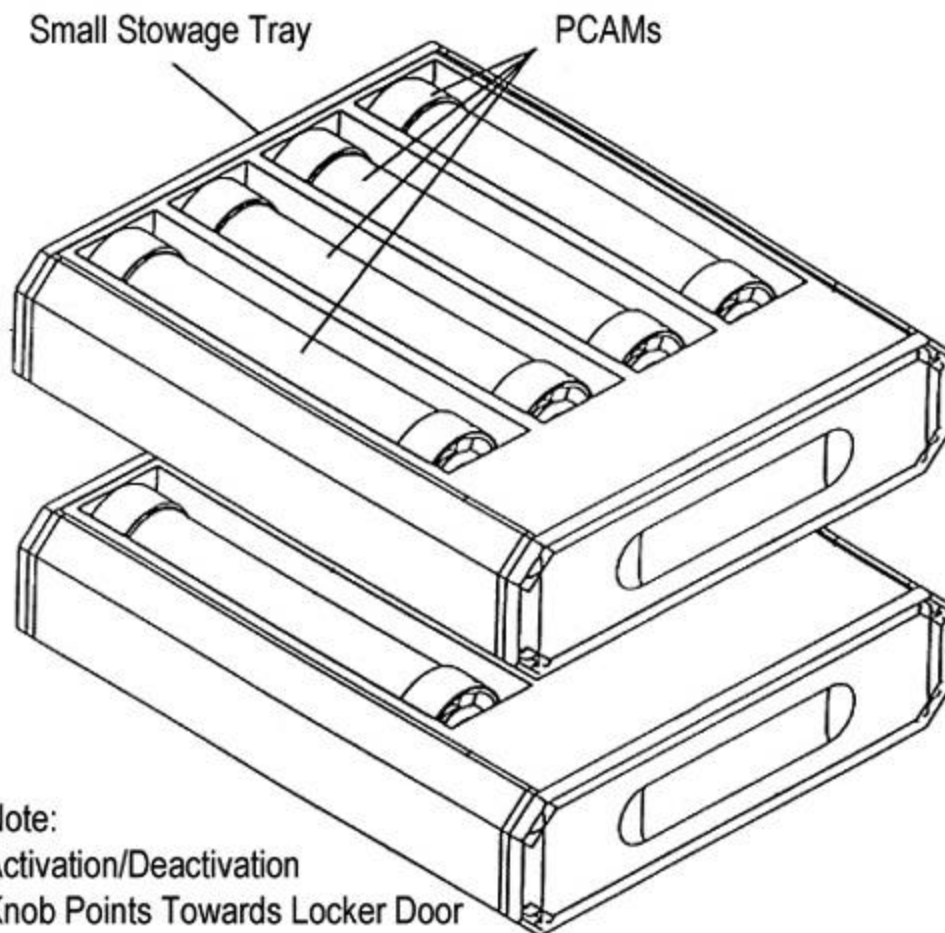
History/Background

While many protein crystal growth microgravity experiments are conducted with stringent temperature controls and extensive participation by shuttle crew members, the Biotechnology Ambient Generic experiments require minimal crew support.

The payloads are flown as stowage items in Atlantis's middeck, where they are subject to normal temperature conditions aboard the shuttle.

Shortly after lift-off, 504 individual experiments, stored in eight cylindrical containers, will be activated. Each experiment consists of two reservoirs separated by a flexible seal. When the seal is opened, the fluid in the protein drop will evaporate, starting the crystallization process. During the mission, this evaporation process will result in the growth of crystals that investigators can later study to determine the molecular structure of protein compounds.

Block I PCAM Single-Locker Configuration



Updated: 04/06/2000

Experiments

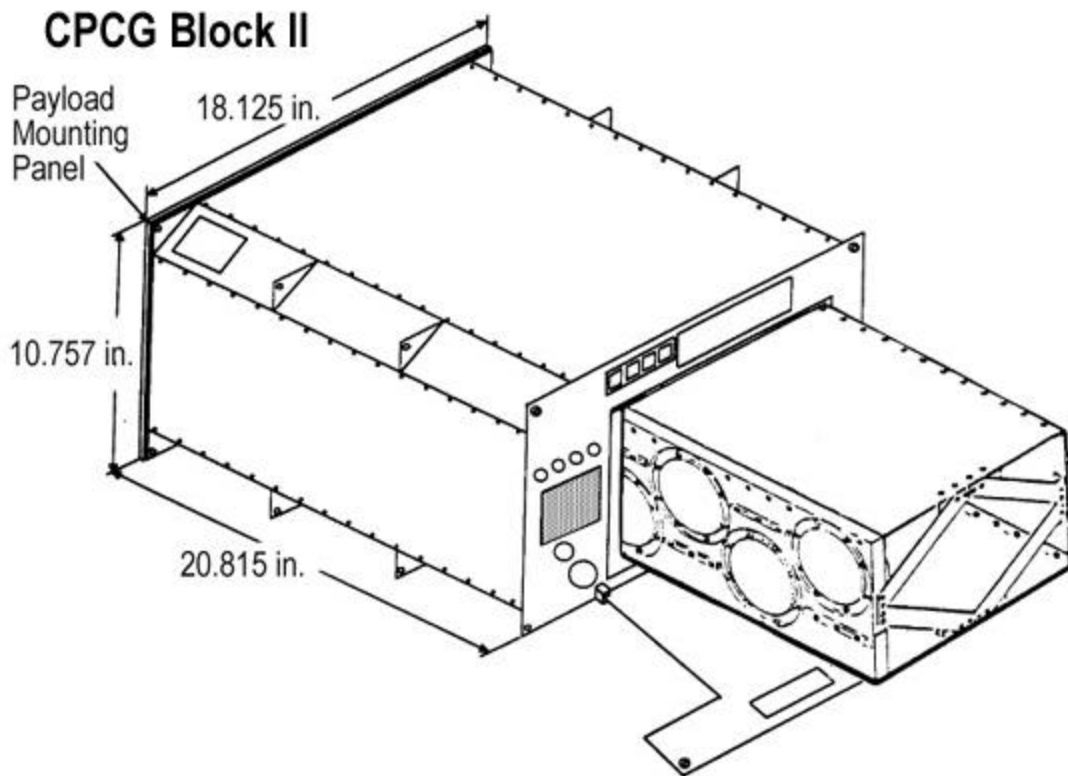
Commercial Protein Crystal Growth

Prime:	Principal Investigator: Dr. Larry DeLucas, director of the Center for Biophysical Science and Engineering at the University of Alabama at Birmingham.
Backup:	Project Scientist: Steve Lide of the Space Product Development Office at the Marshall Space Flight Center in Huntsville, Ala.

Overview

Through protein crystallography, protein crystals are grown in the laboratory and examined to determine their three-dimensional structure. That information is used to develop new drugs targeting the protein's structure. But crystals grown in Earth's gravity frequently have defects that make such analysis difficult or impossible. Space-grown crystals often have fewer defects and are larger than their Earth-grown counterparts, making them easier to examine.

The objective of the STS-101 protein crystal growth experiments is to grow crystals of human alpha interferon 2b--a protein pharmaceutical used against several afflictions, including human viral hepatitis B and C, melanoma, hairy cell leukemia, multiple myeloma and AIDS-related Kaposi's sarcoma. These alpha interferon samples will be crystallized under a range of conditions in sufficient size and quantity to assess the concentration and distribution of impurities. The protein is supplied by the Schering Plough Research Institute of Kenilworth, N.J. The experiments will be performed in the protein crystallization facility that stimulates crystal growth through changes in temperature.



This Commercial Protein Crystal Growth experiment aboard STS-101 is sponsored by the Center for Biophysical Science and Engineering at the University of Alabama at Birmingham. The center is part of NASA's Commercial Space Center Program, which forms a bridge between NASA and private industry to develop methods for crystallizing large molecules in microgravity.

By fostering such commercial projects aboard the space shuttle, NASA contributes to research that may lead to a new generation of drugs for treating diseases such as cancer, rheumatoid arthritis, periodontal disease, influenza, septic shock, emphysema and AIDS.

Updated: 04/06/2000

Experiments

Gene Transfer Experiment using ASTROCULTURE™ Glove Box (ASC-GB)

Prime:	Principal Investigator: Dr. Bratislav Stankovic, Wisconsin Center for Space Automation and Robotics, University of Wisconsin, Madison, Wis
Backup:	Project Scientist: Dr. Weijia Zhou, Wisconsin Center for Space Automation and Robotics, University of Wisconsin, Madison, Wis.

Overview

Objectives: The objective of the experiment is to evaluate a novel method for production of commercially important transgenic plant materials in microgravity using *Agrobacterium tumefaciens*. This transformation method, developed by the Wisconsin Center for Space Automation and Robotics and its industrial partner, was first tested during the STS-95 mission in October 1998. That testing found increased transformation efficiency in comparison to the identical ground experiments.

The gene transfer experiment to be conducted on the STS-101 mission is a cooperative venture between Producers' Natural Processing Corporation (PNP) and the Wisconsin Center for Space Automation and Robotics. PNP is a for-profit, privately owned company which: takes advantage of proprietary patented technologies in genetic transformation that will allow in planta production of proteins, enzymes, antibodies and vaccines; utilizes its relationship with prominent life science companies to deliver specific, identity-preserved crop attributes to the end user; and utilizes its new product development division and partners for the production of nutraceuticals, industrial enzymes, plant-based edible vaccines, and pharmaceutical intermediates.

Description: Crop production and utilization are undergoing significant modifications and improvements that emanate from adaptation of recently developed plant biotechnologies. One of these is the transfer of desirable genes from organisms to economically important crop species in a way that cannot be accomplished with traditional plant breeding techniques. These new technologies offer opportunities to improve crop species in various characteristics, as well as to use source materials for specific industrial applications, and hence, to convert plant materials that originally have no commercial values to plant materials that represent commercially important crop varieties.

For the STS-101 mission, a sample size of 1,000 soybean seeds will be co-incubated on orbit, with *Agrobacterium tumefaciens* containing the proprietary commercial gene and rs-GFP reporter gene that will be used for in vivo detection of transformation events that had occurred during the time the seeds were in microgravity. The results will be analyzed to determine the percentage of transient and stable transformation events, which will be compared with the results obtained during the STS-95 mission. During the STS-101 mission, the transformation procedures will be performed by the crew.

The ASTROCULTURE™ flight experiment series is sponsored by the Space Product Development Program managed at the Marshall Space Flight Center in Huntsville, Ala.

Updated: 04/06/2000

DTO/DSO/RMEs

Monitoring Latent Virus Reactivation and Shedding in Astronauts DSO 493

Prime:

Principal Investigator: Duane L. Pierson

Backup:

Overview

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

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

Updated: 03/27/2000

DTO/DSO/RMEs

Space Flight and Immune Function DSO 498

Prime:

Principal Investigator: Duane L. Pierson

Backup:

Overview

The objective of this DSO is to characterize the effects of space flight 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.

History/Background

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 Russian Mir space station and the International Space Station. The effects of space flight on the human immune system, which plays a pivotal role in warding off infections, is not fully understood. Understanding the changes in immune function caused by exposure to microgravity will allow researchers to develop countermeasures to minimize the risk of infection.

Updated: 03/27/2000

DTO/DSO/RMEs

Cabin Air Monitoring DTO 623

Prime:

Backup:

Overview

A solid sorbent sampler will continuously sample the orbiter's atmosphere throughout the flight for possible impurities due to outgassing and particulate matter. This is the 25th flight for this DTO.

Updated: 03/27/2000

DTO/DSO/RMEs

Crosswind Landing Performance DTO 805

Prime:

Backup:

Overview

This DTO will continue to gather data to demonstrate the capability to perform a manually controlled landing with a 90-degree, 10- to 15-knot steady-state crosswind. This DTO can be performed regardless of landing site or vehicle mass properties. During a crosswind landing, the drag chute will be deployed after nose gear touchdown when the vehicle is stable and tracking the runway centerline. This DTO has been manifested on 58 previous flights.

Updated: 03/27/2000

DTO/DSO/RMEs

SIGI Orbital Attitude Readiness DTO 700-21

Prime:
Backup:

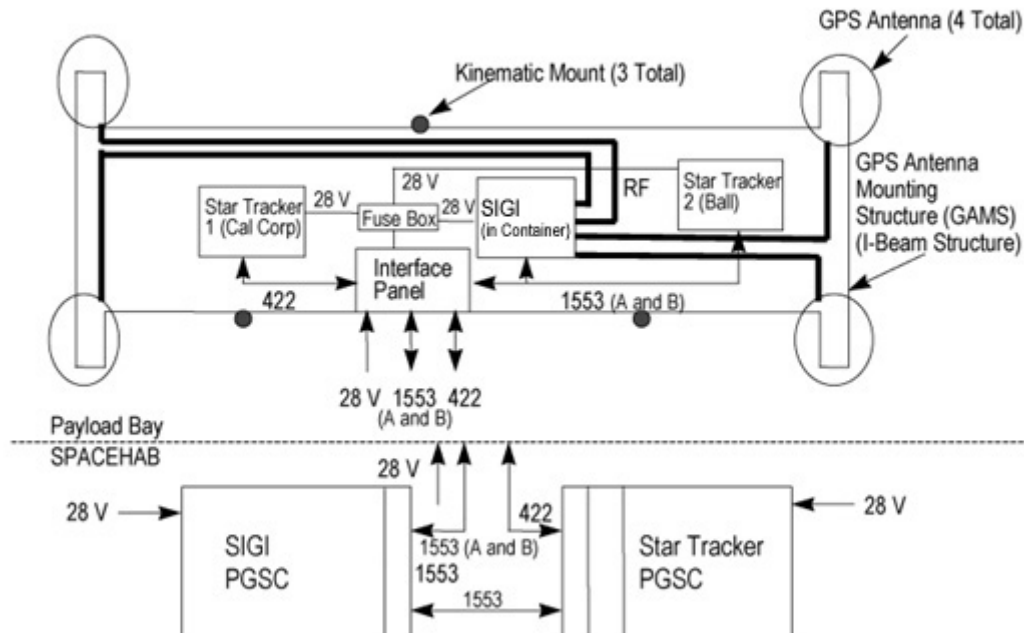
Overview

The objective of DTO 700-21 is to demonstrate the operation of the space integrated Global Positioning System/inertial navigation system (SIGI) on orbit. The SIGI is intended to be the primary GPS source for the International Space Station (ISS) and the primary navigation source for the crew return vehicle (CRV). The ability of the SIGI to perform GPS attitude determination in space has not been demonstrated. Data from this DTO will be used to evaluate the SIGI design before it is used on the ISS or CRV.

The payload consists of the SIGI in a pressurized container on a GPS antenna mounting structure (GAMS). The SIGI has RF connections to four antenna assemblies, which are mounted on the corners of the GAMS. A payload and general support computer (PGSC) located in SPACEHAB is used for commanding and data storage. Data from two star trackers mounted on the GAMS will be collected by a separate PGSC inside SPACEHAB.

This is the first flight of DTO 700-21.

SIGI Orbital Attitude Readiness Configuration



DTO/DSO/RMEs

Single-String Global Positioning System DTO 700-14

Prime:

Backup:

Overview

The purpose of this DTO is to evaluate the performance and operation of the Global Positioning System as a shuttle navigation aid during the ascent, on-orbit, entry and landing phases of the mission. A modified military GPS receiver processor and the orbiter's existing GPS antenna will be used for this evaluation.

This is the ninth flight for DTO 700-14. It was last flown on STS-96.

Updated: 03/27/2000

DTO/DSO/RMEs

Solid-State Star Tracker Size Limitations DTO 847

Prime:

Backup:

Overview

The objective of this DTO is to characterize the performance of the orbiter's solid-state star tracker with a large, bright target-the International Space Station. Laboratory tests show that the SSST can track significantly larger and brighter objects than the orbiter's other star tracker-the image-dissecting tracker. It may be necessary to use the SSST to track the station during orbiter passes because the ISS will reach a size that could prohibit the use of the image-dissecting tracker under certain conditions very early in the assembly sequence.

At a minimum, the SSST should be verified to track the ISS accurately up to 22.6 arcminutes, which is the largest size tested in the lab and the number that was used in analyzing potential problems that might be caused by the size of the ISS. If possible, the absolute upper limit to the size of an object that the SSST can track will be determined.

This DTO will be performed when the orbiter separates from the ISS but only if specific lighting conditions exist.

This is the second of three planned flights for this DTO.

Updated: 03/27/2000

Shuttle Reference and Data

Shuttle Abort Modes

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 (RTL).

ABORT TO ORBIT (ATO)

The ATO mode is designed to allow the vehicle to achieve a temporary orbit that is lower than the nominal orbit. This mode requires less performance and allows time to evaluate problems and then choose either an early deorbit maneuver or an orbital maneuvering system thrusting maneuver to raise the orbit and continue the mission.

ABORT ONCE AROUND (AOA)

The AOA is designed to allow the vehicle to fly once around the Earth and make a normal entry and landing. This mode generally involves two orbital maneuvering system thrusting sequences, with the second sequence being a deorbit maneuver. The entry sequence would be similar to a normal entry.

TRANSOCEANIC ABORT LANDING (TAL)

The TAL mode is designed to permit an intact landing on the other side of the Atlantic Ocean. This mode results in a ballistic trajectory, which does not require an orbital maneuvering system maneuver.

RETURN TO LAUNCH SITE (RTL)

The RTL mode involves flying downrange to dissipate propellant and then turning around under power to return directly to a landing at or near the launch site.

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 RTL, 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 RTL 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. RTL 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.

RETURN TO LAUNCH SITE OVERVIEW

The RTL abort mode is designed to allow the return of the orbiter, crew, and payload to the launch site, Kennedy Space Center, approximately 25

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.

TRANSATLANTIC LANDING ABORT OVERVIEW

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 OVERVIEW

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 OVERVIEW

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 ABORT OVERVIEW

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.

Updated: 03/27/2000

Shuttle Reference and Data

Space Shuttle External Tank

The external tank contains the liquid hydrogen fuel and liquid oxygen oxidizer and supplies them under pressure to the three space shuttle main engines in the orbiter during lift-off and ascent. When the SSMEs are shut down, the ET is jettisoned, enters the Earth's atmosphere, breaks up, and impacts in a remote ocean area. It is not recovered.

The largest and heaviest (when loaded) element of the space shuttle, the ET has three major components: the forward liquid oxygen tank, an unpressurized intertank that contains most of the electrical components, and the aft liquid hydrogen tank. The ET is 153.8 feet long and has a diameter of 27.6 feet.

The ET is attached to the orbiter at one forward attachment point and two aft points. In the aft attachment area, there are also umbilicals that carry fluids, gases, electrical signals and electrical power between the tank and the orbiter. Electrical signals and controls between the orbiter and the two solid rocket boosters also are routed through those umbilicals.

Liquid Oxygen Tank

The liquid oxygen tank is an aluminum monocoque structure composed of a fusion-welded assembly of preformed, chem-milled gores, panels, machined fittings and ring chords. It operates in a pressure range of 20 to 22 psig. The tank contains anti-slosh and anti-vortex provisions to minimize liquid residuals and damp fluid motion. The tank feeds into a 17-inch-diameter feed line that conveys the liquid oxygen through the intertank, then outside the ET to the aft right-hand ET/orbiter disconnect umbilical. The 17-inch-diameter feed line permits liquid oxygen to flow at approximately 2,787 pounds per second with the SSMEs operating at 104 percent or permits a maximum flow of 17,592 gallons per minute. The liquid oxygen tank's double-wedge nose cone reduces drag and heating, contains the vehicle's ascent air data system (for nine tanks only) and serves as a lightning rod. The liquid oxygen tank's volume is 19,563 cubic feet. It is 331 inches in diameter, 592 inches long and weighs 12,000 pounds empty.

Intertank

The intertank is a steel/aluminum semimonocoque cylindrical structure with flanges on each end for joining the liquid oxygen and liquid hydrogen tanks. The intertank houses ET instrumentation components and provides an umbilical plate that interfaces with the ground facility arm for purge gas supply, hazardous gas detection and hydrogen gas boiloff during ground operations. It consists of mechanically joined skin, stringers and machined

panels of aluminum alloy. The intertank is vented during flight. The intertank contains the forward SRB/ET attach thrust beam and fittings that distribute the SRB loads to the liquid oxygen and liquid hydrogen tanks. The intertank is 270 inches long, 331 inches in diameter and weighs 12,100 pounds.

Liquid Hydrogen Tank

The liquid hydrogen tank is an aluminum semimonocoque structure of fusion-welded barrel sections, five major ring frames, and forward and aft ellipsoidal domes. Its operating pressure range is 32 to 34 psia. The tank contains an anti-vortex baffle and siphon outlet to transmit the liquid hydrogen from the tank through a 17-inch line to the left aft umbilical. The liquid hydrogen feed line flow rate is 465 pounds per second with the SSMEs at 104 percent or a maximum flow of 47,365 gallons per minute. At the forward end of the liquid hydrogen tank is the ET/orbiter forward attachment pod strut, and at its aft end are the two ET/orbiter aft attachment ball fittings as well as the aft SRB/ET stabilizing strut attachments. The liquid hydrogen tank is 331 inches in diameter, 1,160 inches long, and has a volume of 53,518 cubic feet and a dry weight of 29,000 pounds.

ET Thermal Protection System

The ET thermal protection system consists of sprayed-on foam insulation and premolded ablator materials. The system also includes the use of phenolic thermal insulators to preclude air liquefaction. Thermal isolators are required for liquid hydrogen tank attachments to preclude the liquefaction of air-exposed metallic attachments and to reduce heat flow into the liquid hydrogen.

ET Hardware

Each propellant tank has a vent and relief valve at its forward end. This dual-function valve can be opened by ground support equipment for the vent function during prelaunch and can open during flight when the ullage (empty space) pressure of the liquid hydrogen tank reaches 38 psig or the ullage pressure of the liquid oxygen tank reaches 25 psig.

The liquid oxygen tank contains a separate, pyrotechnically operated, propulsive tumble vent valve at its forward end. At separation, the liquid oxygen tumble vent valve is opened, providing impulse to assist in the separation maneuver and more positive control of the entry aerodynamics of the ET.

There are eight propellant-depletion sensors, four each for fuel and oxidizer. The fuel-depletion sensors are located in the bottom of the fuel tank. The oxidizer sensors are mounted in the orbiter liquid oxygen feed line manifold downstream of the feed line disconnect. During SSME thrusting, the orbiter general-purpose computers constantly compute the instantaneous mass of the vehicle due to the usage of the propellants. Normally, main engine cutoff is based on a predetermined velocity; however, if any two of the fuel or

The locations of the liquid oxygen sensors allow the maximum amount of oxidizer to be consumed in the engines, while allowing sufficient time to shut down the engines before the oxidizer pumps cavitate (run dry). In addition, 1,100 pounds of liquid hydrogen are loaded over and above that required by the 6:1 oxidizer/fuel engine mixture ratio. This assures that MECO from the depletion sensors is fuel-rich; oxidizer-rich engine shutdowns can cause burning and severe erosion of engine components.

Four pressure transducers located at the top of the liquid oxygen and liquid hydrogen tanks monitor the ullage pressures.

Each of the two aft external tank umbilical plates mate with a corresponding plate on the orbiter. The plates help maintain alignment among the umbilicals. Physical strength at the umbilical plates is provided by bolting corresponding umbilical plates together. When the orbiter GPCs command external tank separation, the bolts are severed by pyrotechnic devices.

The ET has five propellant umbilical valves that interface with orbiter umbilicals: two for the liquid oxygen tank and three for the liquid hydrogen tank. One of the liquid oxygen tank umbilical valves is for liquid oxygen, the other for gaseous oxygen. The liquid hydrogen tank umbilical has two valves for liquid and one for gas. The intermediate-diameter liquid hydrogen umbilical is a recirculation umbilical used only during the liquid hydrogen chill-down sequence during prelaunch.

The ET also has two electrical umbilicals that carry electrical power from the orbiter to the tank and the two SRBs and provide information from the SRBs and ET to the orbiter.

A swing-arm-mounted cap to the fixed service structure covers the oxygen tank vent on top of the ET during the countdown and is retracted about two minutes before lift-off. The cap siphons off oxygen vapor that threatens to form large ice on the ET, thus protecting the orbiter's thermal protection system during launch.

ET Range Safety System

A range safety system provides for dispersing tank propellants if necessary. It includes a battery power source, a receiver/decoder, antennas and ordnance.

Various parameters are monitored and displayed on the flight deck display and control panel and are transmitted to the ground.

The contractor for the external tank is Martin Marietta Aero space, New Orleans, La. The tank is manufactured at Michoud, La. Motorola, Inc., Scottsdale, Ariz., is the contractor for range safety receivers.

Shuttle Reference and 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 T_i

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: 03/29/2000

Shuttle Reference and 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 (41 statute miles). SRB impact occurs in the ocean approximately 122 nautical miles (141 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.

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 gimballed 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

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 servoactuator 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.

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: 03/29/2000

Shuttle Reference and Data

Space Shuttle Super-Lightweight Tank (SLWT)

The super-lightweight external tank (SLWT) made its first shuttle flight June 2, 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 percent stronger and 5 percent 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: 03/29/2000

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 Shuttle 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://shuttle.nasa.gov>

If that address is busy or unavailable, Shuttle Information is available through the Office of Space Flight Home Page:

<http://www.hq.nasa.gov/osf/>

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>

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

<http://www.nasa.gov/today.html>

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

<http://www.nasa.gov/ntv>

Status reports, TV schedules and other information also are available from the NASA headquarters FTP (File Transfer Protocol) server, <ftp.hq.nasa.gov>. Log in as anonymous and go to the directory /pub/pao. Users should log on with the user name "anonymous" (no quotes), then enter their E-mail address as the password. Within the /pub/pao directory there will be a "readme.txt" file explaining the directory structure:

- * Pre-launch status reports (KSC): <ftp.hq.nasa.gov/pub/pao/statrpt/ksc>
- * Mission status reports (KSC): <ftp.hq.nasa.gov/pub/pao/statrpt/jsc>
- * Daily TV Schedules: <ftp.hq.nasa.gov/pub/pao/statrpt/jsc/tvsked>.

NASA Spacelink, a resource for educators, also provides mission information via the Internet. Spacelink may be accessed at the following address:

<http://spacelink.nasa.gov>

Access by CompuServe

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

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SHUTTLE FLIGHTS AS OF MAY 2000

97 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 72 SINCE RETURN TO FLIGHT

					
					
STS-93 07/23/99 - 07/27/99		STS-103 12/19/99 - 12/27/99			
STS-90 04/17/98 - 05/03/98		STS-96 05/27/99 - 06/06/99			
STS-87 11/19/97 - 12/05/97		STS-95 10/29/98 - 11/07/98			
STS-94 07/01/97 - 07/17/97		STS-91 06/02/99 - 06/12/98			
STS-83 04/04/97 - 04/08/97		STS-85 08/07/97 - 08/19/97			
STS-80 11/19/96 - 12/07/96		STS-82 02/11/97 - 02/21/97			
STS-78 06/20/96 - 07/07/96		STS-70 07/13/95 - 07/22/95			
STS-75 02/22/96 - 03/09/96		STS-63 02/03/95 - 02/11/95	STS-86 09/25/97 - 10/06/97		
STS-73 10/20/95 - 11/05/95		STS-64 09/09/94 - 09/20/94	STS-84 05/15/97 - 05/24/97		
STS-65 07/08/94 - 07/23/94		STS-60 02/03/94 - 02/11/94	STS-81 01/12/97 - 01/22/97		
STS-62 03/04/94 - 03/18/94		STS-51 09/12/93 - 09/22/93	STS-79 09/16/96 - 09/26/96		
STS-58 10/18/93 - 11/01/93		STS-56 04/08/83 - 04/17/93	STS-76 03/22/96 - 03/31/96		
STS-55 04/26/93 - 05/06/93		STS-53 12/02/92 - 12/09/92	STS-74 11/12/95 - 11/20/95		
STS-52 10/22/92 - 11/01/92		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-50 06/25/92 - 07/09/92		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-40 06/05/91 - 06/14/91		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-35 12/02/90 - 12/10/90	STS-51L 01/28/86	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-32 01/09/90 - 01/20/90	STS-61A 10/30/85 - 11/06/85	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-28 08/08/89 - 08/13/89	STS-51F 07/29/85 - 08/06/85	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-61C 01/12/86 - 01/18/86	STS-51B 04/29/85 - 05/06/85	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-9 11/28/83 - 12/08/83	STS-41G 10/05/84 - 10/13/84	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-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	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-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51-G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89	STS-61 12/02/93 - 12/13/93	
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51-D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89	STS-57 06/21/93 - 07/01/93	
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51-C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88	STS-54 01/13/93 - 01/19/93	
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	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-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
(27 flights)

OV-104
Atlantis
(20 flights)

OV-105
Endeavour
(14 flights)