ENDEAVOUR: DELIVERING SOLAR ARRAYS TO THE INTERNATIONAL SPACE STATION

STS-97

BOEING

NASA

USA
United Space Alliance

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Mission Overview

ENDEAVOUR'S FLIGHT HELPS THE STATION SPREAD ITS WINGS

During 10 days punctuated by space flight firsts, the Space Shuttle Endeavour on mission STS-97 will see the International Space Station spread its wings -- giant solar arrays that will quintuple the station's electrical power, enabling future unparalleled research.

The 240-foot solar arrays to be attached and unfolded by Endeavour's international crew of five – Commander Brent Jett, Pilot Mike Bloomfield and Mission Specialists Joe Tanner, Carlos Noriega and Canadian Space Agency astronaut Marc Garneau – will be the longest structure to ever fly in space. Endeavour will carry aloft the United States-developed solar arrays, associated electronics, batteries, cooling radiator, and support structure. The entire 17-ton package is called the P6 Integrated Truss Segment, and it will be the heaviest and largest element yet delivered to the station aboard a Shuttle.

The addition of the huge solar arrays – only the first of three identical such sets that will be attached to the station in coming years -- will clearly distinguish the International Space Station from any predecessor spacecraft. They will provide the station with more electrical power, a key to successful modern research, than anything that has flown before. Endeavour also will be the first Space Shuttle to visit an inhabited International Space Station, although the Shuttle crew and station crew of Commander Bill Shepherd, Pilot Yuri Gidzenko and Flight Engineer Sergei Krikalev will not greet one another until the hatches are fully opened between the spacecraft on the seventh day of the mission.

Endeavour is targeted for launch on STS-97 at 10:05 p.m. EST from the Kennedy Space Center, Florida, at the opening of a launch window that extends for between two to five minutes. After two days spent slowly closing in on the complex and checking out equipment, Jett will maneuver Endeavour to dock with the International Space Station just before 2 p.m. on Dec. 2, given an on-time launch.

Immediately after docking, Garneau will use the shuttle's 50-foot, Canadian-built robotic arm to initially lift the truss segment a few feet out of the shuttle cargo bay, holding it in position there overnight to control its temperature. Also, the Shuttle crew will open the station's outermost hatch and stow some early supplies in an outer compartment of the station to await retrieval later in the mission by the Expedition One crew.

On the following day, the crew will begin installing the solar arrays on the station, with Tanner and Noriega conducting the first of two planned six and a half hour space walks. With Tanner and Noriega assisting from outside, Garneau will use the robotic arm to attach the truss segment package, including the folded arrays and electronics, atop a smaller exterior framework already on the station. Tanner and Noriega will visually assist Garneau to properly align the new segment. The two space walkers will tighten attachment bolts to ensure the P6 truss is mechanically secure. Next, they will connect umbilicals for power and data between the new equipment and the rest of the station, as well as release various restraints that were in place to protect equipment during the Shuttle's launch. Near the end of the first space walk, the crew will send commands to begin deploying the solar arrays, folded for launch into a box only 20 inches thick, to their full outstretched length.

A second space walk by Tanner and Noriega on the sixth day of the mission will move a communications antenna to a location high on the new truss segment. During the last half of the space walk, they will prepare the station for the next shuttle visit that will deliver the first laboratory, the United States' Destiny lab, in January 2001. The capability exists to add a third space walk by Tanner and Noriega to the mission if needed.

The Shuttle and station crews will greet one another for the first time on the seventh day of the mission as they fully open the hatches between the two spacecraft. The crews will spend two days working together, transferring supplies and equipment back and forth. Endeavour's visit and the power from the new solar arrays will allow the station crew to begin conducting some of the first experiments aboard the station after Endeavour departs. Those experiments will include: student experiments conducted in conjunction with the national JASON education project that will study the effects of space on soybean and corn seeds; an experiment developed by the Air Force and the Massachusetts Institute of Science and Technology that will study new control mechanisms for satellites; and several medical evaluations that will study the effectiveness of exercise on the station's treadmill and other exercise equipment.

Based an on-time launch on Nov. 30, Bloomfield is scheduled to undock Endeavour from the station just after noon CST on Dec. 8, performing a full-circle flyaround of the complex before departing the vicinity. The day after the undocking will be spent preparing Endeavour for landing, and the Shuttle's touchdown would occur at the Kennedy Space Center about 5:46 p.m. CST on Dec. 10, nine days, 20 hours and 41 minutes after launch.

STS-97 will be the 15th flight of Endeavour and the 101st Space Shuttle mission.

An Overview of STS-92

Flight Day 1: On Flight Day 1, Endeavour and its five-member crew will launch from the Kennedy Space Center. Once on orbit, they will climb out of their launch and entry suits, open the payload bay doors, reconfigure computers and other equipment on board, and activate a three-dimensional IMAX camera. The astronauts will go to sleep approximately five hours after launch.

Flight Day 2: Flight Day 2 is a day of preparation for Endeavour's crew as the astronauts activate and check out the Shuttle's robotic arm using it to conduct a survey of the cargo latched into the payload bay; check out the Space Vision System that will provide Marc Garneau with visual cues as he unberths the P6 truss from the payload bay on Flight Day 3; inspect the space suits that will be worn by Astronauts Joe Tanner and Carlos Noriega on Flight Days 4 and 6; and begin activating wireless instrumentation systems that provide temperature data on the cargo mounted in Endeavour's payload bay.

Flight Day 3: With an on-time launch on November 30, Flight Day 3 will see Endeavour dock to a port on the Unity module of the International Space Station shortly before 2 p.m. CST. After docking, the P6 integrated truss – containing the large solar arrays – will be lifted out of Endeavour's payload bay and moved into an overnight 'parking' position. The astronauts will also begin preparing the docking port for their later entry into the ISS.

Flight Day 4: Astronauts Joe Tanner and Carlos Noriega will take the first of their two scheduled space walks to install the solar arrays that will provide increased power to the U.S. portions of the space station.

Flight Day 5: The astronauts will get some rest following the first of their two scheduled space walks, and begin preparing for their entry into the space station on Flight Day 7.

Flight Day 6: Tanner and Noriega will take their second space walk on Flight Day 6, relocating a communications antenna to the top of the P6 truss that was installed on Flight Day 4. They will also begin preparing the Station for the arrival of the U.S. laboratory Destiny, by relocating some foot restraints and power cables that will be used by the STS-98 crew early next year.

Flight Day 7: After spending six days attached to the International Space Station, the STS-97 and Expedition One (resident) crew will swing open the hatches between Endeavour and the ISS to greet one another and transfer equipment and supplies.

Flight Day 8: With Pilot Mike Bloomfield at the controls, Endeavour will undock from the ISS, flying one full circle around it before firing the Shuttle's engines to begin its final departure from the station. The rest of the day will be spent preparing Endeavour for its return to Earth on Flight Day 10.

Flight Day 9: Endeavour's astronauts begin the process of heading home on Flight Day 9 as they put away the tools, hardware, checklists, cameras and other materials they have used while in space. In addition, Brent Jett, Mike Bloomfield and Marc Garneau will conduct the routine day-before-landing checks of the Shuttle's small reaction control system jets and aero surfaces to ensure their health prior to landing.

Flight Day 10: Flight Day 10 should see Endeavour return to the Kennedy Space Center and conclude its mission to help the growing space station spread its wings. On board, the astronauts will finish putting away last-minute items, climb into their orange launch and entry suits and close the payload bay doors. When they receive a "go" decision from the Flight Control Team in Houston, they will fire Endeavour's engines in a deorbit burn to bring the Shuttle and its five-member crew out of orbit and back to Earth.

Crew Profile Menu

Commander: Brent W. Jett

Brent Jett (Cdr., USN), 42, leads an all-veteran crew on Endeavour's flight to install the sprawling U.S. solar arrays on the International Space Station (ISS) during the STS-97 mission.

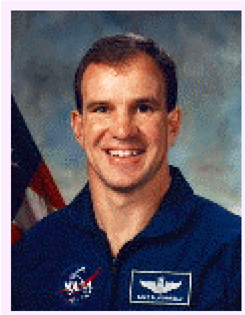
Jett is responsible for the overall success of the flight and the safety of his crew. He will fly Endeavour to its linkup with a new docking port on the ISS and supervise the deployment of the arrays, which when unfurled, will span 240 feet wingtip to wingtip.

After his last flight, Jett spent almost a year as the Director of Operations for NASA at the Gagarin Cosmonaut Training Center in Star City, Russia, overseeing the training of U.S. astronauts involved in preparations for flights to the ISS.

Jett is making his third trip into space, having flown as Pilot on the STS-72 mission in 1996 and the STS-81 mission in 1997 to the Mir Space Station.

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

Pilot: Michael J. Bloomfield



Mike Bloomfield (Lt. Col., USAF), 41, is making his second flight into space as Pilot on the STS-97 mission.

On Endeavour's flight to the ISS, Bloomfield will assist Jett during the rendezvous and approach to the ISS and will be at the controls for Endeavour's undocking from the Station and a subsequent flyaround of the new facility. He will operate Endeavour's robot arm during two space walks planned for the mission, maneuvering a pair of astronauts around the ISS as they conduct their assembly work.

Bloomfield first flew as Pilot of the STS-86 mission to the Mir Space Station in 1997 which delivered Astronaut David Wolf to the Russian outpost and brought Mike Foale home after a four-month stay.

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

Mission Specialist 1: Joseph R. Tanner

Joe Tanner, 50, is making his third flight into space and is designated as Mission Specialist 1 (MS 1). For the flight, he will be seated on the flight deck for Endeavour's launch and the middeck for entry and landing.

He will be responsible for the operation of Endeavour's docking system and will join Noriega for two ISS assembly space walks during this flight. Tanner will work with Noriega to install the photovoltaic arrays on the ISS, hook up electrical and data cables, relocate the Station's S-band communications system and conduct other tasks to prepare the ISS for the arrival of the U.S. Laboratory Destiny early next year.

Tanner will be designated as EV 1 during the two space walks, and will wear the spacesuit bearing the red stripes. Tanner will assist Marc Garneau in the transfer and stowage of logistical items and hardware for the Expedition One crew, aboard the ISS. The former Navy pilot will also share prime responsibility for the systems of the solar arrays and will operate an IMAX camera during the flight to document the crew's activities.

Tanner flew on the STS-66 mission in 1994 and conducted a pair of space walks on the STS-82 mission in 1997 to refurbish the Hubble Space Telescope.

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

Mission Specialist 2: Marc Garneau

Dr. Marc Garneau, 51, of the Canadian Space Agency, is making his third flight into space on the STS-97 mission, having earned the distinction of becoming the first Canadian to fly in space 16 years ago. As Mission Specialist 2 (MS 2), Garneau will serve as flight engineer during Endeavour's launch and landing.

Garneau will assist crewmate Noriega in using a variety of navigational tools to assist Jett in the rendezvous and docking with the International Space Station.

During docked operations, Garneau will use the Canadian-built robot arm to install the large U.S. solar arrays on the ISS. Garneau also will serve as onboard choreographer during the two space walks planned for the flight.

Once aboard the ISS, Garneau will oversee the transfer of cargo to the Expedition One crew and will help ISS Commander Bill Shepherd, Soyuz Commander Yuri Gidzenko and Flight Engineer Sergei Krikalev in the stowage of equipment and other supplies.

He first flew on the STS-41G mission in 1984 and returned to space in 1996 on the STS-77 mission.

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

Mission Specialist 3: Carlos I. Noriega

Carlos Noriega (Lt. Col., USMC), 41, is making his second flight into space aboard Endeavour. Noriega serves as Mission Specialist 3 (MS 3) on STS-97, responsible for the onboard computers and the navigational tools which will be used to assist Jett in his rendezvous with the ISS.

Noriega shares responsibility for all of the systems of the large solar arrays that will be installed on the ISS to provide the most powerful source of electricity of any orbiting spacecraft. During the two space walks in which he and Tanner will supervise the solar array installation and other Station assembly work, Noriega will be designated EV 2, and will wear the pure white spacesuit.

Noriega will be seated in Endeavour's middeck for launch and will take a seat on the Shuttle's flight deck for entry and landing.

Noriega previously flew on the STS-84 mission in 1997, visiting the Mir Space Station as part of the Shuttle/Mir Program.

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

Mission Profile

Endeavour OV105

Launch: Thursday, November 30, 2000
10:05 PM (eastern time)

Crew

Commander:	Brent W. Jett
Pilot:	Michael J. Bloomfield
Mission Specialist 1:	Joseph R. Tanner
Mission Specialist 2:	Marc Garneau
Mission Specialist 3:	Carlos I. Noriega

Launch

Orbiter:	Endeavour OV105
Launch Site:	Kennedy Space Center Launch Pad 39B
Launch Window:	2.5 Minutes
Altitude:	173 Nautical Miles
Inclination:	51.6 Degrees
Duration:	9 Days 20 Hrs. 41 Min.

Vehicle Data

Shuttle Liftoff Weight:	4524410 lbs.
Orbiter/Payload Liftoff Weight:	266185 lbs.
Orbiter/Payload Landing Weight:	197879 lbs.

Payload Weights

PVAA	185 pounds
IEA	17,000 pounds
LS	245 pounds

Software Version:	OI-27

Space Shuttle Main Engines

SSME 1: 2043 **SSME 2:** 2054 **SSME 3:** 2049

External Tank: ET-105A (Super Light Weight Tank)

SRB Set: BI103PF/R074-99

Shuttle Aborts

Abort Landing Sites

RTLS: Kennedy Space Center Shuttle Landing Facility
TAL: Zaragoza
AOA: Edwards Air Force Base, California

Landing

Landing Date:	12/10/00
Landing Time:	6:46 PM (eastern time)
Primary Landing Site:	Kennedy Space Center Shuttle Landing Facility

Payloads

Cargo Bay

PHOTOVOLTAIC ARRAY ASSEMBLY (PVAA):

INTEGRATED EQUIPMENT ASSEMBLY

THE LONG SPACER

Mission Summary

Flight Day Summary

DATE TIME (EST)	DAY	MET	EVENT
11/30/00 10:05:30 PM	1	000/00:00	Launch
11/30/00 10:55:30 PM	1	000/00:50	OMS2 Burn
12/01/00 1:49:30 AM	1	000/03:44	NC1 Burn
12/01/00 1:42:30 PM	2	000/15:37	NC2 Burn
12/01/00 5:51:30 PM	2	000/19:46	NPC Burn
12/01/00 10:41:30 PM	2	001/00:36	NC3 Burn
12/02/00 10:21:30 AM	3	001/12:16	NH Burn
12/02/00 10:51:30 AM	3	001/12:46	NC4 Burn
12/02/00 12:22:30 PM	3	001/14:17	TI Burn
12/02/00 2:53:30 PM	3	001/16:48	Docking
12/02/00 6:10:30 PM	3	001/20:05	ISS Early Egress
12/03/00 2:00:30 PM	4	002/15:55	EVA 1 Start
12/03/00 8:05:30 PM	4	002/22:00	EVA 1 End
12/05/00 2:00:30 PM	6	004/15:55	EVA 2 Start
12/05/00 8:05:30 PM	6	004/22:00	EVA 2 End
12/06/00 1:00:30 PM	7	005/14:55	Joint PMA 3 Ingress
12/07/00 8:35:30 PM	8	006/22:30	ISS Hatch Close
12/08/00 1:18:30 PM	9	007/15:13	ISS Undock
12/08/00 2:25:30 PM	9	007/16:20	Final Sep
12/10/00 5:41:30 PM	11	009/19:36	Deorbit Burn
12/10/00 6:46:30 PM	11	009/20:41	Landing

Updated: 11/09/2000

Rendezvous

Endeavour Docks with the Station

Endeavour’s rendezvous with the International Space Station actually begins with its precisely timed launch from the Kennedy Space Center in Florida. The Shuttle will rendezvous with the Station either on Flight Day 3 or 4, based on the time and date of launch, and at a time based on ISS-orbiter phasing.

The primary pre-rendezvous activities include a check-out of the orbiter's remote manipulator system, or robot arm, (RMS), the extravehicular mobility units (EMUs), the Ku-band antenna, the orbiter docking system (ODS), and the ground command system.

Final rendezvous operations begin about three hours prior to Endeavour’s docking with the ISS. Endeavour will approach the ISS from below, in what is referred to as a plus-R bar approach, to minimize the effects of jet thruster firings on the station and its solar arrays. About 40 minutes prior to the terminal initiation burn (Ti burn) when Endeavour moves within 135,000 feet of the station, the Shuttle’s rendezvous radar system is activated to provide supplemental navigation information. Prior to initiating the Ti burn, the crew will power on the ODS and activate Endeavour’s docking lights.

A series of course correction burns will bring Endeavour to a point almost directly below and behind the International Space Station, at which point Commander Brent Jett initiates the manual portion of his approach to the ISS.

Endeavour will intercept the R-bar at a distance of about 600 feet below the station. Jett will slowly move Endeavour to a point about 500 feet below the station before performing a 180 degree yaw maneuver to position Endeavour in a “tail forward” attitude for the final approach and docking. As Jett gently moves Endeavour toward the station, the Shuttle will stationkeep at distances of 170 feet and 30 feet before initiating the final approach and docking. Solar arrays on the Zarya and Zvezda modules will be feathered (or positioned) and locked during the 170 foot stationkeeping phase. Feathering is initiated by a command to reposition and hold each beta (and alpha) joint at a predetermined angle, which will limit the induced loads.

Endeavour will dock with Pressurized Mating Adapter (PMA) 3 located on the nadir port of the Unity module. This new docking port was installed during the STS-92 mission in October.

At initial contact and capture, the ISS will automatically switch to free drift, and Endeavour will go to free drift to avoid imposing excessive loads on the orbiter docking system (ODS).

After capture, light-emitting diodes (LEDs) on PMA-3 will blink confirming the ISS is in free drift. The crew will be able to see the red indicators through the overhead window on Endeavour’s aft flight deck and verify that the ISS is in the free-drift mode before beginning the automatic rigidization and retraction process and closure of the capture latches between the two docking hatches.

Once a “hard dock” is confirmed, the ODS will be deactivated, Zvezda and Zarya solar arrays will resume sun tracking, and the Endeavour-ISS complex will maneuver to the mated attitude.

Docked Operations

After the orbiter docks with the ISS, the crew will enter PMA-3 to install ground straps, and perform a pressure leak check and center disk removal to prepare for their later entry into the Unity module of the ISS for supply transfer.

Mission Specialists Joe Tanner and Carlos Noriega will perform two scheduled space walks, or EVAs, during docked operations to install the P6 photovoltaic solar array for power distribution to the Station, relocate the S-band antenna installed during the STS-92 mission in October, peform early external thermal control system connections, and complete some “get ahead” tasks for the STS-98/5A mission in February.

Undocking and Flyaround

Before Endeavour undocks and departs on Flight Day 8, ground personnel will update the ISS vector and mass data. These data include attitude departure maneuver data, attitude hold data, post-departure mass properties, and post-departure attitude maneuver data. A navigation platform alignment will be performed. Zvezda and Zarya solar arrays will be commanded to stop sun tracking and will be feathered to the edge-on position.

In preparation for undocking from the ISS, the STS-97 crew will once again power-up the orbiter docking system, turn on the Shuttle's docking lights, terminate all OIU operations, and enable the Shuttle’s navigational aids.

Following its undocking from the ISS, Pilot Mike Bloomfield will slowly back Endeavour away from the ISS at the rate of about 1/10th of a foot-per-second before beginning a flyaround of ISS. Endeavour will move to a point about 450 feet below the station before beginning a tail-forward circuit of the station, arriving once again at a position approximately 600 feet below the ISS. At that point, Bloomfield will perform a final separation burn to move Endeavour away from the station.

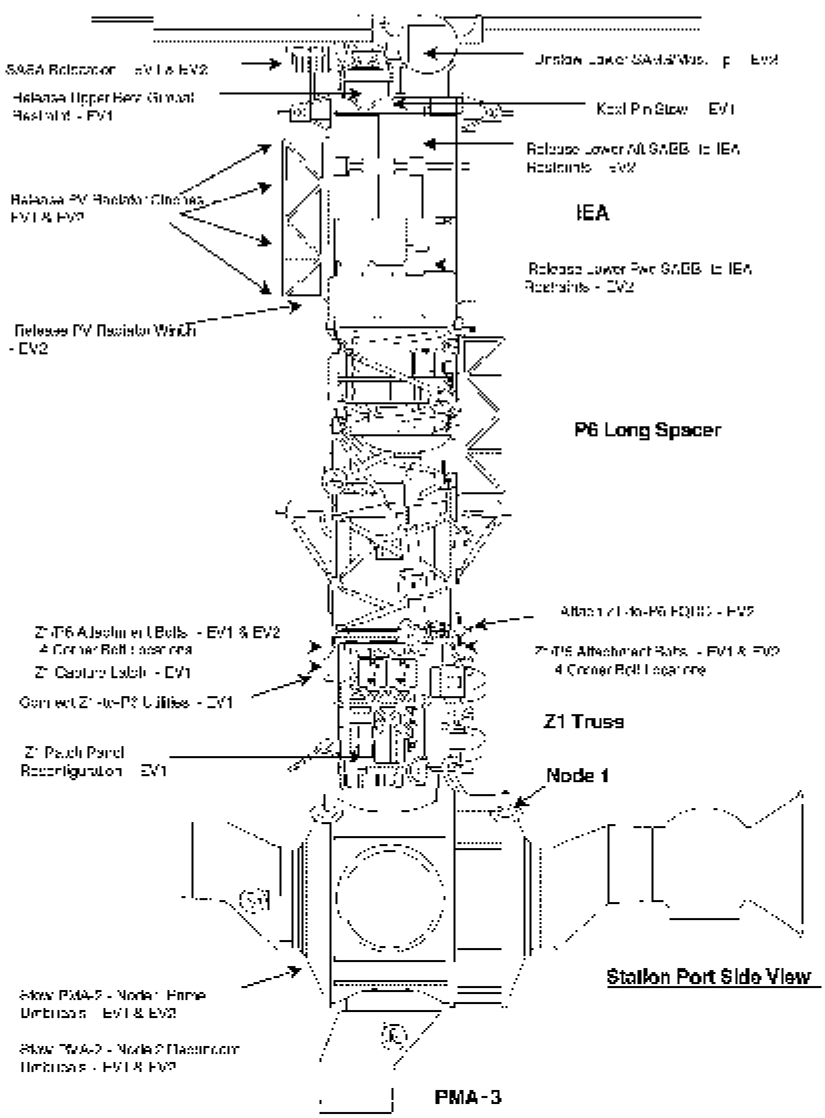
Once Endeavour is about 30 feet away from the station, the Expedition One crew will activate the station’s attitude control systems. The Zvezda module will then maneuver station to is normal orientation for orbital operations, the solar arrays will be commanded to resume sun tracking, and the station docking system and lights will be deactivated.

EVAs

A Pair of Space Walks Brings New Power to the Station

Overview

STS-97 will carry a crew of five on a 10-day mission that includes two space walks or EVAs designed to install the P6 Integrated Truss Segment and its associated solar arrays that will generate power for the U.S. segments of the International Space Station.



Currently, two space walks are scheduled on Flight Days 4 and 6, assuming an on-time launch on Nov. 30, and a Flight Day 3 docking. Mission Specialist Joe Tanner is designated EVA crew member 1 (EV1) and will wear the spacesuit with red stripes on the legs. His space walking partner, Carlos Noriega is designated as EV2 and will be identifiable with his pure white space suit. Inside Endeavour's cabin, Canadian Space Agency astronaut Marc Garneau will be the Intra-vehicular crew member (IV), acting as the on-orbit choreographer of the mission. Garneau also will use Endeavour's robotic arm to attach the P6 truss segment to the International Space Station. Pilot Mike Bloomfield will then take over robotic arm operations for the remaining space walk tasks, freeing Garneau to devote his attention to assisting the two space walkers.

History/Background

EVA 1

After Endeavour docks to the International Space Station, Marc Garneau will use the Shuttle's robot arm to lift the P6 structure out of the payload bay where it will remain attached overnight. Prior to the start of the first space walk, he will use the arm to move the 35,000 pound assembly to the "low hover" position adjacent to Endeavour's payload bay.

Once the P6 is in its low hover position, the EVA crew will exit Endeavour's air lock and begin assembling the tools and hardware they will use during the planned 6 ½ hour space walk.

EV1 Joe Tanner and EV2 Carlos Noriega will take positions on the forward and aft sides of the Z1 truss, respectively, to provide robot arm operator Marc Garneau with visual cues as he unberths the P6 structure. Garneau's primary cues will come from the Space Vision System that provides him with a closed circuit television view of targets located on the P6 and the ISS, but Tanner and Noriega will provide verbal confirmation and additional visual cues throughout the unberthing process.

Once Garneau moves the P6 within its capture envelope, Tanner and Noriega will verify the ready-to-latch position and activate the capture latches on the Z1 truss, initiating a coarse alignment between the P6 and Z1 truss. Noriega will then drive the capture latch assembly to bring the P6 into fine alignment. After the structure is secured in place – by 127 turns of the Capture Latch Assembly (CLA) – Tanner and Noriega will begin securing bolts on each of the four corners of the P6 before releasing the capture latch to allow loads to be carried through the primary bolts.

At that point, Garneau will release the robot arm’s grip on the P6 structure and maneuver it into position to allow Noriega to attach an articulating portable foot restraint. At this point in the space walk, Pilot Mike Bloomfield assumes responsibility for operating the robot arm using it to maneuver Noriega as he connects the nine power, command and data umbilicals from Z1 to the forward face of the P6 that will provide power to the Orbital Replacement Units in anticipation of the deployment of the large solar arrays. Garneau, the back-up EVA crew member, then turns his full attention to acting as the on-board choreographer for the remainder of EVA 1 and all of EVA 2.

As Noriega connects the umbilicals, Tanner sets to work releasing first the starboard and then the port Solar Array Blanket Boxes (SABB) by releasing a series of 5/8” bolts – two on the nadir and six on the zenith ends of each SABB.

Noriega’s next task is to release the starboard Solar Array Wing (SAW) Beta Gimbal launch restraint (BGA) by releasing a pair of retention bolts and allowing the BGA to swing outward and upward or downward into its deployed position. Following the release of the starboard SAW BGA, Tanner will perform a similar function on the port side of the structure.

Both Tanner and Noriega then begin deploying the SABBs by releasing a pip pin on the mast canister and then rotating the boxes 90 degrees from their launch position to their deployable position. Once in the deploy position, a locking arm holds each box in position. The space walkers then release three bolts that hold the mast tip fitting releasing it from the top of the mast canister. At that point, Jett commands the mast to deploy, beginning the unfolding of the large solar arrays.

Noriega’s final scheduled EVA task is to remove six “cinches” around the PV Radiator that hold it in its launch configuration by releasing two winch bar mechanisms and pip pins – one at each end of the radiator.

Noriega and Tanner will then clean up the payload bay and head back in to Endeavour’s airlock concluding the first of two scheduled space walks.

EVA 2

The second space walk, scheduled for Flight Day 6, is designed to reconfigure electrical connections so that power from the newly-installed P6 solar arrays can be distributed to the U.S. elements of the ISS.

Noriega will work on the port side of the truss structure reconfiguring cables and moving them from one connector to the other to support the transfer of power and then removing a thermal shroud from a DC to DC Conversion Unit (DDCU). Tanner will remove a similar shroud from a baseband signal processor (BSP) and prepare to relocate the S-Band Antenna Subassembly (SASA) from its location on the Z1 truss where it was temporarily stowed by the STS-92 crew in October.

The thermal shrouds are removed to allow the DDCU and BSP to dissipate heat as they begin operating off of power generated by the P6 arrays.

One of the major elements of this second EVA is the relocation of the SASA as Tanner and Noriega move it from a temporary stowage location on the starboard side of the Z1 truss to its new location on the top of the P6 array. Tanner will remove the power connections that provide maintenance power to the Z1 truss as he unbolts the SASA. Mike Bloomfield will maneuver the arm to Noriega’s location tethered to the Integrated Equipment Assembly (IEA) where, in a series of “leap frog” like exchanges, Tanner and Noriega will alternate possession of the SASA until the antenna assembly is installed in its operating position on the IEA. They will remove its thermal shroud and gimbal locks, readying the SASA for operation.

Tanner will then descend from the truss assembly to connect thermal system umbilicals between the Z1 and P6 truss assemblies, while Noriega resumes work mating umbilical cables to the Z1 patch panel.

The remaining EVA tasks are designed to pave the way for the arrival of the U.S. Laboratory Destiny early next year. Tanner will mount the robotic arm to mate a pre-routed cable for the centerline berthing camera to the early communications system antenna to provide the STS-98/5A crew with camera views to aid them in attaching the large lab module. Tanner and Noriega then will remove umbilicals from Pressurized Mating Adapter–2 (PMA2) connecting them to a dummy panel located on that docking port preparing it for relocation to the aft end of the Destiny module during the STS-98/5A mission.

Noriega will then release cinches on the aft radiator of the early thermal control system in much the same procedure he followed for the PV Radiator task, and then relocate foot restraints to assist the astronauts who will perform a space walk during the STS-102/5A mission. At the same time, Tanner will begin connecting two electrical jumpers, called H-Jumpers, that will provide increased power capacity to the Zvezda and Zarya modules.

Tanner and Noriega will gather up their tools and hardware before heading back into Endeavour’s airlock concluding the second scheduled space walk of the mission.

EVA Timeline for "A Pair of Space Walks Brings New Power to the Station"

Time	Event
2/15:55	EVA 1 Airlock Egress
2/16:00	EVA 1 Sortie Setup
2/16:30	EVA 1 Attach P6 to Z1 Truss
2/18:00	EVA 1 RMS Ungrapple P6
2/18:00	EVA 1 Release Starboard Solar Array Blanket Boxes (SABB) Restraints
2/18:00	EVA 1 Connect Z1 to P6 Power, Command and Data Umbilical Cables
2/19:00	EVA 1 Release Port Solar Array Blanket Boxes (SABB) Restraints
2/19:10	EVA 1 Release Starboard Solar Array Wing (SAW) Beta Gimbal Launch Restraint
2/19:55	EVA 1 Rotate Integrated Electronics Assembly Keel Pin
2/20:00	EVA 1 Release Port Solar Array Wing (SAW) Beta Gimbal Launch Restraint
2/20:15	EVA 1 Unstow Starboard Blanket Boxes
2/20:35	EVA 1 Release Photo Voltaic Radiator Cinch and Winch
2/20:45	EVA 1 Unstow Port Blanket Boxes
2/21:30	EVA 1 Sortie Cleanup
2/22:00	EVA 1 Airlock Ingress
4/15:55	EVA 2 Airlock Egress
4/16:00	EVA 2 Sortie Setup
4/16:30	EVA 2 Remove AC Base Band Signal Processor Coldplate Thermal Shroud
4/16:30	EVA 2 Z1 Patch Panel Reconfiguration
4/16:40	EVA 2 Remove DC to DC Conversion Unit (DDCU) Coldplate Thermal Shroud
4/16:42	EVA 2 S-Band Antenna Subassembly (SASA) Relocation
4/17:50	EVA 2 Attach Z1 to P6 QD
4/17:50	EVA 2 Z1 Patch Panel Reconfiguration
4/18:00	EVA 2 Pressurized Mating Adapter-2 (PMA2) Relocation Preparations
4/18:30	EVA 2 Centerline Berthing Camera Cable Connection
4/20:00	EVA 2 Release EETCS Station Aft Radiator Cinches and Winches
4/20:15	EVA 2 Electrical Power System (EPS) Jumper Stow
4/20:40	EVA 2 5a Preparation Tasks - APFR Relocate and Deploy MBM Capture Latch
4/21:15	EVA 2 Sortie Cleanup
4:22:00	EVA 2 Airlock Ingress

Payloads

Payload Overview

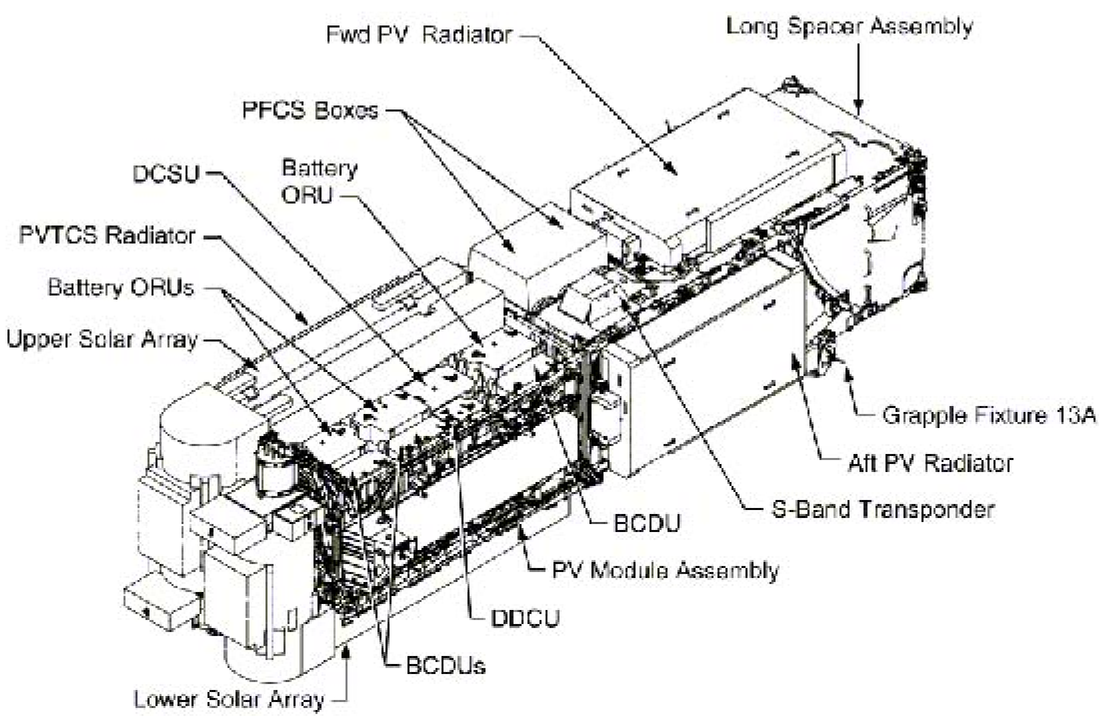
Prime:

Backup:

Overview

STS-97 will build on and enhance the capabilities of the International Space Station (ISS), delivering the first set of U.S.-provided solar arrays and batteries, called the P6 photovoltaic module (PVM) and temporarily install the P6 Integrated truss structure (ITS) on the Z1 truss until it is relocated to its permanent location on the P5 truss during a later assembly mission.

The P6 Integrated Truss Structure is the primary payload for the STS-97 mission and contains three discrete elements: the **Photovoltaic Array Assembly (PVAA)**, the **Integrated Equipment Assembly (IEA)** and the **Long Spacer (LS)**.



The P6 Integrated Truss Structure

Electrical power is the most critical resource for the ISS because it allows astronauts to live comfortably, safely operate the station, and perform complex scientific experiments. Whether used to power the life support system, run a furnace that makes crystals, manage a computerized data network, or operate a centrifuge, electricity is essential.

Since the only readily available source of energy for spacecraft is sunlight, technologies were developed to efficiently convert solar energy to electrical power. One way to do this is by using large numbers of solar cells assembled into arrays to produce high power levels. The cells are made from purified crystal ingots of silicon that directly convert light to electricity through a process called photovoltaics.

Solar cells do the job, but a spacecraft orbiting the Earth is not always in direct sunlight so energy has to be stored. Storing power in rechargeable batteries provides a continuous source of electricity while the spacecraft is in the Earth's shadow.

Payloads

Photovoltaic Array Assembly (PVAA):

Prime:

Backup:

Overview

The STS-97 crew will bring the first of eight sets of solar arrays that – at the completion of Space Station construction in 2006 – will comprise the Station's electrical power system, converting sunlight to electricity.

The ISS derives its power from the conversion of solar energy into electrical power. The Photovoltaic Power Module – or "P6" – performs this energy conversion.

The P6 has four primary functions: the conversion or generation, storage, regulation and distribution of electrical power for the ISS.

The Solar Arrays Unfurl to their Full Length

The P6 has two identical PVAAs which themselves consist of two major elements:

The Solar Array Assembly (SAA) containing two Solar Array Wings (SAW) connected to a mast which is folded into a Mast Canister before deployment.

The Beta Gimbal Assembly (BGA) consists of: a) Mast Canister which houses the folded mast, b) "Bearing, Motor and Roll Ring module" (BMRRM) used to rotate the SAW and transfer power, c) Electronic Control Unit (ECU) used to control the BGA motor and mast rotation, and d) Sequential Shunt Unit (SSU) used to coarsely regulate the SAW output voltage. Power generated by the PVAA is routed via the SSU to the IEA.

There are two solar array wings on the P6 module, each deployed in the opposite direction from each other. Each SAW is made up of two solar panels mounted to a common mast. Prior to deployment, each panel is folded into a Solar Array Blanket Box (SABB) measuring 20 inches high and 15 feet in length.

The mast is housed in a Mast Canister Orbital Replacement Unit (ORU). The mast ORU is comprised of the following items: the canister, the Folding Articulated Square Truss (FAST), upper and lower pivot fittings, tip fitting, a Motor Drive Assembly (MDA), wire harness and beta gimbal platform assembly.

When fully deployed, the SAW extends 115 feet and spans 38 feet across. Since the second SAW is deployed in the opposite direction the total wing span is over 240 feet.

Each Solar Array Wing is the largest ever deployed in space, weighing over 2,400 pounds and using nearly 33,000 solar arrays, each measuring 8-cm square with 4,100 diodes. Each SAW is capable of generating nearly 31 Kilowatts (kW) of direct current power. There are two SAWs on the P6 module yielding a total power generation capability approaches 64 kW, enough power to meet the needs of 30 average homes – without air conditioning (based on an average 2kW of power.)

BGA measures 8 x 8 x 2 feet and provides a structural link between the Integrated Electronics Assembly (IEA.)

The BGA's most visual functions are to deploy and retract the SAW and rotate it about its longitudinal axis. The BGA consist of three major components: the Bearing, Motor and Roll Ring Module (BMRRM), the Electronic Control Unit (ECU) and the Sequential Shunt Unit (SSU).

The motor used to rotate, deploy and retract the solar arrays is a three-phase, 200W DC stepper motor. The system has a rotational pointing accuracy of +/- 1 degree and a maximum rotational rate of +/- 200 degrees per minute. Rotational rate is obtained by pulse width modulation of the input DC power. The motor has a maximum operating torque of 380 in-lb. and a maximum stationary torque of 1,700 in-lb.

The Roll Rings allow the transfer of power from the rotating (Mast Canister) side of the BGA to the stationary (IEA) side of the BGA. These rings can transfer up to 35kW.

The ECU controls the motor that rotates,deploys and retracts the SAW. The ECU operates off of 120 VDc and receives its power from the DDCU located within the IEA. Commanding of the ECU is from a computer also located within the IEA. The ECU measures 23 x 12 x 14 inches.

The SSU is designed to coarsely regulate the solar power collected during periods of insolation – when the arrays collect power during sun-pointing periods . A sequence of 82 separate strings, or power lines, leads from the solar array to the SSU. Shunting, or controlling, the output of each string regulates the amount of power transferred. The regulated voltage setpoint is controlled by a computer located on the IEA and is normally set to around 140 volts. The SSU has an overvoltage protection feature to maintain the output voltage below 200 V DC maximum for all operating conditions. This power is then passed through the BMRRM to the DCSU located in the IEA. The SSU measures 32" by 20" by 12" and weighs 185 pounds.

Payloads

Integrated Equipment Assembly

Payload Bay

17,000 lbs.

Prime:

Backup:

Overview

The Integrated Equipment Assembly measures 16 x 16 x 16 feet, weighs nearly 17,000 pounds and is designed to condition and store the electrical power collected by the photovoltaic arrays for use on board the Station.

The IEA integrates the energy storage subsystem, the electrical equipment, the thermal control system, structural framework and the Solar Array Rotary Joint (SARJ). The IEA consist of three major elements:

1. The power system electronics consisting of the Direct Current Switching Unit (DCSU) used for primary power distribution; the Direct Current to Direct Current Control Unit (DDCU) used to produce regulated secondary power; the Battery Charge/Discharge Unit (BCDU) used to control the charging and discharging of the storage batteries; and the batteries used to store power.

2. The Photovoltaic Thermal Control System consisting of: the coldplate subassembly used to transfer heat from an electronic box to the coolant; the Pump Flow Control System (PFCS) used to pump and control the ammonia coolant; and the Photovoltaic Radiator (PVR) used to dissipate the heat into deep space.

3. The computers used to control the P6 module.

The IEA power system is divided into two independent and nearly identical channels. Each channel is capable of control (fine regulation), storage and distribution of power to the ISS. The PVAA is attached to one end of the IEA and the LS to the other.

Power received from each PVAA is fed directly into the appropriate Direct Current Switching Unit (DCSU). The DCSU is a high-power, multi-path remotely controlled unit that is used for primary and secondary power distribution, protection and fault isolation within the IEA. It also distributes primary power to the ISS. During periods of insolation, the DCSU routes primary power directly to the ISS from its PVAA and also routes power to the power storage system for battery charging. During periods of eclipse the DCSU routes power from the power storage system to the ISS. The DCSU measures 28” by 40” by 12” and weighs 235 pounds.

Primary power from the DCSU is also distributed to the Direct Current to Direct Current Converter Unit (DDCU). The DDCU is a power processing system that conditions the coarsely regulated power from the PVAA to 123 +/- 2 VDC. It has a maximum power output of 6.25 kW. This power is used for all P6 operations employing secondary power.

Primary power from the DCSU is also distributed to the three power storage systems located within each channel of the IEA. The power storage system consists of a Battery Charge/Discharge Unit (BCDU) and two battery assemblies.

The BCDU serves a dual function of charging the batteries during solar collection periods, and providing conditioned battery power to the primary power busses (via the DCSU) during eclipse periods. The BCDU has a battery charging capability of 8.4 kW and a discharge capability of 6.6 kW. The BCDU also includes provisions for battery status monitoring and protection from power circuit faults. Commanding of the BCDU is from the IEA computer.

Each battery assembly consist of 38 lightweight Nickel Hydrogen cells and associated electrical and mechanical equipment. Two battery assemblies connected in series are capable of storing a total of 8 kW of electrical power. This power is fed to the ISS via the BCDU and DCSU respectively. The batteries have a design life of 6.5 years and can exceed 38,000 charge/discharge cycles at 35% depth of discharge. Each battery measures 40” by 36” by 18” and weighs 375 pounds.

In order to maintain the IEA electronics at safe operating temperatures in the harsh space environments, they are conditioned by the Photovoltaic Thermal Control System (PVTCS). The PVTCS consist of ammonia coolant, eight coldplates, two Pump Flow Control Systems (PFCS) and one Photovoltaic Radiator (PVR).

The coldplate subassemblies are an integral part of IEA structural framework. Heat is transferred from the IEA orbital replacement unit (ORU) electronic boxes to the coldplates via fine interweaving fins located on both the coldplate and the electronic boxes. The fins add lateral structural stiffness to the coldplates in addition to increasing the available heat transfer area.

The PFCS is the heart of the thermal system. It consists of all the pumping capacity, valves and controls required to pump the heat transfer fluid to the heat exchanges and radiator, and regulate the temperature of the thermal control system ammonia coolant. The PVTCS is designed to dissipate 6,000 Watts of heat per orbit on average and is commanded by the IEA computer.

Each PFCS consumes 275 Watts during normal operations and measures approximately 40 x 29 x 19 inches, weighing 235 pounds.

The PVR – the radiator – is deployable on orbit and comprised of two separate flow paths through seven panels. Each flow path is independent and is connected to one of the two PFCSs on the IEA. In total, the PVR can reject up to 14 kW of heat into deep space.

The PVR weighs 1,600 pounds and when deployed measures 4 x 12 x 7 inches.

Payloads

The Long Spacer

Payload Bay

245 lbs.

Prime:

Backup:

Overview

The P6 Long Spacer measures 28 x 16 x 16 feet and performs two basic functions: to physically separate the P6 solar arrays from the P4 solar arrays when the P6 is relocated on a later assembly mission; and to provide temporary cooling for the U.S. Laboratory “Destiny” when it arrives on STS-102/5A early next year. Ultimately, Destiny will be cooled by the main Heat Rejection System (HRS) when it is activated on a later assembly flight.

The long spacer thermal system is called the Early External Active Thermal Control System (EEATCS) and is similar to the IEA’s PVTCS with a few exceptions. The EEATCS employs two separate cooling system loops and has two high-power PFCSs each feeding into its own PVR. It also has external ammonia accumulators used for pressure control and heaters to preclude freezing.

The PFCS’s flow control valve regulates the ammonia flow through the PVR in response to the Laboratory heat exchanger temperature. The EEATCS is designed to reject 14,000 Watts of heat per orbit and is commanded by the PFCS is under the control of the IEA computer. Each PFCS consumes 350 Watts during normal operations and the heaters consume 115 Watts. It measures 40 x 29 x 19 inches, and weighs 245 pounds.

Experiments

JASON On Board Seed Experiments

Prime:

Backup:

Overview

Seed Morphology Experiment

This student experiment will be transferred to the ISS during docked operations between Endeavour and the ISS. The study supports the education objectives of the JASON Project.

The experiment utilizes digital photography as a means of documenting the growth of germinating soybean and corn seeds under extreme conditions (spaceflight and, elsewhere under water). The spaceflight images obtained are downlinked and posted to a web site for dissemination to students for their evaluation. Parallel classroom investigations are conducted by the students.

Eight seed pouches will be flown and germinated either under dark or lighted conditions. Each seed pouch contains a grid along its side to provide a scale for data extraction.

Seed Metabolite Experiment

This study explores potential new roles of flavonoids and isoflavonoids in the processes associated with adaptation of plants in general (and soybeans in particular) to microgravity. These compounds have been proposed to play many diverse roles in plants, including protection against insects, pathogens and UV light damage. This class of compounds may play a significant role in plant adaptation to the microgravity environment. The experiment consists of wetting three soybean seed pouches each day, starting at 7 days prior to scheduled landing (R-7) and continuing until R-1. Temperature and light intensity recorders will be used to document environmental conditions in the vicinity of the seed pouches.

After landing, the plants will be frozen to stabilize them for analysis. A delayed ground control experiment will be scheduled post-flight utilizing the KSC Orbiter Environmental Simulator Chamber.

DTO/DSO/RMEs

Structural Dynamics Model Validation

DTO 257

Prime:

Backup:

Overview

This DTO will fire a sequence of primary reaction control system (RCS) jets and observe the effects on the structural dynamics of the mated Shuttle and International Space Station complex. The test is designed to confirm that primary reaction control system jet firings are acceptable for use if vernier reaction control system jets are not available.

DTO/DSO/RMEs

International Space Station On-Orbit Loads Validation

DTO 261

Prime:

Backup:

Overview

This DTO will use the Shuttle’s aft primary RCS jets to measure the structural dynamics (natural frequencies, modal amplitudes, and structural dampening) of the ISS and use the results to validate critical areas of the on-orbit loads prediction models. Tests will obtain photogrammetric measurements of the radiator.

DTO/DSO/RMEs

Single-String Global Positioning System

DTO 700-14

Prime:

Backup:

Overview

The purpose of this DTO is to demonstrate the performance and operation of the Global Positioning System (GPS) during ascent, orbital, and entry phases of the flight. It uses a modified military GPS receiver/processor and the existing orbiter GPS antennas, and records data on a payload and general support computer (PGSC) hard drive.

DTO/DSO/RMEs

Crew Return Vehicle (CRV) Space Integrated Global Positioning System/Inertial Navigation System (SIGI)

DTO 700-22

Prime:

Backup:

Overview

This is the first flight of DTO 700-22, which will measure both GPS only and GPS/INS blended position, velocity, time, and attitude performance during on-orbit and entry operations and will also measure the time to first GPS fix (position, velocity, time) during on-orbit operations after warm or cold starts of the SIGI.

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 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.

DTO/DSO/RMEs

Micro-Wireless Instrumentation System (Micro-WIS)
(Objective 3 Only)

DTO HTD 1403

Prime:

Backup:

Overview

Human Exploration and Development of Space (HEDS) Technology Demonstration (HTDs)

This HTD will demonstrate the operational utility and functionality of Micro-WIS on orbit, initially in the crew cabin of the orbiter and then in the ISS. The Micro-WIS sensor/transmitter will provide important real-time temperature measurements.

DTO/DSO/RMEs

Laser Dynamic Range Imager (LDRI)

DTO HTD 1404

Prime:

Backup:

Overview

Human Exploration and Development of Space (HEDS) Technology Demonstration (HTD)

The purpose of this HTD is to demonstrate the LDRI as an instrument for obtaining static and dynamic range imagery and measurements of space structures for use in validating structural models and for determining position and orientation in real time.

DTO/DSO/RMEs

Educational Activities

DSO 802

Prime:

Backup:

Overview

This DSO will provide live television of the mission to classrooms in hopes of attracting students to careers in science, engineering, and mathematics. The addition of this DSO to a particular flight is coordinated through the JSC Educational Working Group (EWG). The tasks required by this DSO have three objectives:

1. Produce educational products, such as 20-minute video lessons, with scenes recorded both in space and on the ground. The video from space should be about one-third of the finished video product. This objective requires the videotaping of educational activities performed by astronauts in space, and other educational activities deemed appropriate by the EWG and the flight crew.

2. Support the live television of educational activities performed by astronauts for, or involving participation by, students and teachers. Typically, these downlinks are limited to one or two 30-minute live sessions.

3. Explain the live or videotaped television of educational activities by astronauts to a general audience. Typically, these activities are limited to 5 or 10 minutes per demonstration/narration to explain the science and/or principles of the experiments performed by the astronauts.

This educational DSO supports the NASA Administrator's educational initiative and complies with his direction to use live and recorded lessons from astronauts on Space Shuttle missions in NASA's educational programs.

Mission Benefits

Why build the International Space Station?

When studying sound, you go into a quiet room. When studying light, you go into a dark room. When studying the effects of gravity, you'd like to go into an "anti-gravity" room. Since there's no such thing on Earth, we have the International Space Station.

By flying around the Earth at about 17,500 mph, the station and everything in it remain in orbit, a continuous free fall around the planet. In orbit, forces are balanced and the effects of gravity are essentially removed. The result is microgravity, one of the unique aspects of the ISS environment that holds the hope of new discovery. The ISS thus allows long-term exposure to a world nearly unexplored.

Gravity affects everything. From our bodies, to the materials we use to build cars and buildings, to the flames we use to heat our homes, our world is controlled by gravity. For as long as we have curiously investigated our surroundings, we have been limited, until recently, to accepting gravity as a given in all our studies. History shows that changing what once were constants can lead to revolutionary discoveries.

The 19th Century saw temperature and pressure controlled in new ways to harness steam power and revolutionize the way we live. The 21st Century offers the hope of controlling gravity's effects to understand why things behave the way they do. Observing and understanding this behavior is key to new discoveries in many scientific disciplines and using that knowledge is key to the betterment of life on Earth.

The Space Station Mir gave us a platform for long-term microgravity research, and important knowledge about how to live and work in space. Like all research, we must proceed one step at a time. As we open one door, answering one question, we are faced with the opportunity of more doors, more questions.

The ISS is the next step in that journey of discovery, and represents a quantum leap in our capability to conduct research on orbit. In space, electrical power is key to the quantity and quality of research. When complete, the ISS's enormous solar arrays will supply 60 times more power for science than did Mir. This, coupled with the large space available for experiments, will provide scientists with unprecedented access to this unique environment.

Aboard the ISS, and through interaction from the ground, scientists will explore basic questions in the fields of biotechnology, biomedical research and countermeasures, fluid physics, fundamental biology, materials science, combustion science, fundamental physics, Earth science and space science. Space-based research will be supported by research on the ground, with selection of only those experiments requiring the microgravity environment selected for flight on the ISS.

In addition to serving as a research laboratory, the ISS will sustain and strengthen U.S. leadership in other areas. It will provide opportunity to enhance U.S. economic competitiveness and create new commercial enterprises. Companies can use ISS research to build profit-based businesses.

The ISS will maintain the U.S. leadership in space exploration that has inspired a generation of Americans and people throughout the world. Tied in with other NASA assets, the ISS will serve as a virtual classroom in space to the benefit of educators and students alike. Live educational events and programs like EarthKAM (with students operating a camera on the ISS beginning next fall to investigate changes on Earth, will motivate students to understand their world.

Education and inspiration will couple to maintain U.S. economic leadership by raising a new generation of science, math, and technology savvy children that will invent 21st century products and services. Finally, the ISS will serves as a testbed and springboard for further exploration of space. We will learn how the human body responds to the long-term exposure to space, and how to best prepare for the next major human steps into the solar system.

Research on the International Space Station

Early Research Disciplines:

Biomedical Research and Countermeasures: Researchers seek to understand and control the effects of the space environment on space travelers (e.g. muscle atrophy, bone loss, fluid shifts, etc.).

- **Long term Benefits:** enhance the safety of space travel; develop methods to keep humans healthy in low-gravity environments; advance new fields of research in the treatment of diseases.

Fundamental Biology: Scientists study gravity's influence on the evolution, development, growth, and internal processes of plants and animals. Their results expand fundamental knowledge that will benefit medical, agricultural, and other industries.

- **Long term Benefits:** advance understanding of cell, tissue, and animal behavior; use of plants as sources of food and oxygen for exploration; improved plants for agricultural and forestry.

Biotechnology: Microgravity allows researchers to grow three-dimensional tissues that have characteristics more similar to tissues in the body than has ever been previously available and to produce superior protein crystals for drug development.

- **Long term Benefits:** culture realistic tissue for use in research (cancerous tumors, organ pieces); provide information to design a new class of drugs to target specific proteins and cure specific diseases.

Fluid Physics: The behavior of fluids is profoundly influenced by gravity. Researchers use gravity as an experimental variable to explain and model fluid behavior in systems on Earth and in space.

- **Long term Benefits:** improved spacecraft systems designs for safety and efficiency; better understanding of soil behavior in Earthquake conditions; improved mathematical models for designing fluid handling systems for, powerplants, refineries and innumerable other industrial applications.

Additional Research Disciplines (later in the life of ISS):

Advanced Human Support Technology: Researchers develop technologies, systems, and procedures to enable safe and efficient human exploration and development of space.

- **Long term Benefits:** reduce the cost of space travel while enhancing safety; develop small, low power monitoring and sensing technologies with applications in environmental monitoring in space and on Earth; develop advanced waste processing and agricultural technologies with applications in space and on Earth.

Materials Science: Researchers use low gravity to advance our understanding of the relationships among the structure, processing and properties of materials. In low gravity, differences in weight of liquids used to form materials do not interfere with the ability to mix these materials opening the door to a whole new world of composite materials.

- **Long term Benefits:** advance understanding of processes for manufacturing semiconductors, metals, ceramics, polymers, and other materials; determine fundamental physical properties of molten metal, semiconductors, and other materials with precision impossible on Earth.

Combustion Science: The removal of gravity allows scientists to simplify the study of complex combustion (burning) processes. Since combustion is used to produce 85 percent of Earth's energy, even small improvements in efficiency and reduction of soot production (a major source of pollution on earth) will have large environmental and economic benefits.

- **Long term Benefits:** enhance efficiency of combustion processes; enhance fire detection and safety on Earth and in Space; improve control of combustion emissions and pollutants.

Fundamental Physics: Scientists use the low gravity and low temperature environment to slow down reactions allowing them to test fundamental theories of physics with degrees of accuracy that far exceed the capacity of Earthbound science.

- **Long term Benefits:** challenge and expand theories of how matter organizes as it changes state (important in understanding superconductivity); test fundamental theories in physics with precision beyond the capacity of Earth-bound science; potential for improved magnetic materials.

Earth Science and Space Science: Space Station will be a unique platform with multiple exterior attach points from which to observe the Earth and the Universe.

- **Long term Benefits:** Space Scientists will use the location above the atmosphere to collect and search for cosmic rays, cosmic dust, antimatter and “dark” matter. Earth Scientists can obtain global profiles of aerosols, ozone, water vapor, and oxides in order to determine their role in climatological processes and take advantage of the longevity of ISS to observe global changes over many years.

Shuttle Reference 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 (RTLS).

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 (RTLS)

The RTLS 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 RTLS, in that order. The mode chosen is the highest one that can be completed with the remaining vehicle performance.

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

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

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

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

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

RETURN TO LAUNCH SITE OVERVIEW

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

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

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

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

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

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

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.

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 oxidizer sensors sense a dry condition, the engines will be shut down.

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.

Space Shuttle Rendezvous Maneuvers

COMMON SHUTTLE RENDEZVOUS MANEUVERS

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

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

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

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

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

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

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

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

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, the attach ring formed a C and encircled the motor case 270 degrees.

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

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

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

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

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

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

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

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

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

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

The SRB nose caps and nozzle extensions are not recovered.

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

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

HOLD-DOWN POSTS

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

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

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

SRB IGNITION

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

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

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

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

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

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

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

ELECTRICAL POWER DISTRIBUTION

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

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

HYDRAULIC POWER UNITS

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

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

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

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

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

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

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

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

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

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

THRUST VECTOR CONTROL

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

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

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

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

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

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

SRB RATE GYRO ASSEMBLIES

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

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

SRB SEPARATION

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

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

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

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

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

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

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

Space Shuttle Super Light Weight 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% stronger and 5% less dense.

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

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

Acronyms and Abbreviations

A/D	Analog to Digital
ACBM	Active Common Berthing Mechanism
ACBSP	Assembly Contingency Baseboard Signal Processor
ACLS	Advanced Cardiac Life Support
ACS	Attitude Control System
AD	Active Device
AFD	Aft Flight Deck
AGIT	Antenna Group Immediate Frequency Tube
Ah	Ampere Hour
ALSP	Advance Life Support Pack
AOH	Assembly Operations Handbook
APAS	Androgynous Peripheral Assembly System
APCU	Assembly Power Converter Unit
APDS	Androgynous Peripheral Docking System
APFR	Articulating Portable Foot Restraint
APM	Ambulatory Medical Pack
	Attached Pressurized Module
AR	Atmosphere Revitalization
ARCU	American-to-Russian Converter Unit
ASCR	Assured Safe Crew Return
ATV	Automated Transfer Vehicle
AUIAU	ASC/UHF Audio Interface Unit
BC	Bus Controller
BCDU	Battery Charge/Discharge Unit
BDT	Binary Data Transfer
BGA	Beta Gimbal Assembly
BGDTS	Beta Gimbal Deployment/Transition Set
BGHS	Beta Gimbal Housing Subassembly
BG/PVAA	Beta Gimbal/Photovoltaic Array Assembly
BIA	Bus Interface Adapter
BIT	Built-In Test
BITE	Built-In Test Equipment
BIU	Bus Interface Unit
BMR	Body-Mounted Radiator
BMRRM	Bearing, Motor, and Roll Ring Module
BOL	Beginning of Life
BRS	Blanket Restraint System
BSCCM	Battery Signal Conditioning and Control Module
BSP	Baseband Signal Processor
BTLS	Basic Trauma Life Support
C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communications and Tracking

C&W	Caution and Warning
CADU	Channel Access Data Unit
CB	Command Bus
CBCS	Centerline Berthing Camera System
CBM	Common Berthing Mechanism
CC	Central Computer
CCPK	Crew Contamination Protection Kit
CCSDS	Consultative Committee for Space Data Systems
CCTV	Closed-Circuit Television
CDR	Critical Design Review
CDRA	Carbon Dioxide Removal Assembly
CETA	Crew and Equipment Translation Aid
CHeCS	Crew Health Care System
CHIA	Cargo Handling Interface Adapter
CIL	Critical Items List
CMG	Control Moment Gyro
CMO	Crew Medical Officer
COTS	Commercial Off-the-Shelf
CPDS	Crew Passive Dosimeter
CPP	Connector Patch Panel
CRT	Cathode-Ray Tube
CSA-CP	Compound Specific Analyzer-Combustion Product
CSCI	Computer Software Configuration Item
CT 2	Communication and Tracking 2
CTP	Command and Telemetry Processor
CTV	Crew Transfer Vehicle
CWC	Contingency Waste Collection
DC	Docking Compartment
DDCU	DC to DC Converter Unit Direct Current-to-Direct Current Converter Unit
DDCUE	DC to DC Converter Unit External
DDCU-HP	DDCU with Heat Pipe Radiators
DDCUI	DC to DC Converter Unit Internal
DCSU	Direct Current Switching Unit
DIA	Diagnostic
DIO	Discrete Input/Output
DMCU	Docking Mechanism Control Unit
DMS	Data Management System
DSCU	Docking System Control Unit
DTO	Detailed Test Objective
Early Comm	Early Communications System
EATC	External Active Thermal Control
EATCS	External Active Thermal Control System
ECLSS	Environmental Control and Life Support System/Subsystem
ECOMM	Early Communications System

ECU	Electronic Control/Coupling Unit Electronic Control Unit
EDAC	Error Detection and Correction
EDP	Electronic Document Project
EE	End Effector
EEATCS	Early External Active Thermal Control System/Subsystem
EEPROM	Electronically Erasable Programmable Read-Only Memory
EETCS	Early External Thermal Control System
EMI	Electromagnetic Interference
EMI/EMC	Electromagnetic Interference/Electromagnetic Compatibility
EMU	Extravehicular Mobility Unit
EOL	End of Life
EPCS	Early Portable Computer System
EPS	Electrical Power System/Subsystem
ERSU	External RSU
ESA	European Space Agency
ESSMDM	Enhanced Space Station MDM
ESSU	Energy Storage Subsystem Upgrade
ETCS	External Thermal Control System
ETE	End-to-End
ETI	Elapsed Time Indicator
ETSD	External Tool Stowage Device
EV	Extravehicular
EVA	Extravehicular Activity
EVAS	EVA System
FAST	Folding Articulated Square Truss
FCC	Flat Collector Circuit
FCV	Flow Control Valve
FD	Flight Day
FDF	Flight Data File
FDIR	Fault Detection, Isolation, and Recovery
FDS	Fire Detection and Suppression
FGB	Functional Cargo Block
FQDC	Fluid Quick Disconnect Coupling
FRGF	Flight Releasable Grapple Fixture
FRR	Flight Readiness Review
FS	File Server
FSE	Flight Support Equipment
GFE	Government-Furnished Equipment
GLONASS	Global Navigational Satellite System
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

H&S	Health and Safety
H/W	Hardware
HCA	Hollow Cathode Assembly
HDL	High-Rate Data Link
HEDS	Human Exploration and Development of Space
HEI	Hernandez Engineering, Inc.
HGA	High Gain Antenna
HP	Heat Pipe
HPR	Heat Pipe Radiator
HRD	High Rate Data High Rate Dosimeter
HRM	Heart Rate Monitor High-Rate Mode
HRW	Heart Rate Watch
HTD	Human Exploration and Development of Space Technology Demonstration
I/F	Interface Intermediate Frequency
I/O	Input/Output
IACO	Installation, Assembly, and Checkout
IAPFR	
IATC	Internal Active Thermal Control
ICC	Instrumentation Cargo Compartment
ICD	Interface Control Document
ID	Inside Diameter
IDA	Initialization Diode Assembly
IEA	Integrated Electronics Assembly
IEE	Integrated Equipment Assembly
IF	Interface
IMS	Inventory Management System
IMV	Intermodule Ventilation
IOCC	Input/Output Card Controller
IP	International Partner
IRD	Interface Requirement Document
IRED	Interim Resistive Exercise Device
ISS	International Space Station
ISSP	International Space Station Program
ITS	Integrated Truss Segment
IV	Intravehicular
IVA	Intravehicular Activity
IWIS	Internal WIS
JOP	Joint Operating Panel
JSC	Johnson Space Center

kbps	kilobits per second
kg	kilogram
km	kilometer
KSC	Kennedy Space Center
LAN	Local Area Network
LCU	LED Control Unit
LDI	Local Data Interface
LDRI	Laser Dynamic Range Imager
LED	Light Emitting Diode
LFDP	Load Fault Detect/Protect
LGA	Low Gain Antenna
LSAR	Logistics Support Analysis Report
LSE	Launch Support Equipment
LSM	Life Support Module
LSS	Life Support System
LTA	Launch to Activation
LV/LH	Local Vertical/Local Horizontal
MBM	Manual Berthing Mechanism
mbps	megabytes per second
MBSU	Main Bus Switching Unit
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MCC-M	Mission Control Center-Moscow
MCDS	Management Communication and Data System
	Multipurpose Crew Display System
MCS	Motion Control System
MDA	Motor Drive Assembly
MDM	Multiplexer/Demultiplexer
MIL-STD	Military Standard
MIP	Mission Integration Plan
MLI	Multilayer Insulation
mm	millimeter
MM/OD	Micrometeoroid/Orbital Debris
MOD	Mission Operations Directorate
MPEV	Manual Pressure Equalization Valve
MPLM	Mini-Pressurized Logistics Module
	Multipurpose Logistics Module
MPM	Manipulator Positioning Mechanism
MRL	Manipulator Retention Latch
ms	milliseconds
MSC	Mobile Servicing Center
MSID	Measurement Stimulus Identification
MSS	Mobile Servicing System
MT	Mobile Transporter
MU	Match Unit

μs	microseconds
N/A	Not Applicable
n. mi.	nautical mile
NASA	National Aeronautics and Space Administration
NCS	Node Control Software
NCU	Network Control Unit
NIU	Network Interface Unit
NPRV	Negative Pressure Relief Valve
NRZ-M	Non-Return-to-Zero Mark
OCA	Orbiter Communications Adapter
OCC	Onboard Complex Control
OCCS	Onboard Complex Control System
OCS	Onboard Computer System
OD	Outside Diameter
ODF	Operations Data File
ODS	Orbiter Docking System
OIU	Orbiter Interface Unit
OMS	Onboard Measuring Subsystem
OPP	OSVS Patch Panel
ORU	Orbital Replacement Unit
OS	On-Orbit Segment
OSD	Operations Support Department
OSE	Orbital Support Equipment
OSHF	Onboard S-Band High Frequency
OSVS	Orbiter Space Vision System
OSVU	Orbiter Space Vision Unit
OTD	ORU Transfer Device
P6	Port 6
PA	Pressurized Adapter
PBA	Portable Breathing Apparatus
PCBA	Portable Clinical Blood Analyzer
PCBM	Passive Common Berthing Mechanism
PCIA	Portable Computer Interface Adapter
PCMCIA	Portable Computer Memory Card International Adapter
PCMMU	Pulse Code Modulation Master Unit
PCR	Portable Computer Receptacle
PCS	Portable Computer System
PCU	Plasma Contactor Unit
PD	Physical Device
PDI	Payload Data Interface
PDIP	Payload Data Interface Panel
PDRS	Payload Deployment and Retrieval System
PDS	Passive Dosimetry System
PEV	Pressure Equalization Valve

PFCS	Pump and Flow Control Subassembly
PFE	Periodic Fitness Evaluation
	Portable Fire Extinguisher
PFR	Portable Foot Restraint
PG	Product Group
PGSC	Payload General Support Computer
PGT	Pistol Grip Tool
PIT	Preintegrated Truss
PLB	Payload Bay
PM	Pressurized Module
PMA	Pressurized Mating Adapter
PMAD	Power Management and Distribution
PMCA	Power Management Controller Application
PMCU	Power Management Controller Unit
PN	Pseudorandom Noise
POR	Point of Resolution
POST	Power-On Self-Test
$PPCO_2$	Partial Pressure of Carbon Dioxide
PPRV	Positive Pressure Relief Valve
PRCS	Primary Reaction Control System
PRI	Primary
PRLA	Payload Retention Latch Assembly
PSI	Parameter Status Indication
psid	pounds per square inch differential
psig	pounds per square inch gauge
PSP	Payload Signal Processor
PSS	Power Supply System
PTB	Payload Timing Buffer
PTCS	Passive Thermal Control Subsystem
PUI	Program-Unique Identifier
PV	Photovoltaic
PVAA	Photovoltaic Array Assembly
PVCA	Photovoltaic Controller Application
PVCU	Photovoltaic Control Unit
PVM	Photovoltaic Module
PVR	PV Radiator
QD	Quick Disconnect
RACU	Russian-to-American Converter Unit
RAMS	Radiation Area Monitoring System
RBI	Remote Bus Isolator
RCS	Reaction Control System
RF	Radio Frequency
RFG	Radio Frequency Group
RFHX	Radiant Fin Heat Exchanger
RFPDB	RF/Power Distribution Box

RFX	Radiant Fin Heat Exchanger
RHC	Rotational Hand Controller
RIRS	Reflector Interface Ring Structure
RMS	Remote Manipulator System
ROEU	Remotely Operated Electrical Umbilical
ROS	Russian On-Orbit Segment
RPC	Remote Power Controller
RPCM	Remote Power Controller Mode
RPDA	Remote Power Distribution Assembly
RS	Russian Segment
RSA	Russian Space Agency
RSU	Remote Sensing Unit
RT	Remote Terminal
RTAS	Rocketdyne Truss Attachment System
RTD	Resistive Temperature Device Resistive Thermal Device
RTE	Run Time Environment
RTL	Ready to Latch
RTS	Radio Telemetry System
S/W	Software
S0	Starboard-zero
S1	Starboard-one
SABB	Solar Array Blanket Box
SAFER	Simplified Aid for EVA Rescue
SARJ	Solar Array Rotary Joint
SASA	S-Band Antenna Subassembly S-Band Antenna Support Assembly
SAW	Solar Array Wing
SBS	Series Bungee System
SCA	Switchgear Controller Assembly
SDO	Solenoid Driver Output
SDP	Standard Data Processor
SGANT	Space-to-Ground Antenna
SGTRC	Space-to-Ground Transmit/Receive Controller
SHF	S-Band High Frequency
SLD	Subject Load Device
SM	Service Module
SMCC	Service Module Central Computer
SO	Standard Out
SODF	Station Operations Data File
SPD	Serial Parallel Digital Subject Positioning Device
SPDA	Secondary Power Distribution Assembly
SPM	Solar Power Module
SRMS	Shuttle Remote Manipulator System
SSA	S-Band Single Access

SSAF	S-Band Single Access Forward
SSAS	Segment-to-Segment Attachment System
SSC	Station Support Computer
	System Support Computer
SSE	Space Station Eyewash
SSEC	Secondary
SSMDM	Space Station Multiplexer/Demultiplexer
SSOR	Space-to-Space Orbiter Radio
SSP	Standard Switch Panel
	Space Station Program
SSRMS	Space Station Remote Manipulator System
SSSH	Space Shuttle Systems Handbook
SSU	Sequential Shunt Unit
STS	Space Transportation System
SVS	Space Vision System
SWIS	Shuttle-Based WIS
tb	talkback
TBD	To be Determined
TC	Terminal Computer
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TEA	Torque Equilibrium Attitude
TEPC	Tissue Equivalent Proportional Counter
THC	Temperature and Humidity Control
	Translational Hand Controller
TORU	Teleoperator Control System
TRA	Transmit/Receive Amplifier
TRC	Transmit/Receive/Controller
TTCS	Telephone-Telegraph Communication Subsystem
TTL	Transfer Tracking Log
TUS	Trailing Umbilical System
TVIS	Treadmill Vibration and Isolation System
UAS	User Application Software
U.S.	United States
UDM	Universal Docking Module
UHF	Ultrahigh Frequency
USA	United Space Alliance
USOS	United States On-Orbit Segment
VBSP	Video Baseband Signal Processor
VIU	Video Interface Unit
VPU	Video Processing Unit
VSU	Video Switching Unit
VTR	Video Tape Recorder

VTS	Video Teleconferencing System
WIF	Worksite Interface
WIS	Wireless Instrumentation System
WM	Waste Management
WRM	Water Recovery and Management
XPDR	Transponder
ZSR	Zero-g Stowage Rack

Russian Acronyms

АД	Blood Pressure
АСН	Navigation Satellite Instrumentation
АСС	Message Acquisition System
АСУ	Toilet
АФУ	Antenna Feeder Unit
БА СОА	Vozdukh Automatic Control Unit
БВС	Onboard Computer System
БД	Secondary Purification Unit
БЖ	Liquid Unit
БИТС2-12	Onboard Measurement Telemetry Subsystem
БКГА	Gas Analysis Calibration Assembly Gas Analyzer Monitoring Unit
БОА	Vozdukh Valve Panel
БП	Pump Unit
БПА	Nitrogen Purge Assembly
БПО	Preliminary Drying Unit
БПС	Signal Conversion Unit
БТА	Heat Exchanger Unit
ВН	Vacuum Pump
ГЖТА	Gas-Liquid Heat Exchanger Assembly
ДД	Pressure Sensors
ДТ	Temperature Sensors
ЕДВ-СВ	Flush Water Container
ЖЖТ	Liquid-Liquid Heat Exchanger

ИЗОГ	Calf Measurement Device
ИКР	Rodnik Status Panel
ИМ	Mass Measurement Device
ИнПУ	Integrated Control Panel
ИПЖ	Liquid Carryover Indicator
КЛГ	Local Group Commutator
КТВ	Non-Potable Container
КУ	Compressor
КЦП	Central Post Computer
ЛКА	Local Analog Commutator
МНР-НС	Air-Water Separator
ПУРВ-К2М	Condensate Water Processor Control Panel
ПхО	Transfer Compartment
РПГ	Rheoplethsysmography
РПД	Pressure Differential Regulator
СБИ	Onboard Measurement System
СИМВОЛ-Ц	Simvol-Ts
СКВ	Air Conditioning System
СКО	Oxygen Generation Hardware
СОТР	Thermal Control System
СПК-У	Urine Collection Assembly
СРВ-К2М	Condensate Water Processor
СТ-64	Current Regulator
СТТС	SM Audio subsystem
СУВА	Onboard Equipment Control System
СУДН	Motion Control and Navigation System
ТВС	Television Subsystem
ТОРУ	Teleoperator Control System

Media Assistance

NASA Television Transmission

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

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

Status Reports

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

Briefings

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

Internet Information

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

http://spaceflight.nasa.gov

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

http://www.nasa.gov

or

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

Shuttle Pre-Launch Status Reports

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

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

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

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

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

Resources for educators can be found at the following address:

http://education.nasa.gov

Access by Compuserve

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

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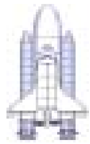
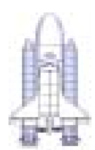
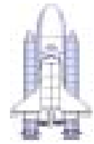
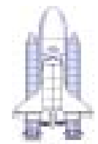
SHUTTLE FLIGHTS AS OF NOVEMBER 2000

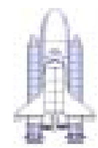
100 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 75 SINCE RETURN TO FLIGHT











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

Table prepared by Richard W. Orloff, 02/2001