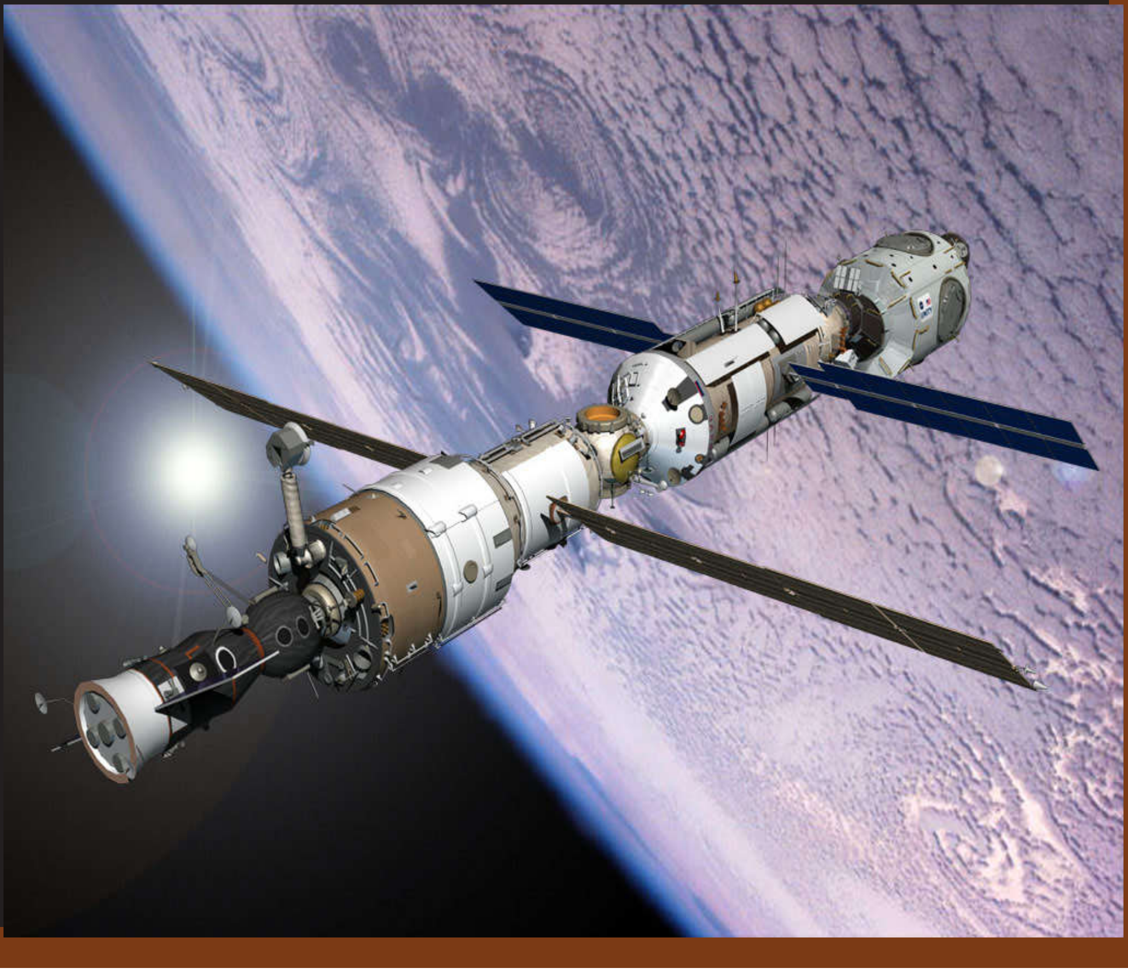
ATLANTIS RETURNS TO THE SPACE STATION

STS-106



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Updated August 29, 2000

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Shuttle Reference and Data

STS-106

Atlantis OV104

Launch: Friday, September 08, 2000
8:45 AM (eastern time)

Crew

Commander:	Terrence Wilcutt
Pilot:	Scott D. Altman
Mission Specialist 1:	Edward T. Lu
Mission Specialist 2:	Richard A. Mastracchio
Mission Specialist 3:	Daniel C. Burbank
Mission Specialist 4:	Yuri I. Malenchenko
Mission Specialist 5:	Boris V. Morukov

Launch

Orbiter:	Atlantis OV104
Launch Site:	Kennedy Space Center Launch Pad 39B
Launch Window:	2.5 Minutes
Altitude:	173 Nautical Miles, 199 Statute Miles
Inclination:	51.6 Degrees
Duration:	10 Days 19 Hrs. 9 Min.

STS-106

Vehicle Data

Shuttle Liftoff Weight:	4519645 lbs.
Orbiter/Payload Liftoff Weight:	254099 lbs.
Orbiter/Payload Landing Weight:	221271 lbs.
Payload Weights	
ICC	4,528 pounds (ICC plus cargo)
LDM	18,000 pounds

Software Version: OI-27

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

SSME 1: 2052 **SSME 2:** 2044 **SSME 3:** 2047

External Tank: ET-103A

SRB Set: BI-102PF/RSRM-75

Shuttle Aborts

Abort Landing Sites

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

Landing

Landing Date:	09/19/00
Landing Time:	3:54 AM (eastern time)
Primary Landing Site:	Kennedy Space Center Shuttle Landing Facility

Payloads

Cargo Bay

Space Experiment Module 8

Getaway Special G-782

Spacehab Logistics Double Module

In-Cabin

Commercial Generic Bioprocessing Apparatus (CGBA)

Mission Overview

Atlantis Returns to the International Space Station

Atlantis returns to the International Space Station (ISS) for the second time in four months on NASA's third Shuttle flight of the year to complete outfitting of the first home in space for the first crew of the rapidly expanding facility.

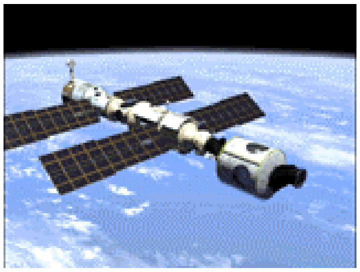
Five American astronauts and two Russian cosmonauts are set to launch on the STS-106 mission no earlier than September 8 at 8:45 a.m. EDT from Launch Pad 39-B at the Kennedy Space Center, Florida. It will be Atlantis' 22nd mission and the 99th flight in Shuttle program history.

Veteran Astronaut Terry Wilcutt (Col., USMC) leads the seven-man crew, commanding his second Shuttle flight and making his fourth trip into space. During the planned 11-day mission, Wilcutt and his crewmates will spend a week inside the ISS unloading supplies from both a double Spacehab cargo module in the rear of Atlantis' cargo bay and from a Russian Progress M-1 resupply craft docked to the aft end of the Zvezda Service Module. Zvezda, which linked up to the ISS on July 26, will serve as the early living quarters for the station and is the cornerstone of the Russian contribution to the ISS.

The goal of the flight is to prepare Zvezda for the arrival of the first resident, or Expedition, crew later this fall and the start of a permanent human presence on the new outpost. That crew, Expedition Commander Bill Shepherd, Soyuz Commander Yuri Gidzenko and Flight Engineer Sergei Krikalev, is due to launch in a Soyuz capsule from the Baikonur Cosmodrome in Kazakhstan in late October for a four-month "shakedown" mission aboard the ISS.

In addition, Dr. Ed Lu and Yuri Malenchenko (Col., Russian Air Force), both making their second flights into space, will conduct a 6 ½hour space walk on the fourth day of the flight to hook up electrical, communications and telemetry cables between Zvezda and the Zarya Control Module, whose computers handed over commanding functions to the Service Module's computers in a smooth transition in late July. Lu and Malenchenko will also install a magnetometer to the exterior of Zvezda. The magnetometer will serve as a three-dimensional compass designed to minimize Zvezda propellant usage by relaying information to the module's computers regarding its orientation relative to the Earth.

It will be the second joint U.S.-Russian space walk outside a Space Shuttle, following on the work conducted by Astronaut Scott Parazynski and Cosmonaut Vladimir Titov outside Atlantis while docked to the Mir Space Station during the STS-86 mission in October 1997. Lu, designated EV 1, will wear the space suit marked by red stripes, while Malenchenko, EV 2, will wear the pure white suit.



This will be Lu's first space walk, while Malenchenko conducted a pair of space walks totaling 12 hours during his four-month stay aboard Mir in 1994. Dan Burbank (Lt. Cmdr, USCG), who is a space rookie, will serve as the space walk choreographer.

Mission Specialist Rick Mastracchio, also a space novice, will be the prime robot arm operator for the mission, using the Canadian-built arm to move Lu and Malenchenko around the ISS as they conduct their assembly work. Mastracchio is backed up on arm operations by Pilot Scott Altman (Cmdr., USN), making his second flight into space.

The final member of the crew is Russian Cosmonaut Dr. Boris Morukov, making his first flight into space. Morukov will be responsible for unloading supplies from the Progress vehicle during the docked phase of the flight.

When Wilcutt guides Atlantis in for its docking with the ISS on the third day of the mission, he will find the new station a much larger facility than the one left by the STS-101 crew during its flight in May. With the addition of the Zvezda and the Progress resupply ship, the ISS will measure 143 feet in length, roughly the height of a 13-story building, and will weigh 67 tons, twice the size of the ISS back in May. The joining of Zvezda to the ISS and the arrival of the Progress provides about 8,800 cubic feet of habitable volume for Station crew members, roughly the size of a comfortable apartment. By the time the U.S. Laboratory Destiny is installed on the ISS in January, the Station will have surpassed both Skylab and Mir in total livable space.

On the fifth day of the flight, Atlantis' crew will enter the ISS, opening the hatch for the first time to Zvezda and to the Progress to begin unloading 1,300 pounds of goods from the Russian craft for the first resident crew, including items ranging from clothing to medical kits, personal hygiene kits, laptop computers, a color printer, vacuum cleaners, food warmers for Zvezda's galley, trash bags and critical life support hardware, including an Elektron oxygen generation unit and a Vozdukh carbon dioxide removal unit. Elektron and Vozdukh will be unstowed from the Progress and moved into Zvezda, but will not be installed and activated until the Expedition One crew arrives on board. The first toilet for the ISS will be delivered to Zvezda on the last day of the crew's work inside the Station for installation this fall once the Expedition 1 crew is on board.

Among the first tasks facing Atlantis' crew will be the installation of three batteries and associated electronic components in Zvezda and replacement of two of the six batteries in the Zarya module, completing the work begun by the STS-101 crew in May. Zvezda was launched from Baikonur on July 12 with five of its eight battery sets already installed. Lu and Malenchenko will be in charge of the installation work in Zvezda. Also earmarked for Zvezda is the activation of two gas masks, which will serve as standard emergency equipment for ISS crews and three fire extinguishers.

In addition, American-Russian power conversion units will be installed in Zvezda on this flight to route electricity from huge solar arrays which will be installed on the STS-97 mission to the Russian modules. Electrical components to charge the batteries of Soyuz or Progress vehicles visiting the ISS will be installed in Zvezda as well.

While Morukov spends most of his time unloading supplies from the Progress, Mastracchio will be in charge of unloading 2 tons of equipment from the Spacehab module, including medical equipment for the ISS' Crew Health Care System, or CheCS, which will serve as the heart of the station's clinic for orbiting crews, and a treadmill device and bicycle ergometer which will serve as the first exercise gear for crews on board the ISS. Associated hardware for the treadmill which will prevent its use from disturbing sensitive microgravity experiments, will be installed by the crewmembers near the end of their stay on board.

On the tenth day of the flight, Atlantis will undock from the ISS and Altman will conduct a flyaround of the newly expanded station to enable his crewmates to conduct photo documentation of the outpost.

Two days later, Wilcutt will fly Atlantis to a predawn landing at the Kennedy Space Center, setting the stage a few days later for the launch of a second Russian Progress ship to the Station and a plethora of Shuttle assembly flights to turn the complex into a working research facility.

International Space Station Assembly Sequence: Revision F (August 2000)

Date	Flight	Launch Vehicle	Element(s)
Nov. 20, 1998	1A/R	Russian Proton	• Zarya Control Module (Functional Cargo Block - FGB)
Dec. 4, 1998	2A	U.S. Orbiter STS-88	• Unity Node (1 Stowage Rack) • 2 Pressurized Mating Adapters attached to Unity
May 27, 1999	2A.1	U.S. Orbiter STS-96	• SPACEHAB - Logistics Flight
May 19, 2000	2A.2a	U.S. Orbiter STS-101	• SPACEHAB - Maintenance Flight
July 12, 2000	1R	Russian Proton	• Zvezda Service Module
Sept. 8, 2000	2A.2b	U.S. Orbiter STS-106	• SPACEHAB - Logistics Flight
Oct. 5, 2000	3A	U.S. Orbiter STS-92	• Integrated Truss Structure (ITS) Z1 • Pressurized Mating Adapter - 3 • Ku-band Communications System • Control Moment Gyros (CMGs)
Oct. 30, 2000	2R	Russian Soyuz	• Soyuz • *Expedition 1 Crew*
Nov. 30, 2000	4A	U.S. Orbiter STS-97	• Integrated Truss Structure P6 • Photovoltaic Module • Radiators
Jan. 18, 2001	5A	U.S. Orbiter STS-98	• Destiny Laboratory Module
Feb. 15, 2001	5A.1	U.S. Orbiter STS-102	• Logistics and Resupply; Lab Outfitting • Leonardo Multi-Purpose Logistics Module (MPLM) carries equipment racks
March 2001	4R	Russian Soyuz	• Docking Compartment 1 (DC-1) • Strela Boom

Date	Flight	Launch Vehicle	Element(s)
April 19, 2001	6A	U.S. Orbiter STS-100	Rafaello Multi-Purpose Logistics Module (MPLM) (Lab outfitting) Ultra High Frequency (UHF) antenna Space Station Remote Manipulator System (SSRMS)
May 17, 2001	7A	U.S. Orbiter STS-104	Joint Airlock High Pressure Gas Assembly
June 21, 2001	7A.1	U.S. Orbiter STS-105	Donatello Multi-Purpose Logistics Module (MPLM)
Oct. 4, 2001	UF-1	U.S. Orbiter STS-109	Multi-Purpose Logistics Module (MPLM) Photovoltaic Module batteries Spares Pallet (spares warehouse)
Jan. 2002	8A	U.S. Orbiter	Central Truss Segment (ITS S0) Mobile Transporter (MT)
Feb. 2002	UF-2	U.S. Orbiter	Multi-Purpose Logistics Module (MPLM) with payload racks Mobile Base System (MBS)
May 2002	9A	U.S. Orbiter	First right-side truss segment (ITS S1) with radiators Crew & Equipment Translation Aid (CETA) Cart A
June 2002	ULF1	U.S. Orbiter	Utilization and Logistics Flight
Oct. 2002	11A	U.S. Orbiter	First left-side truss segment (ITS P1) Crew & Equipment Translation Aid (CETA) Cart B
Oct. 2002	9A.1	U.S. Orbiter	Russian provided Science Power Platform (SPP) with four solar arrays
Dec. 2002	12A	U.S. Orbiter	Second left-side truss segment (ITS P3/P4) Solar array and batteries
Feb. 2003	12A.1	U.S. Orbiter	Third left-side truss segment (ITS P5) Logistics and Supplies

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Date	Flight	Launch Vehicle	Element(s)
April 2003	13A	U.S. Orbiter	• Second right-side truss segment (ITS S3/S4) • Solar array set and batteries (Photovoltaic Module)
June 2003	13A.1	U.S. Orbiter	• Logistics and Supplies
Aug. 2003	3R	Russian Proton	• Universal Docking Module (UDM)
Aug. 2003	5R	Russian Soyuz	• Docking Compartment 2 (DC2)
Oct. 2003	UF-4	U.S. Orbiter	• Express Pallet • Spacelab Pallet carrying "Canada Hand" (Special Purpose Dexterous Manipulator)
Nov. 2003	10A	U.S. Orbiter	• US Node 2
Feb. 2004	1J/A	U.S. Orbiter	• Japanese Experiment Module Experiment Logistics Module (JEM ELM PS) • Science Power Platform (SSP) solar arrays with truss
April 2004	ATV		• European Automated Transfer Vehicle
May 2004	1J	U.S. Orbiter	• Kibo Japanese Experiment Module (JEM) • Japanese Remote Manipulator System (JEM RMS)
June 2004	10A.1	U.S. Orbiter	• Propulsion Module
Sept. 2004	UF-3	U.S. Orbiter	• Multi-Purpose Logistics Module (MPLM) • Express Pallet
Oct. 2004	1E	U.S. Orbiter	• European Laboratory - Columbus Module
Jan. 2005	2J/A	U.S. Orbiter	• Japanese Experiment Module Exposed Facility (JEM EF) • Solar Array Batteries • Cupola
Feb. 2005	UF-5	U.S. Orbiter	• Multi-Purpose Logistics Module (MPLM) • Express Pallet

Date	Flight	Launch Vehicle	Element(s)
TBD	9R	Russian Proton	- Docking and Stowage Module (DSM)
May 2005	14A	U.S. Orbiter	- Science Power Platform (SPP) Solar Arrays - Zvezda Micrometeroid and Orbital Debris (MMOD) Shields
June 2005	UF-6	U.S. Orbiter	- Multi-Purpose Logistics Module (MPLM) - Batteries
July 2005	20A	U.S. Orbiter	- US Node 3
Aug. 2005	8R	Russian Soyuz	- Research Module 1
Sept. 2005	16A	U.S. Orbiter	- Habitation Module
Oct. 2005	17A	U.S. Orbiter	- Multi-Purpose Logistics Module (MPLM) - Destiny racks
Dec. 2005	18A	U.S. Orbiter	- Crew Return Vehicle (CRV)
Jan. 2006	19A	U.S. Orbiter	- Multi-Purpose Logistics Module (MPLM)
March 2006	15A	U.S. Orbiter	- Solar Arrays and Batteries (Photovoltaic Module S6)
March 2006	10R	Russian Soyuz	- Research Module 2
April 2006	UF-7	U.S. Orbiter	- Centrifuge Accommodation Module (CAM)

Notes: Additional Progress, Soyuz, H-II Transfer Vehicle and Automated Transfer Vehicle flights for crew transport, logistics and resupply are not listed.

Mission Objectives

Primary Objective

Among priority tasks to be completed during the STS-106 mission of Atlantis to the International Space Station are:

--Changing Zvezda, the Service Module, from launch to flight configuration by installing six ground repressurization inlet caps, removing fire extinguisher launch restraint bolts and activating gas masks in the module for the Expedition 1 crew.

--Logistics activities, including unloading the Progress cargo vessel into the ISS and transferring equipment, supplies and water from the shuttle to the ISS.

--Removing the TORU docking unit and the aft docking probe from the Zarya module.

--Replacing two batteries on Zarya and installing three batteries and associated electronic equipment on the Zvezda, installing voltage converters in the Zvezda and performing other electrical system work in that module.

--A spacewalk to connect power, data and communications cables between the Zvezda and Zarya, and install a magnetometer.

--Installation of a treadmill and related equipment.

--Air monitoring tasks, formaldehyde monitoring, replace and return three passive dosimeters in Unity and install four others in the Zvezda, as well as performing acoustic measurements in the Zvezda.

--Testing of the Space Integrated Global Positioning System/Internal Navigation System (SIGI).

--Installation of the toilet in the Zvezda.

--Performing ISS reboost with Atlantis and a shuttle flyaround of the ISS, both if propellant is available.

Progress Overview

During STS-106, the astronauts will transfer logistical material from the Progress supply vehicle to the ISS.

The Progress is an automated version of the Soyuz, and was developed to carry propellant and cargo to the Salyut and Mir space station. It will serve the same purpose for the ISS. Although ISS has its own propulsion system, generally it is the Progress vehicle that will perform periodic reboost maneuvers to maintain the ISS orbital altitude.

The Progress is approximately the same size as the Soyuz, but it has a slightly higher mass at launch of approximately 7150 kg. The Progress spacecraft docks automatically to the ISS, and the TORU system acts as a backup remote control docking system.

The Progress is composed of three modules: the Cargo Module, the Refueling Module, and the Instrument/Propulsion Module.

A modified version of the Progress M, called the Progress M1, is planned for operation with the ISS. This version will have more propellant tanks for refueling, as the entire Refueling Module is devoted to fuel. Water will be carried in the Cargo Module.

The Progress payload includes cargo in the pressurized Cargo Module and propellant in the Refueling Module. Excess propellant that is usually in the propulsion system tanks in the Instrumentation/ Propulsion Module can also be used by the ISS.

The table below summarizes the approximate payload capacity of the Progress vehicle.

Category	Progress M	Progress M1
Total payload limit (kg)	2350	2230 - 3200
Maximum pressurized cargo (kg)	1800	1800
Maximum water (kg)	420	In Cargo Module
Maximum air or oxygen (kg)	50	40
Maximum Refueling Module propellant (kg)	850	1700
Propellant surplus available to ISS (kg)	250	185 - 250
Trash disposal in Cargo Module (kg)	1000 - 1600	1000 - 1600
Wastewater (kg)	400	In Cargo Module
Cargo volume (m 3)	6.6	6.6

The relative amounts of pressurized cargo, refueling propellant, air, and water will vary within the constraints of the total payload limit. For example, if the maximum amount of propellant is carried, the amount of pressurized cargo will be less than the maximum amount. The payload masses for Progress M1 will increase within the ranges shown as improvements are made to the Soyuz launch vehicle. The lowest value corresponds to the capability with the current Soyuz launcher.

Cargo Module

The Progress Cargo Module is similar in construction to the Soyuz Orbital Module. The Cargo Module carries pressurized cargo that the crew transfers into the ISS through the docking hatch. After the Cargo Module is unloaded, trash, unwanted equipment, and wastewater can be loaded into the Progress for disposal when the spacecraft leaves the ISS.

Refueling Module

In place of the Soyuz Descent Module, the Progress has a module containing propellant tanks. The Progress is able to transfer propellant into the ISS propulsion system through fluid connectors in the docking ring. The propellant in the Refueling Module can also be used by the thrusters on the Progress vehicle for controlling and reboosting the ISS. The Progress M has four propellant tanks (two each for fuel and oxidizer) and two water tanks. The Progress M1 will have eight propellant tanks and no water tanks. In the Progress M1, water will be delivered in separate containers carried in the Cargo Module.

Instrumentation/Propulsion Module

The Progress Instrumentation/Propulsion Module is similar to the module on Soyuz, but on Progress it is twice as long and contains additional avionics equipment. The larger Instrumentation Compartment carries avionics that would be contained in the Descent Module in the Soyuz.

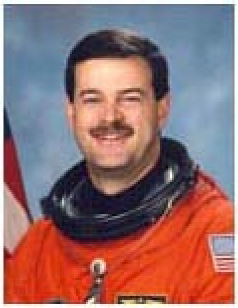
Crew Profile Menu

Commander: Terrence Wilcutt

As Commander, Wilcutt is responsible for mission success and crew safety and is the ultimate authority for all mission decisions. He will be the prime crew member for the rendezvous and docking with the International Space Station.

Previous Space Flights:
Wilcutt flew as the Shuttle pilot on two missions, STS-68 in 1994 and STS-79 in 1996. He previously commanded STS-89 in 1998, the mission that flew Andy Thomas to Mir and returned David Wolf from his 128-day stay on Mir.

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



Pilot: Scott D. Altman

Altman is responsible for many orbiter systems during launch and landing and will back up Commander Terry Wilcutt during the rendezvous and docking with the International Space Station. He will also back up his crewmates on preparations for the space walk and operation of the remote manipulator system.

Previous Space Flights:
Altman previously piloted Columbia during the 1998 STS-90 Neurolab flight.

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

Mission Specialist 1: Edward T. Lu

Lu will be teamed with Yuri Malenchenko to perform the spacewalk. During that EVA, the crew will install FBG/SM power cables, install the foot restraint and magnetometer extension pole on the Service Module, re-install the Magnetometer unit on the pole and dispose the cover on the Shuttle.

Previous Space Flights:
Lu previously served as a mission specialist on STS-84 in 1997.

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

Mission Specialist 2: Richard A. Mastracchio

As the Flight Engineer during Atlantis' launch and landing, Mastracchio will be seated behind Commander Terry Wilcutt and Pilot Scott Altman on the flight deck, monitoring key Shuttle systems. Mastracchio will use the 50-foot long robot arm to aid his EVA crewmates.

Previous Space Flights:
This will be Mastracchio's first flight.

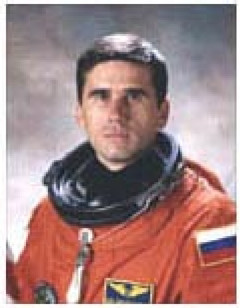
Ascent Seating: Flight Deck - Center Aft
Entry Seating: Flight Deck - Center Aft
RMS

Mission Specialist 3: Daniel C. Burbank

Burbank will serve as a backup spacewalker, and will back up "intravehicular" crew member Boris Morukov during the spacewalk.

Previous Space Flights:
This will be Burbank's first flight.

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



Mission Specialist 4: Yuri I. Malenchenko

Malenchenko will be teamed with Edward Lu to perform the spacewalk. During that EVA, the crew will install FBG/SM power cables, install the foot restraint and magnetometer extension pole on the Service Module, re-install the Magnetometer unit on the pole and dispose the cover on the Shuttle.

Previous Space Flights:
In 1994, Malenchenko served as Commander of Mir 16. He has logged 126 days in space, including 2 EVA's totaling 12 hours.

Ascent Seating: Mid Deck - Center
Entry Seating: Mid Deck - Center
EV2

Mission Specialist 5: Boris V. Morukov

Morukov will serve as the "intravehicular" crew member during the spacewalk, responsible for the choreography of the astronauts' work on the ISS.

Previous Space Flights:
This will be Morukov's first flight.

Ascent Seating: Mid Deck - Starboard
Entry Seating: Mid Deck - Starboard
IV1

Flight Day Summary

DATE TIME (EST)	DAY	MET	EVENT
09/08/00 8:45:00 AM	1	000/00:00	Launch
09/08/00 9:29:00 AM	1	000/00:44	OMS2 Burn
09/08/00 12:30:00 PM	1	000/03:45	NC1 Burn
09/09/00 12:57:00 AM	2	000/16:12	NC2 Burn
09/09/00 4:07:00 AM	2	000/19:22	NPC Burn
09/09/00 7:46:00 AM	2	000/23:01	NC3 Burn
09/09/00 8:45:00 PM	3	001/12:00	NH Burn
09/09/00 9:31:00 PM	3	001/12:46	NC4 Burn
09/09/00 11:02:00 PM	3	001/14:17	TI Burn
09/10/00 1:54:00 AM	3	001/17:09	Docking
09/11/00 1:05:00 AM	4	002/16:20	EVA Start
09/11/00 11:00:00 PM	5	003/14:15	ISS Ingress
09/16/00 3:15:00 AM	9	007/18:30	ISS Egress
09/16/00 11:44:00 PM	10	008/14:59	Undock
09/17/00 1:33:00 AM	10	008/16:48	Final Separation
09/19/00 2:50:00 AM	12	010/18:05	Deorbit TIG
09/19/00 3:54:00 AM	12	010/19:09	KSC Landing

EVAs

STATION ASSEMBLY CONTINUES DURING SPACEWALK

Overview

On the fourth day of Atlantis' flight, Mission Specialists Ed Lu and Yuri Malenchenko will venture outside into the Shuttle's cargo bay to begin the sixth space walk in support of the assembly of the International Space Station (ISS) and the 50th space walk in Shuttle history.

Lu, designated EV 1, will be making his first space walk and will wear the space suit marked by red stripes. Malenchenko, who conducted two space walks totaling 12 hours during his 1994 flight aboard the Russian Mir Space Station, is designated EV 2 and will wear the pure white suit.

The main objective of the planned 6 ½hour space walk by Lu and Malenchenko is to attach a 6-foot long magnetometer and boom to a port on the newly arrived Russian Zvezda Service Module. The magnetometer will serve as a type of navigation tool, or compass, using data acquired from the Earth's magnetic field to "tell" Zvezda's computers how it is oriented in relation to the Earth. In doing so, Zvezda's propellent usage will be minimized in maintaining the orientation of the ISS until the arrival in January of the U.S. Laboratory Destiny, which will take over attitude control, or orientation, of the ISS through the Station's Control Moment Gyroscopes.

With Mission Specialist Rick Mastracchio operating the Shuttle's robot arm and under the watchful eye of space walk choreographer Dan Burbank, who will both work at Atlantis' aft flight deck, Lu and Malenchenko will ride the Canadian-built arm as far as it will take them, about 50 feet above Atlantis' cargo bay. Then they will use tethers and handrails along the ISS' modules to make their way to a point more than 100 feet above the cargo bay for the magnetometer installation, the farthest any tethered space walker has ventured outside a Shuttle. This portion of the space walk should take about an hour and a half. Lu and Malenchenko will be twice as high above the bay as were Story Musgrave and Jeff Hoffman during the STS-61 mission when they mounted the top of the Hubble Space Telescope to replace its magnetometers.

Once the magnetometer hook up is complete, electrical, data and television cables between the newly arrived Zvezda Service Module and the Zarya Control Module to which Zvezda is docked will be connected. In all, nine cables will be rigged between the two spacecraft in a procedure expected to last almost three hours.

Four of the cables are critical power connections required before the end of the STS-97 mission to the ISS to deliver the sprawling U.S. solar arrays. These cables will enable power to flow from the arrays to the Russian modules to augment the solar arrays on both Zarya and Zvezda since the U.S. arrays will shade portions of the Russians arrays once they are installed on the top of the Z-1 truss framework.

Two of the cables will provide an internal closed circuit video feed for crew members in Zvezda so they can monitor the docking of the second Russian Progress resupply mission to the ISS in late September which will linkup to the bottom, or nadir, docking port to Zarya.

Two additional cables will link data from Zvezda to Zarya for, among other things, the commanding of Zarya solar array pointing from Zvezda now that the Zarya's motion control system has been deactivated.

A final fiber optic cable will be strung between Zvezda and Zarya to enable data to flow from the suits worn by Russian space walkers once the ISS airlock is installed at the starboard port of the Unity connecting node to accommodate joint U.S.-Russian space walks. Until then, ISS space walks must be conducted from Zvezda's transfer compartment.

This will be the second joint U.S.-Russian space walk outside a Space Shuttle. On October 1, 1997 on the STS-86 mission, Astronaut Scott Parazynski and Cosmonaut Vladimir Titov performed a five-hour space walk while Atlantis was docked to Mir. Three other space walks have been jointly conducted by astronauts and cosmonauts outside Mir without a Shuttle present:

Jerry Linenger / Vasily Tsibliev	April 29, 1997
Mike Foale / Anatoly Solovyev	September 6, 1997
Dave Wolf / Anatoly Solovyev	January 14-15, 1998

There have been five previous space walks conducted for the assembly of the International Space Station:

STS-88 (Endeavour)	Jerry Ross and Jim Newman conducted three space walks totaling 21 hours, 22 minutes on Dec. 7, 9 and 12, 1998.
STS-96 (Discovery)	Tammy Jernigan and Dan Barry conducted one space walk lasting 7 hours, 55 minutes on May 29, 1999.
STS-101 (Atlantis)	Jeff Williams and Jim Voss conducted one space walk lasting 6 hours, 44 minutes on May 21-22, 2000.

In all, the five space walks performed to date have totaled 36 hours, 1 minute of ISS assembly time.

EVA Timeline for STATION ASSEMBLY CONTINUES DURING SPACEWALK

Time	Event
2/16:20	Egress
2/16:35	EVA Sortie Setup
2/17:50	Magnetometer
2/19:05	FGB-SM Cable Install
2/21:05	EVA Sortie Cleanup
2/22:35	Ingress

Spacehab Logistics Double Module

Payload Bay

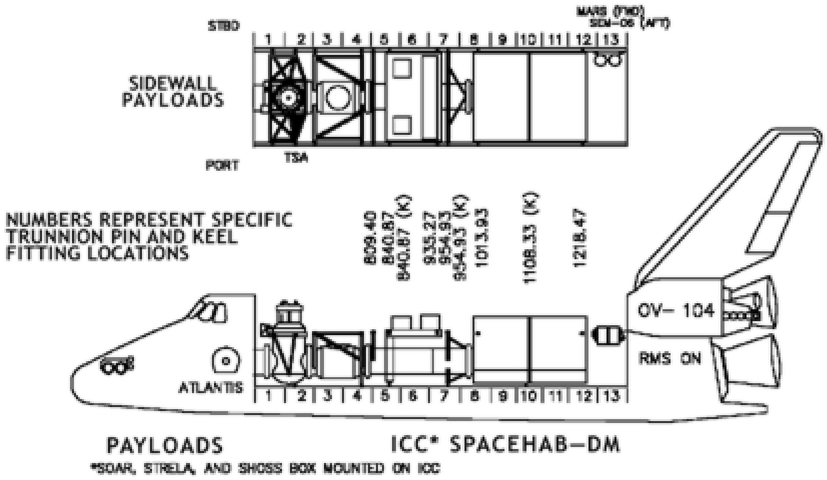
18,000 pounds

Overview

SPACEHAB's Logistics Double Module is a 20-foot long, 14-foot wide, 11.2-foot high pressurized aluminum module carried in Atlantis' payload bay and connected to the middeck area of the orbiter by an access tunnel.

For STS-106, the LDM will carry approximately 8,100 pounds of hardware, equipment and logistical supplies to outfit the International Space Station.

Designed to augment the Shuttle's middeck, the double module has a total cargo capacity of up to 10,000 pounds and contains the systems necessary to support the crewmembers, such as ventilation, lighting and limited power.



History/Background

Boeing-Huntsville developed the Logistics Double Module for SPACEHAB and serves as the mission integration contractor.

Integrated Cargo Carrier

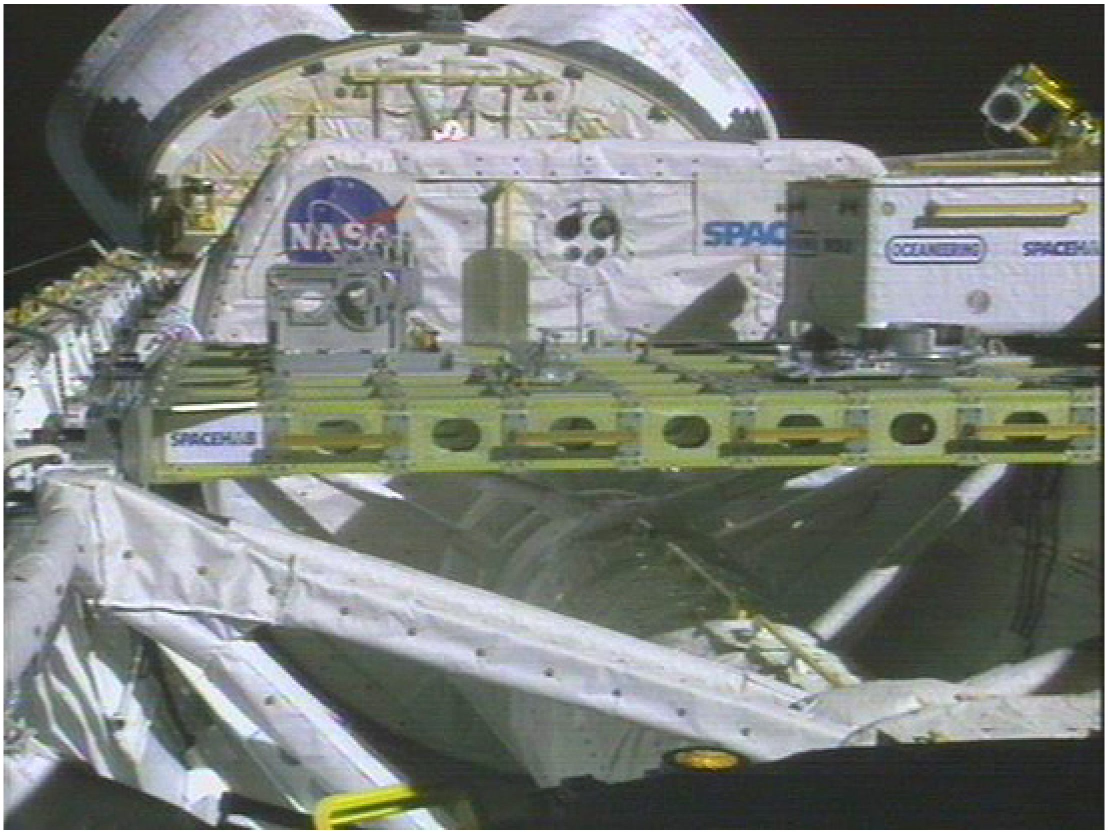
4,528 pounds (ICC plus cargo)

Overview

The Integrated Cargo Carrier is an externally mounted, unpressurized, aluminum flat-bed pallet, coupled with a keel-yoke assembly, that expands the Shuttle's capability to transport cargo.

On STS-106, it will carry 2,865 pounds of cargo to orbit. The ICC is 8 feet long, 15 feet wide and 10 inches thick, with a capacity to carry up to 6,000 pounds of cargo.

The ICC also carries the SPACEHAB-Oceaneering Space System (SHOSS) Box. SHOSS is an unpressurized "tool box" attached to the top of the ICC with the capacity to carry up to 400 pounds of tools and other flight equipment.



Commercial Generic Bioprocessing Apparatus (CGBA)

In-Cabin

Principal Investigator: Dr. Haig Keshishian, Yale University, and
Dr. Timothy Hammond, Tulane University

Project Scientist: Debra Reiss-Bubenheim, NASA Ames Research Center

Overview

CGBA experiments that explore the ways biological processes are affected by microgravity—the near-weightlessness of space—may allow researchers to better understand the nervous system. Scientists also plan to use the CGBA to investigate growing human tissue for use in surgical procedures such as skin grafts and organ transplants and in developing medicines.

Two experiments will be conducted on STS-106.

Synaptogenesis in Microgravity

This primary experiment will examine how space flight affects the developing nervous system of the fruit fly (*Drosophila melanogastor*). Researchers are particularly interested in learning how nerves that control movement navigate through the embryonic central nervous system and attach to the muscle fibers they will control and how synapses, which are the communication junctures between nerves where signals are transferred from one nerve to another, differentiate and develop to their mature form during embryonic and postembryonic life.

The fruit fly is an ideal model for studying the effects of microgravity on normal developmental processes because its development on Earth is well characterized and it has a small set of genes. A better understanding of these effects could have implications not only for long-term space travel, but also for processes related to various diseases and the disorders of aging.

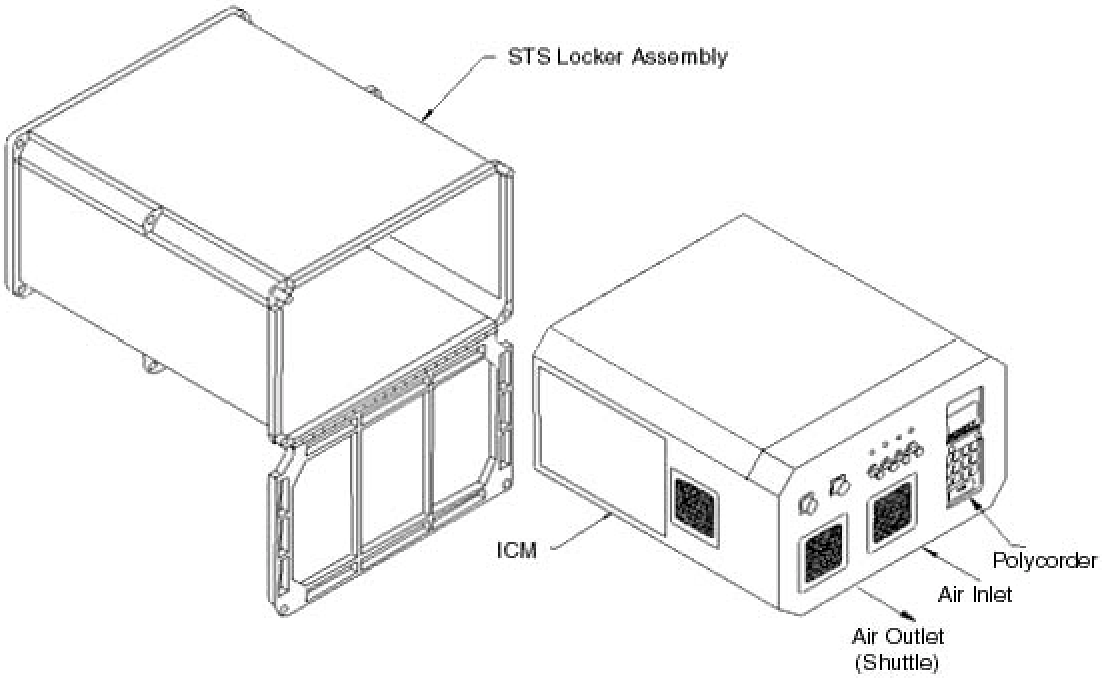
Kidney Cell Gene Expression

The second experiment is a follow-up to an STS-90 investigation. In that earlier experiment, microgravity caused large-scale alterations in kidney cell genes. The follow-up experiment will examine how microgravity alters the gene expression in kidney cells that ultimately enables kidneys to develop and function normally.

The ultimate goal of this experiment is to manipulate the kidney cells to produce specific tissues for use in humans or as models in developing medicines. Cells grown in suspension in space can join together and form three-dimensional tissues similar to their counterparts in an intact organ. These tissues are difficult to produce in Earth's gravity.

History/Background

The Commercial Generic Bioprocessing Apparatus allows automated in-flight processing of a variety of biological experiments contained in eight individually programmable, temperature-controlled devices. The CGBA payload hardware consists of the generic bioprocessing apparatus (GBA), which occupies a single middeck locker, and the isothermal containment module (ICM), a middeck locker apparatus for storing biological samples in a temperature-controlled environment.



The GBA is a self-contained mixing and heating module for processing biological fluid samples. Up to 120 triple-contained glass syringe fluid samples (in Lexan sheaths) are stored in either the ICM or a middeck locker. These fluids are manually mixed in the syringes and transferred to containment vials that are heated and incubated. At the end of the incubation period, the fluid vials are returned to the ICM or stowage locker.

The ICM maintains a preset temperature environment, controls the activation and termination of the experiment samples, and serves as an interface for crew interaction, control, and data transfer.

The fruit fly experiment will occupy seven sample containers, and the kidney cell gene expression experiment will occupy the eighth.

The Commercial Generic Bioprocessing Apparatus is a cooperative commercial experiment facility sponsored by NASA's Space Product Development Program at the Marshall Space Flight Center in Huntsville, Ala. BioServe Space Technologies designed, built, and manages the apparatus. BioServe is a NASA Commercial Space Center with facilities at the University of Colorado in Boulder and Kansas State University.

Yale University and NASA's Ames Research Center at Moffett Field, Calif., are conducting the fruit fly research, which is cosponsored by the National Institutes of Health. The Fundamental Biology Program at Ames is sponsoring the kidney cell experiment.

Various configurations of CGBA have flown on 13 previous Space Shuttle missions and 2 Mir missions. The CGBA technology is being advanced and refined for future use on the International Space Station.

Benefits

The interdisciplinary nature of this research offers unique educational opportunities for undergraduate and graduate students. Improving applications and developing new products will benefit U.S. industry, enhance the quality of life, and propel the field of biotechnology toward new frontiers.

Getaway Special G-782

Payload Bay

Principal Investigator: Keith Bennett, Washington University, St. Louis

Overview

The G-782 payload, or Aria-1 as it is known to its sponsors, is an educational project to give elementary and high school students in the St. Louis area an opportunity to be involved in hands-on space science and perhaps steer them toward science, engineering and technology careers. Aria-1 is a joint project of the School of Engineering and Applied Science of Washington University in St. Louis and the Cooperating School Districts, an educational consortium of 47 school districts in the greater St. Louis metropolitan area.

More than 300 students from eight St. Louis schools prepared hypotheses, designed experiments, collected materials, and prepared flight articles under the guidance of their teachers. After the flight, the students will compare flight samples with ground controls to determine the effects of microgravity, radiation, magnetism, and other possible phenomena experienced in the low Earth orbit environment of the Shuttle mission.

The student experiments are housed in a standard 5-cubic-foot getaway special canister that is attached to the sidewall of Atlantis' payload bay. The payload is completely passive and requires no crew action.

Aria-1 Schools and Experiments

Bristol Elementary School

For this experiment, 50 first graders each drew pictures on two pieces Shrinky Dink plastic that are about 5 inches square. This plastic shrinks about 50% when it is exposed to high heat. One set of 50 plastic pieces will be heated in a toaster oven on Earth so the students can see the effects of heat in gravity. After the mission, the students will examine their Shrinky Dinks that flew on Aria-1 to determine if they were exposed to high temperatures. Each student will also get a souvenir—a piece of plastic that has flown on the Space Shuttle.

Marissa Junior/Senior High School

Fourteen Marissa High School students are sending 18 different kinds of garden, flower, and crop seeds into space on Aria-1. They want to find out if the increased ultraviolet radiation and extreme temperature changes found in space will change how the seeds grow and the appearance of the plants. The experimenters will plant the seeds exposed to space alongside control seeds that remained on Earth and observe any differences in the plants.

Glenridge Elementary School

Eight Glenridge students are investigating the reactions of everyday objects to the unique environment of space. They are studying the chewability of Bubblacious Bubble Gum, the spin patterns and the rate of germination of maple seeds, the ability of mold on bread to survive in space, the effects on dry cement mix and its hardening rate, and the ability of active dry yeast to rise.

Ladue Junior High School

Twelve students have devised experiments whose results may have practical applications in space travel. One experiment will gauge the effect of space on the cleaning power of moist towelettes. Another will study whether space causes toothpaste to become hard and lose its flavor and color. One group of students would like to find out whether microgravity, air pressure, and temperature changes will cause sticky tack to lose its stickiness. In a related experiment, a student will test his hypothesis that glue exposed to microgravity will become thinner and less sticky. An experiment labeled rubberball physics by its developers will try to determine whether space has any lasting effects on a rubber ball. Finally, a student is sending a floppy disk into space to see if the data encoded on it will be affected by zero gravity.

Hazelwood West High School

Hazelwood West High School students have several experiments on Aria-1. One will examine the effects of space flight on the ability of copper and superglue to withstand changes in gravity, temperature, and radiation. Bacteria spores will be studied to determine whether space exposure alters microorganisms. Finally, the experimenters will investigate crystal growth in frozen red beet cells. They want to know if changing the concentration of salt in a solution containing these cells will affect the growth of crystals and cell damage.

Mary Institute Country Day School

The MICDS Middle School Science Club is sending brine shrimp, dry yeast, and two floppy disks into space to determine how the microgravity, temperature extremes, and various atmospheric pressures of space affect them. If the organisms withstand these conditions and "reanimate" when they return to Earth, it may suggest that simple life forms might exist elsewhere in the universe. If the disks retain their ability to read and write data, it may mean that personal computers could be used on the International Space Station and Shuttle missions, which would help make space exploration more economical.

Center for Creative Learning

Fourth and fifth graders designed 13 experiments to answer questions about how different types of materials and organisms react to exposure to space because they realize the importance of these answers as humans move into space to live and build. Their experiments include studying human blood for mutations, observing changes in the growth patterns of bulbs, examining carrot slices infected with agrobacterium tumefacians for any changes in their nuclei, and studying material reactive to airborne particles for changes.

Sacred Heart Elementary School of Florissant

Students from Sacred Heart School will study the effects of space on the decomposition of various items, specifically the rate of decomposition. Samples of seeds, toothpaste, moldy bread, rotting hamburger, hair, soil, water from the Meramec River, and brine shrimp will be sent into space in sealed vials. After the mission, the students will compare the amount of decomposition of the samples exposed to space with that of control samples that remained on Earth. The results of this experiment could lead to a better system of waste reduction than traditional landfills and ultimately promote better stewardship of our environment.

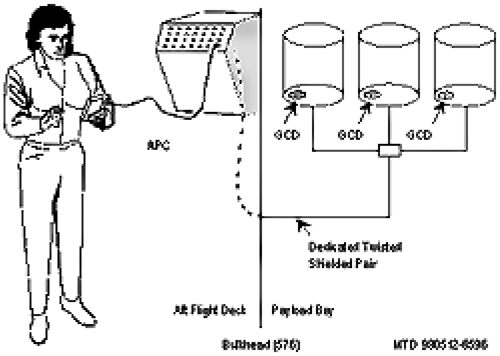
More information on Aria-1, including a list of participating schools and experiment descriptions, is available at http://www.aria.cec.wustl.edu/Aria1.

History/Background

STS-106 is the 36th Shuttle mission to participate in NASA's Getaway Special program. The GAS program was designed as an inexpensive way for educational, international, commercial, and U.S. government users to place a payload on the Space Shuttle. Since the program began, 157 payloads have been flown.

Each payload must meet specific safety criteria and be screened for its propriety as well as its educational, scientific, and technical objectives. These guidelines preclude commemorative items that are intended for sale as objects that have flown in space.

The Goddard Space Flight Center's Wallops Flight Facility, Wallops Island, Va., manages the program. More information on the Getaway Special program can be found at http://www.wff.nasa.gov/~sspp/gas/gas.html.



Getaway Special Control Concept

Space Experiment Module 8

Payload Bay

Overview

Eye lenses, seeds, water, DNA, and steel are just some of the materials that will be the subjects of student research on the eighth flight of the Space Experiment Module (SEM) project, NASA's educational initiative to increase access to space for students from kindergarten to college. All together, 13 passive experiments will be flown on STS-106.

Since the first SEM flight in 1996, tens of thousands of students have flown experiments in space that they have created, designed, and built with the help of teachers or mentors. NASA provides the experiment modules, or containers, which are placed in standard 5-cubic-foot getaway special canisters that are mounted in the orbiter's payload bay.

SEM-08 Experiments

Water, Water Everywhere
Town of Tonawanda School District, Buffalo, N.Y.; Edgemont Union Free School District, Scarsdale, N.Y.; Auxiliary Services for High Schools, New York City Board of Education

Students will observe the effects of space on samples taken from natural bodies of water. The students assume that changes in radiation, gravity, and temperature will have no effect on the abiotic and biotic levels in the samples.

Houston, We Have an Eye Problem
Irwin Altman School 172, Floral Park, N.Y.

The purpose of this experiment is to determine if the high radiation of space will cause the layers of eye lenses to become cloudy and transmit less light. Lenses from sheep and cows will be used in this investigation. Contact lenses also will be tested to determine the effects of radiation on the amount of light they transmit.

Investigation of Antibiotic-Resistant Mutations in a Microgravity Environment
Shoreham-Wading River High School Science Research Program, Shoreham, N.Y.

This experiment will analyze differences in the mutation rates of antibiotic-resistant plasmid DNA exposed to microgravity and controls exposed to Earth's gravity.

R.S.V.P. (Rams Space Variety Package)
Parkside High School, Salisbury, Md.

Students will study the effect of space on seeds, film, minicassettes, and a radiation dosimeter.

The Pittsburgh Steelers in Space
The DePaul Institute for the Deaf, Pittsburgh, Penn.

Students will determine the effects of microgravity and radiation on the oxidation of various types of steel and the minerals involved in the manufacture of steel.

Medicine Cabinet in Space
North Kingstown High School, North Kingstown, R.I.; Cannon School, Concord, N.C.; Williston Northampton School, Easthampton, Mass.; South Middle School, St. Peters, Mo.; Holy Family School, Harrisburg, Pa.; Ramstein American High School, Ramstein Air Base, Germany

The experiment is designed to determine how common items from the medicine cabinet, items that could potentially be found on a long space mission, are altered by the space environment.

Mars Lunch Box
Trinity Lutheran School, Cedar Rapids, Iowa, partnered with students from Wales; Washington Junior High School, Rock Island, Ill., partnered with students in Australia; Northside Middle School, Hampton, Va., partnered with students in Iceland

This experiment will study the effects of space travel on the growth of vegetable seeds.

SINBAD (Scientific and Instructional Ballast Alternative Device)
Florida Institute of Technology, Geospace Physics Laboratory, Melbourne, Fla.

This experiment will study the frequencies of the orbiter during launch, orbit, and landing; examine the effects of space flight on palm tree seeds; and study the reaction of acrylic latex caulking and its outgassing of water vapor.

PEESOIL
Gates Chili High School, Rochester, N.Y.; Mynderse Academy, Seneca Falls, N.Y.; Northampton High School, Northampton, Mass.

The students are studying whether microgravity and radiation have an effect on the fertility of soil samples as determined by the soil's biodiversity. The experimenters will determine the average number of different organisms found before and after the soil is exposed to space.

Process of Germination and Plant Growth
Frank Elementary School, Guadalupe, Ariz.

This experiment will determine how the space environment affects seed germination and plant growth. Kentucky Wonder and Quest seeds will be used in this investigation.

Spaced Popped Popcorn
South Shore Elementary School, Crownsville, Md.

The students predict that unpopped popcorn exposed to microgravity and radiation will pop at a different rate and volume than the control group, which will remain on Earth.

Bounce and Stretch
South Shore Elementary School, Crownsville, Md.

The students predict that microgravity and radiation will affect the physical characteristics of elastic materials, including balls and rubber bands.

Germ Killers in Space
Walter S. Mills-Parole Elementary, Annapolis, Md.

This experiment will study the effects of microgravity, radiation, and temperature on mouthwash and antibacterial hand gel.

History/Background
The Space Experiment Module program is one of a number of educational initiatives of NASA's Shuttle Small Payloads Project. Recognizing the need to provide easy access to space for all students, NASA began the SEM program in 1995. SEM participants are encouraged to focus on the educational act of creating experiments rather than the complexities of engineering.

More information about the SEM program can be found at http://www.wff.nasa.gov/~sspp/sem/sem.html.

Benefits
The SEM program offers simplified access to space for students at every grade level. It uses cross-curriculum learning, particularly in math, science and technology, to promote interest in space exploration.

Experiments

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

In-Cabin

Overview

HTD 1403 will demonstrate the operational utility and functionality of the micro-WIS on orbit, initially in the crew cabin of the Shuttle orbiter and then on the International Space Station.

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

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

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

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

History/Background

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

Benefits

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

Experiments

Protein Crystal Growth (PCG) Enhanced Gaseous Nitrogen (EGN) Dewar

In-Cabin

Principal Investigator: Dr. Alexander McPherson, University of California, Irvine

Overview

The primary purpose of the EGN Dewar experiment is to demonstrate a low-cost platform for conducting a large number of experiments to determine the optimum conditions for growing large, high-quality protein crystals in space. Researchers require crystals of sufficient size and suitable quality for crystallographic analysis of their molecular structure by X-ray diffraction and computer modeling. EGN promises to give researchers greater access to space and the opportunity to conduct a statistically significant number of experiments per mission, which will increase the likelihood of obtaining crystals worthy of X-ray analysis.

Researchers will also use data from EGN in selecting the methodologies and proteins for future liquid-liquid diffusion experiments, which will investigate the factors that influence the nucleation, growth, order, and stability of crystals and determine the effects of microgravity on those phenomena.

Protein samples are flash frozen before a mission and placed inside the Dewar, a vacuum-jacketed container similar to a thermos bottle. An absorbent inner liner is saturated with liquid nitrogen, which keeps the samples frozen until they reach orbit. As the system absorbs heat, the nitrogen boils away and the samples begin to thaw. Crystals begin to grow when the samples have completely thawed.

Astronauts will transfer the EGN payload from Atlantis' middeck to the International Space Station, where the crystals will continue to grow until the package is returned to Earth for analysis on the next Shuttle mission. EGN is the first microgravity science experiment to be conducted on board the International Space Station.

EGN is upgrade of an experiment that was flown on Shuttle-Mir missions. The earlier version allowed the samples to thaw gradually over 12 to 20 days. The enhanced version incorporates heaters that will control the rate of nitrogen boil-off and, thus, the rate of thawing. The new design also includes devices for recording the temperatures inside the Dewar and storing the data.

History/Background

The gaseous nitrogen Dewar was flown on five Shuttle-Mir missions—STS-71, 74, 76, 79, and 81. The experiment packages were transferred from the Shuttle orbiter to a module of the Mir station, and the samples were allowed to grow uninterrupted until the next Shuttle mission.

Benefits

Proteins play an important role in every biochemical reaction in plants and animals. In order to understand the basic processes of living things, scientists must first understand proteins. Computer models of the structures of protein crystals grown in the near-vacuum of space are expected to improve their understanding of the function and behavior of proteins. Scientists also hope to learn more about why biological crystals grow differently in space than they do under the influence of Earth's gravity.

Single-String Global Positioning System

DTO 700-14

Overview

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

This is the tenth flight for DTO 700-14. It was last flown on STS-101.

SIGI Orbital Attitude Readiness
DTO 700-21

Payload Bay

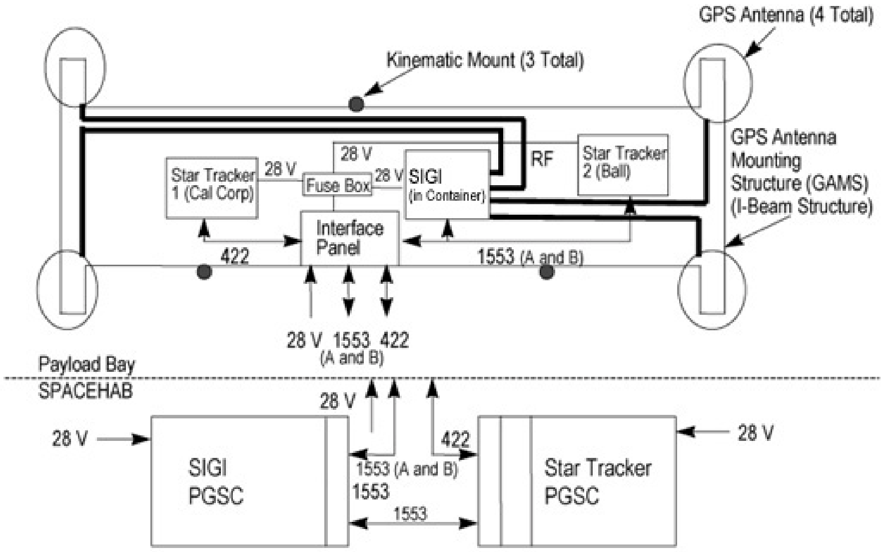
Overview

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

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

This is the second flight of DTO 700-21.

SIGI Orbital Attitude Readiness Configuration



Crosswind Landing Performance

DTO 805

Overview

This DTO will continue to gather data to demonstrate the capability to perform a manually controlled landing with a 90-degree, 10- to 15-knot steady-state crosswind. This DTO can be performed regardless of landing site or vehicle mass properties. During a crosswind landing, the drag chute will be deployed after nose gear touchdown when the vehicle is stable and tracking the runway centerline. This DTO has been manifested on 59 previous flights.

Monitoring Latent Virus Reactivation and Shedding in Astronauts Using Saliva Kits

DSO 493

Overview

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

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

Individual Susceptibility to Postflight Orthostatic Intolerance (Tilt Test)

DSO 496

Overview

It is well known that space flight alters cardiovascular function significantly. One of the most important changes negatively affecting flight operations and crew safety is the postflight loss of orthostatic tolerance, which causes astronauts to have difficulty walking independently and induces lightheadedness or fainting. These may impair their ability to leave the orbiter after it lands.

Susceptibility to postflight orthostatic hypotension is highly individual; some astronauts are affected very little and others have severe symptoms. This DSO will test the hypothesis that orthostatic hypotension is caused, in part, by gender-related differences in the autonomic regulation of arterial pressure and changes in autonomic function brought on by space flight.

Space Flight and Immune Function

DSO 498

Overview

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

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

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

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

Eye Movements and Motion Perception Induced by Off-Vertical-Axis Rotation (OVAR) at Small Angles of Tilt After Space Flight

DSO 499

Overview

Astronauts returning to Earth have experienced perceptual and motor coordination problems caused by sensorimotor adaptation to microgravity. The hypothesis is that the central nervous system changes the way it processes gravitational tilt information that it receives from the vestibular (otolith) system. Eye movements and perceptual responses during constant-velocity off-vertical-axis rotation will reflect changes in otolith function as astronauts readapt to gravity. The length of recovery is a function of flight duration (i.e., the longer astronauts are exposed to microgravity the longer they will take to recover).

This DSO will examine changes in astronauts' spatial neural processing of gravitational tilt information following readaptation to gravity. Postflight oculomotor and perceptual responses during off-vertical-axis rotation will be compared to preflight responses to track the time of recovery.

Shuttle Reference and Data

Shuttle Abort Modes

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

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

INTACT ABORTS

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

Mission Benefits

Why the ISS? It's About Life on Earth & Beyond!

Exploration:

An exciting gateway to new frontiers in human space exploration - meeting the deep-seated need of men and women throughout history to explore the unknown, to understand their world and the universe, and to apply that experience for the benefit of all here on Earth.

Leadership:

Sustains U.S. leadership in exploration and use of outer space which has inspired a generation of Americans and people thoughout the world.

Research:

A unique world-class laboratory providing an international platform for advances in science and technology.

Business:

Provides a stunning opportunity to enhance U.S. economic competitiveness and create new commercial enterprises

Education:

Serves as a virtual classroom in space to the benefit of educators and students alike.

Research on the International Space Station:

The International Space Station represents a quantum leap in our capability to conduct research on orbit. It will serve as a laboratory for exploring basic questions in a variety of disciplines, and as a testbed and springboard for exploration. Research on the ISS will include commercial, science, and engineering research in the following areas:

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; and develop advanced waste processing and agricultural technologies with applications in space and on Earth.

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, . . .).

Long Term Benefits: Enhance the safety of space travel; develop methods to keep humans healthy in low-gravity environments; and 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); and 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; and improved mathematical models for designing fluid handling systems for powerplants, refineries and innumerable other industrial applications

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; and 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; and 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; and 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

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

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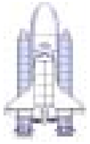
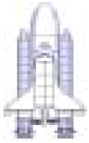
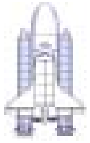
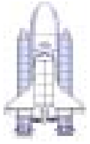
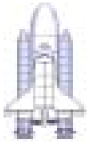
SHUTTLE FLIGHTS AS OF SEPTEMBER 2000

98 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 73 SINCE RETURN TO FLIGHT

OV-102 Columbia (26 flights)	OV-099 Challenger (10 flights)	OV-103 Discovery (27 flights)	OV-104 Atlantis (21 flights)	OV-105 Endeavour (14 flights)
		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-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
STS-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	STS-51G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89	STS-61 12/02/93 - 12/13/93
STS-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89	STS-57 06/21/93 - 07/01/93
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88	STS-54 01/13/93 - 01/19/93
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51A 11/08/84 - 11/16/84	STS-61B 11/26/85 - 12/03/85	STS-47 09/12/92 - 09/20/92
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	STS-41D 08/30/84 - 09/05/84	STS-51J 10/03/85 - 10/07/85	STS-49 05/07/92 - 05/16/92

Table prepared by Richard W. Orloff, 02/2001