Refining the Hubble Space Telescope's View of the Universe

STS-103

SPACE SHUTTLE PRESSKIT

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Mission Overview

DISCOVERY SET TO VISIT HUBBLE SPACE TELESCOPE

Spacewalks by four astronauts to highlight third servicing mission

Space Shuttle Discovery is poised to launch December 9 on the third visit to the Hubble Space Telescope that will include four spacewalks designed to install new equipment and replace old. The liftoff is set to occur at the beginning of a 42-minute launch window opening at 1:10 a.m. Eastern Standard Time. The launch time will be refined one final time closer to the launch when the flight dynamics team obtains updated trajectory data for Discovery's rendezvous with Hubble.

Seven astronauts are ready to pay this visit to Hubble a little sooner than originally planned so that its gyroscope complement can be restored to full capacity. In addition, other tasks will be completed that originally had been scheduled for next year. The mission will feature four spacewalks, or extravehicular activities (EVA's), to ensure the health of the first of NASA's Great Observatories launched nearly a decade ago. Each of the spacewalks is planned to last about six hours with specific tasks laid out to maximize the efficiency of the work to be done.

The primary objective is to replace all six gyroscopes that make up the three Rate Sensor Units. In addition, astronauts will install a new computer that will dramatically increase the computing power, speed, and storage capability of HST. They will change out one of the Fine Guidance Sensors and replace a tape recorder with a new Solid State Recorder. The EVA crew also will install a new S-band single access transmitter and voltage/temperature improvement kit for the telescope's nickel-hydrogen batteries. Finally the crew will begin repair of the insulation on the telescope's outer surface that has deteriorated in the years since it was launched.

Steve Smith services the Hubble Space Telescope during the STS-82 mission

The STS-103 mission will be commanded by veteran astronaut Curt Brown (Col., USAF), who will be making a record-tying sixth voyage to space and third as commander. Making his first flight into space is pilot Scott Kelly (Lt. Cmdr.,USN).

Five mission specialists are assigned to the flight. European Space Agency (ESA) Astronaut Jean-Francois Clervoy is Mission Specialist 2 serving as the flight engineer and primary robot arm operator. He will be making his third flight on the shuttle. The four remaining crewmembers will form two teams to perform the four spacewalks. Mission Specialist 1 and Payload Commander is Steven Smith. He's flying on the shuttle for the third time and will team with John Grunsfeld on the first and third EVAs. Grunsfeld, Mission Specialist 3, also will be making his third flight into space. Mission Specialist 4, Michael Foale, and Mission Specialist 5, Claude Nicollier of the European Space Agency, will team on the second and fourth spacewalks. Foale will be going to space for the fifth time and Nicollier for the fourth.

Though the four spacewalking astronauts began training for this mission more than a year ago, the remaining three crewmembers were not named until this past March when the Hubble project called for this earlier-than-scheduled visit to replace the ailing gyroscopes. The training consisted of underwater activity in the Neutral Buoyancy Laboratory near the Johnson Space Center; and hands-on training in the Goddard Space Flight Center's 12,500 square-foot cleanroom.

As was the case with the previous servicing missions, the crew practiced every task it will have to perform during the four scheduled spacewalks. More than 150 special tools and crew aids have been developed for the servicing missions.

STS-103 will be the 27th flight of Discovery and the 96th mission in the history of the Space Shuttle Program.

HST Servicing Mission 3A -- COST TO TAXPAYERS

NASA's Hubble Space Telescope is the first observatory designed for routine maintenance, upgrade, and refurbishment on orbit. The program is planned as a 20-year mission with periodic servicing by Shuttle astronauts. Hubble's modular design allows for more than 90 spacecraft components and all of its scientific instruments to be replaced on orbit. Servicing maintains the spacecraft, ensures operation at maximum scientific efficiency and allows for incorporation of new technology.

Hubble was launched on April 24, 1990 with a full complement of six scientific instruments. At that time, an inventory of spare HST hardware was available to support future servicing missions. Since launch, HST budgets have been sized to develop new instruments, to maintain the spare hardware, to sustain hardware expertise, to plan and develop servicing activities, and to test and integrate the payloads with the Shuttle.

Due to gyroscope failures, a servicing mission was needed as soon as replacement hardware could be ready. Servicing Mission 3 (scheduled for June 2000) was divided into two flights --- servicing mission 3A (SM3A), and servicing mission 3B (SM3B), scheduled for no earlier than the Spring of 2001. Much of the hardware planned for servicing mission 3 will not be ready in time for the first flight, and will therefore be installed on SM3B.

The cost to carry out this mission is $136 million. This includes $19 million of HST costs for the additional servicing mission, $7 million of HST costs to switch from Columbia to Discovery, and $110 million for the Shuttle to carry out the mission and replace Space Shuttle flight hardware previously assigned to another mission. NASA has also spent approximately $69 million on Servicing Mission 3A, in addition to the $136 million, reflecting the costs of building and testing the planned replacement hardware, ground operations and other related activities.

All six gyroscopes will be replaced during the STS-103 (SM3A) mission. The fourth of the sixth existing gyroscopes failed on Nov. 13, forcing Hubble to suspend scientific operations until the servicing mission is completed.

In addition, the crew will replace a guidance sensor (a unit brought back to the ground after the last mission and refurbished) and the spacecraft's computer. The new computer will reduce the burden of flight software maintenance and significantly lower operating costs. A voltage/temperature kit will be installed to protect spacecraft batteries from overcharging and overheating in certain, infrequent spacecraft modes of operation. A new radio frequency transmitter will replace a failed spare one currently aboard the spacecraft, and a spare solid state recorder will be installed to allow more efficient handling of high-volume data.

HST Program & STS-103 Costs

Servicing Mission Costs - HST	
Planned Servicing Mission Hardware & Software	
Gyroscope	$8 Million
Fine Guidance Sensor	$13 Million
Advanced Computer	$7 Million
Other Flight Hardware	$11 Million
Simulators/Testing	$6 Million
Ops/Software Development	$24 Million
Sub-total	**$69 Million**
Costs for Flight Changes	
HST Cost for Additional Servicing Mission	$19 Million
HST Cost for Switching from Columbia to Discovery	$7 Million
Sub-total	**$26 Million**
HST Total	**$95 Million**
Servicing Mission Costs - Shuttle	
Shuttle Flight Costs	$110 Million
Total STS-103 Mission Costs	
Shuttle	$110 Million
HST	$95 Million
Total	**$205 Million**

Plans for the Future

The Hubble Space Telescope's purpose is to spend 20 years probing the farthest and faintest reaches of the cosmos. Routine servicing missions will continue to refine and enhance the telescope's capabilties. Two additional servicing missions and a close-out mission are planned.

Three instruments are currently in active scientific use on Hubble - the Wide Field and Planetary Camera 2, the Space Telescope Imaging Spectrograph, and Fine Guidance Sensor 1R, which has been designated as the prime Fine Guidance Sensor for astrometric science. Other instrument bays are occupied by the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), which is now dormant due to the depletion of its solid nitrogen cryogen, the Faint Object Camera, which has been decommissioned, and the corrective optical device called COSTAR, which is no longer needed.

Servicing Mission 3B -- Spring 2001

The next servicing mission will focus on installing the Advanced Camera for

Surveys and more efficient rigid solar arrays. Astronauts also will install the aft shroud cooling system. In addition, an advanced cooling system will be installed on NICMOS, which became dormant after its solid nitrogen coolant was exhausted in January 1999. The application of new external thermal

Advanced Camera for Surveys

During this mission, scheduled for Spring 2001, astronauts will install a new science instrument, the Advanced Camera for Surveys (ACS). The Advanced Camera for Surveys will physically replace the Faint Object Camera. This new instrument is designed for survey mode imagery and discovery. It is estimated that the survey capability of the Telescope will be increased tenfold. A major objective for the ACS is mapping the distribution of dark matter throughout the universe. Several other maintenance activities are planned over four EVA days. A few of the activities are discussed below.

Solar Array III

Two large flexible solar array wings provide power to Hubble. During Servicing Mission 1, the original European Space Agency arrays were replaced with a new upgraded set of solar arrays. These arrays consist of silicon cells installed on a thin layer of Kapton blanket. When these arrays are replaced they will have powered the Telescope for nearly 7 years.

The newest arrays are rigid arrays, which do not roll up and therefore are more robust. They are also smaller and more efficient and will slightly reduce the effects of atmospheric drag on the spacecraft. The arrays to be installed on that servicing mission have several enhancements and incorporats new technology: The cells are made from gallium arsenide which is more efficient than the original silicon cells. The frames are made of lightweight Lithium Aluminum alloy tubes, in an "H"-shaped configuration. Each wing can be folded for transport, and then easily locked into place when fully deployed.

NICMOS Cooling System

The NICMOS Cooling System, an experimental mechanical cooling system, will be connected to NICMOS to return it to normal operation.

Aft Shroud Cooling System

This new system is designed to carry heat away from scientific instruments in the Aft Shroud area of the Telescope assembly and to allow the instruments to operate better at lower temperatures. The cooling system allows multiple instruments to operate simultaneously, helping the science team maintain the program's high productivity

Possible Reboost

Although the atmosphere is quite thin at satellite altitudes, it is not a perfect vacuum. Over time, all low Earth orbiting satellites feel the effects of atmospheric drag and lose altitude. If the altitude is not restored, the

Telescope eventually will reenter Earth's atmosphere. Hubble has no on-board propulsion, so the only way to restore lost altitude is by the creative use of shuttle jets. If necessary, Hubble will be reboosted to a higher altitude. This was done on both Servicing Missions 1 and 2.

Servicing Mission 4 -- 2003

Plans for the fourth servicing mission are very preliminary at this time, but two Science Instruments are in development. The corrective optics package installed on the first servicing mission will be removed during this mission to make room for the Cosmic Origins Spectrograph. Wide Field Camera 3 will replace the Wide Field Planetary Camera 2. Also a refurbished Fine Guidance Sensor will be in-stalled leaving Hubble in optimum condition.

Cosmic Origins Spectrograph

The Cosmic Origins Spectrograph (COS) is a medium resolution spectrograph specifically designed to observe into the near and mid ultraviolet. COS coupled to Hubble's optics will be the most sensitive spectrograph ever flown in space. The ultraviolet region is particularly interesting for observing hot objects such as new hot stars and quasars. It is also a good region for viewing the composition and character of interstellar and intergalactic gas. COS will measure the chemical composition of the gas between the galaxies at great distances, as it was when the universe was very young.

Wide Field Camera Three

Wide Field Camera Three (WFC3) will be the last imaging camera mounted on HST. WFC3 will replace the current workhorse of Hubble, Wide Field and Planetary Camera 2. WFC3 will be a "panchromatic" camera, extending Hubble's imaging capability over an enormous range of wavelengths from the ultraviolet to the near-infrared. It will provide important backup to the ACS in visible light and will supersede the near-infrared capability of the aging NICMOS. This upgrade will allow Hubble to maintain good imaging capa-bilities throughout the remainder of its mission.

Fine Guidance Sensor

The Fine Guidance Sensors are systematically refurbished and upgraded. In "round-robin" fashion, one FGS per servicing mission is being replaced. The returned FGS is disassembled and refurbished, and then taken back to Hubble on the next servicing mission to replace the next FGS. By the conclusion of SM4 all three FGS's will have been brought up to optimum condition in this manner.

Closeout Mission -- 2010

NASA will determine the best approach to secure the Telescope, upon the completion of Hubble's 20-year mission. Currently there are several options being considered, ranging from staying in orbit indefinitely through a large reboost, to a return to ground.

Discovery OV103

Launch: Thursday, December 09, 1999
1:10 AM (eastern time)

Crew

Commander:	Curtis L. Brown
Pilot:	Scott J Kelly
Mission Specialist 1:	Steven L. Smith
Mission Specialist 2:	Jean-Francois Clervoy
Mission Specialist 3:	John M. Grunsfeld
Mission Specialist 4:	Michael Foale
Mission Specialist 5:	Claude Nicollier

Launch

Orbiter:	Discovery OV103
Launch Site:	Kennedy Space Center, Florida
Launch Window:	42 minutes
Altitude:	315 NM insertion
Inclination:	28.45 degrees
Duration:	9 Days 22 Hrs. 7 Min.

Vehicle Data

Shuttle Liftoff Weight:	4,506,759 lbs.
Orbiter/Payload Liftoff Weight:	248,000 lbs.
Orbiter/Payload Landing Weight:	211,129 lbs.

Software Version:

Space Shuttle Main Engines

SSME 1: 2053 **SSME 2:** 2043 **SSME 3:** 2049

External Tank: ET-101 (5 Super Light Weight Tank)

SRB Set: OI-26B

Auxiliary Power Units:

APU-1: 310	**APU-2:** 204	**APU-3:** 404

Fuel Cells:

FC-1: 110	**FC-2:** 119	**FC-3:** 122

Landing

Landing Date:	12/18/99
Landing Time:	10:41 PM (eastern time)
Primary Landing Site:	Kennedy Space Center, Florida landing time approximate

Crew Profile Menu

Commander: Curtis L. Brown

Brown will become the fifth man to fly in space six times, joining John Young, Story Musgrave, Franklin Chang-Diaz and Jerry Ross in that exclusive group. Brown is responsible for mission success and crew safety as well as the ultimate authority for all mission decisions. He will be the prime crew member for the rendezvous and retrieval of the Hubble Space Telescope, and vehicle operation following the Telescope's release back into orbit.

Brown flew as a Shuttle pilot on three missions, STS-47 in 1992, STS-66 in 1994 and STS-77 in 1996. He has commanded two previous flights, STS-85 in 1997 and STS-95 in 1998, the mission in which John Glenn returned to space.

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

Pilot: Scott J Kelly

Kelly is responsible for many orbiter systems during launch and landing and will backup Commander Curt Brown during the rendezvous and retrieval of the Hubble Space Telescope. He will backup his crewmates on all rendezvous tools and the preparation of the space suits for the four space walks planned during the flight.

This will be Kelly's first flight.

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

Mission Specialist 1: Steven L. Smith

As Payload Commander, Smith has primary responsibility for the servicing and operation of the Hubble Space Telescope.

He will be the lead space walker for the mission, using three spacewalks' worth of experience acquired as one of four space walkers who serviced Hubble during the last visit of astronauts to the Telescope in 1997.

Smith will be teamed with John Grunsfeld for EVAs 1 and 3. Smith will be designated EV 1 during his spacewalks. He will also serve as the "intravehicular" crew member during EVAs 2 and 4, responsible for the choreography of the astronauts' work in Discovery's payload bay.

Smith has flown in space on two previous missions, STS-68 in 1994, and the second Hubble Space Telescope servicing mission, STS-82, in 1997.

Ascent Seating: Mid Deck - Port
Entry Seating: Mid Deck - Port
EV1

Mission Specialist 2: Jean-Francois Clervoy

Among his other duties, Clervoy is the prime crew member for the operation of Discovery's robot arm during the third Hubble Space Telescope servicing mission.

As the Flight Engineer during Discovery's launch and landing, Clervoy will be seated behind Commander Curt Brown and Pilot Scott Kelly on the flight deck, monitoring key Shuttle systems. Clervoy will use the 50-foot long robot arm to retrieve Hubble, maneuver spacewalking crewmembers around the cargo bay during the four EVAs to service Hubble and redeploy the Telescope for the resumption of its science operations. Clervoy will also assist other crew members with a variety of navigation tools during the rendezvous to grapple Hubble out of its orbit on the third day of the mission.

Clervoy has flown in space twice before, on STS-66 in 1994 and on STS-84 in 1997.

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

Mission Specialist 3: John M. Grunsfeld

Grunsfeld will be teamed with Steve Smith during the first and third spacewalks of the mission, and will be designated EV 2.

A member of the American Astronomical Society, Grunsfeld will have prime responsibility for discussing the science of the Hubble Space Telescope during the flight, and will be responsible for opening Discovery's cargo bay doors shortly after the Shuttle reaches orbit.

Grunsfeld will also backup Jean-Francois Clervoy in the operation of Discovery's robot arm during the second and fourth spacewalks of the mission. He will assist other crew members during the rendezvous operations to retrieve Hubble and will operate a number of on-board computers.

Grunsfeld has flown in space twice, on STS-67 in 1995 and on STS-81 in 1997.

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

Mission Specialist 4: Michael Foale

A veteran of four previous spaceflights on both the Shuttle and the Russian Space Station Mir, Foale will be teamed with Claude Nicollier during the second and fourth spacewalks of the mission and will be designated EV 3.

Foale has two spacewalks to his credit, one on the Shuttle and one on Mir.

Foale will backup Steve Smith in overall responsibility for Hubble servicing operations and will assist others in the checkout of the space suits the astronauts will wear during their spacewalks. Foale will also serve as a science expert during the mission and will act as "intravehicular" crew member during the first and third spacewalks of the flights, responsible for the choreography of the astronauts' work in Discovery's payload bay.

He will be in charge of the closing of Discovery's cargo bay doors shortly before landing.

Foale has previously flown on STS-45 in 1992, STS-56 in 1993, STS-63 in 1995 and STS-84 in 1997 (launched to Mir; returned to Earth on STS-86 in 1997).

Ascent Seating: Mid Deck - Port
Entry Seating: Flight Deck - Starboard Aft
EV3

Mission Specialist 5: Claude Nicollier

Nicollier will be teamed with Mike Foale for the second and fourth spacewalks of the mission and will be designated EV 4.

He previously visited the Hubble Space Telescope for its first servicing in 1993 as the prime operator of the Shuttle's robot arm.

This time, Nicollier will serve as a backup to Jean-Francois Clervoy during the rendezvous to reach the Telescope and as the operator of the robot arm during the first and third spacewalks. He will also assist other crewmembers in discussing the science of the Telescope during the flight.

Nicollier has flown in space three times, on STS-46 in 1992, STS-61 in 1993 and STS-75 in 1996.

Ascent Seating: Mid Deck - Starboard
Entry Seating: Mid Deck - Starboard
EV4

Updated: 11/22/1999

Flight Day Summary

DATE TIME (EST)	DAY	MET	EVENT
12/09/99 1:10:00 AM	0	000/00:00:00	Launch Time
12/09/99 2:00:00 AM	0	000/00:50:00	Post Insertion
12/09/99 3:40:00 AM	0	000/02:30:00	RMS ON-Orbit Init
12/09/99 3:45:00 AM	0	000/02:35:00	RMS ON-Orbit Init
12/09/99 3:50:00 AM	0	000/02:40:00	SSE ACT
12/09/99 4:40:00 AM	0	000/03:30:00	Ergometer S/U
12/09/99 6:00:00 AM	0	000/04:50:00	OMS Burn NC1
12/09/99 8:10:00 AM	0	000/07:00:00	Sleep FDO 1
12/09/99 4:10:00 PM	0	000/15:00:00	FD2 Wakeup
12/09/99 7:20:00 PM	0	000/18:10:00	10.2 CAB DEPR (N)
12/09/99 7:40:00 PM	0	000/18:30:00	RMS Powerup
12/09/99 7:55:00 PM	0	000/18:45:00	MAGR On Orbit Setup
12/09/99 7:55:00 PM	0	000/18:45:00	RMS Checkout
12/09/99 8:05:00 PM	0	000/18:55:00	FC Purge- Manual
12/09/99 8:15:00 PM	0	000/19:05:00	SIGI On Orbit Setup
12/09/99 8:20:00 PM	0	000/19:10:00	OSVS Pwrup
12/09/99 8:40:00 PM	0	000/19:30:00	SSE C/O
12/09/99 8:40:00 PM	0	000/19:30:00	SSE Survey
12/09/99 9:20:00 PM	0	000/20:10:00	FSS PREP for BRTHG
12/09/99 9:20:00 PM	0	000/20:10:00	RMS PLB Survey
12/09/99 9:50:00 PM	0	000/20:40:00	RCS BURN NPC
12/09/99 11:10:00 PM	0	000/22:00:00	MEAL FD 02
12/10/99 12:15:00 AM	0	000/23:05:00	AIRLOCK PREP
12/10/99 12:15:00 AM	0	000/23:05:00	RNDZ Tools C/O
12/10/99 12:45:00 AM	0	000/23:35:00	"EMU C/O #3,4 W/GLVS"
12/10/99 12:45:00 AM	0	000/23:35:00	EVA Tool Unstow/CNFG
12/10/99 12:45:00 AM	0	000/23:35:00	Hand Held Laser C/O
12/10/99 3:00:00 AM	1	001/01:50:00	"EMU C/O #1,2 W/GLVS"
12/10/99 3:00:00 AM	1	001/01:50:00	Fuel Cell MON OPS
12/10/99 3:20:00 AM	1	001/02:10:00	PAO Oppty
12/10/99 3:45:00 AM	1	001/02:35:00	OMS Burn NSR
12/10/99 4:45:00 AM	1	001/03:35:00	RCS Burn NC2
12/10/99 7:40:00 AM	1	001/06:30:00	SLEEP FDO 2
12/10/99 3:40:00 PM	1	001/14:30:00	FD03 Wakeup
12/10/99 4:20:00 PM	1	001/15:10:00	SIMO Dump INIT
12/10/99 5:25:00 PM	1	001/16:15:00	SIMO Dump TERM
12/10/99 6:05:00 PM	1	001/16:55:00	RCS Burn NC3

12/10/99 6:53:00 PM	1	001/17:43:00	HST RNDZ
12/11/99 12:02:00 AM	1	001/22:52:00	HST to Grapple ATT
12/11/99 1:37:00 AM	2	002/00:27:00	HST to DRIFT Mode
12/11/99 1:37:00 AM	2	002/00:27:00	HST BERTH
12/11/99 2:02:00 AM	2	002/00:52:00	LATCH & MATE HST
12/11/99 2:37:00 AM	2	002/01:27:00	Berthed HST Survey
12/11/99 2:37:00 AM	2	002/01:27:00	HST EXTRNL PWR Act
12/11/99 2:54:00 AM	2	002/01:44:00	EVA 1 Tool Config
12/11/99 3:09:00 AM	2	002/01:59:00	Middeck Prep For EVA
12/11/99 4:09:00 AM	2	002/02:59:00	RMS Extended Park
12/11/99 5:10:00 AM	2	002/04:00:00	Next Day's EVA RVW
12/11/99 7:10:00 AM	2	002/06:00:00	SLEEP FD03
12/11/99 3:10:00 PM	2	002/14:00:00	FD04 Wakeup
12/11/99 5:10:00 PM	2	002/16:00:00	EVA 1 Prep
12/11/99 6:40:00 PM	2	002/17:30:00	EMU Purg/Prbrth (:50)
12/11/99 7:55:00 PM	2	002/18:45:00	EVA 1 Start
12/11/99 8:10:00 PM	2	002/19:00:00	Initial EVA Setup
12/11/99 9:10:00 PM	2	002/20:00:00	"RSU #1,2,3 Changout"
12/11/99 11:55:00 PM	2	002/22:45:00	Open NICMOS Valves
12/12/99 12:10:00 AM	2	002/23:00:00	AFT SHRD Door Close
12/12/99 12:20:00 AM	2	002/23:10:00	MFR Swap
12/12/99 12:30:00 AM	2	002/23:20:00	VIK INST
12/12/99 1:40:00 AM	3	003/00:30:00	Daily Closeout
12/12/99 2:20:00 AM	3	003/01:10:00	EVA 1 End A/L Pre Repress
12/12/99 2:40:00 AM	3	003/01:30:00	Post EVA W/H20 Rechg
12/12/99 3:10:00 AM	3	003/02:00:00	RMS Extended Park
12/12/99 3:40:00 AM	3	003/02:30:00	EVA 2 Tool Config
12/12/99 4:55:00 AM	3	003/03:45:00	Next Day's EVA RVW
12/12/99 7:10:00 AM	3	003/06:00:00	SLEEP FD04
12/12/99 3:10:00 PM	3	003/14:00:00	FD05 Wakeup
12/12/99 5:20:00 PM	3	003/16:10:00	EVA 2 PREP
12/12/99 6:50:00 PM	3	003/17:40:00	EMU Purg/Prbrth (:50)
12/12/99 8:05:00 PM	3	003/18:55:00	EVA 2 Start
12/12/99 8:20:00 PM	3	003/19:10:00	Daily Setup
12/12/99 8:50:00 PM	3	003/19:40:00	Computer CHNGOUT
12/12/99 10:45:00 PM	3	003/21:35:00	MFR Swap
12/12/99 10:55:00 PM	3	003/21:45:00	FGS-2 CHNGOUT
12/13/99 1:50:00 AM	4	004/00:40:00	Daily Closeout
12/13/99 2:30:00 AM	4	004/01:20:00	EVA 2 End A/L Pre Repress
12/13/99 2:50:00 AM	4	004/01:40:00	Post EVA W/H20 Rechg
12/13/99 3:40:00 AM	4	004/02:30:00	RMS Extended Park
12/13/99 3:53:00 AM	4	004/02:43:00	EVA 3 Tool CNFG
12/13/99 5:10:00 AM	4	004/04:00:00	Next Day's EVA RVW

12/13/99 5:15:00 AM	4	004/04:05:00	SIMO Dump INIT
12/13/99 6:20:00 AM	4	004/05:10:00	SIMO Dump TERM
12/13/99 7:10:00 AM	4	004/06:00:00	SLEEP FD05
12/13/99 3:10:00 PM	4	004/14:00:00	FD06 Wakeup Post Sleep- STS Crew
12/13/99 5:20:00 PM	4	004/16:10:00	EVA 3 Prep
12/13/99 6:50:00 PM	4	004/17:40:00	EMU Purg/Prbrth (:50)
12/13/99 8:05:00 PM	4	004/18:55:00	EVA 3 Start
12/13/99 8:35:00 PM	4	004/19:25:00	OCE EK INST
12/13/99 9:05:00 PM	4	004/19:55:00	SSA XMTR INST
12/13/99 10:15:00 PM	4	004/21:05:00	SSR/ESTR3 Changeout
12/13/99 11:20:00 PM	4	004/22:10:00	MFR Swap
12/13/99 11:30:00 PM	4	004/22:20:00	MLI Repair Bay 5-10
12/14/99 1:50:00 AM	5	005/00:40:00	Daily Closeout
12/14/99 2:30:00 AM	5	005/01:20:00	EVA 3 End
12/14/99 2:50:00 AM	5	005/01:40:00	Post EVA W/H20 Rechg
12/14/99 3:25:00 AM	5	005/02:15:00	RMS Extended Park
12/14/99 3:50:00 AM	5	005/02:40:00	EVA 4 Tool Config
12/14/99 5:10:00 AM	5	005/04:00:00	Next Day's EVA RVW
12/14/99 7:10:00 AM	5	005/06:00:00	SLEEP FD06
12/14/99 3:10:00 PM	5	005/14:00:00	FD07 Wakeup
12/14/99 5:20:00 PM	5	005/16:10:00	EVA Prep
12/14/99 6:50:00 PM	5	005/17:40:00	EMU Purg/Prbrth (:50)
12/14/99 8:05:00 PM	5	005/18:55:00	EVA 4 Start
12/14/99 8:20:00 PM	5	005/19:10:00	Daily Setup
12/14/99 8:35:00 PM	5	005/19:25:00	SSRF INST
12/14/99 10:15:00 PM	5	005/21:05:00	HGA DPY
12/15/99 12:13:00 AM	5	005/23:03:00	MFR Tether SWAP
12/15/99 12:25:00 AM	5	005/23:15:00	ASLR FOR +V2 Doors
12/15/99 1:10:00 AM	6	006/00:00:00	Final EVA Closeout
12/15/99 2:20:00 AM	6	006/01:10:00	EVA 4 End
12/15/99 2:40:00 AM	6	006/01:30:00	Post EVA W/H20 Rechg
12/15/99 3:40:00 AM	6	006/02:30:00	EVA Tool Stow
12/15/99 4:20:00 AM	6	006/03:10:00	RMS Extended Park
12/15/99 4:20:00 AM	6	006/03:10:00	SIMO Dump INIT
12/15/99 5:35:00 AM	6	006/04:25:00	SIMO Dump TERM
12/15/99 7:10:00 AM	6	006/06:00:00	SLEEP FD07
12/15/99 3:10:00 PM	6	006/14:00:00	FD08 Wakeup
12/15/99 5:56:00 PM	6	006/16:46:00	Prep For Batt CHRG
12/15/99 7:06:00 PM	6	006/17:56:00	HST GRAPPLE For Release
12/15/99 8:06:00 PM	6	006/18:56:00	Umbilical Disc
12/15/99 8:16:00 PM	6	006/19:06:00	HST Unberth & NMVR
12/15/99 8:17:00 PM	6	006/19:07:00	EXT PWR OFF/UMB Disc
12/15/99 9:04:00 PM	6	006/19:54:00	OPEN Aperature Door

12/15/99 9:24:00 PM	6	006/20:14:00	HST Release Prep
12/15/99 10:04:00 PM	6	006/20:54:00	Release (RMS/HST)
12/15/99 10:19:00 PM	6	006/21:09:00	Release & SEP BURNS
12/15/99 10:39:00 PM	6	006/21:29:00	FSS Stow
12/15/99 11:04:00 PM	6	006/21:54:00	RMS Powerdown
12/16/99 1:35:00 AM	7	007/00:25:00	PAO Oppty
12/16/99 2:37:00 AM	7	007/01:27:00	14.7 CAB REPR
12/16/99 6:10:00 AM	7	007/05:00:00	SLEEP FD08
12/16/99 2:10:00 PM	7	007/13:00:00	FD09 Wakeup
12/16/99 5:10:00 PM	7	007/16:00:00	PAO Oppty
12/16/99 5:30:00 PM	7	007/16:20:00	SFA Award Recording
12/16/99 5:45:00 PM	7	007/16:35:00	OFF DUTY
12/16/99 9:40:00 PM	7	007/20:30:00	OPS2 GPS Test
12/16/99 9:50:00 PM	7	007/20:40:00	MEAL
12/16/99 10:50:00 PM	7	007/21:40:00	P EVA ENT PREP (N)
12/17/99 2:15:00 AM	8	008/01:05:00	COMM STRNG1 C/O INIT
12/17/99 5:10:00 AM	8	008/04:00:00	SLEEP FD09
12/17/99 1:10:00 PM	8	008/12:00:00	FD10 Wakeup
12/17/99 3:10:00 PM	8	008/14:00:00	APU HTR ACT
12/17/99 4:10:00 PM	8	008/15:00:00	OPS3 GPS TEST
12/17/99 5:46:00 PM	8	008/16:36:00	CREW CONF
12/17/99 6:31:00 PM	8	008/17:21:00	CREW PHOTO
12/17/99 7:06:00 PM	8	008/17:56:00	FCS C/O
12/17/99 8:05:00 PM	8	008/18:55:00	RCS HOT FIRE
12/17/99 8:25:00 PM	8	008/19:15:00	D/O PREP BRIEF
12/17/99 8:55:00 PM	8	008/19:45:00	MEAL
12/17/99 9:55:00 PM	8	008/20:45:00	CABIN CONFIG/STOW
12/17/99 10:05:00 PM	8	008/20:55:00	RCS BURN Orbit Adjust
12/17/99 11:25:00 PM	8	008/22:15:00	SIMO DUMP INIT
12/18/99 12:25:00 AM	8	008/23:15:00	SIMO DUMPT TERM
12/18/99 1:55:00 AM	9	009/00:45:00	KU STOW
12/18/99 2:10:00 AM	9	009/01:00:00	COMM STRNG1 C/O TERM
12/18/99 5:10:00 AM	9	009/04:00:00	SLEEP FD10
12/18/99 1:10:00 PM	9	009/12:00:00	FD11 Wakeup
12/18/99 3:10:00 PM	9	009/14:00:00	FC PURGE-AUTO
12/18/99 4:03:00 PM	9	009/14:53:00	OSVS PWRDN
12/18/99 4:29:00 PM	9	009/15:19:00	MAGR/SIGI ENTRY S/U
12/18/99 4:35:00 PM	9	009/15:25:00	D/O IMU ALIGN
12/18/99 5:18:00 PM	9	009/16:08:00	DEORBIT PREP

Rendezvous

RENDEZVOUS, RETRIEVAL AND DEPLOY

Overview

Operations associated with rendezvous, retrieval and deploy of the Hubble Space Telescope are similar to those associated with other space shuttle missions.
Discovery's initial rendezvous burn is actually the launch of the shuttle from the Kennedy Space Center, FL. The launch is precisely timed to occur during about a 42-minute launch window as the telescope passes within a prescribed distance of the launch site. After launch, mission control and the crew will oversee a number of orbit adjust and course correction burns to catch up with and retrieve the telescope on flight day three of the mission.

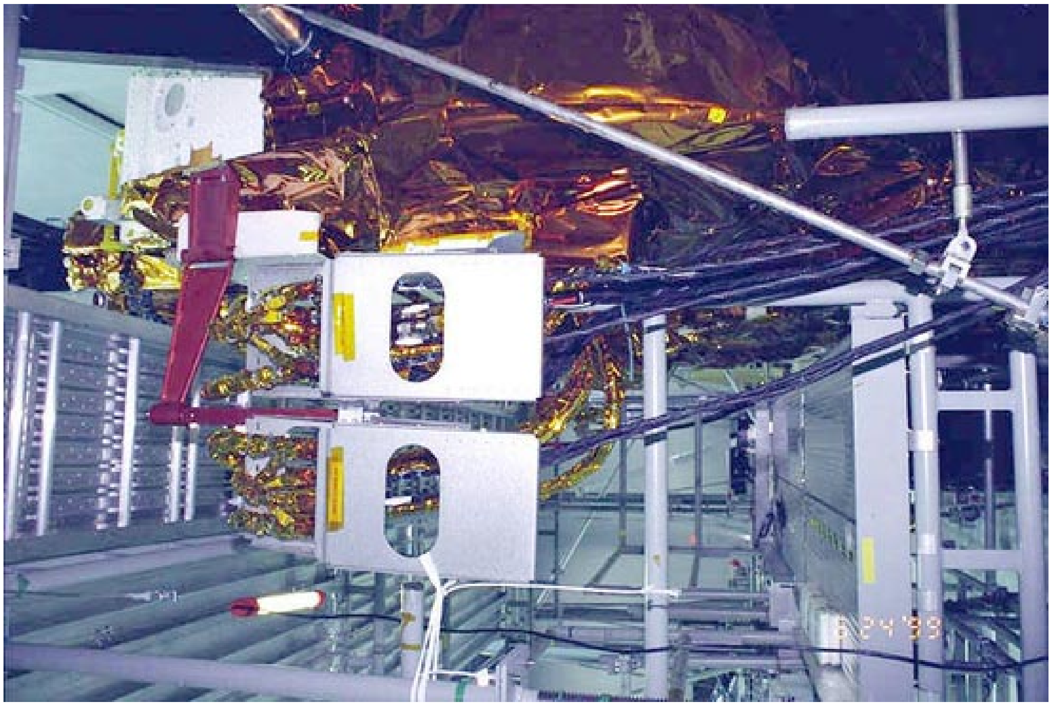
History/Background

Once Discovery is safely in orbit and the payload bay doors are opened, the Ku-band antenna is activated and used to provide radar data to the crew and ground during the rendezvous process. The day after launch, the crew will checkout the shuttle's robot arm (Remote Manipulator System) to be used throughout the mission. Also, activation of the space support equipment is performed. This includes activating the flight support system and heaters on the orbital replacement unit carrier housing the scientific instruments and hardware that will be installed on the telescope.

The terminal initiation burn occurs about two hours prior to capture as the shuttle reaches a distance of about eight miles behind Hubble. Several small correction burns follow before Commander Curt Brown takes over manual control of Discovery at a distance of about 2,500 feet below. The approach from underneath minimizes any potential contamination to the telescope from the shuttle's thruster firings. Because Hubble was placed in a configuration to keep it pointed to the Sun due to its latest gyroscope failure, Brown may have to conduct a partial flyaround of the telescope to align the Shuttle's robot arm with Hubble's grapple fixture.

When Discovery reaches a point about 35 feet from Hubble, astronaut Jean-Francois Clervoy will use the robot arm to capture the telescope's grapple fixture located midway up the HST structure.

Following capture, Hubble will be lowered onto the flight support system, a turntable likened to a 'Lazy Susan' for its ability to rotate and tilt to assist in the servicing tasks. An electrical cable is remotely attached to provide orbiter power to the telescope throughout the servicing portion of the mission.



The Flight Support System Standard Interface Panel

The day after the four space walks are completed, the solar arrays on Hubble will be pointed toward the sun to provide electrical power and to charge the observatory's batteries. The robot arm will be used to grapple the telescope once again followed by transfer of power to Hubble's internal system from the orbiter power. The twin high-gain antennas are deployed and the telescope then will be lifted off of the flight support system and released over the side of the orbiter in similar fashion to the deploy on both previous servicing missions.

The Hubble Space Telescope, following its release from the Shuttle's robot arm during the STS-82 servicing mission.

Updated: 11/22/1999

EVAs

HUBBLE SPACE TELESCOPE EXTRAVEHICULAR ACTIVITY

Overview

The third servicing mission to the Hubble Space Telescope includes four planned space walks by four astronauts completely cross-trained to perform any of the scheduled tasks on any day.

Hubble was designed to be serviced while on orbit through Extravehicular Activity (EVA). The telescope has two grapple fixtures for the shuttle's robot arm, handholds and handrails for use by the astronauts, and electrical connections and bolts designed for easier manipulation by the crew while wearing pressurized space suits.

As was the case on the first two servicing missions in December 1993 and February 1997, the tasks scheduled for the space walks have been prioritized to make maximum use of the time that the astronauts are in the payload bay.

Steve Smith holds one of the tools used during a spacewalk to service the Hubble Space Telescope during the STS-82 mission.

The four astronauts will work in teams of two to perform the work on alternating days to allow a rest day between each space walk. Steve Smith and John Grunsfeld will team together on the first and third excursions outside the crew compartment, and Mike Foale and Claude Nicollier will join forces on space walks two and four.

Recognizing the Spacewalkers:

Steve Smith	Solid Red Stripe
John Grunsfeld	Solid White (no markings)
Mike Foale	Broken Red Stripe
Claude Nicollier	Diagonally Broken Red Stripe

As was the case in the previous servicing missions, while the individual tasks have been prioritized, the various tasks have been designed to take into account the possibility that crew members may encounter unforeseen difficulties that could change the preplanned schedule of installation. The four space walkers have been trained so that any one is capable of performing any given task.

Mission Specialists Steve Smith and John Grunsfeld practice EVA Servicing Tasks

As currently planned, the first space walk will feature the replacement of all three Rate Sensor Units (RSU's) (two were replaced on the first servicing mission - STS 61). Each RSU houses two gyroscopes used to point the telescope for observations. In addition, Smith and Grunsfeld will then install voltage/temperature improvement kits (VIK) to protect Hubble's batteries from overheating as they get older. The VIK lowers each battery's charge termination voltage. They also will open coolant valves and remove caps on the Near Infrared Camera and Multi-Object Spectrometer, which was installed on the second visit to Hubble in 1997. NICMOS was found to be leaking its super-cold coolant shortly after activation. Opening the valves will allow any residual coolant frozen in the line to dissipate in the vacuum of space in preparation for work scheduled on the next visit in 2001.

The second space walk will include the removal of the old computer and installation of a new, improved computer with more power. Foale and Nicollier also will replace one of the Fine Guidance Sensors. An FGS was replaced on the second servicing mission.

The third space walk includes replacement of an S-band transmitter, installation of another Solid State Recorder, which is more efficient than the old-style tape recorder, and attachment of new insulation on equipment bays midway up the side of the telescope.

The fourth and final planned space walk by Foale and Nicollier includes activities termed 'Optional Tasks,' and includes attachment of more insulation around the top of the telescope and covers on handrails with peeling paint. Most of the insulation damage is on the side of the telescope that always faces the Sun.

Throughout the space walks, the flight support system will be rotated so that the area being worked on faces forward to provide better visibility and access by the robot arm.

EVA Time Line for HUBBLE SPACE TELESCOPE EXTRAVEHICULAR ACTIVITY

Time	Event
0:00	EVA 1 Post Depress and Airlock Egress
0:15	EVA 1 Translation Adaptation
1:00	EVA 1 BAPS post install
1:30	EVA 1 RSU-2R Retrieval from COPE
1:45	EVA 1 Open -V3 Doors
2:00	EVA 1 RSU-2 Changeout
2:20	EVA 1 RSU-3R Retrieval from COPE
2:40	EVA 1 RSU-3 Changeout
3:00	EVA 1 RSU-1R Retrieval from COPE
3:15	EVA 1 RSU-1 Changeout
3:35	EVA 1 NICMOS Valve Reconfig
3:50	EVA 1 Close -V3 Doors
4:15	EVA 1 PFR/RSU-1 Stow
4:25	EVA 1 MFR Swap
4:50	EVA 1 VIK Retrieval from Airlock
5:05	EVA 1 VIK Bay 3 Installation
5:30	EVA 1 VIK Bay 2 Installation
5:45	EVA 1 Daily Closeout
6:15	EVA 1 Airlock Ingress and Pre Repress
0:00	EVA 2 Post Depress and Airlock Egress
0:15	EVA 2 Daily Setup
0:20	EVA 2 Translation Adaptation
0:45	EVA 2 Bay 1 Door Opening/DF-224 Removal
0:50	EVA 2 486 Retrieval from LOPE
1:15	EVA 2 Computer Swap
1:45	EVA 2 486 Installation
2:00	EVA 2 NOBL Installation
2:30	EVA 2 MFR Swap
3:00	EVA 2 PFR Retrieval/Installation
3:20	EVA 2 Open +V3 Doors

3:45	EVA 2 FGS-2 Removal from HST
4:15	EVA 2 FGS-2R Removal from FSIPE
4:30	EVA 2 FGS-2R Installation into HST
5:00	EVA 2 FGS-2 Installation into FSIPE
5:30	EVA 2 PFR Stow
5:40	EVA 2 Daily Closeout
6:15	EVA 2 Airlock Ingress and Pre Repress
0:00	EVA 3 Post Depress and Airlock Egress
0:15	EVA 3 Daily Setup
0:45	EVA 3 OCE-EK Mate
1:00	EVA 3 Close Bay C Door
1:15	EVA 3 SSAT-2 Removal
1:30	EVA 3 SSAT-2R Retrieval
1:35	EVA 3 SSAT Swap at Bay 5; SSAT-2 Stow
2:00	EVA 3 SSAT-2R Installation
2:30	EVA 3 ESTR-3 Removal
2:45	EVA 3 SSR-3/ESTR-3 Swap
3:00	EVA 3 SSR-3 Installation
3:05	EVA 3 Bay 5 MLI Removal
3:15	EVA 3 MFR Swap
3:30	EVA 3 NOBL Operations
3:35	EVA 3 Bay 5 & 6 NOBL Retrieval
4:00	EVA 3 Bay 5 & 6 Installation
4:15	EVA 3 Bay 7 & 8 MLI Patch Removal
4:30	EVA 3 Bay 7 & 8 NOBL Retrieval
4:45	EVA 3 Bay 7 & 8 Installation
5:10	EVA 3 Bay 10 MLI Patch Removal
5:20	EVA 3 Bay 9 & 10 NOBL Retrieval
5:40	EVA 3 Bay 9 & 10 Installation
5:45	EVA 3 Daily Closeout
6:15	EVA 3 Airlock Ingress and Pre Repress
0:00	EVA 4 Post Depress and Airlock Egress
0:15	EVA 4 Daily Setup
0:30	EVA 4 SSRF Operations
0:35	EVA 4 Safety Tether Transfer

0:45	EVA 4 SSRF 5,6,7 & Rib Clamp Retrieval
1:00	EVA 4 SSRF Rib Clamp Installation
1:15	EVA 4 SSRF 5,6 & 7 Installation
2:00	EVA 4 SSRF 1,2,3 & 4 Retrieval
2:15	EVA 4 SSRF 1 Installation
2:45	EVA 4 SSRF 2 Installation
3:15	EVA 4 SSRF 3 Installation
3:45	EVA 4 SSRF 4 Installation
4:15	EVA 4 Safety Tether Reconfig
4:20	EVA 4 MFR Swap
4:25	EVA 4 SSRF Caddy Stow
4:30	EVA 4 +V2 Latch Repair
4:45	EVA 4 ASLR Retrieval
5:00	EVA 4 ASLR Installation
5:15	EVA 4 Final Closeout
6:15	EVA 4 Airlock Ingress and Pre Repress

Payloads

Fine Guidance Sensor

Prime:
Backup:

Overview

During the Hubble Space Telescope Servicing Mission 3A, astronauts will exchange the Fine Guidance Sensor (FGS) with a refurbished unit that has an enhanced on-orbit alignment capability. The refurbished FGS on SM3A is the same unit that was returned from Servicing Mission 2. The FGS returned from SM3A will be refurbished and upgraded for re-use on Hubble's 4th Servicing Mission.

An FGS, an optical sensor, consists of a large structure housing a collection of mirrors, lenses, servos, prisms, beam-splitters and photomultiplier tubes. The FGS is 5.5 x 4 x 2 feet, weighs 478 pounds and has 19 watts of power.

There are three fine guidance sensors on Hubble located at 90-degree intervals around the circumference of the Telescope. Two FGSs are used to point the Telescope at an astronomical target and hold that target in the scientific instrument's field of view. The third FGS can then be used as a scientific instrument for astrometry. Astrometry is the science that deals with the determination of precise positions and motions of stars. The FGS's can provide star positions that are about 10 times more precise than those observed from a ground based telescope. When used for astrometric science the fine guidance sensors will let Hubble: search for a wobble in the motion of nearby stars that could indicate the presence of a planetary companion; determine if certain stars really are double stars; measure the angular diameter of stars, galaxies and other celestial objects; refine the positions, distances and energy output of stars; and help determine the true distance scale for the universe.

The fine guidance sensors are one of the sensors used by Hubble's pointing control system to point the Telescope at a target with an accuracy of 0.01 arcsec. An arcsec is the width of a paperclip wire viewed from the distance of two football fields. With this fine precision, the guidance sensors lock on to a star and then measure any apparent motion to an accuracy of 0.0028 arcsec. This gives Hubble the ability to remain pointed at that target with no more than 0.007 arc-sec of deviation over long periods of time. This level of stability and precision is comparable to being able to hold a laser beam focused on a dime that is 200 miles away (the distance from Washington D.C. to New York City).

Payloads

Gyroscopes

Prime:
Backup:

Overview

The gyroscopes, or gyros, on the Hubble Space Telescope are needed for pointing the telescope. They measure attitude when Hubble is changing its pointing from one target (a star or planet, for example) to another, and they help control the telescope's pointing while scientists are observing targets. Three gyros must operate simultaneously to provide enough information to control Hubble. There are a total of six gyros on board, three serve as backups. Each gyroscope is packaged in a Rate Sensor assembly. The Rate Sensors are packaged in pairs in boxes called Rate Sensor Units (RSUs). It is the RSU that astronauts change when they replace gyros, so gyros are always replaced two at a time. The Rate Sensors are 2.75 x 6.5 inches and weigh 6 pounds. The RSUs are 12.8 x 10.5 x 8.9 inches and weigh 24.3 pounds.

The gyros work by a scientific principal called the gyroscopic effect. This effect can be demonstrated by holding a bicycle wheel by the axle and asking someone to spin the tire. If you try to move the axle of the spinning wheel, you would feel a movement in a direction different from the way you were attempting to move it. This movement is similar to the way the gyros move when Hubble moves.

The gyroscopic movement is achieved by a wheel inside each gyro that spins at a constant rate of 19,200 rpm on gas bearings. This wheel is mounted in a sealed cylinder, which floats in a thick fluid. Electricity is carried to the motor by thin wires (approximately the size of a human hair) which are immersed in the fluid. Electronics within the gyro detect very small movements of the axis of the wheel and communicate this information to Hubble's central computer.

The gyros are extraordinarily stable and can detect extremely small movements of the Telescope. The gyros are the most accurate in the world and, combined with other fine pointing devices, keep HST pointing for long periods of time to collect spectacular images of very faint galaxies, planets and stars not visible from Earth.

Currently, only two of the Hubble's six gyros are working and science operations have been suspended.

History/Background

Four new gyros were installed during the First Servicing Mission in 1993. All six gyros were working during the Second Servicing Mission in 1997. Since then, a gyro failed in 1997, the second failed in 1998 and the third failed earlier this year, and the fourth failed on November 13, placing the telescope in temporary hibernation from science operations.

The Hubble team believes they understand the cause of the failures, although they cannot be certain until the gyros are returned from space and taken apart. Based on nearly one and a half years of intensive chemical, mechanical and electrical investigations, the team believes that the thin wires are being corroded by the fluid in which they are immersed and ultimately this corrosion causes them to break. The fluid is very thick (about the thickness of 10W-30 motor oil), and in order to force this fluid into its float cavity, pressurized air was used. The team believes that eventually, oxygen in the air interacted with the fluid to create a small amount of corrosive material and the wires were partially eaten away. Sometimes the wires were strong enough to carry electricity and some-times they were not and they broke. Pressurized nitrogen is now used instead of pressurized air. Using pressurized nitrogen eliminates the introduction of oxygen into this fluid.

Updated: 11/22/1999

Payloads

New Advanced Computer

Prime:
Backup:

Overview

When the Space Shuttle lifts off, it will carry a new advanced computer designed to replace the current computer on the Hubble Space Telescope. Hubble's main computer is responsible for monitoring the health of its many systems, for controlling the movement of the Telescope from target to target, and for holding the Telescope steady when observing.

The current computer, called the DF-224, was designed in the late 1970's and its capabilities are less advanced than today's modern computers. Programming requires very specialized skills, unique to this computer, and maintaining the software is difficult and expensive. The DF-224 computer has degraded over the years and during the First Servicing Mission in 1993 it was augmented with an additional computer called a co-processor. The design of the co-processor was based on the Intel 80386 microchip.

The new advanced computer will be based on the Intel 80486 microchip. This new computer will be 20 times faster, and have six times as much memory, as the current computer on Hubble. In a good example of NASA's goal of "faster, cheaper, better," commercially developed, commonly available equipment was used to build this new computer at a fraction of the price it would cost to build a specialized computer designed specifically for the spaceflight environment. NASA performed a number of mechanical, electrical, radiation and thermal tests to guarantee that the computer would survive the trip to orbit, withstand bombardment by cosmic and solar radiation and work flawlessly in the extreme temperatures of space for the rest of Hubble's life.

As a final check, NASA carried the computer to space in the Space Shuttle for 10 days in 1998 during the STS-95 mission. The computer worked perfectly. The greater capabilities of the new computer will increase productivity for the Hubble observatory by performing more work in space and less work by people on the ground. The computer software will be programmed in a modern programming language, decreasing the cost for software maintenance.

Payloads

New Thermal Blanket Layers

Prime:

Backup:

Overview

During the 1999 servicing mission, astronauts will cover Hubble Space Telescope with permanent sheets called the New Outer Blanket Layer, or NOBL. The crew also will carry a special fabric, called the Shell/Shield Replacement Fabric, or SSRF.

The SSRF is scheduled for installation on Servicing Missions 3A and 3B. During SM3A astronauts will install the SSRF on Hubble's forward shell and light shield if time is available.

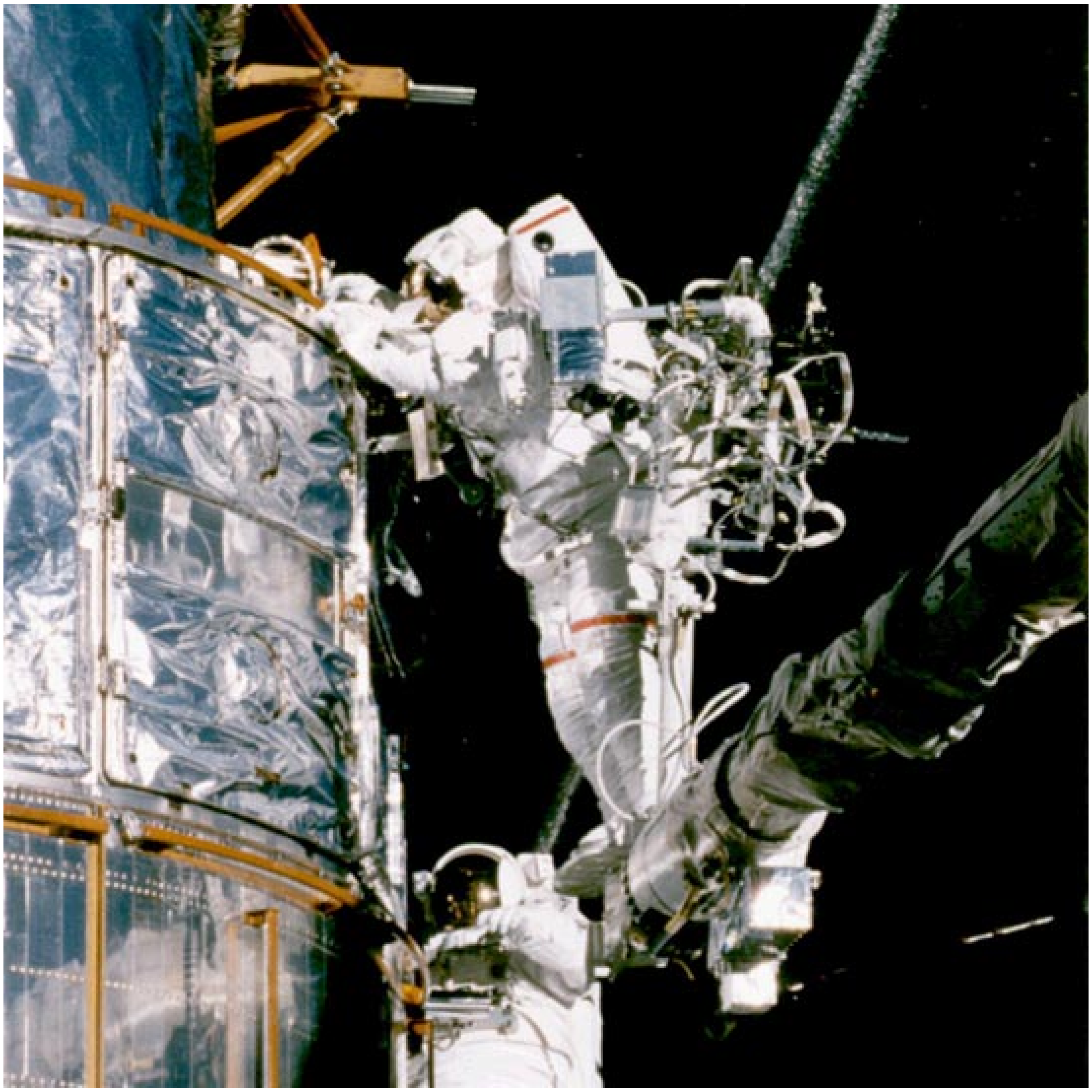
The NOBL covers and SSRF pieces are designed to protect Hubble's external blankets. They will prevent Hubble's insulation from further degradation and maintain normal operating temperatures. NASA tested the materials to ensure that they can withstand exposure to charged particles, X-rays, ultraviolet radiation, and thermal cycling for at least ten years. Astronauts will install seven NOBL covers on Hubble's electronics bay doors. The covers are specially coated stainless steel foil trimmed to fit each particular door. Each cover is supported by a steel picture-frame structure. Expanding plugs, like common kitchen bottle stoppers, fit into door vent holes to allow quick installation.

The SSRF pieces are designed to cover the Telescope's forward shell and light shield. The fabric is composed of flexible, aluminized Teflon© with rip-stop material bonded to the backside. Astronauts will use wire clips to attach each SSRF piece to convenient attachment points such as handrails, brackets and struts. Seven pieces up to 22 feet (7 meters) long will cover 80 percent of the sun-side light shield and forward shell. The fabric pieces are stored in rolls for their trip to orbit.

History/Background

During the Hubble Space Telescope Second Servicing Mission in 1997, astronauts detected damage to some of the Telescope's thermal insulation. Years of exposure to the harsh environment of space had taken a toll on Hubble's protective multi-layer insulation, and some areas were torn or broken. This multi-layer insulation protects the Telescope from the severe and rapid temperature changes it experiences as it moves through its 90-minute orbit from very hot sun to very cold night.

Although the cracks looked dramatic, the damage was limited to the outermost layer and did not affect the insulation's protective function or Hubble's operation. With help from ground controllers, the astronauts used materials aboard the Space Shuttle Discovery in 1997 to fashion temporary patches. They installed them over the most critically damaged areas, mostly on Hubble's sun-facing side.



Astronaut Mark Lee patches insulation on the telescope during STS-82.

Payloads

Payload Overview

Overview

Hubble's Mission

The Hubble Space Telescope's mission is to spend 20 years probing the farthest and faintest reaches of the cosmos. This unique observatory operates around the clock, above the Earth's atmosphere, to gather information for teams of scientists who study virtually all the components of our universe, including planets, star-forming regions of the Milky Way galaxy, distant galaxies and quasars. Crucial to fulfilling this mission is a series of scheduled, on-orbit servicing missions. During these servicing missions, astronauts perform a number of planned repairs and maintenance activities to upgrade the observatory's capabilities. The first servicing mission took place in December 1993, the second in February 1997. Servicing mission 3B is scheduled for 2001. The fourth and final servicing mission is currently planned for 2003.

The Hubble Space Telescope prior to its release during STS-82

Mission Overview

What's Being Replaced

Rate Sensor Units: The Rate Sensor Units allow the Telescope to point at stars, planets and other celestial targets. Three are aboard Hubble, and each unit contains two gyroscopes. Hubble needs three of these six gyroscopes to meet its very precise pointing requirements, and the other three are spares. (Gyroscopes have limited lifetimes, and currently only two are working properly.) As a result, all science operations have been temporarily suspended. Astronauts will replace all three units, leaving Hubble with six fresh gyroscopes.

Fine Guidance Sensor: This is the second in a "round-robin" series of changeouts and refurbishments of the three fine guidance sensors, which allow fine pointing and keep Hubble stable. The SM3A refurbished Fine Guidance Sensor is the same unit that was returned from Servicing Mission 2. The Fine Guidance Sensor returned from this mission will be refurbished and upgraded for re-use on Hubble's fourth Servicing Mission.

New Spacecraft Computer: The radiation-rugged computer will replace Hubble's original, outdated main computer. The new computer will dramatically increase operational capabilities, reduce the burden of flight software maintenance, and significantly lower operational costs.

Voltage/Temperature Improvement Kits: As Hubble's batteries age, they become more susceptible to overheating if overcharged. The Voltage/Temperature Improvement Kit compensates for this by lowering the battery's charge termination voltage. Astronauts will install one kit for each of Hubble's six batteries.

Spare S-Band Single Access Transmitter: The transmitter replaces an aged and failed unit. That unit will be removed, returned to Earth and refurbished for a later flight.

Spare Solid State Recorder: The digital data recorder will serve as a high capacity backup to the Solid State Recorder that replaced a mechanical tape recorder in 1997. It is essential for efficiently handling the high volumes of data from Hubble's newest instruments and for maintaining high science productivity.

New Outer Blanket Layer: Stainless steel sheets will be installed in various locations on the Telescope to help control Hubble's internal temperature. Covered with a protective thermal coating, these sheets will fit over existing insulation that has degraded. The following tasks will be performed on SM3A, time permitting. If there is insufficient time, these tasks will be completed on SM3B:

Shell/Shield Replacement Fabric: Flexible aluminized Teflon sheets will be added to the exterior surfaces of Hubble's forward shell and light shield. This protective covering provides additional insulation against the harsh space environment.

Aft Shroud Latch Repair Kit: Astronauts will replace latches on Hubble's bay door. During Servicing Mission 2, Astronauts observed galling on these latches. The galling was caused by high torque.

Handrail Covers: Fiberglass cloth, called beta cloth, will be fitted like sleeves around the handrails above the Fine Guidance Sensors bay to prevent contamination to the Aft Shroud area. Flaking paint was observed on these handrails during Servicing Mission 2.

Updated: 11/22/1999

Payloads

S-Band Single Access Transmitter

Prime:

Backup:

Overview

During Servicing Mission 3A, astronauts will replace a faulty S-Band Single Access Transmitter (SSAT) with a spare. The SSAT sends the data from Hubble Space Telescope to the ground by radio. There are two identical S-Band Single Access Transmitters on-board Hubble. "S-Band" identifies the radio frequency and "Single Access" specifies a type of antenna on NASA's communications satellites. One of the two SSATs failed in 1998. The other SSAT has been able to shoulder the load and Hubble's observing program has not been affected. Hubble can operate with one transmitter by making additional commands to rotate the telescope. Optimally, the telescope operates with two SSATs.

The SSAT is 14 x 8 x 2 3/4 inches and weighs 8.5 pounds. Some of the cables and connectors are smaller versions of the ones on the back of television sets. Because the connectors are difficult to handle with bulky space suit gloves, special enhancements have been made to the new unit to aid the astronauts. In addition, a special connector tool helps to remove and install the connectors. The failed transmitter will be returned to Earth and refurbished for a later flight.

The purpose of the Hubble Space Telescope is to gather light from cosmic objects so scientists can better understand the universe around us. Hubble is in space, astronomers are on Earth. The light that is gathered and magnified by the Telescope is first sent to one of Hubble's scientific instruments. Devices similar to those in digital cameras convert the light to computer bits of information for processing. The computerized science data are then either transmitted immediately from the spacecraft or stored in one of Hubble's on-board recorders for future transmission.

The transmissions are directed by one of Hubble's two big communications dishes. Strangely enough, Hubble's transmissions don't go down to the ground, only about 360 miles below, they go up. Approximately 22,000 miles above the Earth, nestled among commercial communications satellites, are a few NASA communications satellites. NASA uses these satellites to collect transmissions from its many scientific satellites (including Hubble) and beam them down to a ground station in New Mexico. From there Hubble's scientific data ultimately ends up at Hubble's Space Telescope Science Institute in Baltimore, Md. After processing, the data are available to astronomers.

Updated: 11/22/1999

Payloads

Solid State Recorder

Prime:

Backup:

Overview

To communicate with its operators on the ground, the Hubble Space Telescope uses a group of NASA satellites called the Tracking and Data Relay Satellite System (TDRSS). By way of TDRSS, Hubble sends the data from its science instruments and spacecraft systems to the Space Telescope Operations Control Center at NASA's Goddard Space Flight Center in Greenbelt, Md. When the TDRSS link is not available, Hubble stores its science and engineering data in onboard recorders for playback at a later time. Hubble records all of its science data to prevent any possible loss of unique information.

Prior to the Second Servicing Mission, Hubble used three 1970s-style, reel-to-reel tape recorders. In February 1997, astronauts replaced one of these mechanical recorders with a digital Solid State Recorder. During Servicing Mission 3A, astronauts will remove a second mechanical tape recorder and install a second Solid State Recorder.

Unlike the reel-to-reel recorder it replaces, the Solid State Recorder has no reels, no tape, and no moving parts to wear out and limit lifetime. Data is digitally stored in computer-like memory chips until Hubble's operators command its playback. Although the Solid State Recorder is about the same size and shape as the reel-to-reel recorder, it can hold approximately ten times as much data. It stores 12 gigabits of data, while the tape recorder it replaces can hold only 1.2 gigabits. This ten times greater storage has proven essential in allowing Hubble's new, high-tech scientific instruments to be fully productive. The Solid State Recorder is 12 x 9 x 7 inches and weighs 25 pounds.

State-of-the-art electronics provide the Solid State Recorder with more capability and flexibility than a reel-to-reel recorder. This digital recorder is designed to perform the tasks of two separate mechanical recorders. Unlike a mechanical recorder, the Solid State Recorder can record and play back data simultaneously. Another advantage is its ability to record two data streams at the same time, allowing both the science and engineering data streams to be captured on a single recorder. Unlike the reel-to-reel recorders, data can be played back without having to rewind the tape, and information can be instantly accessed.

Reel-to-reel tape recorders can fall victim to single-point failures, such as a break in the tape or a mechanical defect. The Solid State Recorder does not have mechanically moving parts, and its memory modules have a very low failure rate. This digital recorder is designed to grow old gracefully, compensating for situations such as a bad chip or a bad module. The recorder automatically detects, corrects and reports random errors in memory. If the failure is too difficult to correct, the affected area can be isolated and skipped over, leaving the rest of memory fully functional. The old, mechanical recorders also had to be sealed in a pressurized enclosure to protect the tape and the delicately lubricated moving parts from the hazards of a space vacuum. This special packaging is not necessary for the Solid State Recorder. NASA successfully tested this Solid State Recorder during a 10-day Space Shuttle Mission (STS-95) in October 1998. Based on these results and the on-orbit performance of the unit already aboard Hubble, NASA expects this new recorder to last the life of the Telescope. The Solid State Recorder was developed at Goddard.

Updated: 11/22/1999

Payloads

Voltage/Temperature Improvement Kits

Prime:

Backup:

Overview

In space, the Hubble Space Telescope sees daylight and night every hour and a half. Hubble uses solar energy, collected by the solar arrays, to power its computers and science instruments. At night when there is no Sun, Hubble uses its batteries for power. These batteries are then recharged during Hubble's next day.

Astronauts will install a battery Voltage/Temperature Improvement Kit (VIK) on each of the Hubble's six batteries. Hubble's batteries are fully charged each orbit by the Solar Arrays. Each battery is fully charged when its respective charge controller senses a specific charge cutoff voltage. The VIK modifies the charge cutoff voltage to a lower level to prevent battery overcharging and associated overheating. In the Telescope, the batteries are located in two compartments, called bays, three batteries to a bay. The VIK is a simple device, about the size of a cell phone, weighing about three pounds.

An automobile has a voltage regulator to control the rate of charge into its car battery. Similarly, Hubble has charging regulators for its batteries. Hubble's regulators use battery voltage and battery temperature to control the rate of charge into the batteries. The batteries aboard Hubble are almost 10 years old. They still do the job well but, as they age, they become more sensitive to the way they are charged and become susceptible to overheating.

Updated: 11/22/1999

DTO/DSO/RMEs

Single-String Global Positioning System, with PGSC and GPS
DTO 700-14

Prime:

Principal Investigator: Ray Nuss, Wayne Hensley, Michael Sarafin

Backup:

Overview

This DTO demonstrates the performance and operation of the Global Positioning System (GPS) during orbiter ascent, on-orbit, entry, and landing phases. A modified military GPS receiver-processor and the existing orbiter GPS antennas will be used, and GPS data will be downlinked during all mission phases. A payload and general support computer (PGSC) hard drive may be used (optional) to record GPS data during ascent, entry and/or extended orbital phases.

The single-string GPS supports operational use of GPS as a shuttle navigation aid. This flight test of the single-string GPS configuration--basically an extension of an earlier GPS development flight test--entails the following:

· GPS receiver output data will be downlinked through the flight forward 2 (FF2) multiplexer/demultiplexer (MDM) and operational forward 2 (OF2) MDM for real-time and postflight analysis.

· A PGSC may be connected to the receiver's RS-422 instrumentation port to collect data during ascent, entry and/or orbital phases (optional).

· The crew may be requested to perform various activities, such as exercising certain GPS SOP and navigation commands and/or cycling power to the GPS receiver. Requirements for this option are defined specifically for each mission to achieve the following objectives whenever feasible: (a) incorporate GPS to NAV in OPS 201 (PASS), (b) incorporate GPS to NAV in OPS 301 (PASS and BFS), and (c) perform GPS receiver commands (via crew keyboard item entries) during OPS 201.

History/Background

DTO 700-14 has manifested on nine previous shuttle missions. It last flew on STS-96.

Updated: 11/22/1999

DTO/DSO/RMEs

Space Integrated Global Positioning System/Inertial Navigation System (SIGI)

DTO 700-15

Prime:

Backup:

Overview

The SIGI system is intended to replace the shuttle's onboard tactical navigation system and, eventually, its inertial measurement units. The objective of this DTO is to evaluate the system's performance during space flight and assess the technical and schedule risks of using this new technology in the shuttle navigation systems.

In addition to demonstrating the new navigation system's performance in a realistic space vehicle environment during all mission phases, DTO 700-15 will prove the ability of the modified commercial military-grade unit to accurately perform all required functions and determine if any changes of the unit are needed to support navigation in space.

History/Background

DTO 700-15 has previously manifested on six shuttle missions. It was last flown on STS-96. Fourteen flights are planned.

Updated: 11/22/1999

Media Assistance

NASA Television Transmission

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

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

Status Reports

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

Briefings

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

Internet Information

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

http://www.spaceflight.nasa.gov

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

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

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

http://www.nasa.gov

or

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

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

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

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

http://www.nasa.gov/ntv

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

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

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

http://spacelink.nasa.gov

Access by Compuserve

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

Updated: 11/22/1999

Media Contacts

NASA PAO CONTACTS

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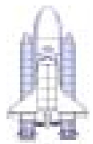
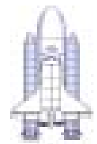
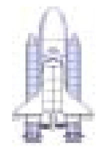
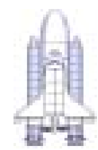
SHUTTLE FLIGHTS AS OF DECEMBER 1999

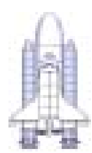
95 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 70 SINCE RETURN TO FLIGHT











OV-102 Columbia (26 flights)	**OV-099 Challenger (10 flights)**	**OV-103 Discovery (26 flights)**	**OV-104 Atlantis (20 flights)**	**OV-105 Endeavour (13 flights)**
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-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-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