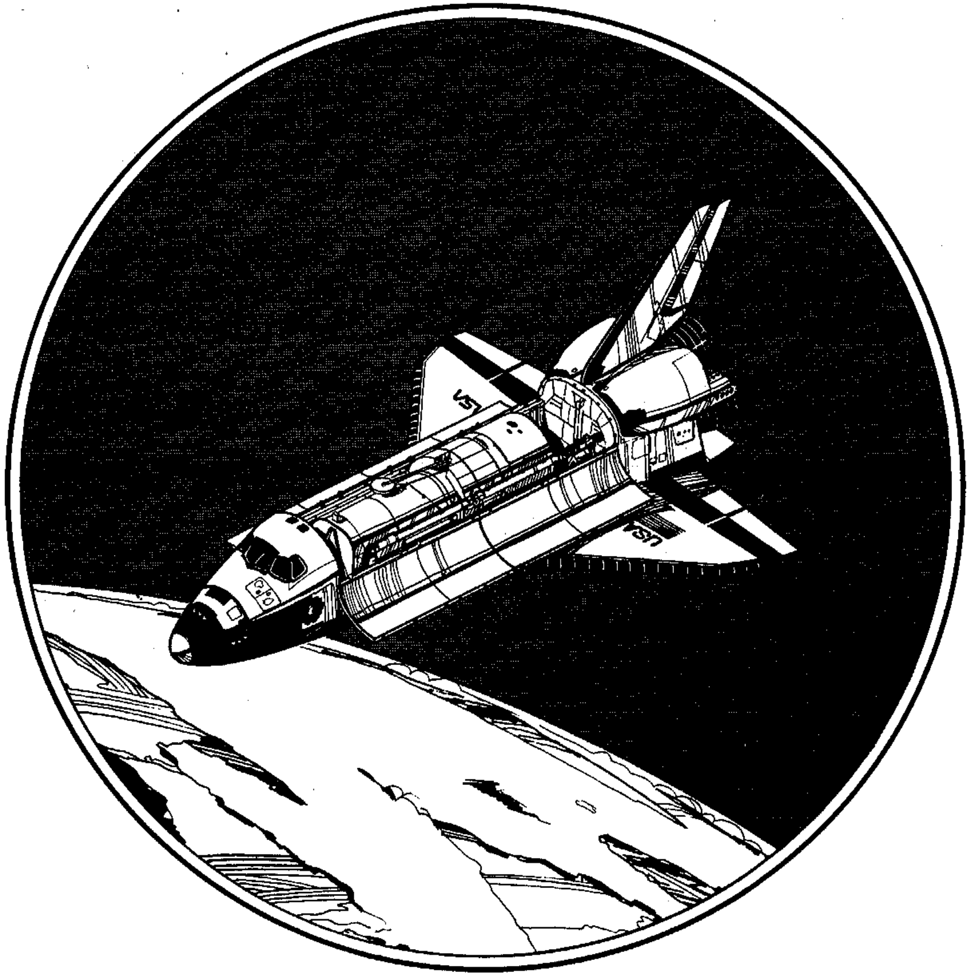


STS-31
PRESS INFORMATION

April 1990

Rockwell International
Space Transportation
Systems Division

Office of Media Relations

PUB 3546-V REV 4-90

CONTENTS

MISSION OVERVIEW

This is the 10th flight of Discovery and the 35th in the space transportation system.

The flight crew for the STS-31 mission consists of commander Loren J. Shriver; pilot Charles F. Bolden; and mission specialists Steven A. Hawley, Bruce McCandless II and Kathyrn D. Sullivan.

The primary objective of this five-day mission is to deploy the Hubble Space Telescope (HST) in Earth orbit. The HST is scheduled to be released by Discovery's remote manipulator system (RMS) at a nominal mission elapsed time of day one, five hours and 23 minutes on orbit 19.

The release of the HST can be delayed until orbit 20 if an extravehicular activity (EVA) is required to manually deploy its appendages.

After the HST has been released by Discovery's RMS, a return rendezvous with the telescope can be requested for as late as 45 hours after the release to accommodate the rendezvous and an EVA to manually open the HST's aperture door. The STS-31 mission will be extended one day if this EVA is required.

Eight secondary payloads are also carried aboard Discovery on this mission. IMAX cameras are located in Discovery's crew compartment and the cargo bay.

The cargo bay camera will film the deployment of the HST and Earth observations. Experiments carried in the crew compartment include protein crystal growth, investigation into membrane processing, radiation monitoring and a student experiment. An ascent particle monitor experiment is carried in Discovery's payload bay. The Air Force Maui Optical Site experiment will collect signature data of Discovery as it passes over Mt. Haleakala on Maui, Hawaii.

This flight of Discovery is the first for the new main landing gear carbon brake. The main landing gear carbon brakes consist of five carbon rotors splined to the inside of the wheel and rotate with the wheel and four carbon stators splined to the outside of the axle assembly and do not rotate with the wheel. The goal of the carbon brake program is to increase maximum energy absorption to 82 million foot-pounds and provide a one-time stop of 100 million foot-pounds. The previous improved main landing gear brakes provided approximately 65 million foot-pounds.

Because this will be the first deployment of the HST, this mission features several other firsts: highest direct-insertion altitude, 330 nautical miles (379 statute miles); longest orbital maneuvering system and deorbit thrusting periods, approximately 4.5 minutes (494 and 527 feet per second, respectively); longest planned reaction control system thrusting period, approximately two minutes (limit is 2.5 minutes); longest auxiliary power unit run time, approximately one hour, 21 minutes during deorbit, entry and landing; and two extravehicular mobility units (EMUs) and a spare EMU upper torso to support mission success in the event HST contingency EVA is required.

MISSION STATISTICS

Launch: The maximum launch range window for any day of launch will be limited to four hours. The launch window's duration is two hours, 30 minutes for flight crew members on their backs after reaching the first T zero.

4/10/90 8:47 a.m. EDT
7:47 a.m. CDT
5:47 a.m. PDT

Mission Duration: 120 hours (five days), one hour, 15 minutes

Landing: Nominal end of mission is on orbit 76.

4/15/90 10:02 a.m. EDT
9:02 a.m. CDT
7:02 a.m. PDT

Inclination: 28.5 degrees

Ascent: The ascent profile for this mission is a direct insertion. Only one orbital maneuvering system thrusting maneuver, referred to as OMS-2, is used to achieve insertion into orbit. This direct-insertion profile lofts the trajectory to provide the earliest opportunity for orbit in the event of a problem with a space shuttle main engine.

The OMS-1 thrusting maneuver after main engine cutoff plus approximately two minutes is eliminated in this direct-insertion ascent profile. The OMS-1 thrusting maneuver is replaced by a 5-foot-per-second reaction control system maneuver to facilitate the main propulsion system propellant dump.

Altitude: 310 by 330 nautical miles (356 by 379 statute miles), then circularized at 330 nautical miles (379 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,516,297 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 220,662 pounds

Payload Weight Up: Approximately 28,784 pounds

Payload Weight Down: Approximately 4,937 pounds

Orbiter Weight at Landing: Approximately 189,655 pounds

Payloads: Hubble Space Telescope, IMAX cameras in payload bay and in middeck, Protein Crystal Growth (PCG)-III-03, Investigation Into Polymer Membrane Processing (IPMP) 01, Air Force Maui Optical Site (AMOS)-05, Radiation Monitoring Experiment (RME) III-01, Student Experiment (SE) 82-16, and Ascent Particle Monitor (APM)-01.

Flight Crew Members:
Commander: Loren J. Shriver, second space shuttle flight
Pilot: Charles F. Bolden, second space shuttle flight
Mission Specialist 1: Bruce McCandless II, second space shuttle flight
Mission Specialist 2: Steven A. Hawley, third space shuttle flight
Mission Specialist 3: Kathyrn D. Sullivan, second space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Loren Shriver
Flight deck front right seat, pilot Charles Bolden
Flight deck aft center seat, MS-2 Steven Hawley
Flight deck aft right seat, MS-1, Bruce McCandless
Middeck, MS-3, Kathyrn Sullivan

Entry Seating:
Flight deck aft center seat, MS-2 Steven Hawley

Flight deck aft right seat, MS-3 Kathyrn Sullivan
Middeck, MS-1, Bruce McCandless

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut 1 would be Bruce McCandless and EV 2 would be Kathyrn Sullivan.

Angle of Attack: Entry, 40 degrees

Entry: Automatic mode will be used until subsonic; then the control stick steering mode will be used.

Runway: Nominal end-of-mission landing will be on lake bed Runway 17.

Notes:

- The remote manipulator is installed in Discovery's payload bay for the deployment of the HST. The galley is installed in the middeck of Discovery.

- The text and graphics system is the primary text uplink and can only uplink images using the Ku-band. TAGS consists of a facsimile scanner on the ground that sends text and graphics through the Ku-band communications system to the text and graphics hard copier in the orbiter. The hard copier is installed on a dual cold plate in avionics bay 3 of the crew compartment middeck and provides an on-orbit capability to transmit text material, maps, schematics, maneuver pads, general messages, crew procedures, trajectory and photographs to the orbiter through the two-way Ku-band link using the Tracking and Data Relay Satellite system. It is a high-resolution facsimile system that scans text or graphics and converts the analog scan data into serial digital data. Transmission time for an 8.5- by 11-inch page can vary from approximately one minute to 16 minutes, depending on the hard-copy resolution desired.

  The text and graphics hard copier operates by mechanically feeding paper over a fiber-optic cathode-ray tube and then through a heater-developer. The paper then is cut and stored in a tray accessible to the flight crew. A maximum of 200 8.5- by 11-inch sheets are stored. The status of the hard copier is indicated by front panel lights and downlink telemetry.

  The hard copier can be powered from the ground or by the crew.

  Uplink operations are controlled by the Mission Control Center in Houston. Mission Control powers up the hard copier and then sends the message. In the onboard system, light-sensitive paper is exposed, cut and developed. The message is then sent to the paper tray, where it is retrieved by the flight crew.

- The teleprinter will provide a backup on-orbit capability to receive and reproduce text-only data, such as procedures, weather reports and crew activity plan updates or changes, from the Mission Control Center in Houston. The teleprinter uses the S-band and is not dependent on the TDRS Ku-band. It is a modified teletype machine located in a locker in the crew compartment middeck.

  The teleprinter uplink requires one to 2.5 minutes per message, depending on the number of lines (up to 66). When the ground has sent a message, a *msg rcv* yellow light on the teleprinter is illuminated to indicate a message is waiting to be removed.

MISSION OBJECTIVES

- Deployment of the HST
- Secondary payloads
    - IMAX camera in Discovery's payload bay and IMAX camera in Discovery's middeck.
    - PCG-III-03
    - IPMP-01
    - AMOS-05
    - RME III-01
    - SE 82-16
    - APM-01

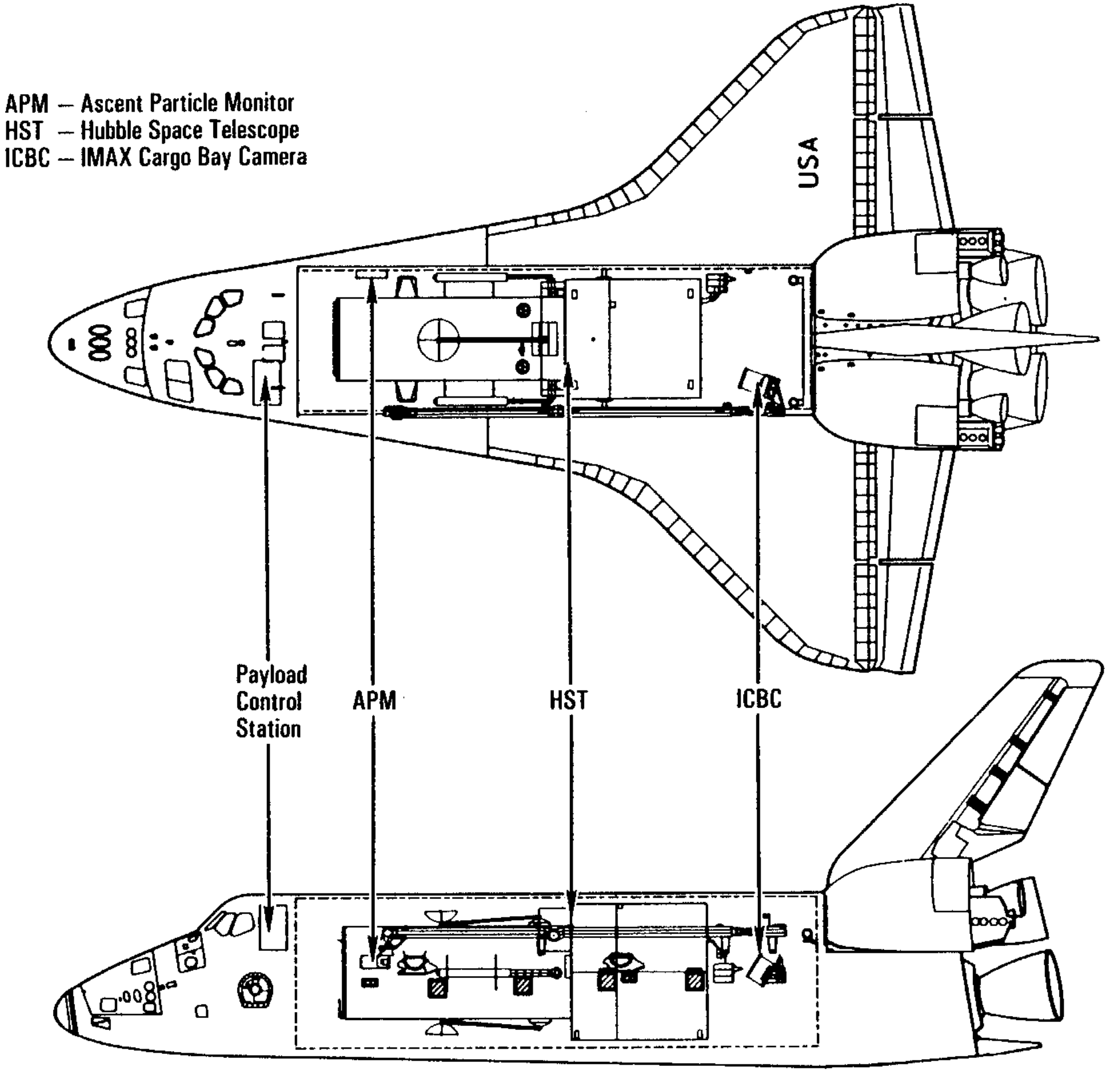
DEVELOPMENT TEST OBJECTIVES

- Gravity gradient attitude control
- Ascent structural capability evaluation
- Entry structural capability
- Direct external tank insertion
- Crew module distortion
- Entry aerodynamic control surfaces test
- Ascent compartment venting
- Descent compartment venting
- Vibration and acoustic
- Cabin growth
- Microbial filter design

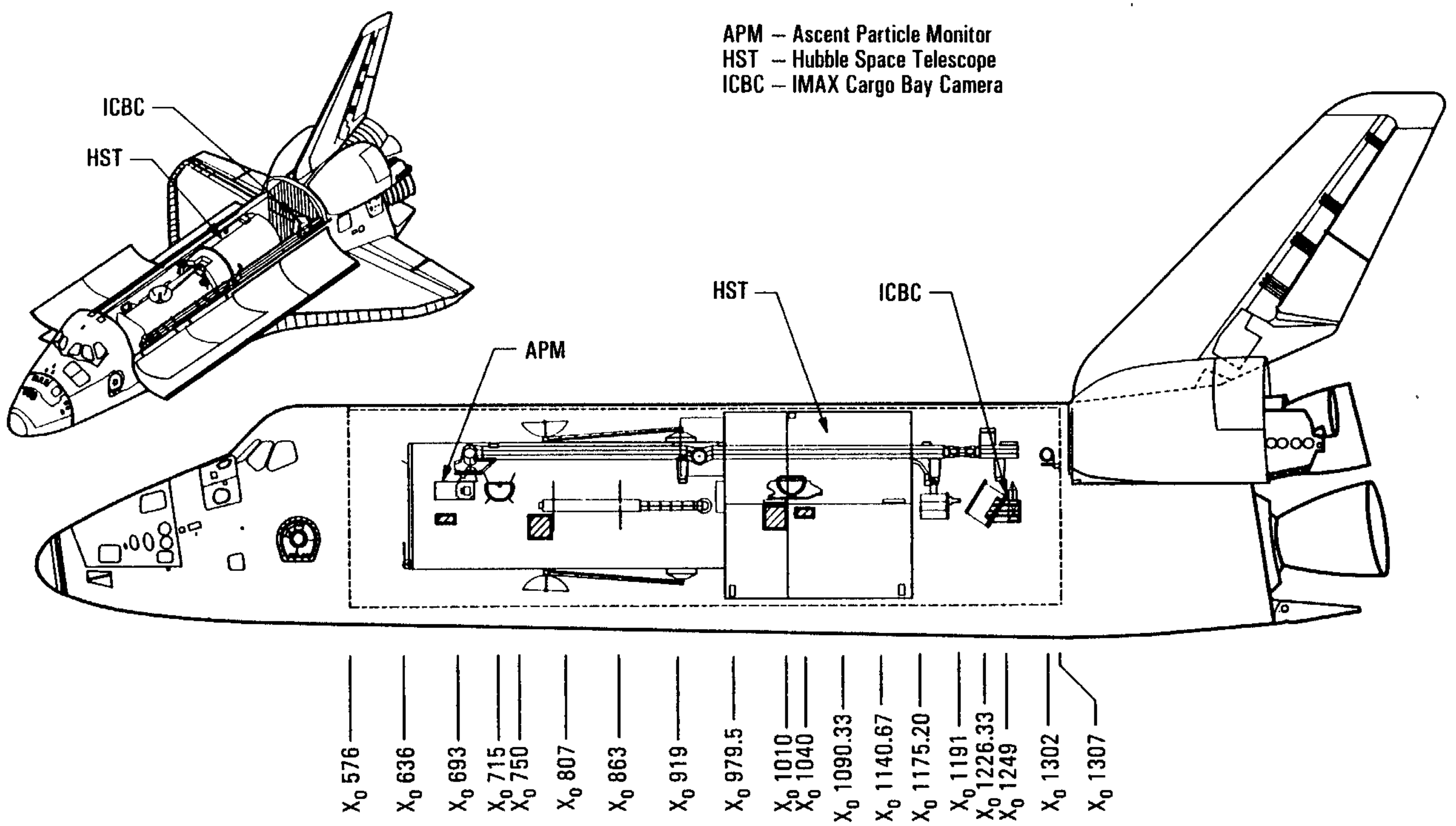
DETAILED SUPPLEMENTARY OBJECTIVES

- Noninvasive estimation of central venous pressure
- In-flight radiation dose distribution
- In-flight intraocular pressure
- Delayed-type hypersensitivity
- Hypersmotic fluid countermeasure
- Documentary television
- Documentary motion picture photography
- Documentary still photography

PAYLOAD CONFIGURATION

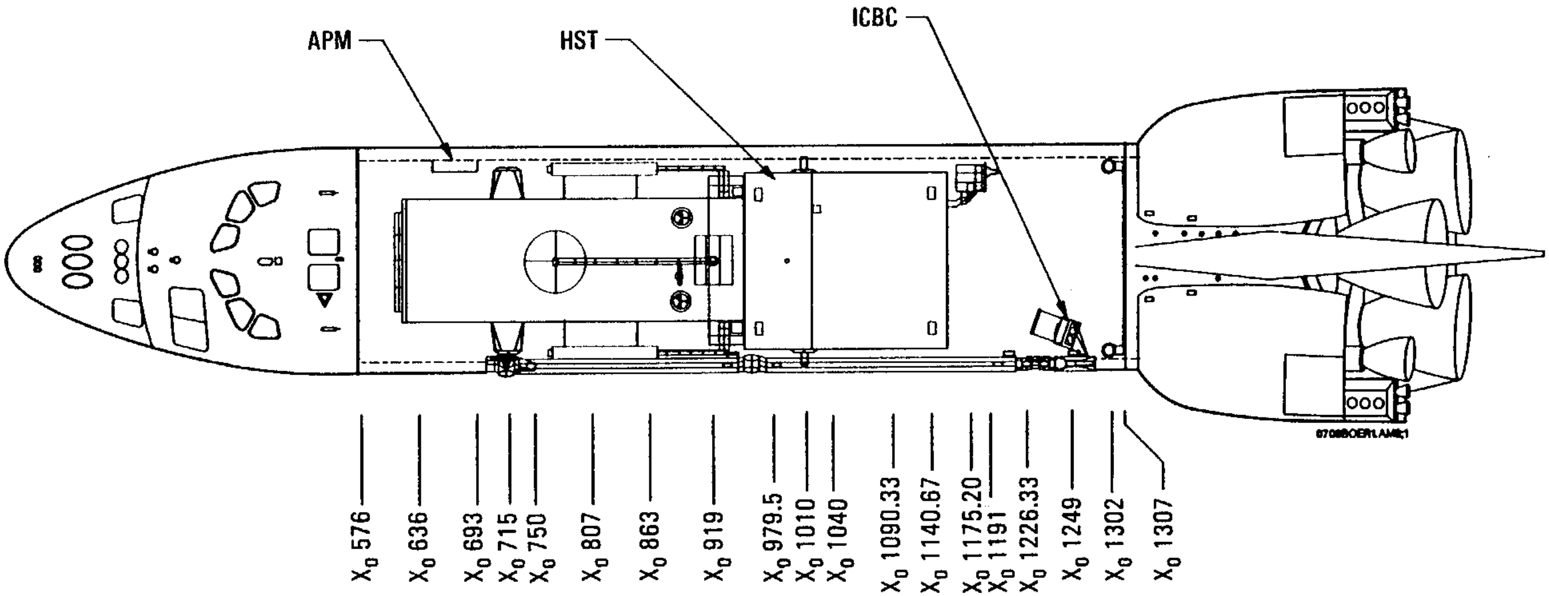


STS-31 Payloads



STS-31 Payloads, Side View

APM — Ascent Particle Monitor
HST — Hubble Space Telescope
ICBC — IMAX Cargo Bay Camera



STS-31 Payloads, Top View

HUBBLE SPACE TELESCOPE

In October 1983, the Space Telescope was renamed the Edwin P. Hubble Space Telescope in honor of one of the nation's foremost astronomers. Edwin Paul Hubble, born November 20, 1889, in Marshfield, Mo., revolutionized our knowledge of the size, basic structure and properties of the universe.

Placing the Hubble Space Telescope (HST) in Earth orbit from the space shuttle orbiter Discovery will allow the telescope to perform many functions impossible to duplicate on Earth. For example, interference from atmospheric filtering, haze, twinkling and light pollution will be eliminated in Earth orbit.

The HST is the most powerful telescope ever built. The largest Earth-based telescopes in operation today can see 2 billion light years into space. The HST will be able to see much deeper—14 billion light-years. Some scientists believe the universe was formed nearly 14 billion years ago, so the HST might provide views of galaxies at the time they were formed.

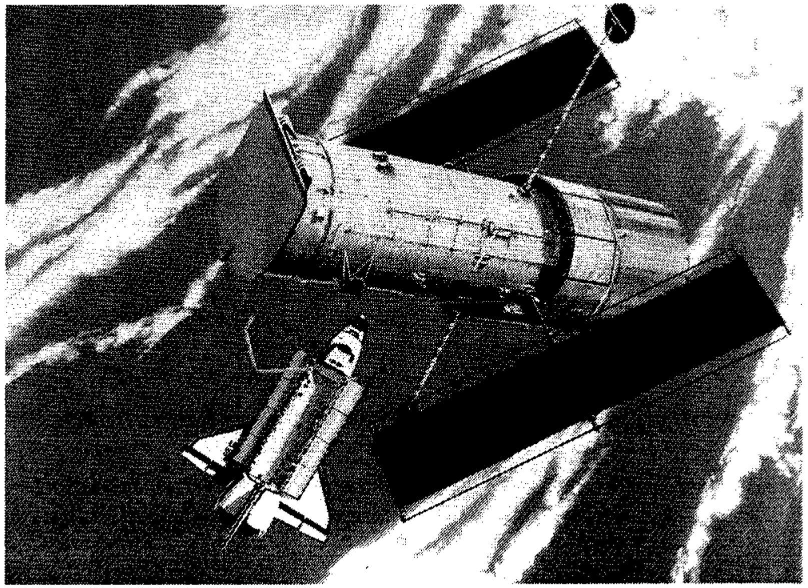
Studying the stars isn't merely a matter of distance, however; it is also one of clarity. All Earth-bound seeing devices have distorted vision because the Earth's atmosphere blurs the view and smears the light. The clearer images provided by the HST will enable scientists to evaluate the mass, size, shape, age and evolution of the universe more comprehensively.

Using the HST, scientists will be able to look at celestial objects that are 50 times fainter than those seen by the most powerful telescopes, such as quasars, galaxies, gaseous nebulae and Cepheid variable stars. Within the solar system, they can monitor atmospheric and surface phenomena of the planets. With the HST in Earth orbit, long time exposure images more than 10 times sharper than those from the ground can be achieved. Another great advantage of orbital observation is the absence of atmospheric material that absorbs the ultraviolet and infrared radiation from stars.

The crisper images produced by the HST, combined with the darker sky background, will also permit much fainter objects to be detected. Concentrating starlight into a smaller area improves the contrast with the background (which is lower due to the absence of scattered light and airglow emission) and reduces the exposure times to reach a given brightness level.

The HST should be able to photograph objects perhaps 50 times fainter than the same detection system on the ground could photograph.

A further advantage of the HST for observational programs lies in its accessibility to all the sky and almost continuous observing conditions. With ground-based observations, most optical observations are made only during twilight and dark hours and, even then, only when the sky is reasonably clear. The HST will be able to make some observations even in sunlight (although not to the faintest levels) and realize about 4,500 hours of observation per year (excellent ground-based observatories achieve about 2,000 hours per year).



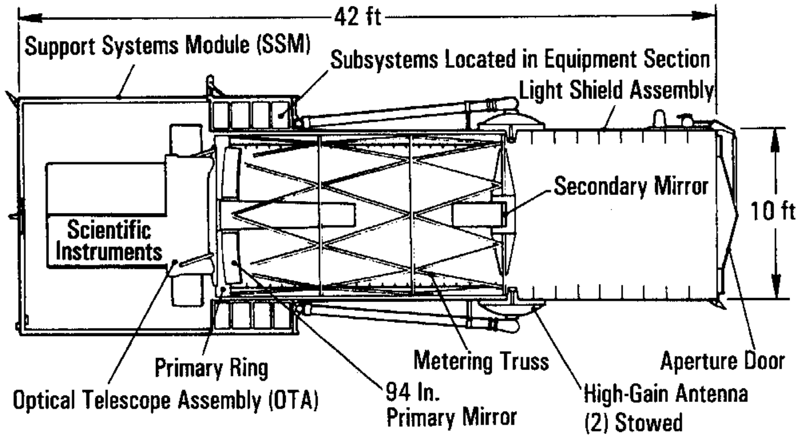
Hubble Space Telescope Deployment With Aperture Door Closed

The HST is expected to contribute a great deal to the knowledge of little-understood energy processes in celestial objects, the early stages of star and solar system formation, the nature of such highly evolved objects as supernovae remnants and white dwarf stars, and the origin of the universe.

Using the HST, scientists can look at galaxies so far away that they will see them as they were billions of years ago. This should tell the scientists much about the birth and growth of cosmic structures like our galaxy.

The HST may be able to search for planets that orbit other stars as the Earth orbits the sun. This data would identify basic physical processes of the universe and indicate the chances that other life-supporting planets exist. It would also provide a new perspective on our neighboring planets, giving continuous information about their physical conditions and atmospheres—information needed to build and equip spacecraft for planetary exploration.

The HST is 43 feet long and 14 feet in diameter. It weighs approximately 25,000 pounds. The HST is composed of three major elements: the optical telescope assembly, the support systems module and the scientific instruments. The OTA holds the 94-inch reflecting Cassegrain-type telescope. A meteoroid shield and sunshade protect the optics.



Hubble Space Telescope

The telescope itself will have a Ritchey-Cretien folded optical system with the secondary mirror inside the prime focus.

The primary mirror is made of ultralow-expansion glass. The mirror will be heated during operation to about optical shop temperatures of 70 F to minimize variations from its original accuracy. Additional heat required to maintain the 70 F temperature will come from electrical strip heaters that will radiate to the back of the mirror.

The open front end of the telescope will be similar to those of most Earth-bound telescopes and will admit light to the primary mirror in the back of the telescope. The primary mirror will project the image to a smaller secondary mirror in front. The beam of light will then be reflected back through a hole in the primary mirror to the scientific instruments in the rear.

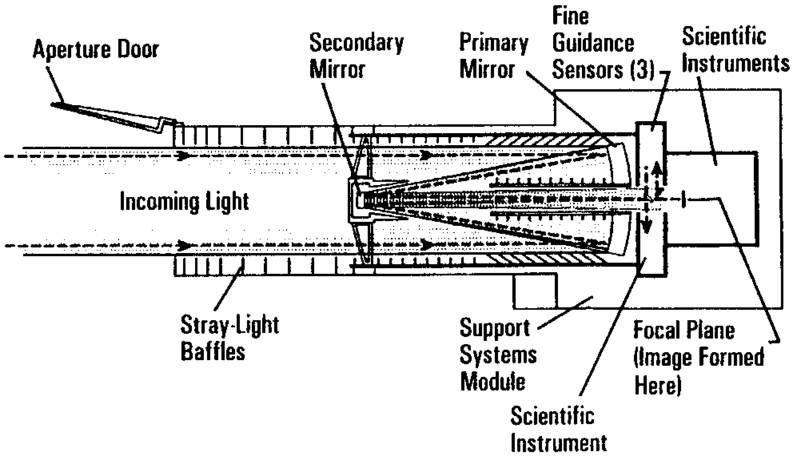
The telescope's two mirrors are held precisely 16 feet apart by a truss structure made of material specially designed not to expand or contract due to temperature extremes as the HST moves from sunlight to darkness in its orbits around Earth. The truss will not allow the distance between the two mirrors to vary more than one-ten thousandth of an inch. That is one-thirtieth the thickness of the sheet of paper on which these words are printed.

The pointing and stabilization control system on the telescope can locate a position in the sky to within 0.01 arc-second, then hold it to within 0.007 arc-second of that position for as long as 24 hours. This angle is only slightly larger than that made by a dime viewed from Washington, D.C., to Boston or equivalent to sinking a 1,500-mile golf putt on a green stretching from Dallas to Washington, D.C.

The references used to achieve pointing stability are established by using precision gyros and bright field stars or "guide" stars. Because it is designed to point at distant objects with extreme accuracy, the HST will be rotated from one light source to another very slowly. It will take 15 minutes to turn the telescope 90 degrees—the same rotation as that of the minute hand on a clock.

The scientific instruments allow telescope images to be converted to useful scientific data. The instruments and their sensors are located directly behind the telescope and communicate images in a variety of ways. The modular instruments fit behind the focal plane and contain imaging systems, spectrum analyzers (to find out about the atomic structure and material content of objects observed), and light intensity and polarization calibrators. Devices for precise control of temperature, direction, and stability and the equipment to generate power are located in similar modular packages.

The apertures of the scientific instruments are located at the principal focus. Since suppressing stray light is extremely important in reaching faint light levels, the forward end of the telescope is enclosed and baffled, with the aperture door serving as a sunshield. The scientific instruments include two cameras, two spectrometers and a photometer.



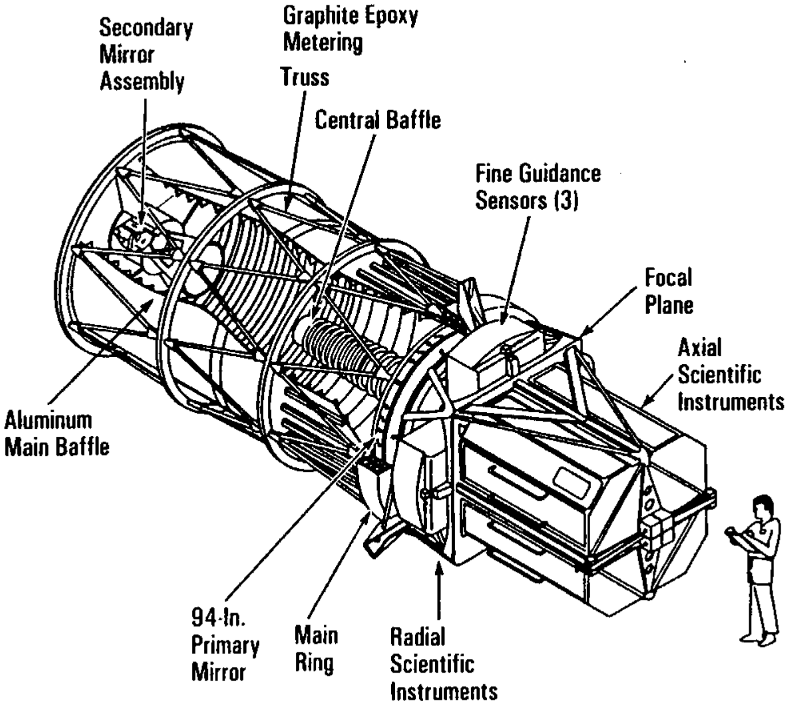
Incoming light is projected by the 94-in. primary mirror to the secondary mirror, and from there back through a hole in the primary mirror for analysis by several scientific instruments, including a faint object camera, faint object spectrograph, high-speed photometer and wide-field planetary camera. The light baffles preclude entry of unwanted light, which may have been deflected off some part of the HST, from reaching the image formed within the scientific instruments.

Optical Telescope Assembly

The faint object camera, provided by the European Space Agency (ESA), and the wide-field planetary camera are distinguished by their fields of view, spatial resolution and wavelength range. Both instruments cover the ultraviolet and blue regions of the spectrum.

The telescope will be able to detect light soures 25 times farther away than ground-based observatories can. Using its science instruments and precise mirrors, the telescope can detect the light from a typical two-battery flashlight that is a quarter of a million miles away—the distance from the Earth to the moon.

Due to the filtering effect of the atmosphere, Earth-based



Optical Telescope Assembly

telescopes can see only visible light. The HST will be able to study ultraviolet and infrared rays.

The wide-field planetary camera covers the red and near-infrared regions. It will be able to photograph the entire facing hemisphere of planets in our solar system in a single exposure with an image sharpness equivalent to being able to read a license plate about 30 miles away.

The faint object camera can record such fine detail that it could discern the head or tail on a nickel 6 miles away. It will intensify images to 100,000 times their original brightness. That is equivalent to increasing the light of a candle flame to the brightness of the noonday sun.

The two spectrographs—the high-resolution spectrograph and the faint object spectrograph—will provide a wide range of spectral resolutions that would be impossible to cover with a single instrument. Both instruments will record ultraviolet radiation. Only the faint object spectrograph covers the visible and red regions of the spectrum.

The Goddard Space Flight Center's high-resolution spectrograph will be able to obtain data at time intervals as closely spaced as one-twentieth of a second. It can take five separate data samples in the blink of a human eye.

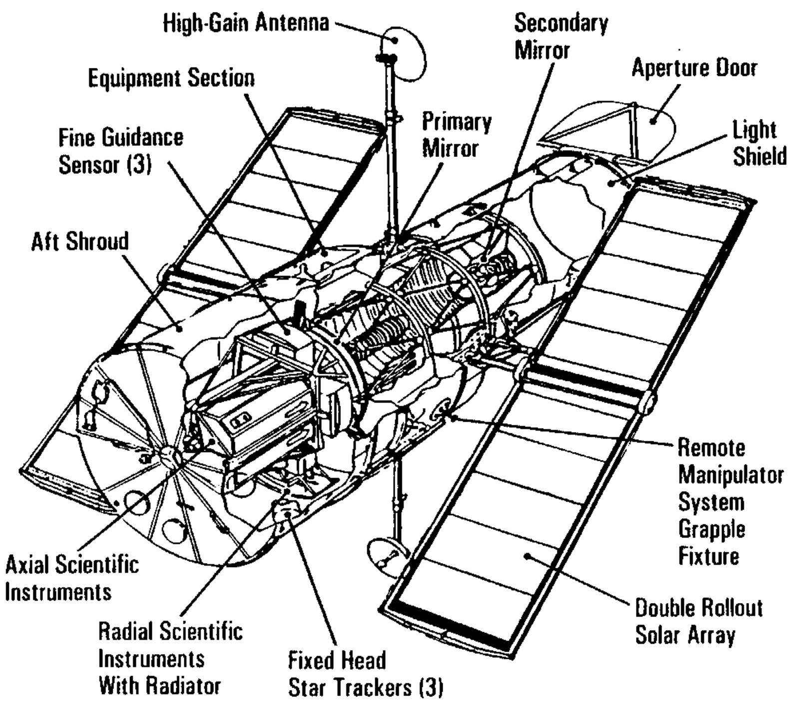
The faint object spectrograph will be able to resolve, or detect individually, objects separated by as little as 0.1 arc-second. That is equivalent to distinguishing a car's left and right headlights at a distance of 2,500 miles, as far as from Atlanta to San Francisco.

The fifth instrument, the high-speed photometer, is a relatively simple device capable of measuring rapid brightness variability over time intervals as frequent as every one-one hundred thousandths of a second. In the time it takes a bullet speeding from the muzzle of a hunting rifle to travel 1 inch, the photometer can complete three measurements. The photometer can also be used to measure ultraviolet polarization and to calibrate other instruments.

The support systems module encloses the optical telescope assembly and scientific instruments and also provides all interfaces with the space shuttle orbiter. The module contains a very precise pointing and stabilization control system, communications system, thermal control system, data management system and electrical power system.

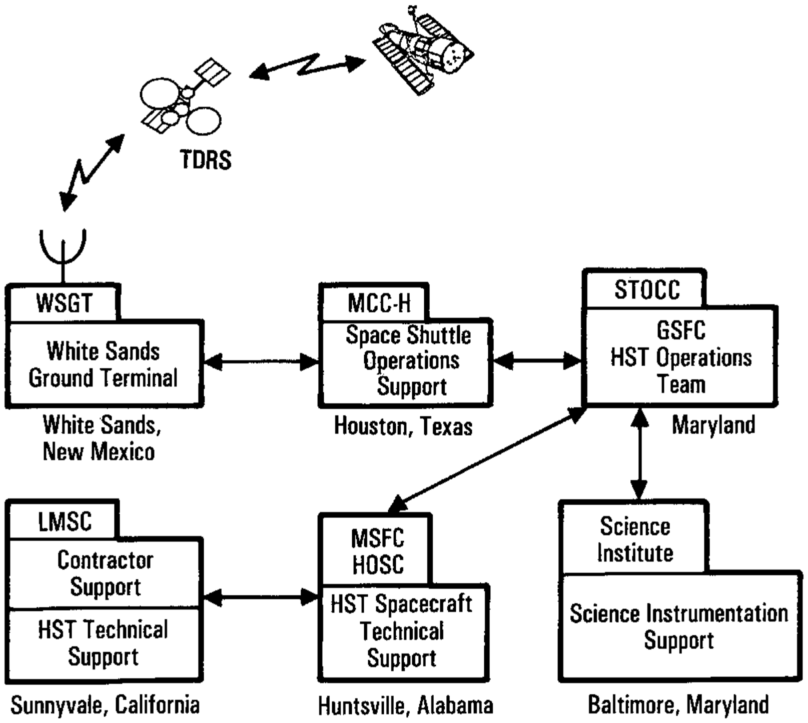
Electrical power to operate the telescope is provided by batteries that are charged by two solar panels during the sun side of the orbit.

The complex and versatile scientific instruments on the telescope are each about the size of a refrigerator. Individually, they consume only 110 to 150 watts, about the amount of power required to light a typical three-way bulb.



Hubble Space Telescope

Images received by the telescope will be transmitted to Earth by telemetry. The pictures, spectral information and brightness measurements from the telescope will be transmitted as electronic signals at a rate of up to 1 million bits per second. At that rate, the entire contents of a 30-volume encyclopedia could be transmitted in 42 minutes.



HST – Hubble Space Telescope
GSFC – Goddard Space Flight Center
WSGT – White Sands Ground Terminal
MCC-H – Mission Control Center Houston
STOCC – Space Telescope Operations Control Center
MSFC – Marshall Space Flight Center
LMSC – Lockheed Missiles and Space Company
HOSC – Huntsville Operations Support Center

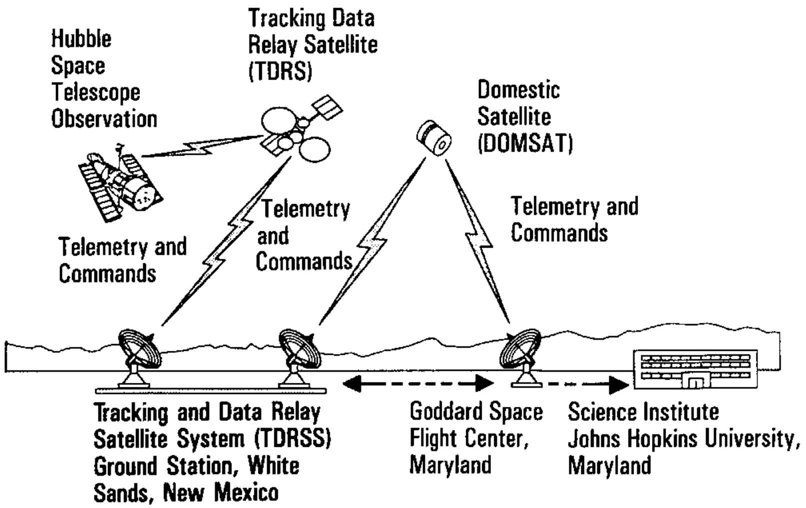
Hubble Space Telescope Communication Links

HST DEPLOYMENT

The HST will require an extensive period of activation, adjustment and checkout before it is turned over to the scientific community for their investigations. This process is referred to as orbital verification. Engineers and scientists will control this process from the Space Telescope Operations Control Center located at the Goddard Space Flight Center (GSFC) in Greenbelt, Md.

Orbital verification is divided into two phases. The first includes the deployment of the HST, activation of its systems and preliminary pointing and focusing. A team from NASA's Marshall Space Flight Center (MSFC) in Huntsville, Ala., will be stationed at Goddard to manage this portion of the verification. The Marshall manager in charge of this team, referred to as the director of orbital verification, will give the final go-ahead for each step of the process. Another Marshall team working in Huntsville will provide technical engineering support. Actual commands will be sent to the telescope by the Goddard center mission operations contractor.

The second phase of orbital verification will be managed by

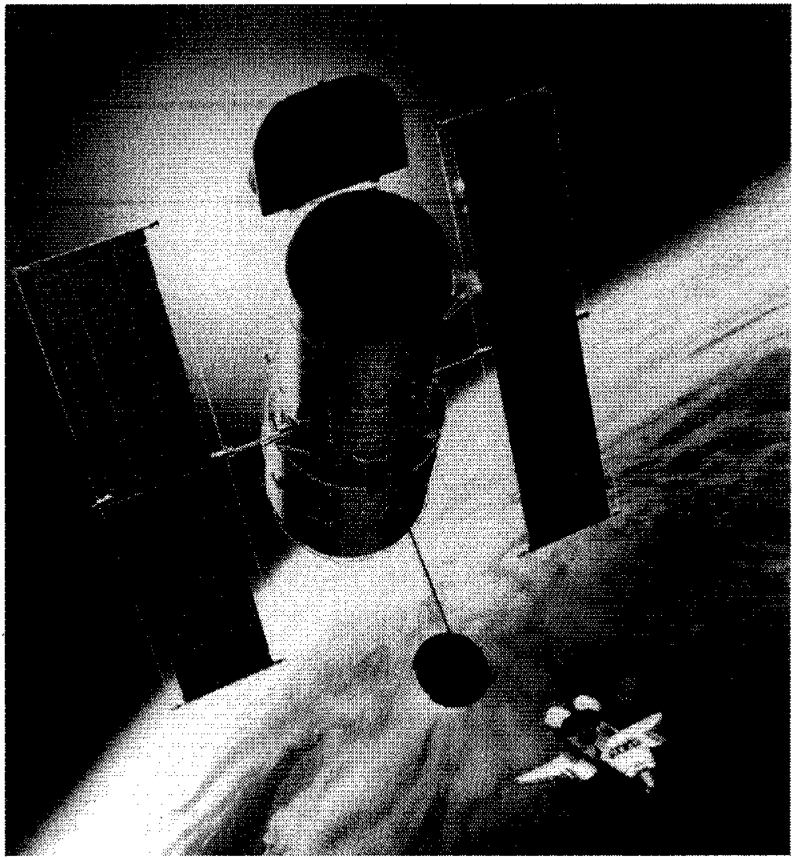


Tracking Data Relay Satellite (TDRS)

GSFC with continued technical support by MSFC. Activation and final calibration of the scientific instruments, as well as refinements of alignment and focusing, will be accomplished during this period.

Deployment of the HST will be a joint effort of the Discovery flight crew and the orbital verification ground control team at the Space Telescope Operations Control Center.

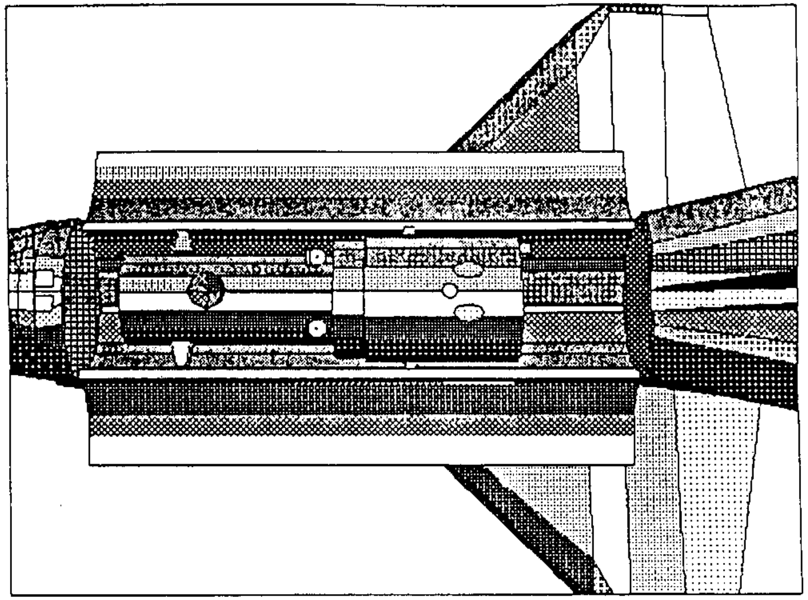
For launch aboard Discovery, the HST basically will be dormant except for the electrical power required from Discovery for a few essential HST systems. Once on orbit, Discovery's payload bay doors will be opened, to allow air inside the telescope to vent to space, eliminating the possibility of electrical arcing when main electrical power is supplied.



Hubble Space Telescope Deployed on Orbit With Aperture Door Open

After allowing sufficient time for the air to escape from the HST, the MSFC director of orbital verification will give the go-ahead to switch on the main power from Discovery's aft flight deck station. This begins orbital verification, and from this point on the HST will be under direct control of the Space Telescope Operations Control Center.

An initial series of commands will be sent to the [illegible] the HST communications system will respond by sending information about the HST's condition to the control center. The operations team will confirm that the telescope has received the commands. Simultaneously, the technical support team at the MSFC Operations Support Center in Huntsville will evaluate the data from the HST, verify that the HST is responding properly to the



Hubble Space Telescope, Stowed Configuration commands, and verify that the HST is in the proper configuration.

The orbital verification team will begin a process called thermal safing. On orbit, spacecraft are exposed to temperatures ranging from heat in direct sunlight to extreme cold during the portion of orbit when the Earth is between the spacecraft and the sun. Multilayer insulation protects the HST from the higher temperatures, but without a heating system, components left exposed to space could suffer damage in a short period of time. Thermal safing activates the HST's heaters and thermostats to assure that the delicate components do not suffer from these temperature extremes.

To support the deployment of the HST on the second day of the mission, Discovery's remote manipulator system will be powered for checkout shortly after the orbiter reaches Earth orbit.

If extravehicular activity (EVA) is required on the second day of the mission to manually deploy the HST's appendages because they failed to deploy automatically or the HST's aperture door failed to open automatically after HST deployment, an EVA also will be required on the fifth day of the mission.

To support the EVA, Bruce McCandless and Kathryn Sullivan have been designated extravehicular astronauts (EV-1 and EV-2, respectively). On the first day of the mission, they will initiate a prebreathe of 100 percent oxygen for 60 minutes using the helmet retention assembly connected to Discovery's oxygen system. Upon completion of the prebreathe, Discovery's crew cabin will be depressurized from 14.7 to 10.2 psia to support the EVAs on the second or fifth day of the mission, if required.

There are two extravehicular mobility units (EMUs), or space suits, and one EMU upper torso aboard Discovery to support the EVAs. The EMUs will also be checked out on the first day of the mission.

Towards the end of the first day on orbit, the verification team will activate the computer that controls the HST and check its memory to make sure it was not altered during launch. The HST's automatic control system will be activated if it loses communications with the ground.

During the flight crew's first eight-hour sleep period, the Space Telescope Operations Control Center will monitor and manage the HST's systems in preparation for its deployment from Discovery's payload bay on the second day of the mission.

After the flight crew completes the postsleep activity on the second day of the mission, McCandless and Sullivan will don liquid-cooled ventilation garments and portions of the EMUs. When the crew is given a go for HST release, EV-1 and EV-2 will complete the remainder of the EMU donning and prebreathe. If it is then determined that EVA is required to support the deployment of the HST, they will be given a go for airlock depressurization.

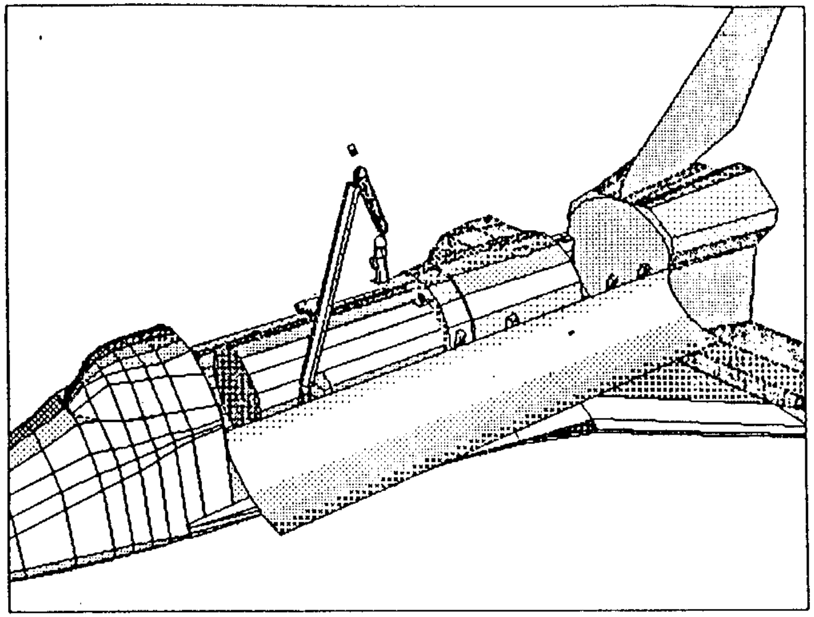
If an EVA is required, the release of the HST into Earth orbit will be delayed until orbit 20.

Discovery's remote manipulator system will be activated to grapple the HST at its starboard grapple fixture. After the RMS grapples the HST, the payload bay longeron retention latch assemblies and payload bay keel retention latch assembly will be activated from Discovery's aft flight deck panel A6U. The payload retention latch assemblies are controlled by dual-redundant, alternating-current electric motors. The motors release the latch assemblies, which release the HST. The latch assemblies can also be actuated to the latch position.

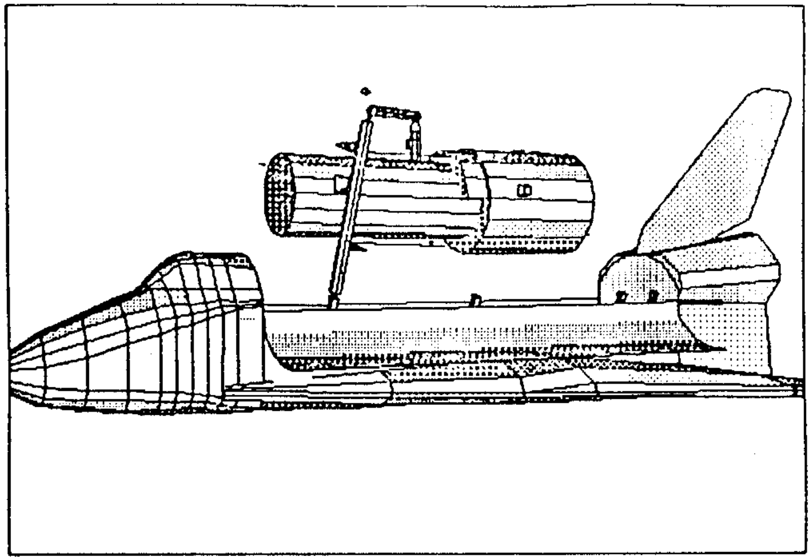
Positioning a *payload retention latches* switch to *release* provides power to the dual electric motors associated with the retention latch of the selected payload, driving the retention latch open. The operating time of the latch with both motors operating is 30 seconds; with only one motor operating, it is 60 seconds. The talkback indicator immediately above a *retention latches* switch indicates *rel* when the latch is fully open. There are two microswitches for the *rel* talkback indication; however, only one is required to control the talkback indicator. The *payload retention latches ready for latch* talkback indicator of a *retention latches* switch is barberpoled when the payload latch is set in the release position. There are two microswitches for the ready-for-latch talkback indication; however, only one is required to control the talkback indicator.

After the HST is transferred to internal power from Discovery's aft flight deck, the flight crew will be given a go to disconnect the HST umbilical from Discovery. The HST will then be unberthed from Discovery using the RMS and positioned above the payload bay with the HST's aperture door away from the sun.

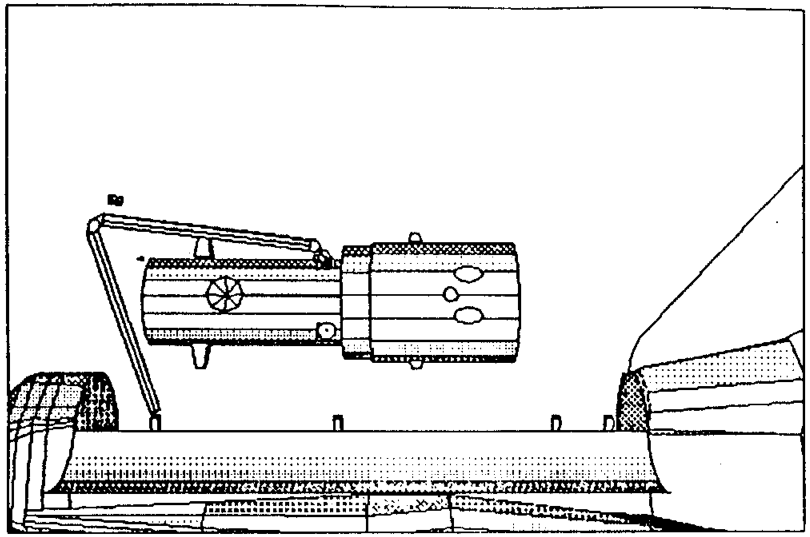
The verification team will then send the signal to deploy the HST's solar arrays. The deployed arrays collect energy from the sun on daylight-side passes around the Earth to charge the six batteries on the HST. The batteries also supply electrical power to the HST when it is on the dark side of the Earth.



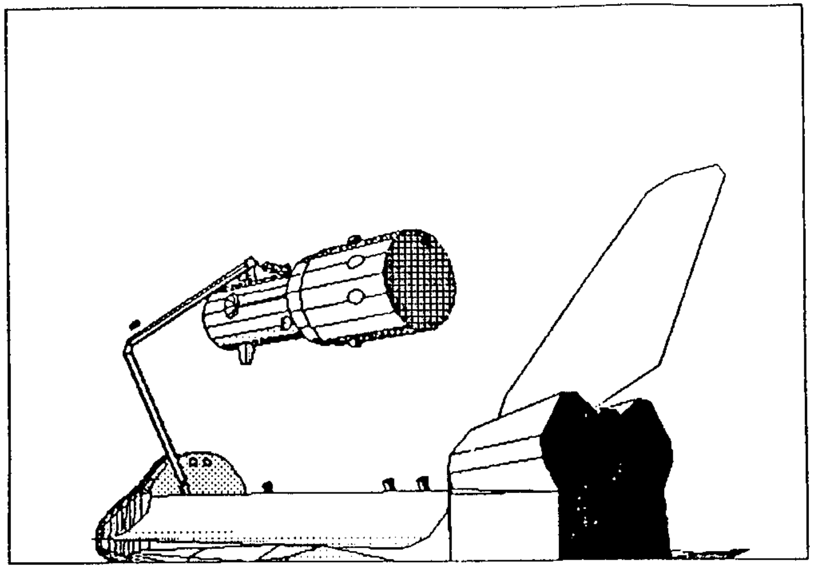
Remote Manipulator System Grapple of Hubble Space Telescope at Starboard (Right) Side Grapple Fixture



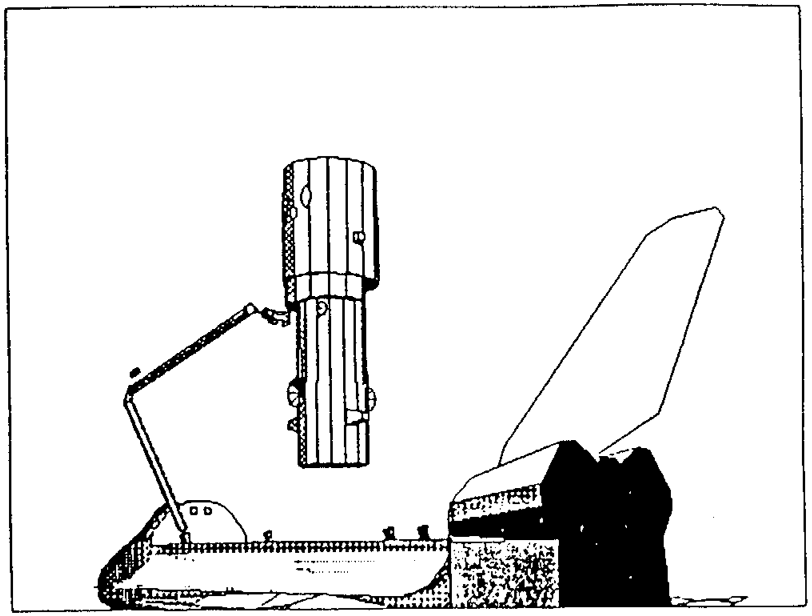
Low Hover Position From Umbilical Disconnect



90-Deg Roll Position Provides Clearance Between Hubble Space Telescope and Remote Manipulator System



High Hover Position

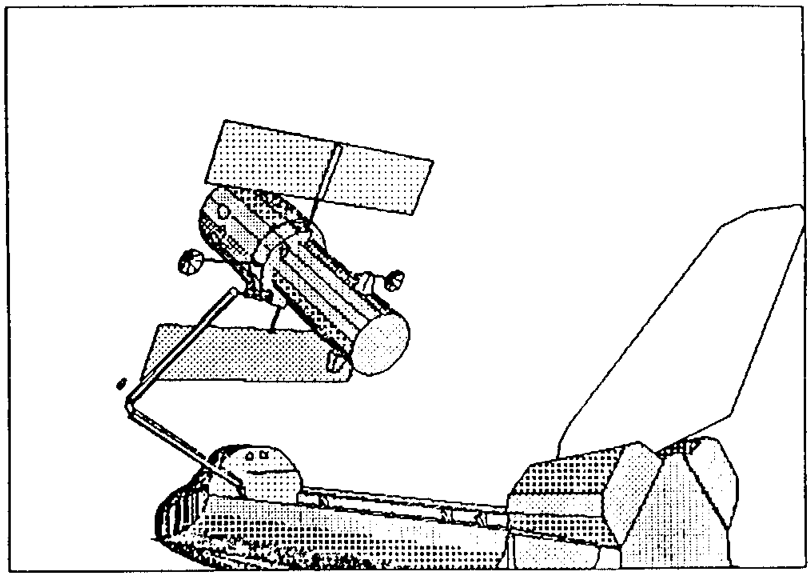


90-Deg Pitch Position

The decision to perform an EVA will be made within 30 minutes after the attempt to deploy the first secondary deployment mechanism of the HST solar arrays fails. McCandless and Sullivan would then continue their EVA preparations. A 50-minute prebreathe of 100 percent oxygen in the EMU is required before Discovery's airlock is depressurized for an EVA. It is estimated that it will take approximatley 25 to 50 minutes to manually deploy both solar arrays.

During EVA preparations, the flight crew will release the HST's aperture door latch and deploy the two high-gain antennas in accordance with the nominal time line. If either of the antennas fails to deploy automatically, an EVA will be required to deploy them manually. The high-gain antennas will be used to transmit information on the health and safety of the HST and scientific instrument images to the control center through NASA's Tracking and Data Relay Satellite system.

If this EVA is required, the HST will not be released from Discovery's RMS until orbit 21.

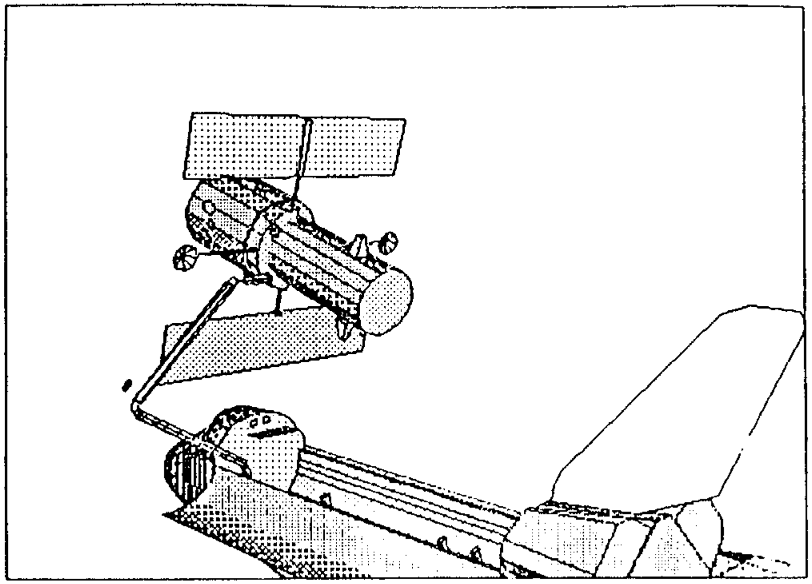


Appendage Deploy Position

The HST's pointing systems will then be activated to ensure the HST stays in the correct orientation with respect to the sun. Then the director of orbital verification will give a go for Discovery's flight crew to release the HST from the RMS and set it free in Earth orbit.

After the HST is released, Discovery will be maneuvered into a parallel orbit approximately 40 miles behind the HST. The orbiter will remain there for approximately two days so the crew can respond to problems that occur on the HST. If no action is required, Discovery will continue with the remainder of the mission activities.

After a nominal HST deployment, the aperture door of the HST must be opened before the telescope can be adjusted and focused. However, the verification team must be very sure of the HST's orientation before it gives the command to open the aperture door. Because the HST is designed to study faint, faraway objects, its detectors are very sensitive and light from the sun, moon, or Earth could damage them. Thus the orbital verification team will perform a series of tests on the HST pointing control system to determine the telescope's attitude, or orientation, in space. When the director of orbital verification is confident that the HST's instruments are reading correctly and the aperture door is pointed away from the sun, the aperture door will be commanded to open. Light from space will then reach the HST's precision-ground mirrors for the first time, an event referred to by the HST team as first light.



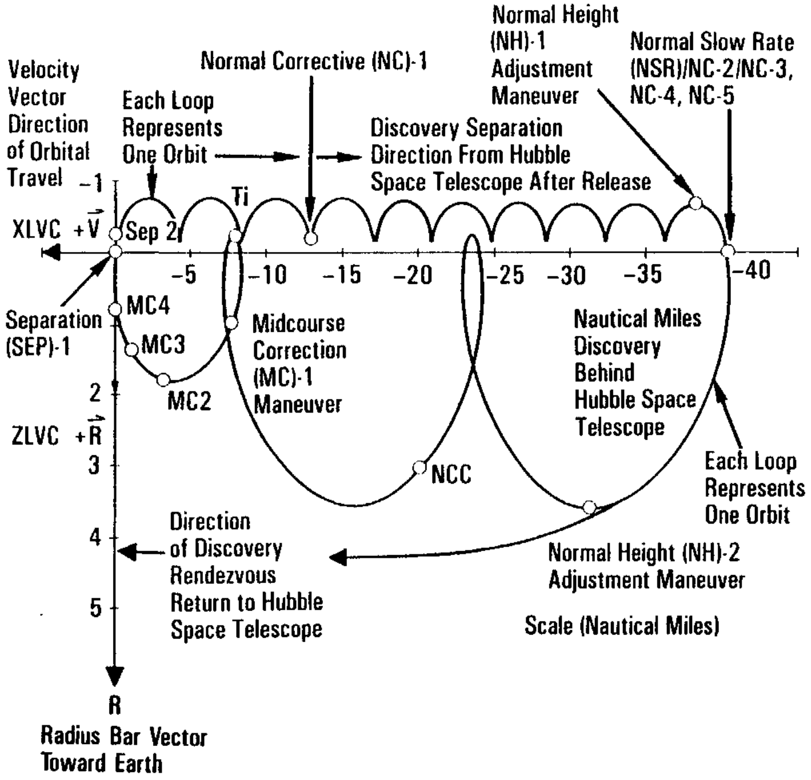
Release Position

If the aperture door fails to open in the nominal deployment sequence, Discovery can be requested to rendezvous with the HST as late as 45 hours after nominal deployment release of the HST from Discovery's RMS. Discovery's flight crew will be given a go for a rendezvous after it completes an eight-hour sleep period on the fourth day of the mission. Rendezvous with the HST and an EVA to manually open the aperture door would be planned for the fifth day of the mission.

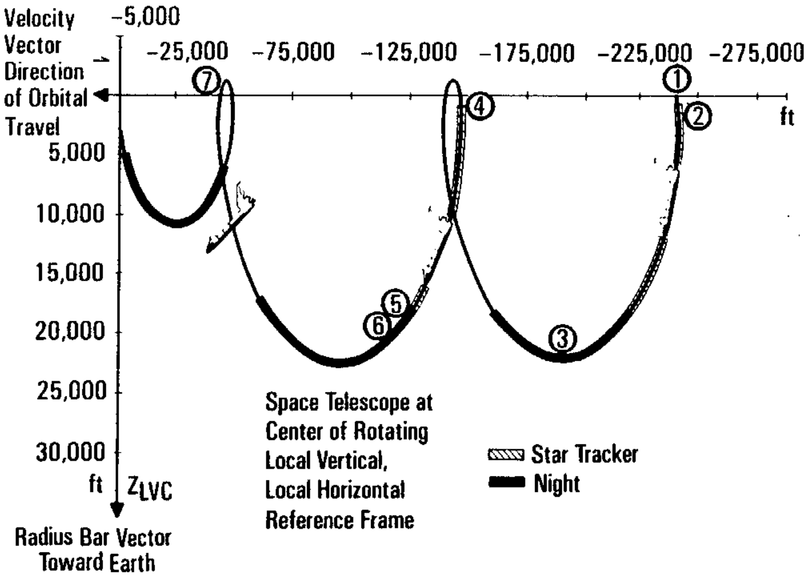
It should be noted that the crew cabin pressure has not been increased from 10.2 to 14.7 psia at this point in the mission. In addition, McCandless and Sullivan will have met the initial prebreathe and EMU checkout requirements on the first day of the mission.

Discovery will be maneuvered to rendezvous with the HST, and the RMS will grapple the HST after the ground commands the HST to slew the solar arrays and retract the two high-gain antennas. McCandless and Sullivan will prebreathe 100 percent oxygen in the EMUs for 40 minutes before the airlock is depressurized for the EVA.

After the RMS grapples the HST, McCandless and Sullivan will open the aperture door manually. After completing the EVA, which is expected to take approximately 15 minutes, McCandless and Sullivan will not repressurize the airlock until the two high-gain antennas have been redeployed on the HST. After the deployment of the antennas, the HST will again be placed in the proper position for deployment into Earth orbit from Discovery's RMS on orbit 63. An extra day will be added to Discovery's mission to support this activity.

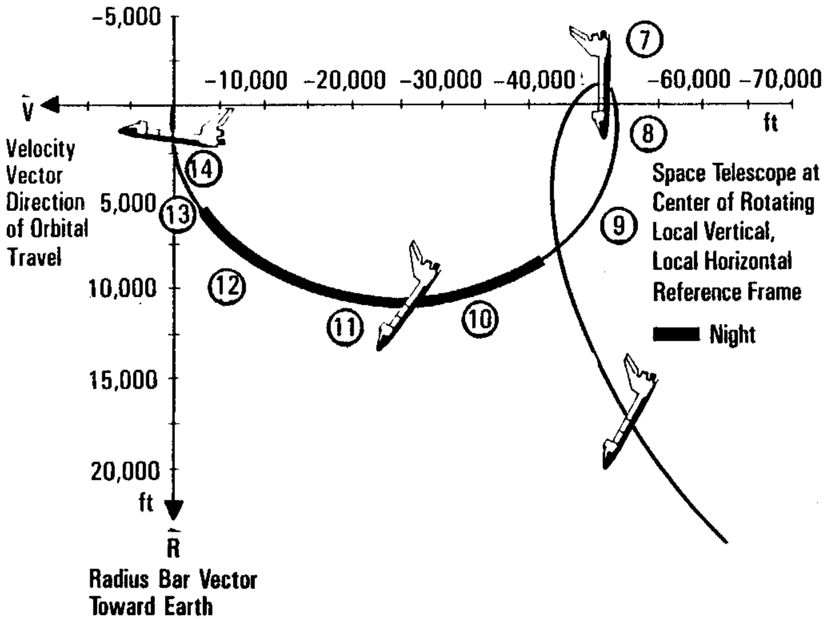


Contingency Rendezvous Profile—Hubble Space Telescope Relative Motion Profile Overview



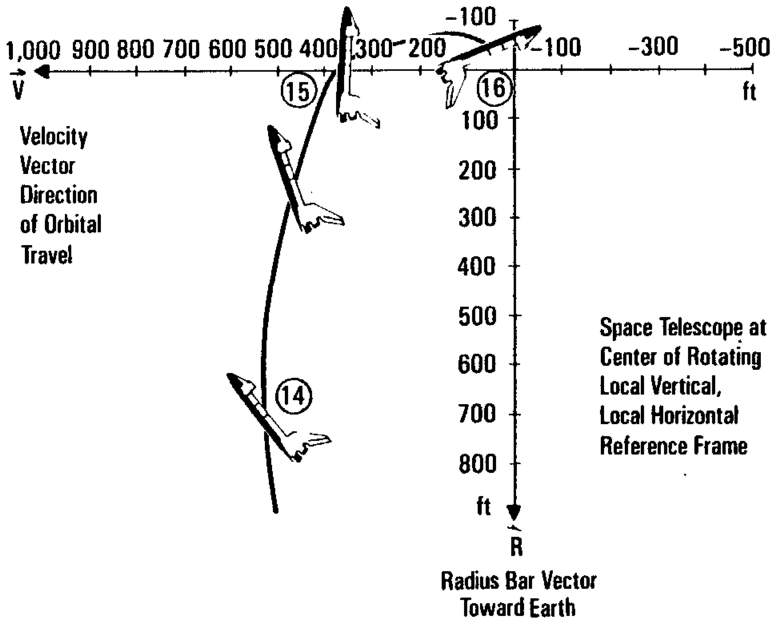
Day/Night	Phased Elapsed Time (hr/min)	Event
①	-3:14	Normal Corrective (NC) -5 Thrusting Maneuver
②	-3:10	Star Tracker Navigation
③	-2:25	Normal Height (NH) -2 Adjustment of Thrusting Maneuver, If Required
④	-1:33	Star Tracker Navigation
⑤	-1:00	Normal Corrective Combination (NCC) Thrusting Maneuver
⑥	-0:55	Rendezvous Radar Navigation
⑦	0:00	Terminal Phase Initiation (TI) Burn

Contingency Rendezvous Hubble Space Telescope



Star Tracker	Rendezvous Radar	Day/Night	Phased Elapsed Time (hr/min)	Burn		Event Description
			0:00	TI	⑦	Terminal Phase Initiation (TI) Thrusting Maneuver
			0:04		⑧	Rendezvous Radar Navigation—Post TI
			0:26	MCI	⑨	Midcourse Correction 1
		■	~ 0:37	OOPN	⑩	Out-of-Plane Null Maneuver
		■	0:53	MC2	⑪	Midcourse Correction 2
		■	1:03	MC3	⑫	Midcourse Correction 3
		■	1:13	MC4	⑬	Midcourse Correction 4
			1:15		⑭	Begin Manual Trajectory Control (MTC)

Contingency Rendezvous—Hubble Space Telescope



Rendezvous Radar	Day/Night		Phased Elapsed Time (hr/m)	Event Description
		⑭	1:25	Continue Manual Trajectory Control
		⑮	1:36	Arrive at VBAR
		⑯	1:59	Stable at 35 ft
	■		2:11	Sunset
	■			HST Grapple

Contingency Rendezvous—Hubble Space Telescope

Radar Rendezvous Range

Passive Skin Track

Range 100 Feet to 12 Nautical Miles (14 Statute Miles)

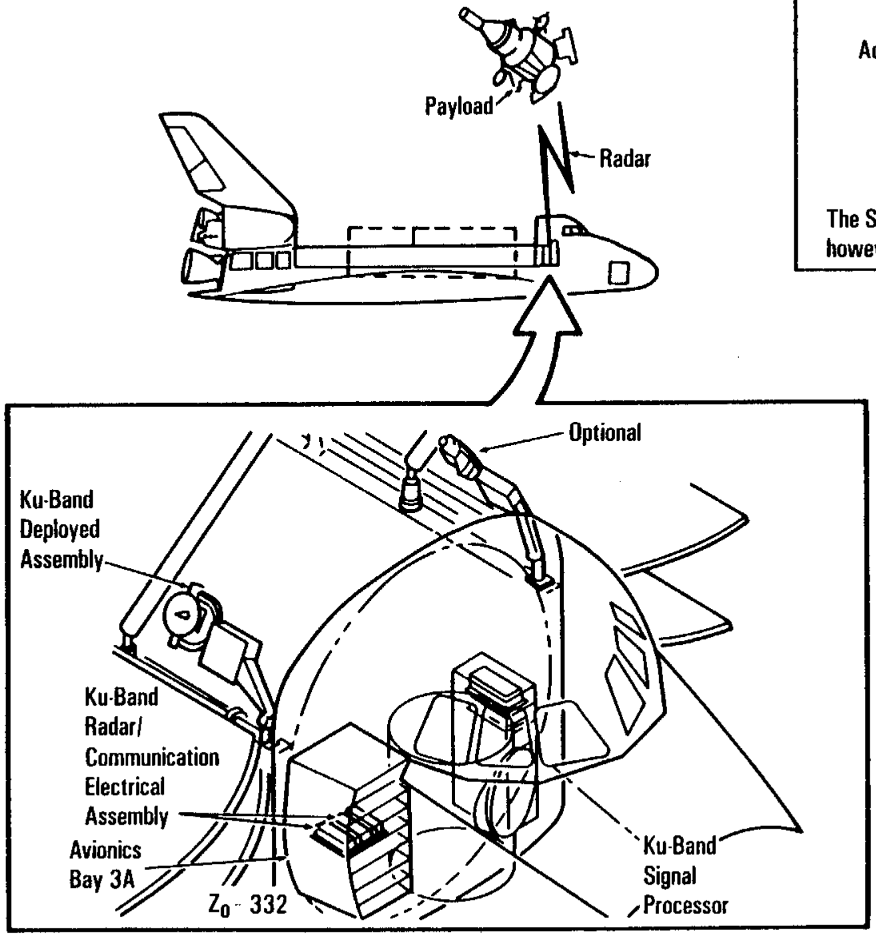
Range Rate 148 Feet-per-Second Opening Maximum to 75 Feet-per-Second Closing Maximum

Active (Transponder on the Vehicle Being Tracked)

Range 100 Feet to 300 Nautical Miles (345 Statute Miles)

Range Rate 1,500 Feet-per-Second Opening Maximum to 300 Feet-per-Second Closing Maximum

The Space Shuttle program has not baselined a transponder; however, TRW has a transponder that can be placed on a payload.



Ku-Band Radar System

HST ON-ORBIT ACTIVATION AND EVALUATION

Once the HST begins receiving light, the sequential process of activating and evaluating its sophisticated systems will begin. The MSFC management team at GSFC will continue to direct activities according to its step-by-step orbital verification time line. However, with the HST orbiting on its own and its solar array and antennas activated, timing of the action is a bit more flexible.

This stage of orbital verification has four major goals: fine-tuning pointing accuracy, focusing the telescope, activating the scientific instruments, and evaluating the performance of both the HST the ground control systems. All these action must be well under way before quality images can be transmitted to Earth. Therefore, it will be several weeks or even months after the launch before the first pictures from the HST will be seen by the public.

To use the HST, astronomers must be able to accurately locate the astronomical object they wish to study and lock on to that position. The HST's pointing control system is designed to accomplish this task with great precision. The system is made up of a series of components, each providing pointing accuracy better than the last.

The initial attitude of the HST is determined before its aperture door is opened by comparing information from the telescope's sun sensors, magnetometers and gyroscopes. The sun sensors tell controllers where the telescope is pointing in relation to the sun, and the magnetometer sense its orientation relative to the Earth's magnetic field. Reaction wheels, interacting with the HST's computer, are capable of controlling the direction that the HST is pointing. Engineers compare data from the gyros, positioning programs stored in the flight computer, and information received from the fixed-head star trackers to more exactly determine the HST's pointing. In subsequent stages of orbital verification, the fine guidance sensors will be used along with the star trackers and gyroscopes to fine-tune pointing control. A gradual process of measuring, comparing and measuring again will point the HST with a remarkable degree of accuracy.

The years of work and millions of dollars invested in perfecting the HST's mirrors could all be wasted if they are not focused properly. Instead of precise points of light that can be accurately measured and studied, astronomers would see bright blurs or rings of light. Focusing is a step-by-step process. Even the name given to part of the focusing process hints at this. Engineers call it "bootstrapping." The fine guidance sensors will lock on to selected stars, and the orbital verification team will gradually adjust the position of the secondary mirror until the images become precise and sharp.

One phenomenon that makes focusing necessary is called desorption. When materials are manufactured on Earth, a certain amount of water vapor is inevitably absorbed into them. In the vacuum of space, the water gradually works its way out of the material. The truss that holds the two mirrors in precise relation to one another is specifically designed to neither expand nor contract in the temperature extremes of space. However, a minimal amount of initial contraction will occur as this water loss, or desorption, occurs. Several dozen exacting adjustments in the position of the mirror may be required to compensate for the contraction and to refine the focus.

The light collected by the HST is received and analyzed by sophisticated scientific instruments. Each one was designed specifically for the HST. Though all have been thoroughly tested and evaluated on Earth, it is the quality of their performance in space that will determine the success of the space telescope program. The instruments must each be activated gradually, first in a warm-up mode, than at low voltage, and finally at full power. Many of the individual components within each instrument require specialized attention. Engineers at the Space Telescope Operations Control Center will bring the instruments up to full power and make sure they are operating properly. They also will activate and evaluate the science computer that controls them. Actual fine-tuning of the instruments is part of scientific verification, but orbital verification will not be over until the scientific instruments are fully activated and ready for use.

The methodical steps required for pointing, focus adjustment and activation will take place over a period of months under the watchful eyes of the orbital verification team. In addition, all of the HST's systems will be constantly check to make sure they are functioning properly. About 5,500 specific items of information on the HST's status, call telemetry points, are monitored by computer. Safe limits at any given stage of activation for each individual telemetry point have been established. Engineers for both the mission operations contractor at Goddard and the Marshall technical support team at Huntsville will track those systems in their areas of specialty. If any item does not perform within its predicted limits, the computer screens will flash a warning. It will be up to the orbital verification team to determine if the problem is in the HST itself or in the ground system and then decide how to resolve it. With a spacecraft as unique and complex as the HST, it is almost inevitable that some problems will arise. One of the purposes of orbital verification is to reveal the problems before they grow into situations that could hamper the telescope's performance.

After orbital verification is complete, further calibration of the instruments and evaluation of the HST's performance will be accomplished. The next effort, call science verification, will be managed by Goddard. It will be carried out through the Space Telescope Science Institute, which was established by GSFC to select the telescope's observing agenda. During this period, astronomers who contributed to the HST's design will be given an opportunity to us the telescope to determine its full research potential. However, only after scientific verification is complete will the telescope by ready to begin it full-scale investigations.

The precision steps of HST verification could be compared to those required for cutting a fine diamond. Each step is important. Each must be completed correctly. Rushing or skipping a step could be disastrous. But in the end, the finished product is one of incalculable value.

ORBITAL VERIFICATION TEAM

At the beginning of the space telescope program, the NASA Office of Space Science and Applications in Washington, D.C., assigned specific areas of responsibility to different NASA centers. This division of assignments allowed each center to make valuable contributions in areas where it is uniquely qualified. However, shared responsibility makes orbital verification a team effort.

Verification is controlled and managed from the Space Telescope Operations Control Center at the Goddard Space Flight Center in Maryland. Overall management of the program, however, is the responsibility of the Marshall Space Flight Center in Huntsville, Ala. Marshall was NASA's lead center for the design, development, assembly prelaunch checkout and orbital verification of the HST. It is MSFC's responsibility to verify that all of the telescope's systems are working properly before turning it over to Goddard for science verification and day-to-day operation.

A group from Marshall will travel to Maryland to direct verification from deployment through performance evaluation of the HST itself. Heading the team will be the director of orbital verification, who will approve each step of the timeline and ensure that all steps are carried out as planned. The Marshall staff at Goddard will include a systems analyst to oversee problem resolution, element managers for five major facets of the program and a management team support group.

Technical support will be provided by a team at the Huntsville Operations Support Center at MSFC. Should problems with deployment or activation arise, experts on the systems involved will analyze the problems and suggest solutions to the management team at GSFC.

Commands will be sent to the spacecraft from the mission operations room in Goddard's Space Telescope Operations Control Center. This facility will be staffed primarily by employees of Lockheed Missiles and Space Co., the contractor that assembled the space telescope, under the supervision of Goddard's mission operations manager. During the first phase of verification, authorization to proceed with commands will come from the Marshall management team. As verification proceeds, a transition will be made to Goddard management. The Goddard mission operations manager will authorize the initiation of subsequent steps in the verification process, just as the Marshall director of orbital verification will in the first phase.

GSFC was responsible for the development of the telescope's science instruments and its ground support system. The Goddard mission operations room staff will control and operate the HST during its 15-year lifetime.

The Space Telescope Science Institute, located on the campus of Johns Hopkins University in Baltimore, will help prepare spacecraft commands and schedule their execution during verification. The institute was established to determine the observing agenda for the telescope throughout its years of service.

The Johnson Space Center in Houston, Texas, will supply flight support for the critical launch and deployment phases of verification. In addition to the astronaut crew and its regular mission control team, Johnson also will furnish a special space telescope team. These people, along with Marshall representatives at Johnson, will provide a communications link between the Space Telescope Operations Control Center and shuttle mission control.

The Kennedy Space Center provides prelaunch processing and space shuttle launch support.

The HST prime contractors are Lockheed Missiles and Space Co. of Sunnyvale, Calif., which designed and developed the support systems module and is responsible for systems engineering and HST assembly and verification, and Hughes Danbury Optical Co. (formerly Perkin-Elmer) of Danbury, Conn., which designed and developed the optical telescope assembly and the fine guidance sensors.

The European Space Agency provides the HST faint object camera and the solar arrays and will furnish support at the Science Institute. In return, ESA will be allocated 15 percent of the observing time.

Universities whose staff members have made major contributions to the program include the California Institute of Technology (wide-field planetary camera), the University of Wisconsin (high-speed photometer), the University of California at San Diego (faint object spectrograph) and the University of Texas at Austin (astrometry).

HST SERVICING IN ORBIT

The HST was designed specifically to allow extensive maintenance in orbit. This is the most practical way to keep the equipment functioning and current during its 15 years or more in space with a minimum of downtime. Some of the components have a life expectancy of less than 15 years and will need to be replaced from time to time. New technology will make it possible to design more sophisticated scientific instruments over the years. In fact, several improved instruments are already under development. On-orbit servicing allows worn parts to be replaced and new instruments to be substituted for the original equipment without the great expense, risk and delay of bringing the HST back to Earth.

Space shuttle orbiters will serve as bases from which EVA astronauts will repair the HST by replacing modular components, including new instrument packages. Because of their modular design, many HST components may be pulled out and replacements plugged in without disturbing other systems. Doors on the exterior of the HST allow EVA astronauts access to these modular components, called orbital replacement units. Handrails and portable foot restraints have been provided for astronauts working on the HST, and a special container that can be carried in the space shuttle orbiter's payload bay has been designed for replacement parts and tools.

The HST will be serviced by EVA astronauts about every five years. In case of an emergency, special space shuttle missions may be launched.

On servicing missions, the space shuttle orbiter will rendezvous with the HST, and the orbiter's RMS will grapple the HST and mount it in a maintenance platform in the payload bay. Astronauts will be able to replace batteries or solar arrays, a computer, one of the scientific instruments or any of the more than 25 orbital replacement units. The orbiters could also be used to place the HST in its original orbit if atmosphere drag has caused its orbit to descend.

Once the maintenance is finished, the HST will be released and carefully reactivated by ground controllers to resume its exploration.

IMAX CAMERA

The IMAX project is a collaboration between NASA and the Smithsonian Institution's National Air and Space Museum to document significant space activities using the IMAX film medium. This system, developed by the IMAX Systems Corp. of Toronto, Canada, uses specially designed 70mm cameras and projectors to record and display very high definition, large-screen color motion pictures.

IMAX cameras have been flown on space shuttle missions STS 41-C, 41-D, 41-G, 29, 34 and 32 to document crew operations in the payload bay and the orbiter's middeck and flight deck as well as to film spectacular views of space and Earth. Film from those missions was used as the basis for the IMAX production "The Dream Is Alive."

On STS 61-B, an IMAX camera mounted in the payload bay recorded extravehicular activities involving space construction demonstrations.

On this mission, the IMAX cameras located in Discovery's payload bay and in the crew compartment will cover the deployment of the Hubble Space Telescope and gather material on the use of observations of Earth from space for the production "Exploring the Blue Planet."

The IMAX cargo bay camera is a 70mm color motion picture camera system that consists of a camera, a lens assembly and a film magazine containing approximately 2,000 feet of film. The camera is housed in an insulated, pressurized enclosure with a movable lens window cover. The container is mounted on the port (left) side of Discovery's aft payload bay on an extended adaptive payload carrier. The camera is controlled from Discovery's aft flight deck by the getaway special autonomous payload controller.

The IMAX camera in the crew compartment is also a 70mm system. The camera and supporting equipment are stowed in the middeck.

Opportunities for filming will be provided the flight crew before the flight and in real time during flight.

PROTEIN CRYSTAL GROWTH

In collaboration with the University of Alabama in Birmingham, NASA's Marshall Space Flight Center, Huntsville, Ala., is continuing a series of experiments in protein crystal growth that may prove to be a major benefit to medical technology.

These experiments could improve food production and lead to innovative drugs to combat cancer, AIDS, high blood pressure, organ transplant rejection, rheumatoid arthritis and many other diseases. Protein crystal growth experiments were first conducted during the Spacelab 2 mission in April 1985 and have been flown six times. The first four flights primarily were designed to develop techniques and hardware for growing crystals in space. The STS-26, 29 and 32 experiments were the first scientific attempts to grow useful crystals by vapor diffusion in microgravity. The STS-26, 29 and 32 payloads, unlike those on previous flights, featured temperature control and the automation of some of the required processes to improve accuracy and reduce the flight crew's time.

During this mission, 60 different PCG experiments will be conducted simultaneously, using 12 different proteins. Though there are three processes used to grow crystals on Earth—vapor diffusion, liquid diffusion and dialysis—only vapor diffusion will be used in this set of experiments. The PCG is installed and operated in Discovery's middeck.

Protein crystals, like inorganic crystals, such as snowflakes, are structured in a regular pattern. With a good crystal roughly the size of a grain of table salt, scientists are able to study the protein's molecular architecture.

Determining a protein crystal's molecular shape is an essential step in several phases of medical research. Once the three-dimensional structure of a protein is known, it may be possible to design drugs that will either block or enhance the protein's normal function within the body. Though crystallographic techniques can be used to determine a protein's structure, this powerful technique has been limited by problems encountered in obtaining high-quality crystals well ordered and large enough to yield precise structural information.

Protein crystals grown on Earth are often small and flawed. The problem associated with growing these crystals is analogous to filling a sports stadium with fans who all have reserved seats. Once the gate opens, people flock to their seats and, in the confusion, often sit in someone else's place. On Earth, gravity-driven convection keeps the molecules crowded around the "seats" as they attempt to order themselves. Unfortunately, protein molecules are often content to take the wrong places in the structure.

As would happen if you let the fans into the stands slowly, microgravity allows the scientist to slow the rate at which molecules arrive at their places. Since the molecules have more time to find their spots, fewer mistakes are made, creating better and larger crystals.

On this mission, the PCG experiments will begin shortly after the orbiter arrives on orbit. A flight crew member will combine each of the protein solutions with other solutions containing a precipitation agent to form small droplets on the ends of double-barreled syringes positioned in small chambers. Water vapor will diffuse from each droplet to a solution absorbed in a porous reservoir that lines each chamber. The loss of water by this vapor diffusion process will produce conditions in the droplets that cause protein crystals to grow. The samples will be processed at 22 C, as on STS-26 and 29.

Just prior to descent, a mission specialist will photograph the droplets in the trays. Then all the droplets and any protein crystals grown will be drawn back into the syringes. The syringes then will be resealed for reentry. Upon landing, the hardware will be turned over to the investigating team for analysis.

The 12 proteins to be used on this mission are as follows:

— Isocitrate lyase. A target enzyme for fungicides. Better understanding of the enzyme should lead to more potent fungicides for treating serious crop diseases, such as rice blast.

— Porcine pancreatic phospholipase A_2. An enzyme associated with many human disease states, including rheumatoid arthritis and septic shock. Successful structure analyses of phospholipase crystals may led to the development of drugs to treat these conditions.

— Human gamma interferon (GIF-D'). An enzyme that stimulates the body's immune system and is used clinically in the treatment of cancer.

— Human serum transferrin. The major iron transport protein in human serum. It transports iron from storage sites to hemoglobin-synthesizing red blood cells and also is a necessary component in media for cell growth.

— Porcine pancreatic elastase. An enzyme associated with the degradation of lung tissue in people suffering from emphysema. A better understanding of the enzyme's structure will be useful in studying the causes of this debilitating disease.

— Type IV collagenase. An enzyme obtained from snake venom (haemmioragic). It is related to collagenase secreted by invasive cancer cells.

— Canavalin. The major storage protein of leguminous plants, such as beans and peas, and a major source of dietary protein for humans and domestic animals.

— Malic enzyme. An enzyme isolated from nematodes. Characterizing the structural differences between it and the mammalian version could lead to the development of an anti-parasite drug.

— Anti-HPr fab fragment/fab. The detailed structure would provide a picture of an antibody binding site that recognizes a bacterial "foreign" protein antigen. By learning what antibody binding sites look like, we may better understand how antibodies function in the immune system.

— Factor D. An enzyme necessary for the activation of a part of the immune system that plays an important role in host defense against pathogens.

— Turkey/quail lysozyme. Sugars are often found associated with proteins, and these sugar/protein interactions are fundamental in all the processes of living organisms. However, very little is known about these interactions.

— Carboxyl ester hydrolase. An enzyme that catalyzes the breakdown of carboxylic acid esters like those found in fats. Understanding how this enzyme functions will be valuable in learning how fats and related molecules are made and metabolized.

The PCG experiments are sponsored by NASA's Office of Commercial Programs and the Microgravity Science and Applications Division with management provided through the Marshall Space Flight Center. Richard E. Valentine is the mission manager and Blair Herron is the PCG experiments manager for Marshall.

Dr. Charles E. Bugg, director of the Center for Macromolecular Crystallography, a NASA-sponsored center for the commercial development of space located at the University of Alabama in Birmingham, is lead investigator for the PCG research team.

The STS-31 industry, university and government PCG research investigators include DuPont de Nemours & Co.; the U.S. Naval Research Laboratory; BioCryst Inc.; Schering Plough Corp.; the Georgia Institute of Technology; Vertex Pharmaceuticals; Texas A&M University; the University of California at Riverside; Upjohn Co.; the National Research Council of Canada; the Center for Macromolecular Crystallography; Laboratoire de Cristallographie et Cristallisation de Macromoles Biologiques—Faculte Nord, Marseille, France; and Eastman Kodak Co.

Protein Description/Affiliation for STS-31

Principal Investigator	Affiliation	Protein	Description
George I. Birnbaum	National Research Council of Canada	anti-HPr fab fragment/fab	The detailed structure would provide a picture of an antibody binding site that recognizes a bacterial ''foreign'' protein antigen. By learning what antibody binding sites look like, we may better understand how antibodies function in the immune system.
Larry DeLucas	UAB, Center for Macromolecular Crystallography	Factor D	Factor D is an enzyme necessary for activation of the complement system, which plays an important role in host defense against pathogens.
Howard M. Einspahr	The Upjohn Co.	Malic enzyme	The sample of malic enzyme is an NAD + – dependent version isolated from a parasitic nematode. The goal is to characterize structural differences between it and the mammalian NADP + – dependent version and exploit these differences for development of an anti-parasite drug.
Juan Fontecilla-Camps	Laboratoire de Cristallographie et Cristallisation de Macromoles Biologiques-Faculte Nord	Turkey/quail lysozyme	Sugars are often found associated with proteins (glycoproteins), and sugar/protein interactions are fundamental in all the processes of a living organism. Very little is known about these interactions.
Alexander McPherson	University of California at Riverside	Canavalin	This is the major storage protein of leguminous plants and a major source of dietary protein for humans and domestic animals. It is a target of protein-engineering efforts.
Edgar F. Meyer	Texas A&M University	Type IV collagenase	While this enzyme is obtained from snake venom (haemmioragic), it is related to collagenase secreted by invasive cancer cells.
Manuel A. Navia	Vertex Pharmaceuticals	Porcine pancreatic elastase	This enzyme is associated with the degradation of lung tissue in people suffering from emphysema. A more detailed knowledge of this enzyme's structure will be useful in studying the causes of this debilitating disease.
Paul Reichert	Schering Plough Corp.	Human gamma interferon (GIF-D ')	Gamma interferon, either alone or in combination with other cytokines or cytotoxic agents, has potential as an anti-tumor agent against solid tumors, leukemias and lymphomas. Gamma interferon has additional utility as an anti-infective agent, including anti-viral, anti-bacterial and anti-parasitic activities.
Byron Rubin	Eastman Kodak Co.	Carboxyl ester hydrolase	Carboxyl ester hydrolase catalyzes the breakdown of carboxylic acid esters like those found in fats. Understanding how this enzyme functions will be valuable in learning how fats and related molecules are made and metabolized.

Protein Description/Affiliation for STS-31 (Cont)

Principal Investigator	Affiliation	Protein	Description
F.L. Suddath	Georgia Institute of Technology	Human serum transferrin	Transferrin is the major iron transport protein in human serum. It transports iron from storage sites to hemoglobin-synthesizing sites. It is also a necessary component in media for cell growth.
Keith Ward	Naval Research Laboratory	Procine pancreatic phospholipase A_2	Phospholipase is an enzyme that is associated with many human disease states, including rheumatoid arthritis and septic shock. Successful structure analyses of phospholipase crystals will lead to the development of drugs to treat these conditions.
Patricia Weber	DuPont de Nemours & Co.	Isocitrate lyase	This is a target enzyme for fungicides. Better understanding of this enzyme should lead to more potent fungicides to treat serious crop diseases, such as rice blast.

INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING

Investigations into polymer membrane processing (IPMP) is a middeck payload developed by the Battelle Advanced Materials Center for the Commercial Development of Space (CCDS) in Columbus, Ohio. Sponsored by NASA's Office of Commercial Programs, the Battelle CCDS was formed in November 1985 to conduct research into commercially important advanced materials, such as polymers, catalysts, electronic materials and superconductors. The IPMP marks the beginning of the center's work in microgravity polymer membrane processing.

Polymer membranes have been used in the separations industry for many years for such applications as the desalination of water, filtration during the processing of food products, atmospheric purification, medicinal purification and dialysis of kidneys and blood.

One method of producing polymer membranes is evaporation casting. In this process, a membrane is prepared by forming a mixed solution of polymer and solvent into a thin layer and evaporating the solution to dryness. The polymer membrane is left with a certain degree of porosity and can then be used for the applications described above.

Although polymer chemists do not fully understand the importance of the evaporation step in the formation of thin-film membranes, a study has demonstrated that convective flows during processing do, in fact, influence the structure of the membrane. Convective flows are a natural result of the effects of gravity on liquids or gases that are not uniform in specific density. The microgravity of space will permit researchers to study polymer membrane casting in a convection-free environment.

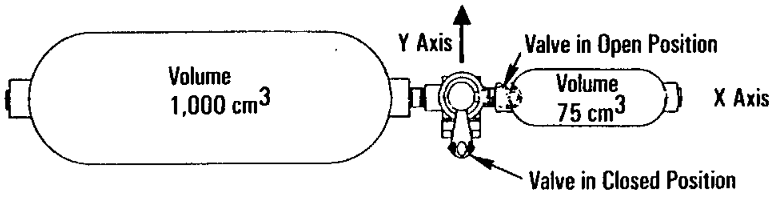
The IPMP payload on STS-31 consists of two experimental units and their contents. Each IPMP unit consists of two sample cylinders connected to each other by a valve. The larger of the two cylinders is 8 inches long and 4 inches in diameter and has a volume of 1,000 cubic centimeters. The smaller cylinder measures 4.5 by 2 inches and has a capacity of 75 cubic centimeters. The overall dimensions of each IPMP unit are 18.6 by 3.5 by 4.41 inches. The total weight of the flight hardware (both units) is approximately 17 pounds.

Before launch, the larger cylinder, which is sealed on one end, will be evacuated and sealed on the other end by closing the valve. The valve will then be secured to preclude accidental opening during ground processing activities.

A thin-film polymer membrane is swelled in a solvent solution. In this first flight experiment, the polymer will be swollen with a binary mixture of solvents. The resultant swollen gel (viscous fluid) will be measured and inserted into a sample tube, which will be inserted into the smaller of the two cylinders. This cylinder will be sealed at ambient pressure (14.7 psia) and attached to the other side of the valve. The procedure will be repeated for the second unit.

When Discovery's on-orbit activities permit, a flight crew member will release and open the valve on each unit. Opening the valve causes the solvents in the smaller cylinder to flash-evaporate into the vacuum of the larger cylinder. The remaining thin-film polymer membrane will have a porosity related to the evaporation of the solution. The system will reach an equilibrium state, which will be maintained for the remainder of the flight. The minimum duration needed for adequate results is 24 hours.

The IPMP occupies the space of a single small stowage tray (half of a middeck locker). The two units are positioned in foam inserts in the stowage tray. The IPMP is self-contained and requires no power from Discovery. Upon landing, the IPMP will be returned to Battelle for analysis.



Investigations Into Polymer Membrane Processing (IPMP)

The principal investigator for the IPMP is Dr. Vince McGinniss of Battelle. Lisa A. McCauley, associate director of the Battelle CCDS, is the program manager.

STUDENT EXPERIMENT

Student Experiment (SE) 82-16, located in Discovery's mid-deck, will observe the effects of microgravity on an electric arc. The absence of convection currents in a weightless environment will keep the arc from rising. The experiment will also study the effect of a magnetic field on an arc without correction. An Arriflex 16mm camera will be used to photograph the experiment.

Gregory S. Peterson is the experimenter and his sponsor is Morton Thiokol.

AIR FORCE MAUI OPTICAL SITE

The Air Force Maui optical site tests allow ground-based electro-optical sensors located on Mt. Haleakala, Maui, Hawaii, to collect imagery and signature data of Discovery during cooperative overflights. This experiment is a continuation of tests made on the STS-29, 30, 34 and 32 missions. The scientific observations made of Discovery while it performs reaction control system thruster firings and water dumps or activates payload bay lights are used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models. The AMOS tests involve no payload-unique flight hardware and only require that Discovery perform certain operations in predefined attitudes and be in predefined lighting conditions.

The AMOS facility was developed by the Air Force Systems Command through its Rome Air Development Center at Griffiss Air Force Base, N.Y., and is administered and operated by the AVCO Everett Research Laboratory on Maui. The co-principal investigators for the AMOS tests on the space shuttle are from AFSC's Air Force Geophysics Laboratory at Hanscom Air Force Base, Mass., and AVCO.

Flight planning and mission support activities for the AMOS test opportunities are provided by a detachment from AFSC's Space Systems Division at the Johnson Space Center in Houston. Flight operations are conducted at the JSC Mission Control Center in coordination with the AMOS facilities in Hawaii.

RADIATION MONITOR EXPERIMENT

The radiation monitor experiment measures radiation at different locations throughout the orbiter. The equipment contains a liquid crystal display for the real-time display of data and a keyboard for controlling its functions. Information from this experiment will be used to expand the data base to characterize radiation environments for space flight.

ASCENT PARTICLE MONITOR

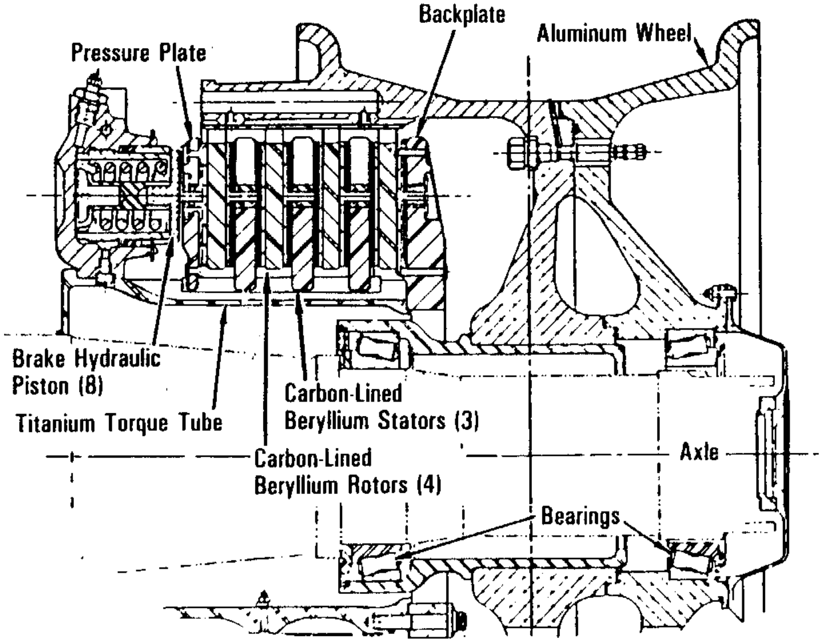
The ascent particle monitor is located on the starboard (right) side of Discovery's payload bay. The APM will sample particulate contamination within the payload bay during ascent.

MAIN LANDING GEAR CARBON BRAKES

Each of the orbiter's four main landing gear wheels has electrohydraulic disc brakes and an anti-skid system.

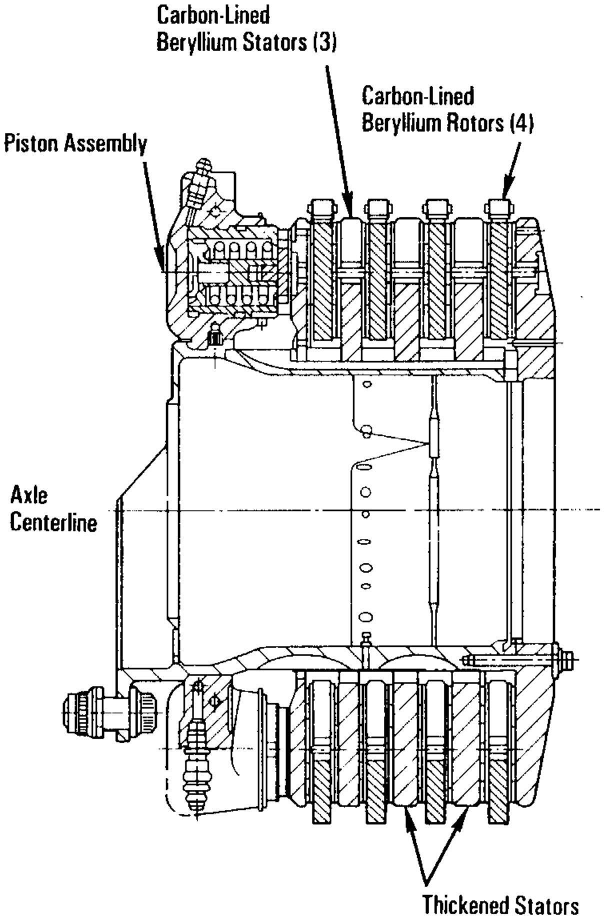
Each of the original main landing gear wheels has a disc brake assembly consisting of nine discs, four rotors, three stators, a backplate, and a pressure plate. The carbon-lined beryllium rotors are splined to the inside of the wheel and rotate with the wheel. The carbon-lined beryllium stators are splined to the outside of the axle assembly and do not rotate with the wheel.

Because problems were encountered with the main landing gear braking system in most of the first 24 landings, an improvement program was implemented for the main landing gear and braking system in addition to a long-term improvement program for the main landing gear brakes.



Original Wheel Brake Assembly

Main landing gear axle stiffness was increased to reduce brake-to-axle deflections to preclude brake damage, which occurred in previous landings. This also minimized tire wear. With the increased axle thickness, existing axle/bearing and axle/sensor interfaces were maintained. All main landing gear axles were changed before the three orbiters returned to flight.



Return to Flight—Improved Main Landing Gear Brake Assembly

Six orifices were added to the hydraulic passages in the brake hydraulic piston housing to restrict circular fluid flow within the chambers in order to stop the whirl phenomenon, which was identified as the cause of brake damage.

The electronic brake control boxes were modified to provide hydraulic pressure balancing between adjacent brakes in order to equalize energy applications. This resulted in higher efficiency and allowed full capability of adjacent brakes. The anti-skid circuitry that reduced brake pressure to the opposite wheel if a flat tire was detected was removed.

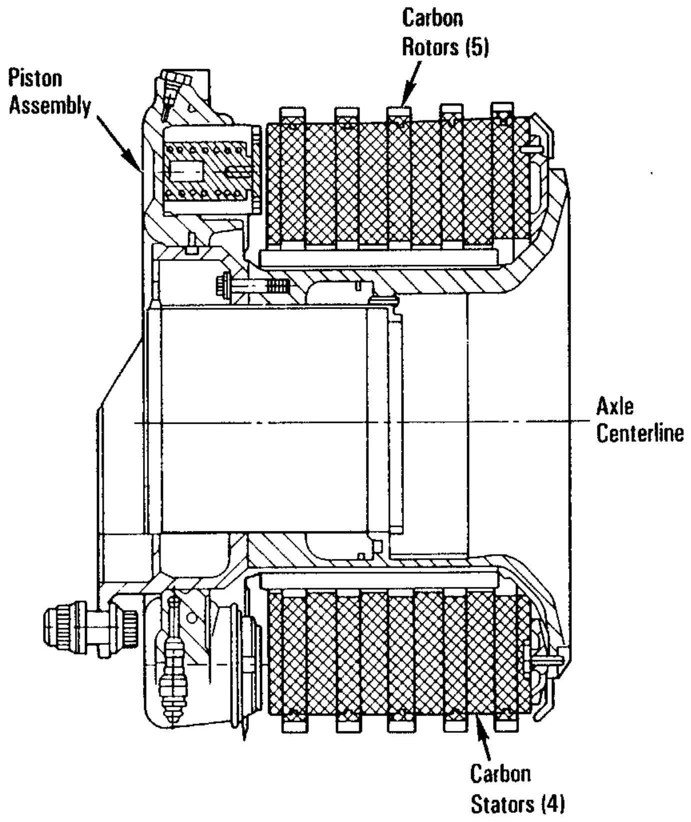
In return-to-flight orbiters, thinner, carbon-lined beryllium stator discs were replaced in two positions with thicker discs to provide a significant increase in braking energy capability. The material added to the stators enhanced the heat capacity, with resulting lower temperatures, and provided the stators with greater strength. Note that the return-to-flight improved main landing gear brakes, which were exposed to two 14-million-foot-pound wear-in cycles added before installation on the orbiter, reduced damage to the brakes during landing. The thicker stator discs provided approximately 65 million foot-pounds of energy absorption, which was a significant increase over the thinner stator discs.

The new main landing gear carbon brake program flown for the first time on Discovery's 10th flight on the STS-31 mission consists of five rotors, four stators, nine discs, a backplate, and a pressure plate. The five carbon rotors are splined to the inside of the wheel and rotate with the wheel. The four carbon stators are splined to the outside of the axle assembly and do not rotate with the wheel. The goal of the carbon brake is to increase maximum energy absorption capability to 82 million foot-pounds. In addition, the goal is to have the capability of providing a one-time stop of 100 million foot-pounds.

The inboard landing gear wheel on each main landing gear used with the carbon brakes is a deep-dish magnesium wheel instead of the original forged aluminum halves. The deep-dish magnesium wheel forging is machined with extra material in the flange area to provide potential roll-on-rim capability. No change has been made to the forged aluminum outboard main landing gear wheel halves.

The brake torque tube in each main landing gear wheel brake is strengthened for use with the carbon brakes.

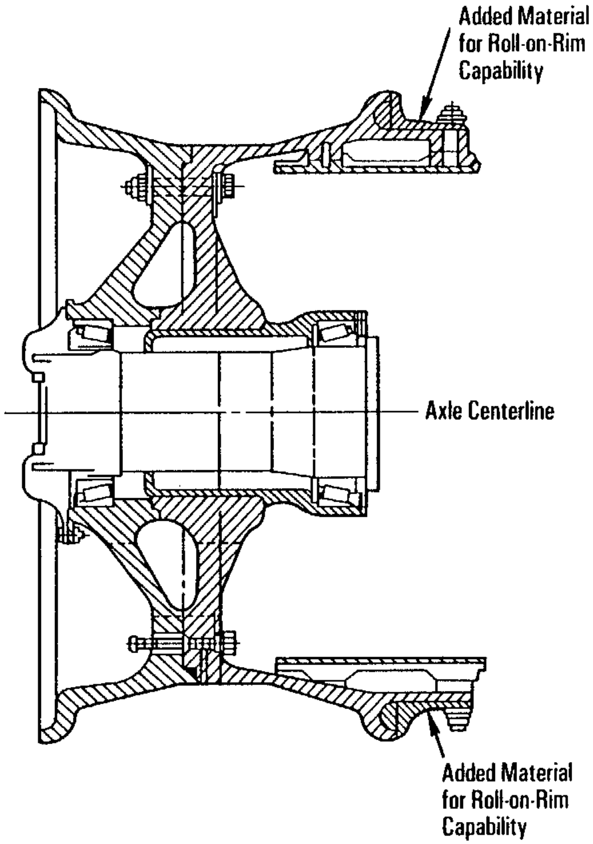
Each of the four main landing gear wheel brake assemblies is supplied with pressure from two different hydraulic systems. Each brake hydraulic piston housing has two separate brake supply chambers. One chamber receives hydraulic source pressure from hydraulic system 1 and the other from hydraulic system 2. There are eight hydraulic pistons in each brake assembly. Four are mani-



Main Landing Gear Carbon Brake Assembly folded together from hydraulic system 1 in a brake chamber. The remaining four pistons are manifolded together from hydraulic system 2. When the brakes are applied, the eight hydraulic pistons press the discs together, providing brake torque.

In the event of the loss of hydraulic system 1 or 2 source pressure, switching valves provide automatic switching to the standby hydraulic system 3 when the active hydraulic system source pressure drops below approximately 1,000 psi. If hydraulic system 1 is unavailable, it has no effect on the braking system because standby system 3 would automatically replace system 1. Loss of hydraulic system 2 or both 1 and 2 would also have no effect on the braking system because system 3 would automatically switch to replace system 2 or 1 and 2. Loss of hydraulic system 1 and 3 would cause the loss of half of the braking power on each wheel, and additional braking distance would be required. Loss of hydraulic systems 2 and 3 would also cause the loss of half of the braking power on each wheel, requiring additional braking distance.

Each of the three hydraulic systems' source pressure of 3,000 psi is reduced by a regulator in each of the brake hydraulic systems to 1,500 psi in the original brake hydraulic systems and return-to-flight improved brake hydraulic systems. In the carbon brake system, the hydraulic systems' source pressure of 3,000 psi is reduced by a regulator in each of the brake hydraulic systems to 2,000 psi for better system stability. The change in the hydraulic systems' pressure for use with the carbon brakes requires minimum modifications to the brake/anti-skid control loops, hydraulic brake valve modules, and readjustment of the hydraulic systems' brake regulators.



Roll-on-Rim Inboard Wheel Assembly for Use With Carbon Brake—Main Landing Gear

DEVELOPMENT TEST OBJECTIVES

GRAVITY GRADIENT ATTITUDE CONTROL

The purpose of this development test objective is to find a precise gravity gradient attitude that balances aerodynamic, angular momentum, and gravity gradient forces so that attitude oscillations are minimized compared to steady-state ones. The second objective is to determine steady-state attitude oscillations and the sensitivity of these oscillations to attitude and rate errors at gravity gradient initiation. Data will be used to refine the computer models used to predict release attitudes. Discovery's attitude during gravity gradient attitude will be positive X local vertical, positive Y velocity vector, or nose-to-earth, wings in plane, with payload bay, north.

ASCENT STRUCTURAL CAPABILITY

The purpose of this DTO is to collect data only to expand the data base of ascent dynamics for various weights.

ASCENT COMPARTMENT VENTING

This DTO is intended solely to collect data to expand the data base to verify vent models.

DESCENT COMPARTMENT VENTING

The purpose of this DTO is to expand the data base to verify vent models.

ENTRY STRUCTURAL CAPABILITY

This DTO will collect data to expand the data base of flight loads during entry.

VIBRATION AND ACOUSTIC

This DTO is for the collection of data to expand the data base vibration and acoustic data during ascent.

CABIN GROWTH

This DTO will measure the effect cabin distortion has on the crew escape pole system attach fittings in the middeck.

MICROBIAL FILTER RESIN CHECKOUT

This DTO will evaluate a new system for introducing iodine into the drinking water.

ENTRY AERODYNAMIC CONTROL SURFACES TEST

The purpose of this DTO is to provide preprogrammed test inputs.

NON-INVASIVE ESTIMATION OF CENTRAL VENOUS PRESSURE

This detailed supplementary objective will measure the physiological adaptation to the headward fluid shift that occurs in microgravity. The non-invasive technique of determining central venous pressure uses a mouthpiece with varying resistance and a probe that utilizes Doppler flowmetry. The specified crew member will begin measurements as early as possible on flight day one and as often as possible during pre- and postsleep periods.

IN-FLIGHT RADIATION DOSE DISTRIBUTION

This DSO will establish, evaluate and verify analytical and measurement methods for assessing and managing health risks from exposure to space radiation. The radiation environment will be measured inside the orbiter with a tissue equivalent phantom of the human head. This phantom head will be mounted at a thinly shielded region of the starboard middeck wall. Characterization of the neutron components and of heavy ions from stopping protons will be accomplished.

IN-FLIGHT INTRAOCULAR PRESSURE

Intraocular pressures observed during bedrest studies during zero-gravity conditions on KC-135 flights and on the German D-1 Spacelab mission were 20 to 25 percent above normal preflight levels. The possible deleterious effects of sustained deviations in intraocular pressure are difficult to predict since no statistically valid in-flight data exists. Even though a few days or weeks of elevated pressure would be harmless, months or years of sustained high pressure due to microgravity could cause ocular disturbances. The purpose of this DSO is to collect baseline data to define normal intraocular pressure ranges in microgravity and to determine the magnitude of pressure rises to be expected in crew members. A tono-pen will be used to measure the intraocular pressure of each crew member.

DELAYED-TYPE HYPERSENSITIVITY

The purpose of this DSO is to detect immunological alterations in the human system resulting from space flight. The impairment of in vivo cell-mediated immunity and the medical significance of immune dysfunction events also will be assessed.

HYPEROSMOTIC FLUID COUNTERMEASURE

This DSO will compare different concentrations of salt and water in order to determine which concentration provides optimum protection against orthostatic stresses when astronauts return to Earth. When osmolality is greater, protection against orthostatic intolerance lasts longer. Each crew member will drink one container of a premixed saline solution at each meal on the day before entry.

DOCUMENTARY TELEVISION

This DSO will provide live television or videotaped dumps of crew activity, orbiter operations, payload deployment/retrieval and operations, Earth views, and rendezvous and proximity operations. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. The broadcast is accompanied with operational air-to-ground and/or operational intercom audio. Videotaping may be used when live television is not possible.

DOCUMENTARY MOTION PICTURE PHOTOGRAPHY

This DSO will provide documentary and public affairs motion picture photography of the orbiter's basic capabilities and key flight objectives. Documentation will include launch, crew activities, Hubble Space Telescope deployment, landing and unscheduled items of interest.

DOCUMENTARY STILL PHOTOGRAPHY

This DSO will provide 35mm and 70mm still photography of crew activities, orbiter operations, Hubble Space Telescope deployment/retrieval and operations, Earth views and unscheduled items of interest. The 70mm format is required for exterior shots and the 35mm for interior shots.

An airlock is located in the crew cabin middeck. The airlock and airlock hatches permit EVA flight crew members to transfer from the middeck crew compartment into the payload bay in EMUs without depressurizing the orbiter crew cabin.

Normally, two EMUs are stowed in the airlock. A third EMU upper torso is carried aboard Discovery in this mission. The EMU is an integrated space suit assembly and life support system that enables flight crew members to leave the pressurized orbiter crew cabin and work in space.

The airlock has an inside diameter of 63 inches, is 83 inches long and has two 40-inch-diameter D-shaped openings that are 36 inches across, plus two pressure sealing hatches and a complement of airlock support systems. The airlock's volume is 150 cubic feet.

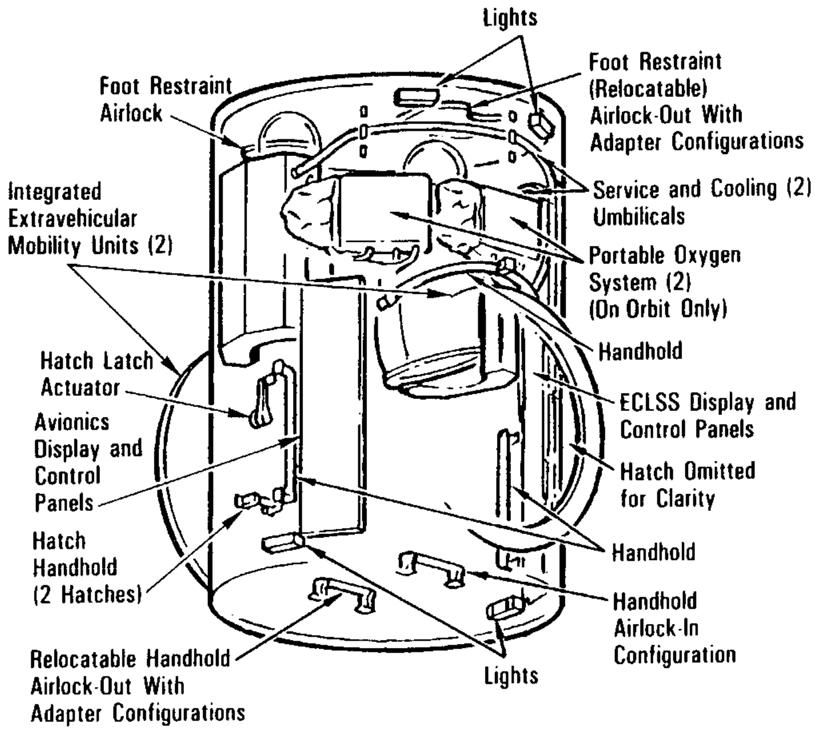
The airlock, which is sized to accommodate two fully suited flight crew members simultaneously, provides airlock depressurization and repressurization, EVA equipment recharge, liquid-cooled garment water cooling, EVA equipment checkout donning and communications. All EVA gear, the checkout panel and recharge stations are located against the internal walls of the airlock.

The airlock hatches are mounted on the airlock. The inner hatch is mounted on the exterior of the airlock (orbiter crew cabin middeck side) and opens into the middeck. The inner hatch isolates the airlock from the orbiter crew cabin. The outer hatch is mounted in the interior of the airlock and opens into the airlock. The outer hatch isolates the airlock from the unpressurized payload bay when closed and permits the EVA crew members to exit from the airlock to the payload bay it is when open.

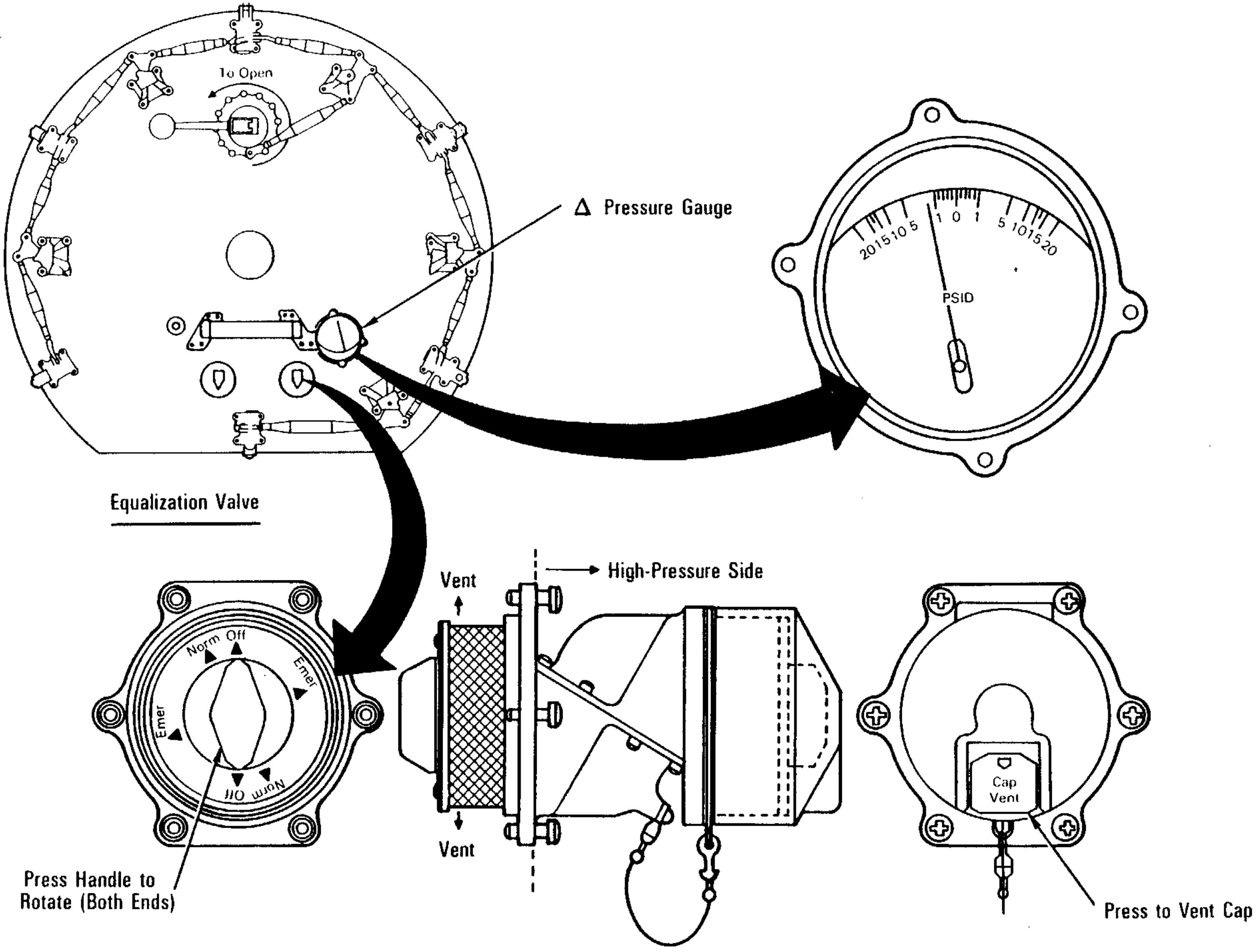
Airlock repressurization is controllable from the orbiter crew cabin middeck and inside the airlock. It is performed by equalizing the airlock and cabin pressure with airlock-hatch-mounted equalization valves on the inner hatch. Depressurization of the airlock is controlled from inside the airlock. The airlock is depressurized by venting the airlock pressure overboard. The two D-shaped airlock hatches are installed to open toward the primary pressure source, the orbiter crew cabin, to achieve pressure-assist sealing when closed.

Each hatch has six interconnected latches with gearbox and actuator, a window, a hinge mechanism and hold-open device, a differential pressure gauge on each side and two equalization valves.

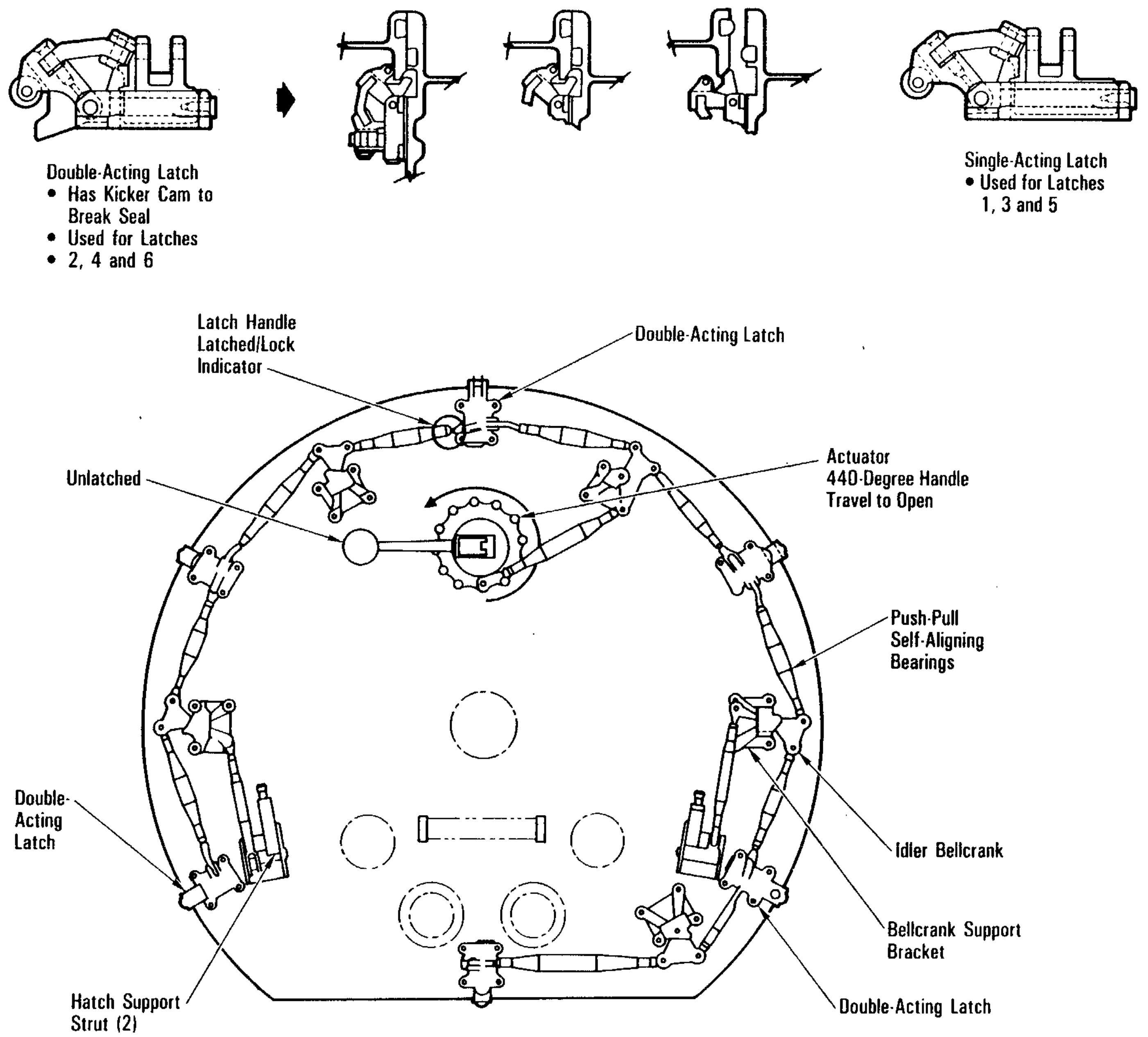
The window in each airlock hatch is 4 inches in diameter. The window is used for crew observation from the cabin and airlock



Airlock



Airlock Repressurization



Airlock Hatch Latches

and the airlock and payload bay. The dual window panes are made of polycarbonate plastic and are mounted directly to the hatch using bolts fastened through the panes. Each hatch window has dual pressure seals with seal grooves located in the hatch.

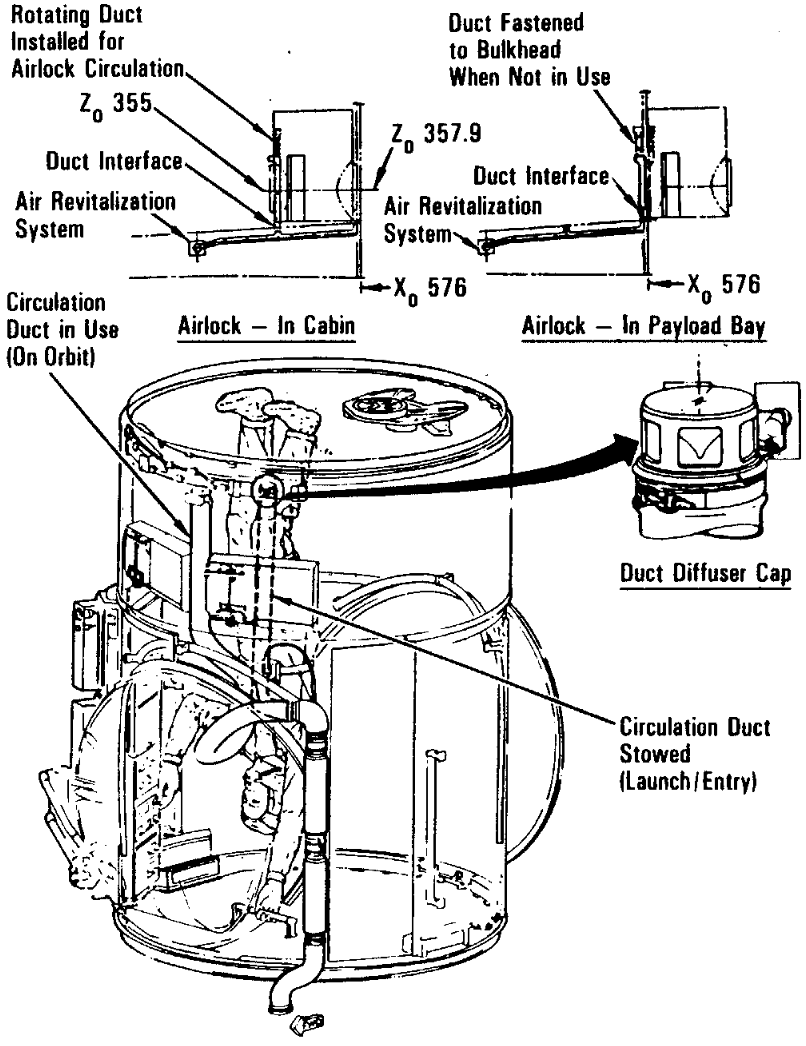
Each airlock hatch has dual pressure seals to maintain the airlock's pressure integrity. One seal is mounted on the airlock hatch and the other on the airlock structure. A leak check quick disconnect is installed between the hatch and the airlock pressure seals to verify hatch pressure integrity before flight.

The gearbox with latch mechanisms on each hatch allows the flight crew to open or close the hatch during transfers and EVA operations. The gearbox and the latches are mounted on the low-pressure side of each hatch, and a gearbox handle is installed on both sides to permit operation from either side of the hatch.

Three of the six latches on each hatch are double-acting. They have cam surfaces that force the sealing surfaces apart when the latches are opened, thereby acting as crew assist devices. The latches are interconnected, with push-pull rods and an idler bellcrank installed between the rods for pivoting the rods. Self-aligning dual rotating bearings are used on the rods to attach the bellcranks and the latches. The gearbox and the hatch's open support struts are also connected to the latching system, using the same rod and bellcrank and bearing system. To latch or unlatch the hatch, a rotation of 440 degrees on the gearbox handle is required.

The hatch actuator and gearbox are used to provide the mechanical advantage to open and close the latches. The hatch actuator lock lever requires a force of 8 to 10 pounds through an angle of 180 degrees to unlatch the actuator. A minimum rotation of 440 degrees with a maximum force of 30 pounds applied to the actuator handle is required to operate the latches to their fully unlatched positions.

The hinge mechanism for each hatch permits a minimum opening sweep into the airlock or the crew cabin middeck. The inner hatch (airlock to crew cabin) is pulled and pushed forward into the crew cabin approximately 6 inches. The hatch pivots up and to the right side. Positive locks are provided to hold the hatch in both an intermediate and a full-open position. To release the lock, a spring-loaded handle is provided on the latch hold-open bracket. Friction is also provided in the linkage to prevent the hatch from moving if released during any part of the swing.



Airlock

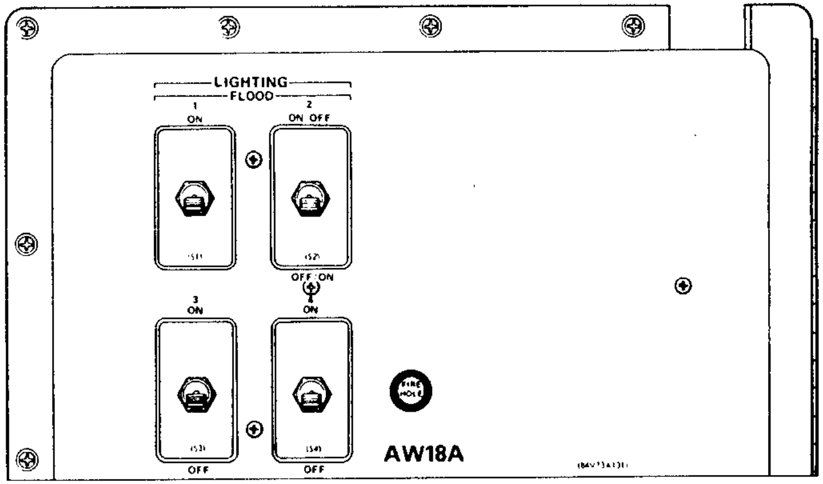
The outer hatch (in the airlock to payload bay) opens and closes to the contour of the airlock wall. The hatch is hinged to be pulled first into the airlock and then pulled forward at the bottom and rotated down until it rests with the low-pressure (outer) side facing the airlock ceiling (middeck floor). The linkage mechanism guides the hatch from the close/open, open/close position with friction restraint throughout the stroke. The hatch has a hold-open hook that snaps into place over a flange when the hatch is fully open. The hook is released by depressing the spring-loaded hook handle and pushing the hatch toward the closed position. To support and protect the hatch against the airlock ceiling, the hatch incorporates two deployable struts. The struts are connected to the hatch linkage mechanism and are deployed when the hatch linkage mechanism is rotated open. When the hatch latches are rotated closed, the struts are retracted against the hatch.

The airlock hatches can be removed in flight from the hinge mechanism via pip pins, if required.

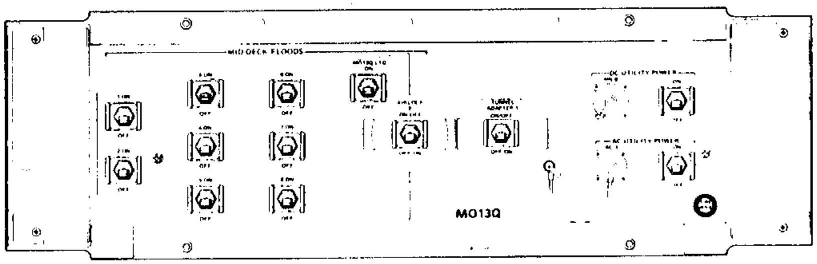
An air circulation system provides conditioned air to the airlock during non-EVA operation periods. The airlock revitalization system duct is attached to the outside airlock wall at launch. When the airlock hatch is opened in flight, the duct is rotated by the flight crew through the cabin and airlock hatch and installed in the airlock. It is held in place by a strap holder. The duct has a removable air diffuser cap on the end of the flexible duct that can adjust the air flow from zero to 216 pounds per hour. The duct must be rotated out of the airlock before the cabin and airlock hatch is closed for airlock depressurization. During the EVA preparation period, the duct is rotated out of the airlock and can be used as supplemental air circulation in the middeck.

To assist the crew member in pre- and post-EVA operations, the airlock incorporates handrails and foot restraints. Handrails are located alongside the avionics and environmental control and life support system panels. Oval aluminum alloy handholds 0.75 by 1.32 inches are mounted in the airlock. They are painted yellow. The handrails are bonded to the airlock walls with an epoxy-phenolic adhesive. Each handrail has a clearance of 2.25 inches from the airlock wall to allow it to be gripped in a pressurized glove. Foot restraints are installed on the airlock floor nearer the payload bay side. A ceiling handhold installed nearer the cabin side of the airlock was removed to make room to stow a third EMU. The foot restraints can be rotated 360 degrees by releasing a spring-loaded latch and lock every 90 degrees. A rotation release knob on the foot restraint is designed for shirt-sleeve operation; therefore, it must be positioned before the suit is donned. The foot restraint is bolted to the floor and cannot be removed in flight. It is sized for the EMU boot. The crew member first inserts his foot under the toe bar and then rotates his heel from inboard to outboard until the heel of the boot is captured.

There are four floodlights in the airlock. The lights are controlled by switches in the airlock on panel AW18A. Lights 1, 3 and 4 are controlled by a corresponding *on/off* switch on panel



Panel AW18A



Panel M013Q

AW18A. Light 2 can be controlled by an *on/off* switch on panels AW18A and M013Q, allowing illumination of the airlock prior to entry. Lights 1, 3 and 4 are powered by main buses A, B and C, respectively, and light 2 is powered by essential bus 1 BC. The circuit breakers are on panel ML86B.

The airlock provides two service and cooling umbilicals and miscellaneous support equipment.

The prime contractor to NASA for the space suit and life support system is United Technologies' Hamilton Standard Division in Windsor Locks, Conn. Hamilton Standard is program systems manager, designer and builder of the space suit and life support system. Hamilton Standard's major subcontractor is ILC Dover of Frederica, Del., which fabricates the space suit.

The EMUs provide the necessities for life support, such as oxygen, carbon dioxide removal, a pressurized enclosure, temperature control and meteoroid protection during EVA.

The EMU space suit comes in various sizes so that flight crew members can pick their suits before launch. Components are designed to fit men and women from the 5th to the 95th percentiles of body size.

The self-contained life support system contains seven hours of expendables, such as oxygen, a battery for electrical power, water for cooling, lithium hydroxide for carbon dioxide removal and a 30-minute emergency life support system during an EVA.

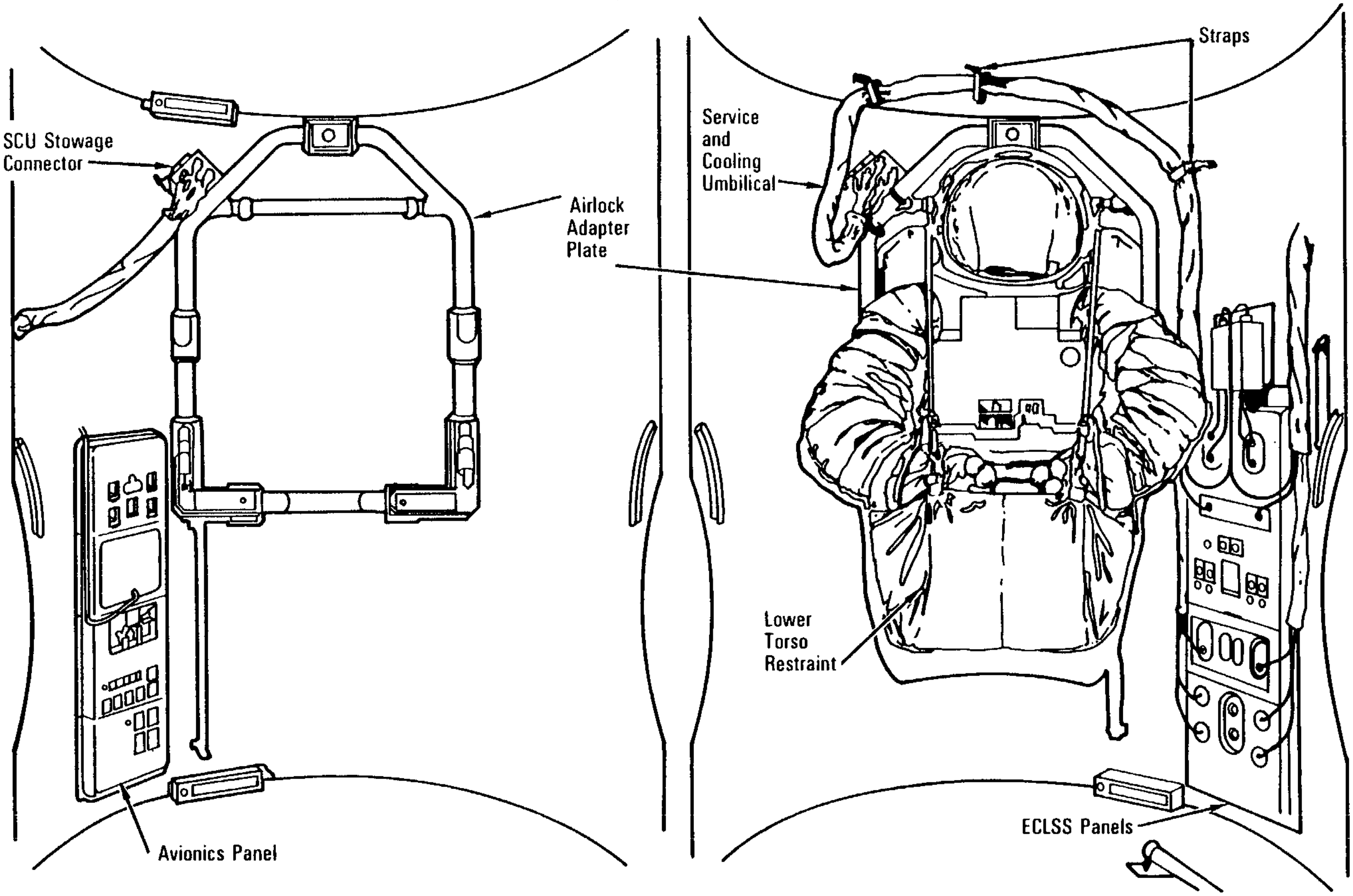
The airlock adapter plate in the airlock also provides a fixed position for the EMUs to assist the crew member during donning, doffing, checkout and servicing. The EMU weighs approximately 225 pounds, and its overall storage envelope is 26 by 28 by 40 inches. For launch and entry, the lower torso restraint, a cloth bag attached to the airlock adapter plate with straps, is used to hold the lower torso and arms securely in place.

The EMU is pressurized to 4 psid. It is designed for a 15-year life with cleaning and drying between flights. The EMU consists of a hard upper torso, lower torso assembly, gloves, helmet and visor assembly, communications carrier assembly, liquid cooling and ventilation garment, urine collection device and operational bioinstrumentation system. The upper torso, including arms, is that portion of the pressure suit above the waist, excluding the gloves and helmet. It provides the structural mounting for most of the EMU—helmet, arms, lower torso, portable life support system, display and control module and electrical harness. The arm assembly contains the shoulder joint and upper arm bearings that permit shoulder mobility as well as the elbow joint and wrist bearing.

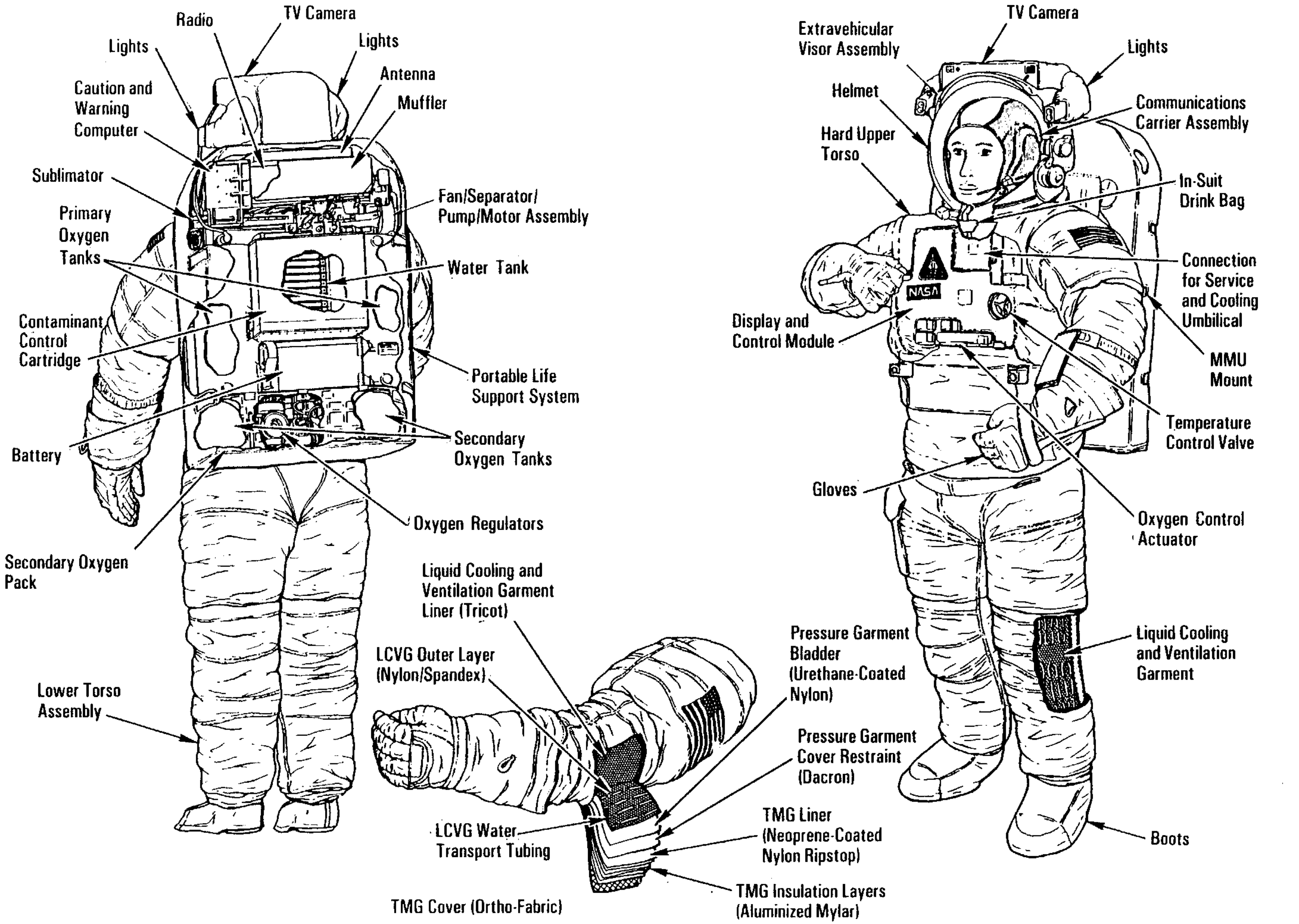
The portable life support system (PLSS) is made of fiberglass and provides a mounting for other EMU components. It includes oxygen bottles; water storage tanks; a fan, separator and pump motor assembly; a sublimator; a contaminant control cartridge; various regulators, valves and sensors; communications; bioinstrumentation; and a microprocessor module. The secondary oxygen pack attaches to the bottom of the PLSS. The PLSS expendables include 1.2 pounds of oxygen pressurized to 850 psia in the primary bottles, 2.6 pounds of oxygen at 6,000 psia in the secondary pack, 10 pounds of water for cooling in three bladders and lithium hydroxide in the contaminant control cartridge.

The primary oxygen system and water bladders provide enough of these expendables for seven hours inside the EMU, including 15 minutes for checkout, six hours of EVA, 15 minutes for EMU doffing and 30 minutes for reserve. The SOP will supply oxygen and maintain suit pressure for 30 minutes in the event of a failure in the primary system or depletion of the primary oxygen system.

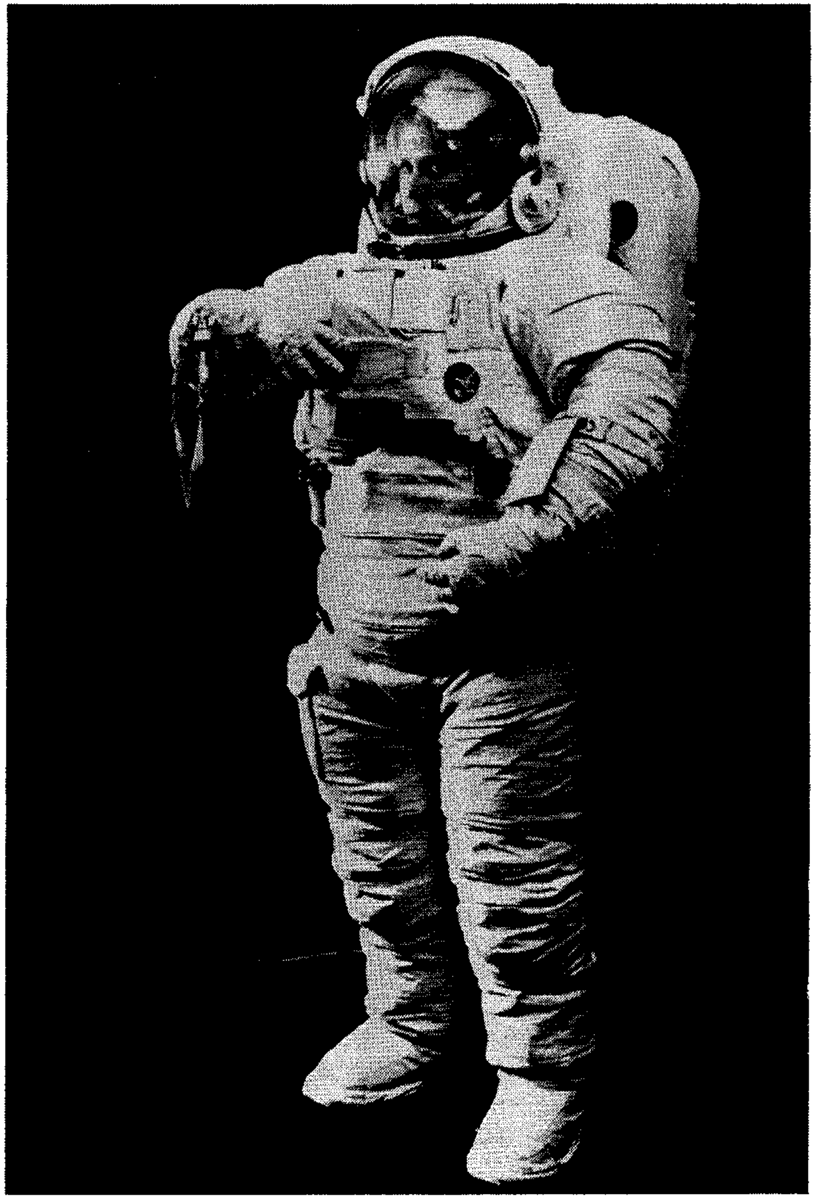
The lower torso assembly is that portion of the EMU below the waist, including boots. It consists of pants and hip, knee and ankle joints. The lower torso comes in various sizes and connects to the hard upper torso by a waist ring. It is composed of several layers, beginning with a pressure bladder of urethane-coated nylon, a restraining layer made of Dacron, an outer thermal garment made of neoprene-coated nylon, four layers of aluminized



Airlock Stowage Provisions



Extravehicular Mobility Unit



Extravehicular Mobility Unit

Mylar and a surface layer of Gortex and Nomex. The foot section consists of specialized socks that contain return air ports. The EVA crew members' feet are fitted with boot inserts that fit into the boots.

The gloves contain the wrist connection, wrist joint and insulation padding for palms and fingers. They connect to the arms and are available in 15 sizes.

The helmet is a clear polycarbonate bubble with a neck disconnect and ventilation pad that provides pressurization for the head. An assembly that goes over the helmet contains visors that are manually adjusted to shield the EVA crew members' eyes from micrometeoroids and from ultraviolet and infrared radiation from the sun. Two EVA lights are attached on each side of the helmet. A TV camera can also be attached to the helmet.

A cap, known as the Snoopy cap, is worn under the EMU helmet. It fits over the crew member's head and is held in place by a chin guard. It contains a microphone and headphones for two-way communications and receiving caution and warning tones.

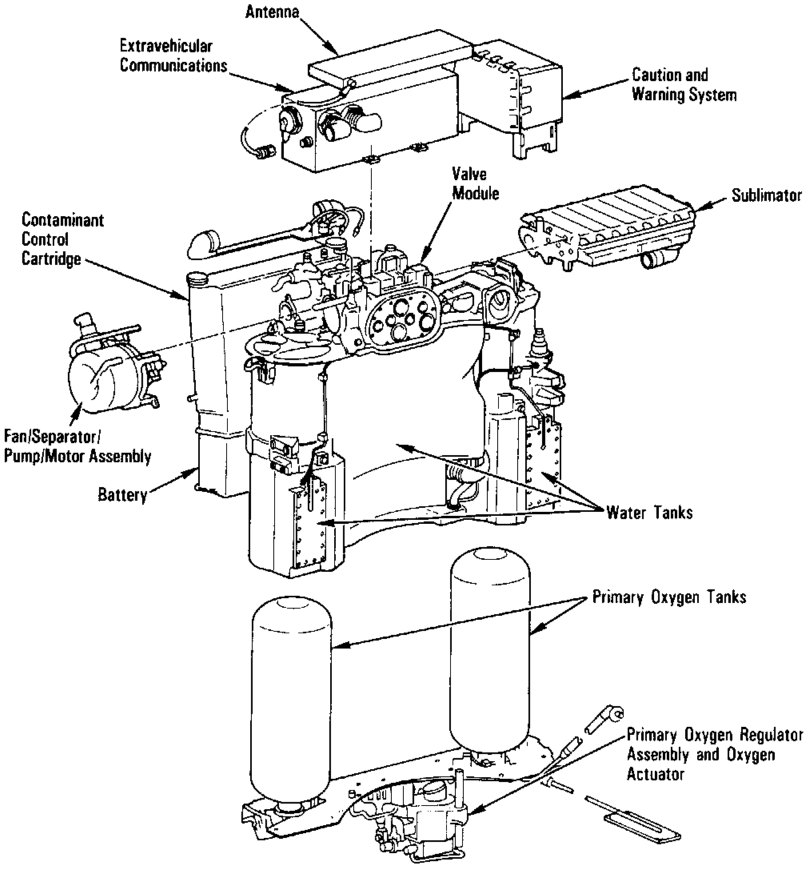
The liquid cooling and ventilation garment worn by the EVA crew member under the pressure suit has sewn-in tubes. It provides circulation of cooling water and pickup of vent flow at the extremities. It is a mesh one-piece suit made of spandex and has a zipper in the front for entry. It has 300 feet of plastic tubing that carries cooling water at a rate of 240 pounds per hour. It is controlled by a valve on the display and control module. Ducting along the garment's arms and legs directs oxygen and carbon dioxide from the suit to the life support system for purification and recirculation. The garment weighs 6.5 pounds and provides cooling to maintain desired body temperature and physical activity that nominally generates 1,000 Btu per hour and can generate up to 2,000 Btu per hour, which is considered extremely vigorous.

The urine collection device can store approximately 1 quart of urine. It consists of adapter tubing, a storage bag and disconnect hardware for emptying after an EVA to the orbiter waste water tank.

The bioinstrumentation system monitors the EVA crew member's heart rate (electrocardiogram) during an EVA.

An in-suit drink bag stores approximately 0.5 quart of drinking water in the upper torso. A tube from the upper hard torso to the helmet permits the EVA crew member to drink water while suited.

The life support system consists of the portable life support system, display and control module, contaminant control cartridge, battery, secondary oxygen pack, and EVA communicator and EMU antenna. The PLSS is also referred to as a backpack. The PLSS normally provides the EVA crew member with oxygen for breathing, ventilation and pressurization and water for cooling.

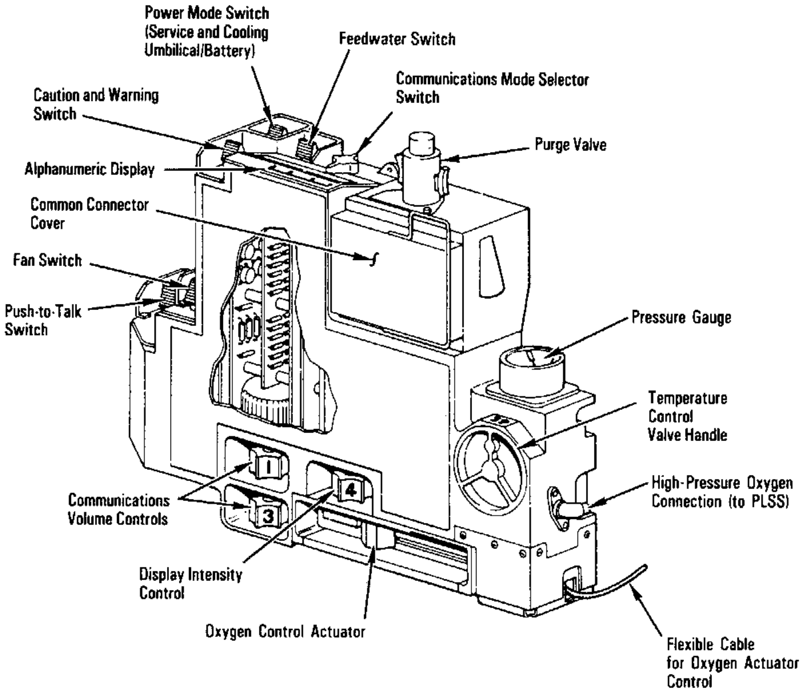


Portable Life Support System

The contaminant cartridge consists of lithium hydroxide, charcoal and filters to remove carbon dioxide, odors, particulates and other contaminants from the ventilation circuit. It is replaceable upon completion of an EVA.

A silver-zinc battery provides all electrical power used by the EMU and life support system. It is stored dry, filled, sealed and charged before flight. It is rechargeable upon completion of an EVA and is rated at 17 volts dc.

The SOP provides oxygen for breathing, ventilation, pressurization and cooling in the event of a PLSS malfunction. It is

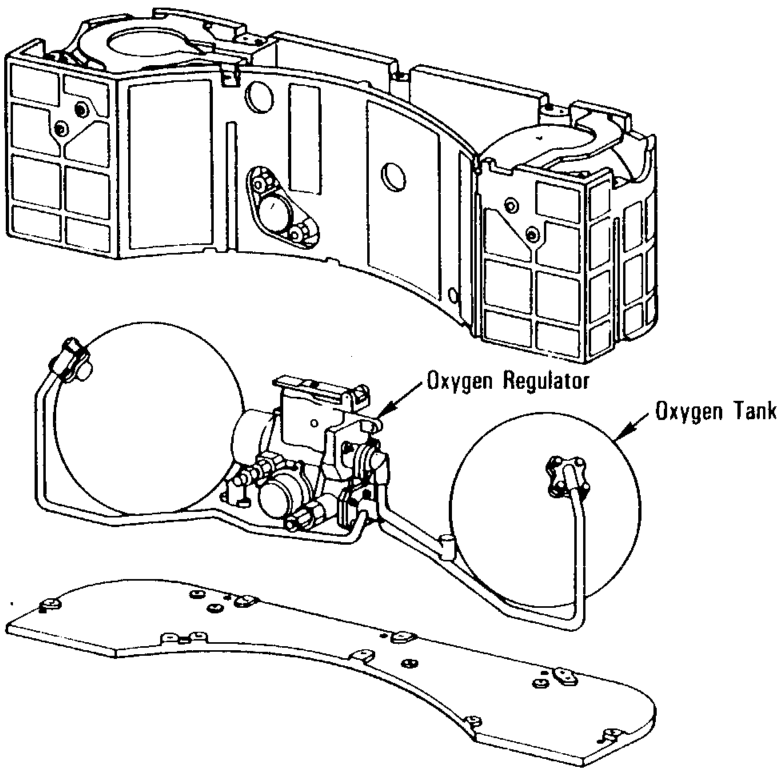


Displays and Controls

mounted at the base of the PLSS and contains a 30-minute oxygen supply, a valve and a regulator assembly.

The EVA communicator and EMU antenna provide EVA communications via its transceiver and antenna between the suited crew member and the orbiter. In addition, the crew member's electrocardiogram is telemetered through the communicator to the orbiter. It is a separate subassembly that attaches to the upper portion of the life support system at the back of the hard upper torso. The controls are located on the display and control module mounted at the front of the upper torso.

The radios for space walk communications have two single-UHF-channel transmitters, three single-channel receivers and a switching mechanism. In addition, telemetry equipment is included so that ground personnel can monitor the astronaut's heart beat. These backpack radios have a low-profile antenna, a 1-foot-long rectangular block fitted to the top of the packs. The radios weigh 8.7 pounds and are 12 inches long, 4.3 inches high and 3.5 inches wide.



Secondary Oxygen Package

The EMU electrical harness provides biomedical instrumentation and communications connections to the PLSS. The harness connects the communications carrier assembly and the biomedical instrumentation subsystem to the hard upper torso, where internal connections are routed to the EVA communicator. The cable routes signals from the electrocardiogram sensors, which are attached to the crew member, through the bioinstrumentation system to the EVA communicator. It also routes caution and warning signals and communications from the communicator to the crew member's headset.

The DCM is an integrated assembly that attaches directly to the front of the hard upper torso. The module contains a series of mechanical and electrical controls, a microprocessor, and an alphanumeric LED display easily seen by a crew member wearing the space suit. It contains the displays and controls associated with the operation of the EMU.

The function of the display and control module is to enable the crew member to control the PLSS and the secondary oxygen pack. It also indicates the status of the PLSS and the suit visibly and audibly.

The mechanical controls consist of a suit purge valve, the liquid cooling and ventilation garment cooling valve, and the oxygen actuator control, which has four positions: *off*, *iv* (which turns primary oxygen on to a 0.5-psid suit pressure setting), *press* (which turns primary oxygen on to a 4.1-psid suit pressure setting), and *ev* (which leaves primary oxygen on the 4.1-psid setting and turns the secondary oxygen pack on). The electrical controls include a voice communications mode switch, dual volume controls, push-to-talk switches, a power mode switch, feedwater and C/W switches and the LED display brightness control. The displays on the module are a 12-digit LED display, a built-in test equipment indicator and an analog suit pressure gauge.

The display and control module is connected to the hard upper torso and to the PLSS by both internal and external hookups. A multiple-function connector links the display module to the service and cooling umbilical, thus enabling the use of the display module controls during suit checkout inside the airlock station.

The display module interacts with a microprocessor in the PLSS that contains a program that enables the crew member to cycle the display through a series of systems checks and thereby determine the condition of a variety of components. The microprocessor monitors oxygen pressure and calculates the time remaining at the crew member's present use rate. It signals an alarm at high oxygen use in the primary oxygen tanks. It also monitors water pressure and temperature in the cooling garment. The carbon dioxide level is monitored and an alarm is signaled when it reaches high concentrations in the suit. The microprocessor monitors the power consumed and signals at high current-drain rates and also when an estimated 30 minutes of battery power is left. All the warnings are displayed on the LED display.

Oxygen from the system enters the suit at the helmet and flows from behind the head down through the suit. Oxygen and carbon dioxide are removed from the suit through the liquid cooling and ventilation garment at ports near the crew member's wrists and feet. Return air goes first through the contaminant control cartridge, where activated charcoal and lithium hydroxide beds remove carbon dioxide, odors and dust. From there the return air goes through a water separator, where moisture from exhalation and the lithium hydroxide and carbon dioxide reaction is removed. The oxygen then goes through the fan, which maintains air flow at 6 cubic feet per minute. It is then routed through the sublimator, where it is cooled to 85 F, and then passes through a vent and flow detector and back to the suit. Oxygen for the air system is fed from the primary oxygen containers through regulators that maintain suit pressure at 4.1 psid.

The system is protected from suit overpressure, primary oxygen supply depletion or mechanical failure by regulators, sensors and the secondary oxygen pack. The secondary oxygen pack can maintain suit pressure at 3.45 psid. A purge valve on the display and control module allows a crew member to completely replace system oxygen in the suit if, for instance, the carbon dioxide level rises too high too quickly.

The cooling water system takes the warm water from the cooling garment and divides it into two loops. One loop goes to the sublimator, where the water in that loop is cooled and sent back to the cooling control valve. The other loop goes directly back to the cooling control valve, where the loops are recombined and full flow goes back to the cooling garment. Thus, the cooling garment has a constant flow of cooling water at a temperature set by the crew member using the cooling control valve. During the process, the full flow from the cooling garment goes through a gas separator, where gas is removed from the loop, and then through a pump that maintains a flow of 260 pounds per hour. Another side loop circulates 20 pounds per hour through the contaminant control cartridge to cool the lithium hydroxide canister since the lithium hydroxide and carbon dioxide reaction produces heat and needs to be kept cool for an efficient reaction.

Since the system is a closed-loop design, water from the water separator is fed back to the water system, and air from the gas trap is fed back to the oxygen system. Water from the water tanks is also fed, through regulators, into the cooling system. However, the primary purpose of the water tanks is to feed water to the sublimator. The sublimator works on the principle of sublimation, that is, the process by which a solid turns directly into a vapor, bypassing the liquid phase. In this case, ice is formed on the sublimator evaporator sieve and is allowed to vaporize to space, removing heat with it. Air and cooling water are passed through fins in the sublimator, which extracts heat from each system.

The PLSS sensors detect system air flow, air pressure, water flow, water pressure, differential water pressure (between the circulating system and the water tanks), water temperature and carbon dioxide content in the return air. In addition, there are a number of crew-selectable valves, including a purge valve, a cooling control valve (infinitely variable), oxygen supply and a direct-reading air pressure gauge. The sensors supply information to the display and control module, where a microprocessor maintains an automatic watch over system integrity.

Normally, the day before an EVA, the orbiter crew compartment cabin pressure is allowed to decrease from 14.7 psia to 12.5 psia through metabolic usage. One hour before depressurizing the crew compartment from 12.5 psia to 10.2 psia, the EVA crew member and prebreathes 100-percent oxygen for 60 minutes in the helmet retention assembly. The crew compartment is then depressurized from 12.5 psia to 10.2 psia and remains at this pressure until after the EVA is completed. This is necessary to remove nitrogen from the EVA crew member's blood before the EVA crew member works in the pure oxygen environment of the EMU. Without the prebreathing, bends can occur. When an individual fails to reduce nitrogen levels in the blood before working in a pressure condition, nitrogen can come out of solution in the form of bubbles in the bloodstream. This condition results in pain in the body joints, possibly because of restricted blood flow to connective tissues or because of the extra pressure caused by bubbles in the blood in the joint area.

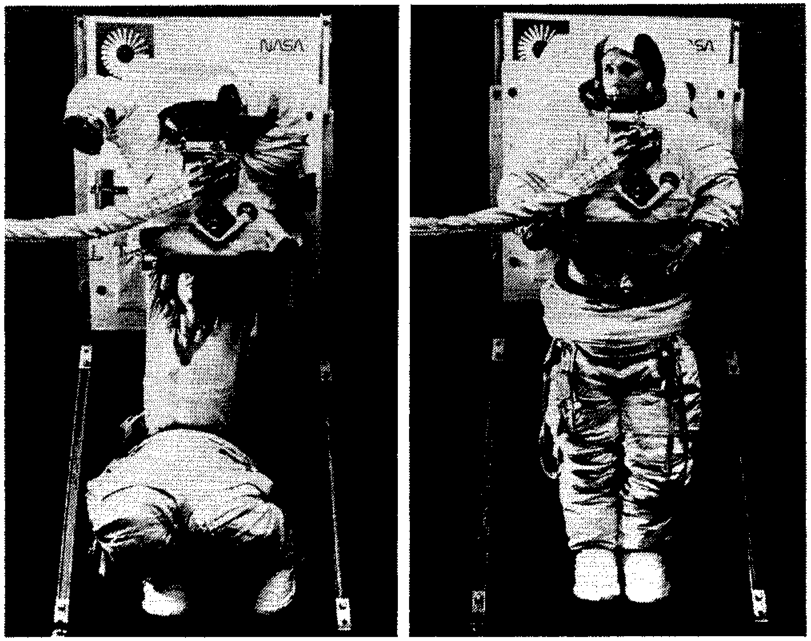
In preparation for an EVA, the crew member dons the liquid cooling and ventilation garment first, enters the airlock and dons the lower torso assembly. The crew member then squats under the hard upper torso mounted on the airlock adapter plate and slides up into the upper torso. The upper and lower torsos are connected with a waist ring. The gloves and helmet are then put on, and the EMU is disconnected from the AAP.

The orbiter provides electrical power, oxygen, liquid cooling and ventilation garment cooling and water to the EMUs in the airlock via the service and cooling umbilical for EVA preparation and after EVA operations.

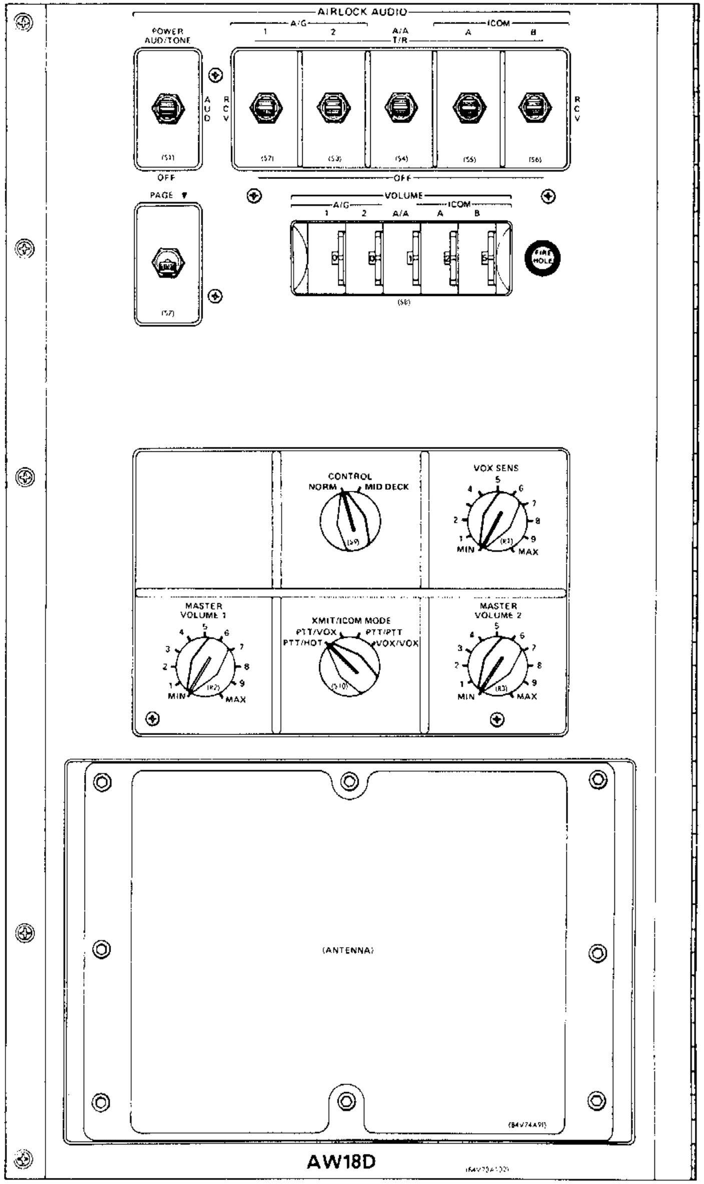
The service and cooling umbilical contains communication lines, electrical power, water, water drain line and oxygen recharge lines. The umbilical permits the EVA crew member to check out the suit in the airlock without using the EMU supply of water, oxygen and battery power.

The SCU is launched with the orbiter end fittings permanently connected to the appropriate ECLSS panels in the airlock and the EMU connected to the airlock adapter plate stowage connector. It allows all supplies (oxygen, water, electrical and communication) to be transported from the airlock control panels to the EMU before and after EVA without using the EMU expendable supplies of water, oxygen and battery power that are scheduled for use in the EVA. The SCU also provides EMU recharge. The SCU umbilical is disconnected just before the crew member leaves the airlock on an EVA and is reconnected when he returns to the airlock. Each SCU is 144 inches long, 3.5 inches in diameter and weighs 20 pounds. Actual usable length after attachment to the control panel is approximately 7 feet.

The airlock has two display and control panels. The airlock control panels are basically split to provide either ECLSS or avionics operations. The ECLSS panel provides the interface for the

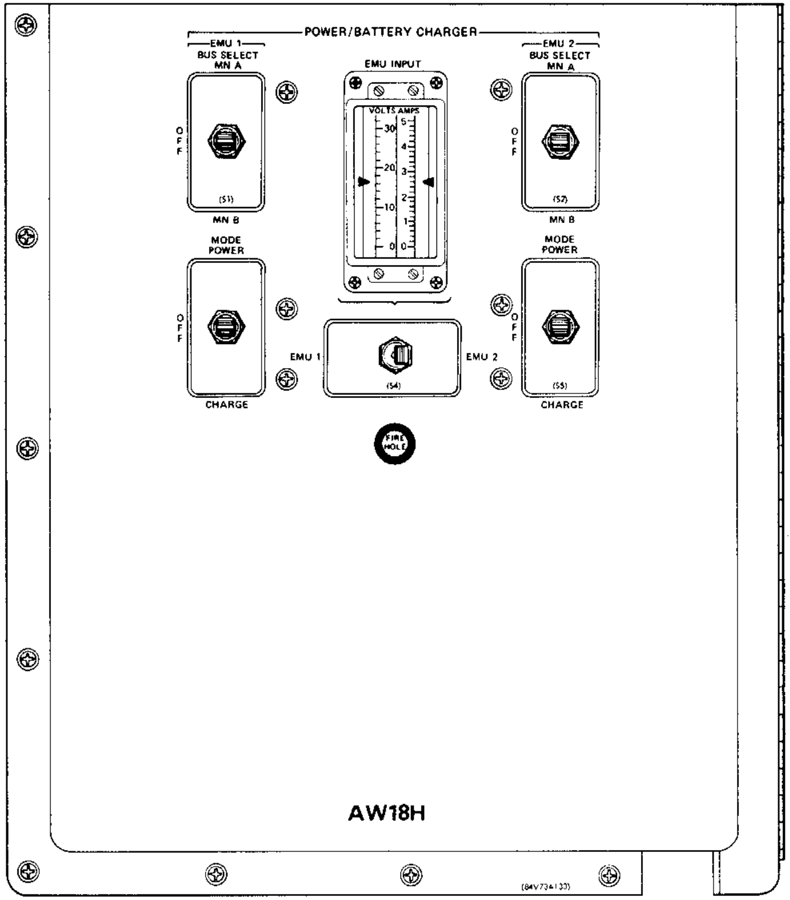


Extravehicular Mobility Unit



Panel AW18D

SCU waste and potable water, liquid cooling and ventilation garment cooling water, EMU hardline communications, EMU power and oxygen supply. The avionics panel includes the airlock lighting, airlock audio system and EMU power and battery recharge controls. The avionics panel is located on the right side of the cabin airlock hatch and the ECLSS panel is on the left side. The airlock panels are designated AW18H, AW18D and AW18A on the left side and AW82H, AW82D and AW82B on the right side. The

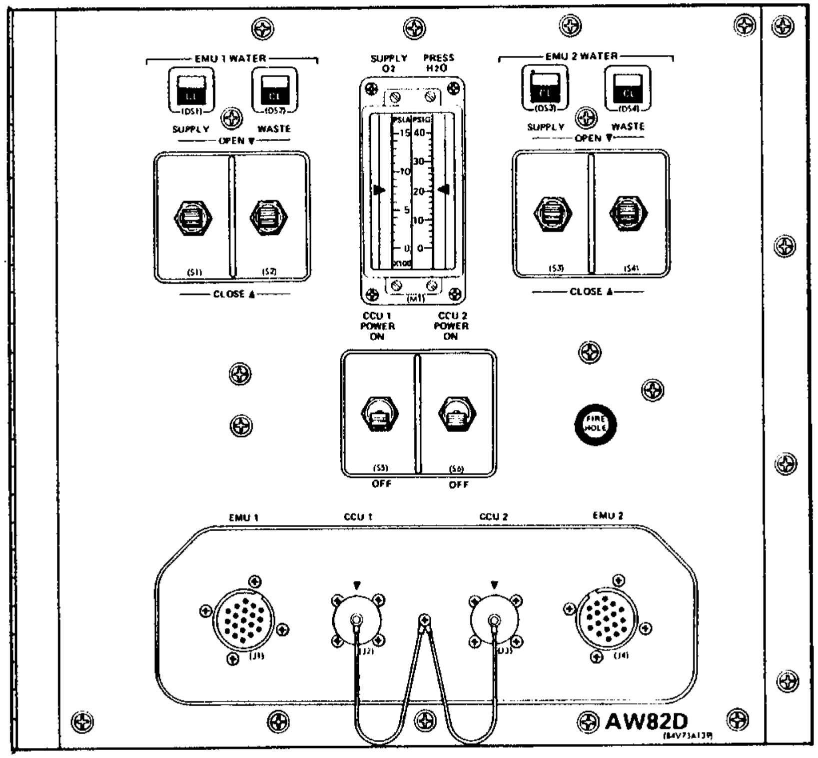


Panel AW18H

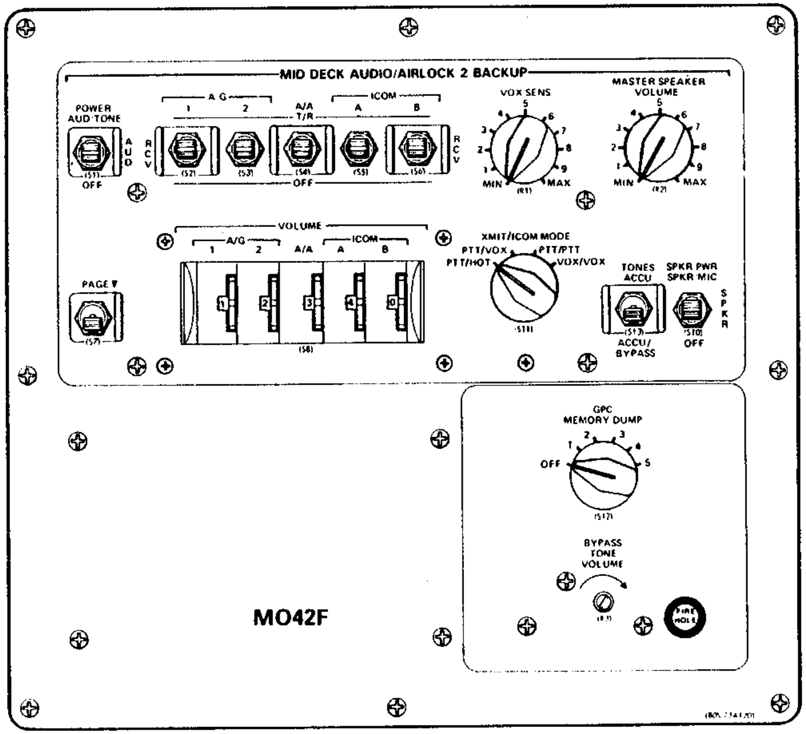
ECLSS panel is divided into EMU 1 functions on the right side and EMU 2 functions on the left.

Airlock communications are provided with the orbiter audio system at airlock panel AW82D, where connectors for the headset interface units and the EMUs are located at airlock panel AW18D, the airlock audio terminal. The HIUs are inserted in the crew member communications carrier unit connectors on airlock panel AW82D. The CCUs are also known as the Snoopy caps. The adjacent two-position switches labeled *CCU1* and *CCU2 power* enable transmit functions only, as reception is normal as soon as the HIUs are plugged in. The EMU 1 and EMU 2 connectors on the panel to which the SCU is connected include contacts for EMU hardline communications with the orbiter before EVA. Panel AW18D contains displays and controls used to select access to and control the volume of various audio signals. Control of the airlock audio functions can be transferred to the middeck ATUs on panel M042F by placing the control knob to the *middeck* position.

During EVA, the EVA communicator is part of the same UHF system that is used for air-to-air and air-to-ground voice communications between the orbiter and landing site control tower. The EVA communicator provides full duplex (simultaneous transmission and reception) communications between the orbiter and the EVA crew members. It also supplies continuous data reception of electrocardiogram signals from each crew member by the orbiter and processing by the orbiter and relay of electrocardiogram signals to the ground. The UHF airlock antenna in the forward portion of the payload bay provides the UHF EVA capability.



Panel AW82D



Panel M042F

Panel AW18H in the airlock provides 17 volts dc, plus or minus 0.5 volt dc, at 5 amperes at both EMU electrical connector panels on panel AW82D and in EVA preparation. Main bus A or B can be selected on the *bus select* switch; then the *mode* switch is positioned to *power*. The *bus select* switch provides a signal to a remote power controller that applies 28 volts dc from the selected bus to the power and battery recharger. The *mode* switch in the *power* position makes the power available at the SCU connector and also closes a circuit that provides a battery feedback voltage charger control that inhibits EMU power when any discontinuity is sensed in the SCU/EMU circuitry. The *mode* switch in the *power* position also applies power through the SCU for the EMU microphone amplifiers for hardline communication. When the SCU umbilical is disconnected for EVA, the EMU operates on its self-contained battery power. After EVA, when the SCU is reconnected to the EMU, selecting a bus and the *charge* position on the *mode* switch charges the PLSS battery at 1.55 amps, plus or minus 0.05 amp. When the battery reaches 21.8 volts dc, plus or minus 0.1 volt dc, or the charging circuit exceeds 1.55 amps, plus or minus 0.05 amp, a solenoid-controlled switch internal to the battery charger removes power to the charging circuitry.

Cooling for flight crew members before and after the EVA is provided by the liquid-cooled garment circulation system via the SCU and LCG supply and return connections on panel AW82B. These connections are routed to the orbiter LCG heat exchanger, which transfers the collected heat to the orbiter Freon-21 coolant loops. The nominal loop flow of 250 pounds per hour is provided by the EMU and PLSS water loop pump. The system circulates chilled water at 50 F maximum to the liquid cooling and ventilation garment inlet and provides a heat removal capability of 2,000 Btu per hour per crew member. When the SCU is disconnected, the PLSS provides the cooling. Upon return from the EVA, the PLSS is reconnected to the SCU, and crew member cooling is as it was in the EVA preparation.

With the suit connected to the SCU, oxygen at 900 psia, plus or minus 500 psia, is supplied through airlock panel AW82B from the orbiter's oxygen system when the oxygen valve is in the *open* position on the airlock panel. This provides the suited crew member with breathing oxygen and prevents depletion of the PLSS oxygen tanks before the EVA. Before the crew member seals the helmet, an oxygen purge adapter hose is connected to the airlock panel to flush nitrogen out of the suit.

When the SCU is disconnected, the PLSS provides oxygen for the suit. When the EVA is completed and the SCU is reconnected, the orbiter's oxygen supply begins recharging the PLSS, assuming that the oxygen valve on panel AW82B is open. Full oxygen recharge takes approximately one hour (allowing for thermal expansion during recharge), and the tank pressure is monitored on the EMU display and control panel as well as on the airlock oxygen pressure readout.

The EMU water supply and waste valves are opened during the EVA preparation by switches on panel AW82D. This provides the EMU, via the SCU, access to the orbiter's potable water and waste water systems. The support provided to the EMU PLSS is further controlled by the EMU display and control panel. Potable water (supplied from the orbiter at 16 psi, plus or minus 0.5 psi; 100 to 300 pounds per hour; and 40 to 100 F) is allowed to flow to the feedwater reservoir in the EMU that provides pressure, which would top off any tank not completely filled. Waste water condensate developed in the PLSS is allowed to flow to the orbiter waste water system via the SCU whenever the regulator connected at the bacteria filters (airlock end of the SCU) detects upstream pressure in excess of 16 psi, plus or minus 0.5 psi.

When the SCU is disconnected from the EMU, the PLSS assumes its functions. When the SCU is reconnected to the EMU upon completion of the EVA, it performs the same functions it did before the EVA except that the water supply is allowed to continue until the PLSS water tanks are filled, which takes approximately 30 minutes.

In preparation for the EVA, the airlock hatch to the orbiter crew cabin is closed and depressurization of the airlock begins.

Airlock depressurization is accomplished in two stages by a three-position valve located on the ECLSS panel AW82A in the airlock. The airlock depressurization valve is covered with a pressure and dust cap. Before the cap is removed from the valve, it is necessary to vent the area between the cap and valve by pushing the vent valve on the cap. In flight, the pressure and dust cap is stored next to the valve. The airlock depressurization valve is connected to a 2-inch-inside-diameter stainless steel overboard vacuum line. The airlock depressurization valve controls the rate of depressurization by varying the valve's diameter. Closing the valve prevents any air flow from escaping to the overboard vent system.

When the crew members have completed the 40-minute prebreathe in the EMUs, the airlock is depressurized from 10.2 psia to 5 psia by moving the airlock depressurization valve to the *5* position, which opens the depressurization valve and allows the pressure in the airlock to decrease at a controlled rate. The airlock depressurization valve must be closed to maintain 5 psia. During depressurization, pressure can be monitored by the delta pressure gauge on either airlock hatch. A delta pressure gauge is installed on each side of both airlock hatches.

At this time, the flight crew performs an EMU suit leak check, electrical power is transferred from the umbilicals to the EMU batteries, the umbilicals are disconnected, and the suit oxygen packs are brought on-line.

The second stage of airlock depressurization is accomplished by positioning the airlock depressurization valve to *0*, which increases the valve's diameter and allows the pressure in the airlock to decrease from 5 psia to zero psia. The suit sublimators are activated for cooling, EMU system checks are performed, and the airlock and payload bay hatch can be opened. The hatch is capable of opening against a 0.2 psia differential maximum.

Hardware provisions are installed in the orbiter payload bay for use by the crew member during the EVA.

Handrails and tether points are located on the payload bulkheads, forward bulkhead station X_O 576 and aft bulkhead station X_O 1307 along the sill longeron on both sides of the bay to provide translation and stabilization capability for EVA crew members and facilitate movement in the payload bay. The handrails are designed to withstand a load of 200 pounds, or 280 pounds maximum, in any direction. Tether attach points are designed to sustain a load of 574 pounds, 804 pounds maximum, in any direction.

The handrails have a cross section of 1.32 inches by 0.75 inch. They are made of aluminum alloy tubing and are painted yellow. The end braces and side struts of the handrails are constructed of titanium. An aluminum alloy end support standoff functions as the terminal of the handrail. Each end support standoff incorporates a 1-inch-diameter tether point.

A 25-foot safety tether is attached to each crew member at all times during an EVA.

The tether consists of a reel case with an integral D-ring, a reel with a light takeup spring, a cable and a locking hook. The safety tether hook is locked onto the slidewire before launch, and the cable is routed and clipped along the left and right handrails to a position just above the airlock and payload bay hatch. After opening the airlock hatch but before leaving the airlock, the crew member attaches a waist tether to the D-ring of the safety tether to be used. The other end of the waist tether is hooked to a ring on the EMU waist bearing. The crew member may select either the left or the right safety tether. With the selector on the tether in the locked position, the cable will not retract or reel out. Moving the selector to the unlocked position allows the cable to reel out and the retract feature to take up slack. The cable is designed for a maximum load of 878 pounds. The routing of the tethers follows the handrails, which allows the crew member to deploy and restow his tether during translation.

The two slidewires, approximately 46.3 feet long, are located in the longeron sill area on each side of the payload bay. They start approximately 9.3 feet aft of the forward bulkhead and extend approximately 46.3 feet down the payload bay. The slidewires withstand a tether load of 574 pounds with a safety factor of 1.4 or 804 pounds maximum.

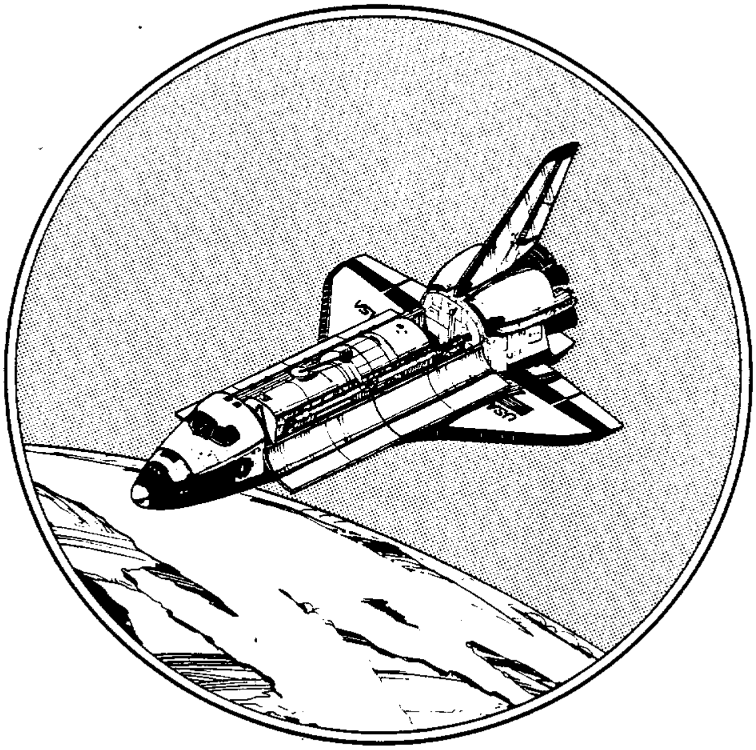
EVA support equipment may consist of a small work station, tool caddies and equipment tethers. The work station contains a universal attachment tether for crew member restraint and a carrying location for the tool caddies. The caddies hold the tools and provide tethers for them when they are not in use.

. A cargo bay stowage assembly installed in the orbiter payload bay contains miscellaneous tools for use in the payload bay during an EVA. The CBSA is approximately 42 inches wide, 24 inches deep and 36 inches high. The CBSA weighs 573 pounds.

The airlock and cabin hatch has two pressure equalization valves that can be operated from both sides of the hatch to repressurize the airlock volume. Each valve has three positions—*closed*, *norm* (normal) and *emerg* (emergency)—and is protected by a debris pressure cap on the intake (high-pressure) side of the valve. The pressure cap on the outer hatch must be vented for removal. The caps are tethered to the valves and also have small Velcro spots that allow them to be stored temporarily on the hatch. The exit side of the valve contains an air diffuser to provide uniform flow out of the valve.

Through the use of the equalization valves, the airlock is initially pressurized to 5 psia, and the space suit is connected to the umbilical in the airlock and electrical power is transferred back to umbilical power. After the airlock is pressurized to the 10.2-psia cabin pressure, the EVA crew members remove and recharge their EMUs. Shortly thereafter, the crew compartment cabin is pressurized from 10.2 psia to 14.7 psia.

The orbiter can accommodate three six-hour EVAs by two crew members per flight at no weight or volume cost to the payload. Two of the EVAs are for payload support; the third is reserved for orbiter contingency. Additional EVAs can be considered with consumables charged to payloads.



STS-31

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

April 1990

Rockwell International
Space Transportation
Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the 10th flight of Discovery and the 35th for the space shuttle.

The flight crew for the STS-31 mission consists of commander Loren J. Shriver, pilot Charles F. Bolden, and mission specialists Steven A. Hawley, Bruce McCandless II and Kathyrn D. Sullivan

The primary objective of this 5-day mission is to deploy the Hubble Space Telescope in earth orbit. The HST is scheduled to be released from Discovery's remote manipulator system at a nominal mission elapsed time of day 1, 5 hours and 23 minutes on orbit 19.

The release of the telescope can be delayed until orbit 20 if extravehicular activity is required for manual deployment of its appendages.

When the telescope has been released by Discovery's mechanical arm, a request for a return rendezvous with it can be made as late as 45 hours after release to accommodate an EVA to open the telescope's aperture door manually. The STS-31 mission would be extended one day if this EVA is required.

Eight secondary payloads are also aboard Discovery in this mission: an IMAX camera located in crew compartment in addition to an IMAX cargo bay camera for filming Hubble Space Telescope deployment and Earth observations; a protein crystal growth experiment, an investigation into membrane processing, a student experiment and a radiation monitoring experiment located in the crew compartment; an ascent particle monitor experiment located in the payload bay; and the Air Force Maui Optical Site experiment to collect signature data of Discovery as it passes over Mt. Haleakala on Maui, Hawaii.

Discovery's STS-31 mission is the first flight of the new main landing gear carbon brakes. The brakes consist of five carbon rotors splined to the inside of the wheel that rotate with the wheel; four carbon stators splined to the outside of the axle assembly do not rotate with the wheel. The goal of the carbon brake program is to increase maximum energy absorption capability to 82 million foot-pounds and to provide a one-time-stop capability of 100 million foot-pounds. The previous improved main landing gear brakes absorbed approximately 65 million foot-pounds.

Because of the deployment of the Hubble Space Telescope, this mission has several additional firsts: highest direct insertion altitude of 330 nautical miles (379 statute miles); longest orbital maneuvering system (OMS-2) thrusting period and deorbit thrusting periods of approximately 4.5 minutes (494 and 527 feet per second, respectively); longest planned reaction control system thrusting period of approximately 2 minutes (limit is 2.5 minutes); longest auxiliary power unit run time of approximately 1 hour, 21 minutes, during deorbit, entry and landing; and two extravehicular mobility units plus a spare EMU upper torso in the event of contingency extravehicular activity requirements to support successful telescope deployment.

MISSION STATISTICS

Launch: The maximum launch-range window for any day of launch will be limited to 4 hours. The launch window duration is 2 hours, 30 minutes, with flight crew on their backs after reaching the first T zero:

4/10/90 8:47 a.m., EDT
7:47 a.m., CDT
5:47 a.m., PDT

Mission Duration: 120 hours (5 days), 1 hour, 15 minutes

Landing: Nominal end of mission is on orbit 76.

4/15/90 10:02 a.m., EDT
9:02 a.m., CDT
7:02 a.m., PDT

Inclination: 28.5 degrees

Ascent: The ascent profile for this mission is a direct insertion. Only one orbital maneuvering system thrusting maneuver, referred to as OMS-2, is used to achieve insertion into orbit. This direct-insertion profile lofts the trajectory to provide the earliest opportunity for orbit in the event of a problem with a space shuttle main engine.

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 2 minutes is eliminated in this direct-insertion ascent profile. The OMS-1 thrusting maneuver is replaced by a 5-foot-per-second reaction control system maneuver to facilitate the main propulsion system propellant dump.

Altitude: 310 by 330 nautical miles (356 by 379 statute miles), then circularized at 330 nautical miles (379 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: approximately 4,516,297 pounds

Orbiter Weight, Including Cargo, at Lift-off: approximately 220,662 pounds

Payload Weight Up: approximately 28,784 pounds

Payload Weight Down: approximately 4,937 pounds

Orbiter Weight at Landing: approximately 189,655 pounds

Payloads: Hubble Space Telescope, IMAX camera in payload bay and middeck, protein crystal growth III-03, investigation into polymer membranes processing 01, Air Force Maui Optical Site 05, radiation monitoring equipment III-01, student experiment 82-16 and ascent particle monitor 01.

Flight Crew Members:
Commander: Loren J. Shriver, second space shuttle flight
Pilot: Charles F. Bolden, second space shuttle flight
Mission Specialist 1: Bruce McCandless II, second space shuttle flight
Mission Specialist 2: Steven A. Hawley, third space shuttle flight
Mission Specialist 3: Kathyrn D. Sullivan, second space shuttle flight

Ascent Seating:
  Flight deck front left seat, commander Loren Shriver
  Flight deck front right seat, pilot Charles Bolden
  Flight deck aft center seat, MS-2, Steven Hawley
  Flight deck aft right seat, MS-1, Bruce McCandless II
  Middeck, MS-3, Kathyrn Sullivan

Entry Seating:
  Flight deck aft center seat, MS-2, Steven Hawley
  Flight deck aft right seat, MS-3, Kathyrn Sullivan
  Middeck, MS-1, Bruce McCandless II

Extravehicular Activity Crew Members, If Required:
  Extravehicular astronaut 1, Bruce McCandless II; EV-2, Kathyrn Sullivan

Entry Angle of Attack: 40 degrees

Entry: Automatic mode until subsonic, then control stick steering

Runway: Nominal end-of-mission landing on lake bed runway 17, Edwards Air Force Base, CA

Notes:

- The remote manipulator is installed in Discovery's payload bay for the deployment of the HST. The galley is installed in the middeck.

- The text and graphics system is the primary text uplink and can only uplink images using the Ku-band. TAGS consists of a facsimile scanner on the ground that sends text and graphics through the Ku-band communication system to the text and graphics hard copier in the orbiter. The hard copier is installed on a dual cold plate in avionics bay 3 of the crew compartment middeck and provides an on-orbit capability to transmit text material, maps, schematics, maneuver pads, general messages, crew procedures, trajectory and photographs to the orbiter through the two-way Ku-band link using the Tracking and Data Relay Satellite system. It is a high-resolution facsimile system that scans text or graphics and converts the analog scan data into serial digital data. Transmission time for an 8.5- by 11-inch page can vary from approximately 1 minute to 16 minutes, depending on the hard-copy resolution desired.

  The text and graphics hard copier operates by mechanically feeding paper over a fiber-optic cathode-ray tube and then through a heater-developer. The paper then is cut and stored in a tray accessible to the flight crew. A maximum of 200 8.5- by 11-inch sheets are stored. The status of the hard copier is indicated by front panel lights and downlink telemetry.

  The hard copier can be powered from the ground or by the crew.

  Uplink operations are controlled by the Mission Control Center in Houston. Mission Control powers up the hard copier and then sends the message. In the on-board system, light-sensitive paper is exposed, cut and developed. The message is then sent to the paper tray, where it is retrieved by the flight crew.

  The teleprinter provides a backup on-orbit capability to receive and reproduce text-only data, such as procedures, weather reports and crew activity plan updates or changes, from the Mission Control Center in Houston. The teleprinter uses the S-band and is not dependent on the TDRS Ku-band. It is a modified teletype machine located in a locker in the crew compartment middeck.

  The teleprinter uplink requires one to 2.5 minutes per message, depending on the number of lines (up to 66). When the ground has sent a message, a *msg rcv* yellow light on the teleprinter is illuminated to indicate a message is waiting to be removed.

MISSION OBJECTIVES

- Deployment of the HST
- Secondary payloads
  - IMAX cameras in payload bay and in middeck.
  - PCG-III-03
  - IPMP-01
  - AMOS-05
  - RME III-01
  - SE 82-16
  - APM-01

DEVELOPMENT TEST OBJECTIVES

- Gravity-gradient attitude control
- Ascent structural capability evaluation
- Entry structural capability
- Direct external tank insertion
- Crew module distortion
- Entry aerodynamic control surfaces test
- Ascent compartment venting
- Descent compartment venting
- Vibration and acoustic levels
- Cabin growth
- Microbial filter resin

DETAILED SUPPLEMENTARY OBJECTIVES

- Noninvasive estimation of central venous pressure
- In-flight radiation dose distribution
- In-flight intraocular pressure
- Delayed-type hypersensitivity
- Hyperosmotic fluid countermeasure
- Documentary television
- Documentary motion picture photography
- Documentary still photography

PRELAUNCH COUNTDOWN

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
06:00:00	Verification of the launch commit criteria is complete at this time. The liquid oxygen and liquid hydrogen systems chill-down commences in order to condition the ground line and valves as well as the external tank (ET) for cryo loading. Orbiter fuel cell power plant activation is performed.
05:50:00	The space shuttle main engine (SSME) liquid hydrogen chill-down sequence is initiated by the launch processing system (LPS). The liquid hydrogen recirculation valves are opened and start the liquid hydrogen recirculation pumps. As part of the chill-down sequence, the liquid hydrogen prevalves are closed and remain closed until T minus 9.5 seconds.
05:30:00	Liquid oxygen chill-down is complete. The liquid oxygen loading begins. The liquid oxygen loading starts with a "slow fill" in order to acclimate the ET. Slow fill continues until the tank is 2-percent full.
05:15:00	The liquid oxygen and liquid hydrogen slow fill is complete and the fast fill begins. The liquid oxygen and liquid hydrogen fast fill will continue until that tank is 98-percent full.
05:00:00	The calibration of the inertial measurement units (IMUs) starts. The three IMUs are used by the orbiter navigation systems to determine the position of the orbiter in flight.
04:30:00	The orbiter fuel cell power plant activation is complete.
04:00:00	The Merritt Island (MILA) antenna, which transmits and receives communications, telemetry and ranging information, alignment verification begins.
03:45:00	The liquid hydrogen fast fill to 98 percent is complete, and a slow topping-off process is begun and stabilized to 100 percent.
03:30:00	The liquid oxygen fast fill is complete to 98 percent.
03:20:00	The main propulsion system (MPS) helium tanks begin filling from 2,000 psi to their full pressure of 4,500 psi.
03:15:00	Liquid hydrogen stable replenishment begins and continues until just minutes prior to T minus zero.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
03:10:00	Liquid oxygen stable replenishment begins and continues until just minutes prior to T-0.
03:00:00	The MILA antenna alignment is completed.
03:00:00	The orbiter closeout crew goes to the launch pad and prepares the orbiter crew compartment for flight crew ingress.
03:00:00 Holding	Begin 2-hour planned hold. An inspection team examines the ET for ice or frost formation on the launch pad during this hold.
03:00:00 Counting	Two-hour planned hold ends.
02:30:00	Flight crew departs Operations and Checkout (O&C) Building for launch pad.
02:00:00	Checking of the launch commit criteria starts at this time.
02:00:00	The ground launch sequencer (GLS) software is initialized.
01:50:00	Flight crew orbiter and seat ingress occurs.
01:50:00	The solid rocket boosters' (SRBs') hydraulic pumping units' gas generator heaters are turned on and the SRBs' aft skirt gaseous nitrogen purge starts.
01:50:00	The SRB rate gyro assemblies (RGAs) are turned on. The RGAs are used by the orbiter's navigation system to determine rates of motion of the SRBs during first-stage flight.
01:35:00	The orbiter accelerometer assemblies (AAs) are powered up.
01:35:00	The orbiter reaction control system (RCS) control drivers are powered up.
01:35:00	Orbiter crew compartment cabin closeout is completed.
01:30:00	The flight crew starts the communications checks.
01:25:00	The SRB RGA torque test begins.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
01:20:00	Orbiter side hatch is closed.
01:10:00	Orbiter side hatch seal and cabin leak checks are performed.
01:10:00	IMU preflight align begins.
01:00:00	The orbiter RGAs and AAs are tested.
00:50:00	The flight crew starts the orbiter hydraulic auxiliary power units' (APUs') H_2O (water) boilers preactivation.
00:45:00	Cabin vent redundancy check is performed.
00:45:00	The GLS mainline activation is performed.
00:40:00	The eastern test range (ETR) shuttle range safety system (SRSS) terminal count closed-loop test is accomplished.
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.
00:30:00	The gaseous nitrogen system for the orbital maneuvering system (OMS) engines is pressurized for launch. Crew compartment vent valves are opened.
00:26:00	The ground pyro initiator controllers (PICs) are powered up. They are used to fire the SRB hold-down posts, liquid oxygen and liquid hydrogen tail service mast (TSM), and ET vent arm system pyros at lift-off and the SSME hydrogen gas burn system prior to SSME ignition.
00:25:00	Simultaneous air-to-ground voice communications are checked. Weather aircraft are launched.
00:22:00	The primary avionics software system (PASS) is transferred to the BFS computer in order for both systems to have the same data. In case of a PASS computer system failure, the BFS computer will take over control of the shuttle vehicle during flight.
00:21:00	The crew compartment cabin vent valves are closed.
00:20:00	A 10-minute planned hold starts.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
Hold 10 Minutes	All computer programs in the firing room are verified to ensure that the proper programs are available for the final countdown. The test team is briefed on the recycle options in case of an unplanned hold.
	The landing convoy status is again verified and the landing sites are verified ready for launch.
	The chase planes are manned.
	The IMU preflight alignment is verified complete.
	Preparations are made to transition the orbiter onboard computers to Major Mode (MM)-101 upon coming out of the hold. This configures the computer memory to a terminal countdown configuration.
00:20:00	The 10-minute hold ends.
Counting	Transition to MM-101. The PASS onboard computers are dumped and compared to verify the proper onboard computer configuration for launch.
00:19:00	The flight crew configures the backup computer to MM-101 and the test team verifies the BFS computer is tracking the PASS computer systems. The flight crew members configure their instruments for launch.
00:18:00	The Mission Control Center-Houston (MCC-H) now loads the onboard computers with the proper guidance parameters based on the prestated lift-off time.
00:16:00	The MPS helium system is reconfigured by the flight crew for launch.
00:15:00	The OMS/RCS crossfeed valves are configured for launch.
	The chase aircraft engines are started.
	All test support team members verify they are "go for launch."
00:12:00	Emergency aircraft and personnel are verified on station.
00:10:00	All orbiter aerosurfaces and actuators are verified to be in the proper configuration for hydraulic pressure application. The NASA test director gets a "go for launch" verification from the launch team.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:09:00 Hold 10 Minutes	A planned 10-minute hold starts. NASA and contractor project managers will be formally polled by the deputy director of NASA, National Space Transportation System (NSTS) Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records. All test support team members verify that they are "go for launch." Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins. The chase aircraft are launched. From this point the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the onboard orbiter PASS redundant-set computers.
00:09:00	Operations recorders are on. MCC-H, Johnson Space Center, sends a command to turn these recorders on. They record shuttle system performance during ascent and are dumped to the ground once orbit is achieved.
00:08:00	Payload and stored prelaunch commands proceed.
00:07:30	The orbiter access arm (OAA) connecting the access tower and the orbiter side hatch is retracted. If an emergency arises requiring flight crew activation, the arm can be extended either manually or by GLS computer control in approximately 30 seconds or less.
00:05:00	Orbiter APUs start. The orbiter APUs provide pressure to the three orbiter hydraulic systems. These systems are used to move the SSME engine nozzles and aerosurfaces.
00:05:00	ET/SRB range safety system (RSS) is armed. At this point, the firing circuit for SRB ignition and destruct devices is mechanically enabled by a motor-driven switch called a safe and arm device (S&A).

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:04:30	As a preparation for engine start, the SSME main fuel valve heaters are turned off.
00:04:00	The final helium purge sequence, purge sequence 4, on the SSMEs is started in preparation for engine start.
00:03:55	At this point, all of the elevons, body flap, speed brake and rudder are moved through a preprogrammed pattern. This is to ensure that they will be ready for use in flight.
00:03:30	Transfer to internal power is done. Up to this point, power to the space vehicle has been shared between ground power supplies and the onboard fuel cells. The ground power is disconnected and the vehicle goes on internal power at this time. It will remain on internal power through the rest of the mission.
00:03:30	The SSMEs' nozzles are moved (gimbaled) through a preprogrammed pattern to ensure that they will be ready for ascent flight control. At completion of the gimbal profile, the SSMEs' nozzles are in the start position.
00:02:55	ET liquid oxygen prepressurization is started. At this point, the liquid oxygen tank vent valve is closed and the ET liquid oxygen tank is pressurized to its flight pressure of 21 psi.
00:02:50	The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted.
00:02:35	Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the onboard tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:00:38	The onboard computers position the orbiter vent doors to allow payload bay venting upon lift-off and ascent in the payload bay at SSME ignition.
00:00:37	The gaseous oxygen ET arm retract is confirmed.
00:00:31	The GLS sends "go for redundant set launch sequence start." At this point, the four PASS computers take over main control of the terminal count. Only one further command is needed from the ground, "go for main engine start," at approximately T minus 9.7 seconds. The GLS in the integration console in the launch control center still continues to monitor several hundred launch commit criteria and can issue a cutoff if a discrepancy is observed. The GLS also sequences ground equipment and sends selected vehicle commands in the last 31 seconds.
00:00:28	Two hydraulic power units in each SRB are started by the GLS. These provide hydraulic power for SRB nozzle gimbaling for ascent first-stage flight control.
00:00:21	The SRB gimbal profile is complete. As soon as SRB hydraulic power is applied, the SRB engine nozzles are commanded through a preprogrammed pattern to assure that they will be ready for ascent flight control during first stage.
00:00:21	The liquid hydrogen high-point bleed valve is closed.
00:00:18	The onboard computers arm the explosive devices, the pyrotechnic initiator controllers, that will separate the T-0 umbilicals, the SRB hold-down posts, and SRB ignition, which is the final electrical connection between the ground and the shuttle vehicle.
00:00:16	The aft SRB multiplexer/demultiplexer (MDM) units are locked out. This is to protect against electrical interference during flight. The electronic lock requires an unlock command before it will accept any other command.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
	The MPS helium fill is terminated. The MPS helium system flows to the pneumatic control system at each SSME inlet to control various essential functions. The GLS opens the prelift-off valves for the sound suppression water system in order to start water flow to the launch pad.
00:00:15	If the SRB pyro initiator controller (PIC) voltage in the redundant-set launch sequencer (RSLS) is not within limits in 3 seconds, SSME start commands are not issued and the onboard computers proceed to a countdown hold.
00:00:10	SRB SRSS inhibits are removed. The SRB destruct system is now live.
	LPS issues a "go" for SSME start. This is the last required ground command. The ground computers inform the orbiter onboard computers that they have a "go" for SSME start. The GLS retains hold capability until just prior to SRB ignition.
00:00:09.7	Liquid hydrogen recirculation pumps are turned off. The recirculation pumps provide for flow of fuel through the SSMEs during the terminal count. These are supplied by ground power and are powered in preparation for SSME start.
00:00:09.7	In preparation for SSME ignition, flares are ignited under the SSMEs. This burns away any free gaseous hydrogen that may have collected under the SSMEs during prestart operations.
	The orbiter goes on internal cooling at this time; the ground coolant units remain powered on until lift-off as a contingency for an aborted launch. The orbiter will redistribute heat within the orbiter until approximately 125 seconds after lift-off, when the orbiter flash evaporators will be turned on.
00:00:09.5	The SSME engine chill-down sequence is complete and the onboard computers command the three MPS liquid hydrogen prevalves to open. (The MPS's three liquid oxygen prevalves were opened during ET tank loading to permit engine chill-down.) These valves allow liquid hydrogen and oxygen flow to the SSME turbopumps.
00:00:09.5	Command decoders are powered off. The command decoders are units that allow ground control of some onboard components. These units are not needed during flight.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:00:06.6	The main fuel and oxidizer valves in each engine are commanded open by the onboard computers, permitting fuel and oxidizer flow into each SSME for SSME start.
	All three SSMEs are started at 120-millisecond intervals (SSME 3, 2, then 1) and throttle up to 100-percent thrust levels in 3 seconds under control of the SSME controller on each SSME.
00:00:04.6	All three SSMEs are verified to be at 100-percent thrust and the SSMEs are gimbaled to the lift-off position. If one or more of the three SSMEs do not reach 100-percent thrust at this time, all SSMEs are shut down, the SRBs are not ignited, and an RSLS pad abort occurs. The GLS RSLS will perform shuttle and ground systems safing.
	Vehicle bending loads caused by SSME thrust buildup are allowed to initialize before SRB ignition. The vehicle moves towards ET including ET approximately 25.5 inches.
00:00:00	The two SRBs are ignited under command of the four onboard PASS computers, the four hold-down explosive bolts on each SRB are initiated (each bolt is 28 inches long and 3.5 inches in diameter), and the two T-0 umbilicals on each side of the spacecraft are retracted. The onboard timers are started and the ground launch sequence is terminated. All three SSMEs are at 104-percent thrust. Boost guidance in attitude hold.
00:00	Lift-off.

MISSION TIMELINE

DAY ZERO

T PLUS DAY/ HR:MIN:SEC	EVENT
0/00:00:06.8	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:09	Positive roll maneuver (right-clockwise) is started. Pitch profile is heads down (astronauts), wings level.
0/00:00:16	Roll maneuver ends.
0/00:00:28	All three SSMEs throttle down from 104 to 67 percent for maximum aerodynamic load (max q).
0/00:00:52	Max q occurs.
0/00:00:59	All three SSMEs throttle to 104 percent.
0/00:02:06	SRBs separate.
	When chamber pressure (P_C) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse in another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:04:07	Negative return. The vehicle is no longer capable of return-to-launch-site abort at Kennedy Space Center runway.
0/00:06:30	Single engine to main engine cutoff.
0/00:07:28	All three SSMEs throttle down from 104 percent—vehicle acceleration capability no greater than 3g's.
0/00:08:26	All three SSMEs throttle down to 65 percent for MECO.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/00:08:32	MECO occurs at approximate velocity 25,841 feet per second, 325 by 27 nautical miles (374 by 31 statute miles).
0/00:08:50	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	ET liquid oxygen valve is opened at separation to induce ET tumble for Pacific Ocean impact area footprint.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	5-fps RCS maneuver, 11 seconds in duration, facilitates the MPS dump.
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs.
	— Remaining residual propellants are vented to space vacuum, inerting the MPS.

T PLUS DAY/ HR:MIN:SEC	EVENT
	— Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads.
	— MPS vacuum inerting terminates.
0/00:48	OMS-2 thrusting maneuver is performed, approximatly 4.5 minutes in duration, at 494.7 fps, 311 by 331 nautical miles (357 by 380 statute miles).
0/00:53	Mission specialist leaves seat.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS sets preliminary middeck configuration.
0/00:59	MS sets aft flight station configuration.
0/01:08	PLT activates payload bus.
0/01:10	CDR and PLT configure communications.
0/01:12	PLT maneuvers vehicle to payload bay door opening attitude, negative Z local vertical attitude.
0/01:16	Orbit 2 begins.
0/01:17	Commander activates radiators.
0/01:19	MS configures for payload bay door operations.
0/01:28	PLT opens payload bay doors in automatic mode.
0/01:29	CDR loads payload data interleaver.
0/01:35	CDR, at panel 06, turns on star tracker power.
0/01:36	Mission Control Center in Houston gives "go for orbit operations."
0/01:37	CDR and PLT leave seats.
0/01:38	CDR and PLT configure clothing.
0/01:39	MSs configure clothing.
0/01:49	CDR deploys Ku-band antenna.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/01:50	PLT performs fuel cell auto purge.
0/01:51	MS activates teleprinter.
0/01:52	CDR configures post-payload-bay-door radiator operations.
0/01:55	MS removes and stows specialist seats.
0/01:56	CDR conducts tracker self-test/door open.
0/01:57	PLT, at panel ML86B:A, sets circuit breaker *supply H_2O dump isolation* to closed, panel R12L, *supply H_2O dump isolation valve*, to open.
0/01:58	MS configures middeck.
0/02:00	MS performs extravehicular activity aspirin protocol.
0/02:01	PLT activates APU steam vent heater—panel R2, *boiler controller/heater,* 3 to A, *power*, 3 to on.
0/02:03	CDR activates Ku-band in communication mode.
0/02:10	CDR configures for vernier RCS control.
0/02:12	CDR and PLT configure controls for on-orbit operations, install heads-up display covers.
0/02:19	MS configures remote manipulator system.
0/02:20	PLT enables hydraulic systems thermal conditioning, panel R2, *hydraulic circulation pump,* 3 to MNA
	FLIGHT PLAN EZ ACTIVITIES
	— LES cleaning and drying, 25 minutes
	— Lamp and fire suppression test, 10 minutes
	— Food preparation, 30 minutes
0/02:24	MS resets caution/warning system.
0/02:25	Vehicle maneuvers to IMU alignment attitude.
0/02:26	MS unstows and installs treadmill in middeck.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/02:28	PLT switches APU coolant system, panel R2, *APU fuel pump/valve cool,* A to off and B to auto.
0/02:29	PLT plots fuel cell performance.
0/02:31	Remote manipulator system is powered up.
0/02:31	MSs, Bruce McCandless (EV-1) and Kathryn Sullivan (EV-2), initiate 100-percent oxygen prebreathe in helmet retention assembly prior to 10.2-psi cabin depressurization.
0/02:40	IMU is aligned using star tracker.
0/02:40	Extravehicular activity equipment is prepared.
0/02:45	Vehicle is maneuvered to biased negative Z local vertical, positive Y velocity vector attitude.
0/02:45	RMS is checked out.
0/02:45	Photo/TV equipment is set up for Space Telescope.
0/02:52	Orbit 3 begins.
0/03:06	Systems management cockpit initiation, orbit operations.
0/03:10	All crew members unstow cabin equipment.
0/03:21	Preparation is made for depressurization of crew cabin from 14.7 to 10.2 psia.
0/03:30	Photo/TV equipment is activated—HST inspection scenes.
0/03:30	Crew cabin is depressurized from 14.7 to 10.2 psia.
0/03:40	APU steam vent heater is deactivated, *boiler power,* 3 to off, panel R2.
0/03:50	RMS is powered down.
0/04:00	APU cool-off begins, panel R2, *APU fuel pump/valve cool,* B to off.
0/04:05	Crew cabin is configured for 10.2 psia.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/04:05	Bruce McCandless and Kathryn Sullivan terminate HRA prebreathe of 100-percent oxygen.
0/04:05	Payload interleaver configuration for HST in bay is checked out.
0/04:11	Autonomous payload controller is unstowed and set up.
0/04:16	Aft flight deck controllers are checked out.
0/04:20	Radiation dosimeter, medical detailed supplementary objective, is set up.
0/04:20	IMAX cargo bay camera main power is turned on.
0/04:25	Environmental control and life support system cryogenic oxygen tank heater sensor is checked.
0/04:29	Orbit 4 begins.
0/04:35	All crew members eat.
0/05:06	HST main bus is activated for in-bay checkout.
0/05:30	The three extravehicular mobility units are checked out.
0/05:35	Photo/TV camera is assembled.
0/05:45	*APU heater gas generator/fuel pump,* 3 is set to A (auto), panel A12.
0/05:51	Video tape recorder is set up for HST inspection.
0/06:05	Orbit 5 begins.
0/06:05	VTR is played back; HST inspection at Tracking and Data Relay Satellite West from 0/06:05 to 0/06:25.
0/07:11	RCS thrusting maneuver is performed, 32.2 fps, 330 by 331 nautical miles (379 by 380 statute miles).
0/07:15	Vehicle is maneuvered to biased negative Z local vertical, negative Y velocity vector attitude.
0/07:42	Orbit 6 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/07:50	Radiation monitoring equipment is activated/ checked out.
0/07:50	Protein crystal growth experiment is set at 22 degrees.
0/08:05	Crew begins presleep activity.
0/08:06	Central venous pressure, medical DSO, is taken.
0/08:30	Coarse optical alignment sight, panel 01, is set to off; COAS is mounted forward.
0/08:35	Crew has private medical conference.
0/08:50	Vehicle is maneuvered to IMU alignment attitude.
0/08:50	Central venous pressure, medical DSO, is taken.
0/08:58	IMU is aligned using ST.
0/09:04	Vehicle is maneuvered to COAS calibration attitude.
0/09:10	COAS is calibrated.
0/09:18	Orbit 7 begins.
0/09:25	Vehicle is maneuvered to biased negative Z local vertical, negative Y velocity vector attitude.
0/09:40	Digital autopilot B is changed to B1.
0/09:45	Panel 01, *COAS*, is set to off; COAS is stowed.
0/09:55	Panel L1, *radiator controller outlet temperature*, is set to normal; then, immediately, *flash evaporator controller primary*, A is set to off, B to on.
0/10:55	Orbit 8 begins.
0/11:05	Crew begins 8-hour sleep period.
0/12:32	Orbit 9 begins.
0/14:09	Orbit 10 begins.
0/15:46	Orbit 11 begins.
0/17:22	Orbit 12 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/18:59	Orbit 13 begins.
0/19:05	Crew ends 8-hour sleep period; begins postsleep activity.
	FLIGHT PLAN EZ ACTIVITIES
	— One-hour exercise period for all crew members
	— Food preparation, 30 minutes
	— PCG fan inlet cleaning and temperature check
0/19:30	Panel L1, *flash evaporator controller primary,* A, B are set to off.
0/19:40	IMU is aligned using ST.
0/19:55	Rate gyro assembly for HST checkout is commanded from ground.
0/20:20	IMU is aligned using ST.
0/20:35	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
0/20:35	Panel L1, *flash evaporator controller primary,* A, B are set to on.
0/20:36	Orbit 14 begins.
0/20:50	Supply water dump is initiated.
0/21:11	Central venous pressure, medical DSO, is taken.
0/21:40	Private medical conference is held.
0/21:55	Panel A8L, *port RMS heater,* 2 is set to auto.
0/22:06	Photo/TV equipment is set up on flight deck for HST deployment.
0/22:07	IMAX camera is unstowed.
0/22:13	Orbit 15 begins.
0/22:21	Photo/TV equipment is set up on flight deck.
0/22:22	IMAX camera is set up.

T PLUS DAY/ HR:MIN:SEC	EVENT
0/22:31	Bruce McCandless and Kathryn Sullivan prepare for EVA; Charles Bolden prepares for intravehicular activity.
0/22:45	Vehicle is maneuvered to HST appendage deployment attitude.
0/22:57	RMS is powered up.
0/23:01	HST radar self-test is performed.
0/23:05	Panel L1, *flash evaporator controller primary,* A, B are set to off.
0/23:10	Photo/TV and HST deployment activities take place.
0/23:18	HST is grappled by RMS.
0/23:23	Payload retention latch assemblies are released so that HST can move from payload bay on RMS.
0/23:36	HST is transferred to internal power.
0/23:43	Deadface umbilical between HST and Discovery.
0/23:47	HST umbilical disconnects from Discovery.
0/23:50	Orbit 16 begins.
0/23:51	HST is unberthed from Discovery's payload bay; RMS moves HST to low hover position.
DAY ONE	
1/00:12	HST is positioned by RMS to high hover.
1/00:35	Vehicle is maneuvered to HST appendage deployment attitude.
1/00:45	HST preappendage deployment is performed by ground command.
1/01:14	HST solar array primary deployment mechanism is activated by ground command.
1/01:14	Flight crew is told to go to free-drift attitude.

T PLUS DAY/ HR:MIN:SEC	EVENT
1/01:26	Orbit 17 begins.
1/01:38	Flight crew is told to go to attitude control.
1/01:43	Early TDRS handover uplink occurs—Ku-band only.
1/01:47	Flight crew is told to go to free-drift attitude.
1/01:48	HST solar array secondary deployment mechanism is activated by ground command; solar arrays unfurl.
	To support nominal HST deployment, Bruce McCandless and Kathryn Sullivan have been designated as EV-1 and EV-2, respectively. In order to perform expedient extravehicular activity, if required, McCandless and Sullivan will have donned their respective liquid-cooled ventilation garments and portions of the extravehicular mobility units.
	When Discovery's flight crew receives a "go" for HST release, EV-1 and EV-2 continue to complete the remainder of the EMU donning and prebreathing.
	If an EVA is required, they are given a "go" for airlock depressurization. The requirement for EVA would delay the release of HST to orbit 20.
1/02:00	All crew members eat.
1/02:06	Flight crew is told to go to free-drift attitude.
1/02:07	HST solar array secondary deploy mechanism is activated by ground command.
1/02:18	Flight crew is told to go to attitude control.
1/02:20	HST power is reconfigured and aperture door latch is released.
1/03:03	Orbit 18 begins.
1/03:08	HST high-gain antenna is deployed by ground command.
1/04:25	Vehicle is maneuvered to HST release attitude.

T PLUS DAY/ HR:MIN:SEC	EVENT
1/04:25	Aft flight station is configured for HST release.
1/04:40	Orbit 19 begins.
1/04:41	HST is positioned for release by RMS.
1/05:23	RMS releases HST in earth orbit.
1/05:24	Discovery performs separation (SEP-1) thrusting maneuver, 0.6 fps, 330 by 332 nautical miles (379 by 382 statute miles).
1/05:51	Discovery performs SEP-2 thrusting maneuver, 1 fps, 331 by 332 nautical miles (380 by 382 statute miles).
1/05:56	RMS is powered down but manipulator positioning mechanisms are not stowed.
1/06:00	Post-EVA activities are performed by EV-1, EV-2, and IV-1 (Charles Bolden).
1/06:00	Discovery performs postrelease operations.
1/06:06	VTR of HST deployment is set up.
1/06:17	Orbit 20 begins.
1/06:23	DAP A, B, are configured to A1, B1.
0/06:31	Investigation into polymer membrane processing is activated.
1/06:31	Photo/TV equipment is set up for PCG scenes.
1/06:35	Panel L1, *flash evaporator controller primary,* A, B are set to on.
1/06:40	Ku-band is configured for communication.
1/06:40	Panel L1, *radiator controller outlet temperature*, is set to high.
1/06:45	VTR of HST deployment is played back from 1/06:45 to 1/07:15.
1/07:01	PCG seeding is set at 22 degrees.
1/07:01	Photo/TV equipment is activated for PCG.

T PLUS DAY/ HR:MIN:SEC	EVENT
1/07:15	Filter cleaning, inflight maintenance, scheduled maintenance are performed.
1/07:30	Vehicle is maneuvered to IMU align attitude.
1/07:45	IMU is aligned using ST.
1/07:50	Vehicle is maneuvered to negative Y local vertical, negative Z velocity vector attitude.
1/07:54	Orbit 21 begins.
1/08:00	Central venous pressure; medical DSO, is measured.
1/08:00	Crew begins pre-sleep activity.
1/08:30	Intraocular pressure, medical DSO, is measured.
1/08:35	Star tracker target for HST is acquired.
1/08:50	Private medical conference.
1/09:05	Today's IMAX scenes and film usage are reported.
1/09:16	Radar navigation for normal corrective (NC)-1 thrusting maneuver is performed.
1/09:31	Orbit 22 begins.
1/09:40	Ku-band for communications is configured.
1/10:42	NC-1 thrusting maneuver is performed.
1/10:56	Panel L1, *radiator controller outlet temperature, normal,* then immediately, *flash evaporator controller primary* A is set to off, (B) to on.
1/11:00	Crew begins 8-hour sleep period.
1/11:07	Orbit 23 begins.
1/12:44	Orbit 24 begins.
1/14:21	Orbit 25 begins.
1/15:58	Orbit 26 begins.
1/17:35	Orbit 27 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
1/19:00	Crew ends 8-hour sleep period; post-sleep activity begins.
	FLIGHT PLAN EZ ACTIVITIES
	— All crew members exercise for 1 hour
	— Food preparation, 30 minutes
	— PCG fan inlet is cleaned and temperature is checked
1/19:11	Orbit 28 begins.
1/20:05	Central venous pressure, medical DSO, is measured.
1/20:05	Manual fuel cell is purged.
1/20:25	Vehicle is maneuvered to IMU align attitude.
1/20:45	IMU is aligned using ST.
1/20:45	Vehicle is maneuvered to biased plus X local vertical, negative Y velocity vector attitude.
1/20:48	Orbit 29 begins.
1/21:12	On-orbit RCS thrusting period begins and normal height adjust maneuver (NH)-1 is performed.
1/21:20	Interocular pressure, medical DSO, is measured.
1/22:01	On-orbit RCS thrusting period, normal slow rate maneuver (NSR)-1 begins.
1/22:05	Supply water dump is performed.
1/22:10	Photo/TV equipment is set up: IMAX scenes and PCG.
1/22:25	Orbit 30 begins.
0/22:30	Photo/TV PCG is activated.
0/22:30	PCG is seeded at 22 degrees.
1/23:05	Photo/TV setup is activated: IMAX, earth scenes.

T PLUS DAY/ HR:MIN:SEC	EVENT
1/23:20	Vehicle is in gravity gradient free drift, positive X local vertical, positive Y velocity vector attitude.
1/23:20	Photo/TV equipment is set up for middeck scenes.
1/23:30	RCS regulator is reconfigured, Panel 07/08, *helium pressure,* A, three to *open,* B, three to *open,* then GPC, A, three to *close*.
1/23:45	Photo/TV setup is activated for middeck scenes.
1/23:50	RCS heater is reconfigured to B.
1/23:50	Student Experiment (SE) 82-16, investigation of Arc and Ion behavior in microgravity (ION ARC), is performed.

DAY TWO

T PLUS DAY/ HR:MIN:SEC	EVENT
2/00:02	Orbit 31 begins.
2/00:55	Photo/TV setup is activated: IMAX, Okavango Swamp, Botswana.
2/01:05	Panel MD 44F, pin *cabin temperature controller* activator linkage to actuator 2, Panel L1, *cabin temperature controller* is set to 2.
2/01:25	Humidity separator reconfiguration, Panel L1, *humidity separator* B is set to *off,* A to *on.*
2/01:35	RME memory module is replaced.
2/01:39	Orbit 32 begins.
2/02:00	Meal time begins for all crew members.
2/03:00	Panel L1, *radiator controller outlet temperature,* is to high.
2/03:15	Orbit 33 begins.
2/03:55	Photo/TV setup is activated: IMAX, Isthmus of Panama.
2/04:52	Orbit 34 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
2/05:30	Photo/TV setup is activated: IMAX, Galapagos Islands, Peruvian Andes, Rio de Janeiro, and Sao Paulo, Brazil.
2/06:29	Orbit 35 begins.
2/07:00	Crew begins pre-sleep activity.
2/07:00	Today's IMAX scenes and film usage are reported.
2/07:45	Configuration of DAP, A, B, to A1, B1 is accomplished.
2/07:45	Vehicle is maneuvered to IMU align attitude.
2/08:05	IMU is aligned using ST.
2/08:05	Central venous pressure, medical DSO, is measured.
2/08:05	Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude.
2/08:06	Orbit 36 begins.
2/08:30	Panel L1, *radiator controller outlet temperature* is set to *normal*; then immediately *flash evaporator controller primary* A, B is set to off, on.
2/08:30	Intraocular pressure, medical DSO, is measured.
2/09:20	On-orbit RCS thrusting period, normal corrective (NC)-2 is performed.
2/09:43	Orbit 37 begins.
2/10:00	Crew begins 8-hour sleep period.
2/11:19	Orbit 38 begins.
2/12:56	Orbit 39 begins.
2/14:33	Orbit 40 begins.
2/16:10	Orbit 41 begins.
2/17:47	Orbit 42 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
2/18:00	Crew ends 8-hour sleep period; post-sleep activities begin. FLIGHT PLAN EZ ACTIVITIES — All crew members exercise for 1 hour — Food preparation, 30 minutes — PCG fan inlet is cleaned and temperature checked
2/18:25	Vehicle is maneuvered to biased negative Z local vertical, negative Y velocity vector attitude.
2/18:40	Supply water dump is performed.
2/19:24	Orbit 43 begins.
2/20:00	Central venous pressure, medical DSO, is measured.
2/20:04	On-orbit RCS thrusting period, NC-3, operations are performed.
2/20:30	Intraocular pressure, medical DSO, is measured.
2/20:40	Vehicle is maneuvered to IMU align attitude.
2/21:00	IMU aligned using ST.
2/21:00	Orbit 44 begins.
2/21:00	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
2/21:00	Photo/TV equipment is set up for IMAX scenes.
2/21:01	Orbit 44 begins.
2/21:35	Panel L1, *flash evaporator controller primary,* A, B are set to off.
2/21:40	IMAX ICBC standby is enabled.
2/21:40	Photo/TV setup is activated; IMAX scenes, Kenya Rift Valley.
2/21:50	Photo/TV setup is activated; IMAX scenes, Madagascar, ICBC activation.

T PLUS DAY/ HR:MIN:SEC	EVENT
2/22:05	Panel L1 *flash evaporator controller primary,* A, B are set to on.
2/22:10	*IMAX, ICBC standby* is disabled.
2/22:37	Orbit 45 begins.
DAY THREE	
3/00:14	Orbiter 46 begins.
3/00:45	Panel L1 *flash evaporator controller primary A, B,* are set to off.
3/00:45	*IMAX, ICBC standby* is enabled.
3/01:05	Photo/TV equipment is activated: IMAX, ICBC activation, Namib Desert.
3/01:10	Photo/TV equipment is activated: IMAX scenes, Okavango Swamp, Botswana.
3/01:15	Crew members eat.
3/01:51	Orbit 47 begins.
3/02:20	Photo/TV equipment is activated: IMAX scenes, ICBC activation, Cuba, Jamaica, Haiti, West Indies.

In the event the aperture door of the HST fails to open by ground command, a request for a rendezvous of Discovery for return to the HST can be made as late as HST nominal release plus 45 hours (a mission elapsed time of day 3, 2 hours, and 23 minutes).

An EVA would be required by the Discovery EV-1 and EV-2 crew members to manually open the aperture door.

Upon Discovery's rendezvous with the HST, the ground must slew the HST solar arrays and command the high-gain antennas to be retracted prior to the grapple of HST by Discovery's PMS.

T PLUS DAY/ HR:MIN:SEC	EVENT
	The EV-1 and EV-2 crew members will don the EMUs for the EVA and prebreathe 100-percent oxygen in the EMU for 40 minutes before the airlock is depressurized for the EVA. The crew compartment would still be pressurized at 10.2 psia at this time.
	Once Discovery's RMS has grappled HST, EV-1 and EV-2 would proceed into the EVA to manually open the HST aperture door. This task is estimated to take approximately 15 minutes.
	After manually opening the aperture door, EV-1 and EV-2 will remain available to support manual deployment of the high-gain antenna, if required; then they will complete the EVA by repressurizing th airlock. The RMS would then release the HST in earth orbit on orbit 63
	If this EVA is required, the STS-31 mission would be extended an additional day.
3/02:25	Photo/TV equipment is activated: IMAX scenes, French Guiana coast.
3/02:40	Photo/TV equipment is activated: IMAX scenes, ICBC activation, mouths of the Amazon.
3/02:55	Delayed hypersensitivity, medical DSO, is measured.
3/02:55	Panel L1 *flash evaporator controller primary, A, B* are set to on.
3/03:10	*IMAX ICBC standby* is disabled.
3/03:28	Orbit 48 begins.
3/03:40	RME memory module is replaced.
3/04:10	Photo/TV equipment is activated: IMAX, Isthmus of Panama.
3/04:35	RMS is powered down.
3/04:50	Crew cabin is repressurized to 14.7 psia.
3/04:50	Photo/TV equipment is set up for middeck scenes.
3/05:04	Orbit 49 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
3/05:20	Photo/TV equipment is activated for middeck scenes.
3/05:20	Post-EVA preparation are made.
3/05:35	Panel 019, COAS power is set to off; COAS is mounted aft.
3/05:35	Planel L1 *flash evaporator controller primary,* A, B are set to off.
3/05:35	*IMAX, ICBC standby* is enabled.
3/05:50	Photo/TV equipment is activated: IMAX scenes; Peruvian Andes.
3/05:50	Photo/TV equipment is activated: IMAX scenes; ICBC is activated, Andes, Lake Titicaca.
3/06:00	Crew begins pre-sleep activity.
3/06:10	Panel L1 *flash evaporator control primary, A, B* are set to on.
3/06:17	NH-2 thrusting maneuver is performed, 2 fps, 329 by 330 nautical miles (378 by 379 statute miles).
3/06:20	*IMAX, ICBC standby* is disabled.
3/06:20	Vehicle is maneuvered to IMU align attitude.
3/06:40	IMU is aligned using ST.
3/06:41	Orbit 50 begins.
3/06:45	COAS is calibrated.
3/06:50	Panel 019, *COAS* set to power off; COAS is stowed.
3/06:50	Today's IMAX scenes and film usage are reported.
3/07:05	On-orbit RCS thrusting period, NSR-2, is accomplished.
3/07:10	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
3/07:10	Central venous pressure, medical DSO, is measured.

T PLUS DAY/ HR:MIN:SEC	EVENT
3/07:30	Supply water dump is performed.
3/07:45	Intraocular pressure, medical DSO, is measured.
3/08:20	Waste water dump is accomplished.
3/08:18	Orbit 51 begins.
3/09:00	Crew begins 8-hour sleep period.
3/09:55	Orbit 52 begins.
3/11:31	Orbit 53 begins.
3/13:08	Orbit 54 begins.
3/14:45	Orbit 55 begins.
3/16:21	Orbit 56 begins.
3/17:00	Crew ends 8-hour sleep period, and begins post-sleep activity.
	FLIGHT PLAN EZ ACTIVITIES
	— Crew exercises for 1 hour.
	— Food preparation, 30 minutes.
	— PCG fan inlet cleaned and temperature checked.
	Note: One extra container of fluid is to be consumed with meal.
3/17:58	Orbit 57 begins.
3/18:20	Supply water dump is accomplished.
3/18:35	Central venous pressure, medical DSO, is measured.
3/19:05	Intraocular pressure, medical DSO, is measured.
3/19:15	Vehicle is maneuvered to IMU align attitude.
3/19:35	IMU is aligned using ST.
3/19:35	Orbit 58 begins.
3/19:35	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.

T PLUS DAY/ HR:MIN:SEC	EVENT
3/19:35	Photo/TV equipment is set up for IMAX scene.
3/19:55	APU *steam vent heater* is activated; *boiler controller/heater*, 3 is set to B, *power*, 3 is set to on.
3/20:05	Photo/TV equipment is activated: IMAX scenes, Niger River, Kenya Rift Valley.
3/20:20	Flight control system is checked out.
3/20:20	Photo/TV equipment is set up for crew conference opportunity scenes.
3/21:12	Orbit 59 begins.
3/21:40	RCS hot fire test is performed.
3/21:50	DAP is configured, A to A1
3/21:55	Photo/TV equipment is set up for PCG scenes.
3/21:55	Photo/TV equipment is set up for IMAX scenes, Kenya Rift Valley.
3/22:05	Vehicle is maneuvered to TDRS attitude.
3/22:25	Panel R2, *APUCOOL* is set to off; APU *fuel pump/ valve cool A* is set to off.
3/22:25:	Photo/TV equipment is activated for PCG scenes.
3/22:25	PCG is deactivated, 22 degrees.
3/22:48	Orbit 60 begins.
3/22:55	APU heater is reconfigured.
3/23:45	Crew conference opportunity.
3/23:50	Photo/TV equipment is activated for crew conference opportunity scenes.

DAY FOUR

T PLUS DAY/ HR:MIN:SEC	EVENT
4/00:15	Panel L1 *flash evaporator controller primary, A, B* are set to off.
4/00:15	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.

T PLUS DAY/ HR:MIN:SEC	EVENT
4/00:25	Orbit 61 begins.
4/00:40	AMOS RCS test is conducted.
4/01:00	Crew eats meal.
4/02:02	Orbit 62 begins.
4/02:05	Configure *pressure control system* 1 is set to 2.
4/02:23	AMOS RCS test is performed.
4/02:30	*DAP, A1/auto/vernier* are configured.
4/02:30	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
4/02:40	Photo/TV is activated for IMAX scenes, Isthmus of Panama.
4/02:45	APC is stowed for IMAX ICBC.
4/02:45	Panel L1, *flash evaporator control primary, A, B* are set to on.
4/02:50	RME is deactivated and RME is stowed.
4/03:00	DAP B is changed to B1.
4/03:00	Crew cabin stowage is configured.
4/03:05	Radiation dosimetry, medical DSO, is stowed.
4/03:39	Orbit 63 begins.
4/05:15	Orbit 64 begins.
4/06:00	Today's IMAX scenes and film usage are reported.
4/06:00	Crew begins pre-sleep activity.
4/06:30	Vehicle is maneuvered to IMU align attitude.
4/06:50	IMU is aligned using ST.
4/06:50	Central venous pressure, medical DSO, is measured.
4/06:50	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
4/06:52	Orbit 65 begins.

T PLUS DAY/ HR:MIN:SEC	EVENT
4/07:15	Supply water dump is accomplished.
4/07:20	Intraocular pressure, medical DSO, is measured.
4/08:29	Orbit 66 begins.
4/09:00	Crew begins 8-hour sleep period.
4/10:05	Orbit 67 begins.
4/11:42	Orbit 68 begins.
4/13:19	Orbit 69 begins.
4/14:56	Orbit 70 begins.
4/16:32	Orbit 71 begins.
4/17:00	Crew ends 8-hour sleep period, and begins post-sleep activity.
	FLIGHT PLAN EZ ACTIVITIES
	— Air is sampled.
	— Fluid loading preparation; 4-drink containers are filled with 8 ounces H_2O each (per person).
	— Hyperosmotic fluid countermeasures.
4/17:50	Vehicle is maneuvered to IMU align attitude.
4/18:09	Orbit 72 begins.
4/18:10	IMU is aligned using ST.
4/18:10	Vehicle is maneuvered to biased negative X solar inertial.
4/19:05	Central venous pressure, medical DSO, is measured.
4/19:35	Intraocular pressure, medical DSO.
4/19:46	Orbit 73 begins.
4/20:02	Cathode-ray tube (CRT) timer is set up
4/20:06	Coldsoak attitude is initiated.
4/20:17	Crew stows radiators, if required.

T PLUS DAY/ HR:MIN:SEC	EVENT
4/20:35	Crew configures data processing system (DPS) for deorbit preparation.
4/20:37	MCC updates IMU pad, if required.
4/20:47	Crew configures for payload bay door closure.
4/20:57	Crew stows Ku-band antenna, if required.
4/21:04	Vehicle is maneuvered to IMU alignment attitude.
4/21:05	DAP is set to *B/auto/normal*.
4/21:12	Radiator is set to *bypass*, and FES is checked out.
4/21:14	MCC issues "go for payload bay door closure" command.
4/21:18	IMU is aligned with ST.
4/21:22	Payload bay doors are closed.
4/21:23	Orbit 74 begins.
4/21:32	Preliminary deorbit update/uplink occurs.
4/21:34	Entry switch list is verified.
4/21:35	Hydraulic thermal conditioning is performed.
4/21:36	MS seat is installed.
4/21:42	Crew configures dedicated displays.
4/21:45	MCC issues "go for OPS 3" command.
4/21:52	SSME hydraulic repressurization.
4/21:57	Crew configures DPS for entry.
4/22:07	All crew members verify entry switch list.
4/22:22	All crew members perform entry review.
4/22:37	Command and pilot don LES clothing.
4/22:52	MSs don LES clothing.
4/22:59	Orbit 74 begins.
4/23:02	Commander and pilot ingress seats.

T PLUS DAY/ HR:MIN:SEC	EVENT
4/23:14	Deorbit update is performed.
4/23:19	Flight crew performs OMS gimbal check.
4/23:36	Vent doors are closed.
4/23:40	MCC issues "go for deorbit thrusting maneuver" command.
4/23:46	Crew maneuvers vehicle to deorbit ignition attitude.
4/23:48	Crew terminates vehicle to deorbit ignition attitude.
4/23:48	MSs ingress seats.
4/23:56	First APU is activated.
DAY FIVE	
5/00:01	Deorbit thrusting maneuver is performed: 5 minutes, 11 seconds in duration, 553 fps.
5/00:07	Crew proceeds to major mode (MM) 303.
5/00:08	Crew maneuvers vehicle to post-deorbit thrusting attitude.
5/00:10	Forward RCS dump is performed, if required.
5/00:12	Crew terminates vehicle post-deorbit thrusting attitude.
5/00:31	Crew starts two remaining APUs.
5/00:36	Orbit 76 begins.
5/00:38	SSME hydraulic systems are repressurized.
5/00:39	MM 304 is selected.
5/00:44	Vehicle achieves entry interface (EI), 400,000-foot altitude.
5/00:48	RCS roll thrusters are deactivated automatically.
5/00:55:58	Preprogrammed test input (PTI) maneuver 1 is initiated.
5/00:56:13	PTI maneuver 1 is terminated.

T PLUS DAY/ HR:MIN:SEC	EVENT
5/00:56:43	RCS pitch thrusters are deactivated automatically.
5/00:58:16	PTI maneuver 2 is initiated.
5/00:58:32	PTI maneuver 2 is terminated.
5/01:00:15	Initiate first roll reversal.
5/01:00:19	PTI maneuver 3 is initiated.
5/01:00:35	PTI maneuver 3 is terminated.
5/01:03:23	PTI maneuver 4 is initiated.
5/01:03:38	PTI maneuver 4 is terminated.
5/01:04:06	Crew initiates second roll reversal.
5/01:05:54	PTI maneuver 5 is initiated.
5/01:06:09	PTI maneuver 5 is terminated.
5/01:07:06	PTI maneuver 6 is initiated.
5/01:07:18	PTI maneuver 6 is terminated.
5/01:07:27	Crew initiates third roll reversal.
5/01:07:27	Crew initiates air data system (ADS) deployment.
5/01:08:08	PTI maneuver 7 is initiated.
5/01:08:21	PTI maneuver 7 is terminated.
5/01:08:52	Entry/terminal area energy management (TAEM) interface is reached.
5/01:08:57	Crew initiates payload venting; vent doors are opened.
5/01:09:12	PTI maneuver 8 is initiated.
5/01:09:24	PTI maneuver 8 is terminated.
5/01:11:02	RCS yaw thrusters are deactivated automatically.
5/01:11:04	Vehicle is at 50,000 foot attitude
5/01:13:58	TAEM approach and landing (A/L) interface is reached.

T PLUS DAY/ HR:MIN:SEC	EVENT
5/01:14:56	Landing gear deployment is initiated.
5/01:15:18	Vehicle has weight on main landing gear wheels.
5/01:15:26	Vehicle has weight on nose landing gear wheels.
5/01:15:59	Braking is initiated.
5/:01:15:56	Wheels stop.
5/01:29	Flight crew safes OMS/RCS.
5/01:32	Sniff checks are performed.
5/01:34	Aft vehicles are positioned.
5/01:44	Ground purge unit (transport) is connected to right-hand (starboard) T-O orbiter umbilical, and ground cooling unit (transporter) is connected to left-hand (port) T-O orbiter umbilical.
5/01:44	Crew compartment side hatch access vehicle is positioned.
5/01:51	Orbiter crew egress/ingress side hatch is opened.
5/02:19	Orbiter flight crew and ground crew are exchanged.

GLOSSARY

AA	accelerometer assembly
ADSF	automatic directional solidification furnace
AES	atmosphere exchange system
A/L	approach and landing
AMOS	Air Force Maui Optical Site
AMU	attitude match update
AOA	abort once around
APC	autonomous payload controller
APU	auxiliary power unit
ARC	Aggregation of Red Blood Cells Experiment
ARS	attitude reference system
ASE	airborne support equipment
CAP	crew activity plan
CAPS	crew altitude protection suit
CBSA	cargo bay stowage assembly
CCTV	closed-circuit television
CEC	control electronics container
CFES	continuous flow electrophoresis system
CIU	communications interface unit
COAS	crewman optical alignment sight
CRT	cathode-ray tube
CSS	control stick steering
DAP	digital autopilot
DEX	dextroamphetamine
DMOS	diffusive mixing of organic solutions
DPS	data processing system
DSO	detailed supplementary objective
DTO	detailed test objective
EAFB	Edwards Air Force Base
EAC	experiment apparatus container
ECLSS	environmental control and life support system
EEP	electronics equipment package
ELRAD	Earth Limb Radiance Experiment
EMU	extravehicular mobility unit
EPS	electrical power system
ET	external tank
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FES	flash evaporator system
fps	feet per second
FSS	flight support structure
FSS	flight support system
GAS	getaway special
GEM	generic electronics module
GHCD	Growth Hormone Concentration and Distribution

GLS	ground launch sequencer
GPC	general-purpose computer
GSFC	Goddard Space Flight Center
HDRS	high data rate system
HGAS	high-gain antenna system
HRA	helmet-retention assembly
HRM	hand-held radiation meter
HST	Hubble Space Telescope
HUD	head-up display
ICBC	IMAX cargo bay camera
IEF	Isoelectric Focusing Experiment
IFM	inflight maintenance
IMU	inertial measurement unit
IPMP	investigation into polymer membrane processing
IRCFE	Infrared Communications Flight Experiment
IUS	inertial upper stage
IV	intravehicular
JEA	joint endeavor agreement
JSC	Johnson Space Center
kbps	kilobits per second
KSC	Kennedy Space Center
LDEF	long-duration exposure facility
LEASAT	leased communication satellite
LES	launch entry suit
LPS	launch processing system
LRU	line replaceable unit
MC	midcourse correction maneuver
MCC-H	Mission Control Center-Houston
MDM	multiplexer/demultiplexer
MEB	main electronics box
MECO	main engine cutoff
MEM	middeck electronics module
MET	mission elapsed time
MFR	manipulator foot restraint
MILA	Merritt Island antenna
MLE	Mesoscale Lightning Experiment
MLR	monodisperse latex reactor
MM	major mode
MMU	manned maneuvering unit
MPESS	mission-peculiar equipment support structure
MPM	manipulator positioning mechanisms
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center

NC	normal corrective maneuver
NCC	normal corrective combination maneuver
NH	normal height adjust maneuver
nmi	nautical mile
NPC	normal plane change maneuver
NSR	normal slow rate maneuver
O&C	operations and checkout
OCP	Office of Commercial Programs
OASIS	Orbiter Experiment Autonomous Supporting Instrumentation System
OEX	orbiter experiment
OAST	Office of Aeronautics and Space Technology
OMS	orbital maneuvering system
OSSA	Office of Space Sciences and Applications
OSTA	Office of Space and Terrestrial Applications
PALAPA	Indonesian communication satellite
PAM	payload assist module
PCP	payload control panel
PCS	pressure control system
PCG	protein crystal growth
PDI	payload data interleaver
PFR	portable foot restraint
PGC	plant growth chamber
PGU	plant growth unit
PI	payload interrogator
PIC	pyro initiator controller
PL	payload
PM	polymer morphology
POCC	Payload Operations Control Center
PPE	Phase Partitioning Experiment
PRCS	primary reaction control system
PRLA	payload retention latch assembly
PRM	pocket radiation meter
PS	payload specialist
PTI	preprogrammed test input
PVTOS	Physical Vapor Transport Organic Solids Experiment
RAHF-VT	research animal holding facility-verification test
RCC	reinforced carbon-carbon
RCS	reaction control system
RGA	rate gyro assembly
RME	radiation monitoring equipment
RMS	remote manipulator system
RTGS	radioisotope thermoelectric generators
RTLS	return to launch site
S&A	safe and arm
SAS	space adaption syndrome
SCOP	scopolamine
SESA	special equipment stowage assembly

SHARE	Space Station Heat Pipe Radiator Element Experiment
SL	Spacelab
sm	statute mile
SM	systems management
SMS	space motion sickness
SRB	solid rocket booster
SRSS	shuttle range safety system
SSBUV	Shutter Solar Backscatter Ultraviolet
SSIP	shuttle student involvement project
SSME	space shuttle main engine
ST	star tracker
STEX	Sensor Technology Experiment
STS	space transportation system
SYNCOM	synchronous communication satellite

TACAN	tactical air navigation
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite system
TI	terminal phase initiation
TIG	time of ignition
TLD	thermoluminescent dosimeter
TPAD	trunnion pin acquisition device
TPF	terminal phase final maneuver
TPI	terminal phase initiation maneuver
TPS	thermal protection system
TV	television

VCGS	vapor crystal growth system
VRCS	vernier reaction control system
VTR	video tape recorder
VWFC	very wide field camera

WCS	waste collection system