

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

**SPACE SHUTTLE  
MISSION  
STS-31**

**PRESS KIT  
APRIL 1990**



**HUBBLE SPACE TELESCOPE (HST) DEPLOY**

## **STS-31 INSIGNIA**

*STS031-S-001 - The mission insignia for NASA's STS-31 mission features the Hubble Space Telescope (HST) in its observing configuration against a background of the universe it will study. The cosmos includes a stylistic depiction of galaxies in recognition of the contribution made by Sir Edwin Hubble to our understanding of the nature of galaxies and the expansion of the universe. The STS-31 crew points out that it is in honor of Hubble's work "that this great observatory in space bears his name." The depicted Space Shuttle trails a spectrum symbolic of both the red shift observations that were so important to Hubble's work and new information which will be obtained with the HST. Encircling the art work, designed by the crewmembers are their names: Loren J. Shriver, mission commander; Charles F. Bolden, pilot, and Steven A. Hawley, Bruce McCandless II and Kathryn D. Sullivan, mission specialists.*

*The NASA insignia design for space shuttle flights is reserved for use by the astronauts and for other official use as the NASA Administrator may authorize. Public availability has been approved only in the form of illustrations by the various news media. When and if there is any change in this policy, which we do not anticipate, it will be publicly announced.*

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**RELEASE: 90-44**

**April 1990**

## **DISCOVERY TO STATION HUBBLE SPACE TELESCOPE IN EARTH ORBIT**

Highlighting mission STS-31, the 35th flight of the Space Shuttle, will be deployment in Earth orbit of the Hubble Space Telescope (HST).

HST, the largest on-orbit observatory ever built, is capable of imaging objects up to 14 billion light years away. Unhampered by Earth's atmospheric distortion, resolution of HST images is expected to be 7 to 10 times greater than images from Earth-based telescopes.

Orbiting at an altitude of 330 nautical miles, the telescope will observe celestial sources such as quasars, galaxies and gaseous nebulae. HST also will monitor atmospheric and surface phenomena of the planets in Earth's solar system.

After launch, and once the payload bay doors are opened, the HST main power busses will be activated allowing initial communications to be established. This will begin a 90-day orbital verification period in which the telescope will be checked to ensure that all systems are operational and functioning. During this period, the crew cabin will be depressurized in preparation for contingency activities that may arise related to the telescope's deployment.

HST, which measures 43.5 feet long and 14 feet in diameter, is scheduled to be deployed on the second day of the 5-day flight. Umbilical disconnect is planned on orbit 16 followed by solar array extension and slew tests on orbits 17 and 18. The high gain antennae boom deployment also is scheduled for orbit 18. During HST checkout operations prior to release from the remote manipulator system (RMS) arm, Mission Specialists Bruce McCandless and Kathryn Sullivan will be prepared for an extravehicular activity (EVA) if necessary.

The RMS will maneuver the telescope to the release position on orbit 19 with release scheduled for 1:47 p.m. EDT on April 13 based on a nominal launch time. The IMAX Cargo Bay Camera will film various points of the checkout and release of HST. Once HST is released, Discovery's crew will maneuver the orbiter away from HST to a distance of about 40 nautical miles. For the next 45 hours, the crew will trail HST in the event a rendezvous and spacewalk are required in response to a failure during the opening of the telescope's aperture door which protects the 94 1/2 inch mirror -- the smoothest ever made. Activation of HST's six onboard scientific instruments will follow aperture door opening on flight day three, orbit 39. The remainder of the flight is reserved for middeck experiment operations.

Joining HST in the payload bay will be the Ascent Particle Monitor to measure particle contamination or particle detachment during the immediate prelaunch period and during Shuttle ascent. Also in the payload bay is an IMAX camera containing about 6 minutes of film. Discovery's middeck will carry a variety of experiments to study protein crystal growth, polymer membrane processing, and the effects of weightlessness and magnetic fields on an ion arc.

Commander of the mission is Loren J. Shriver, Air Force Colonel. Charles F. Bolden Jr., Marine Corps Colonel, will serve as pilot. Shriver was pilot of Discovery's third flight, STS-51C in January 1985, the first dedicated Department of Defense Shuttle mission. Bolden previously was pilot of Columbia's seventh flight in January 1986.

Mission specialists are Steven A. Hawley, Bruce McCandless II and Dr. Kathryn D. Sullivan. Hawley will operate and release HST from the RMS arm. Hawley's previous spaceflight experience includes Discovery's maiden voyage, STS-41D and Columbia's seventh flight, STS-61C. McCandless previously flew on STS-41B, Challenger's fourth flight. Sullivan flew on Challenger's sixth mission, STS-41G.

Liftoff of the tenth flight of Discovery is scheduled for 9:21 a.m. EDT on April 12 from Kennedy Space Center, Fla., launch pad 39-B, into a 330 by 310 nautical mile, 28.5 degree orbit. Nominal mission duration is expected to be 5 days 1 hour 15 minutes. Deorbit is planned on orbit 75, with landing scheduled for 10:36 a.m. EDT on April 17 at Edwards Air Force Base, Calif.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS.)

## **GENERAL INFORMATION**

### **NASA Select Television Transmission**

NASA Select television is available on Satcom F-2R, Transponder 13, C-band located at 72 degrees west longitude, frequency 3960.0 MHz, vertical polarization, audio monaural 6.8 MHz.

The schedule for TV transmissions from the orbiter and for the change-of- shift briefings from Johnson Space Center, Houston, will be available during the mission at Kennedy Space Center, Fla.; Marshall Space Flight Center, Huntsville, Ala.; Johnson Space Center; Goddard Space Flight Center, Greenbelt, Md. and NASA Headquarters, Washington, D.C. The schedule will be updated daily to reflect changes dictated by mission operations.

TV schedules also may be obtained by calling COMSTOR, 713/483-5817. COMSTOR is a computer data base service requiring the use of a telephone modem. Voice updates of the TV schedule may be obtained by dialing 202/755-1788. This service is updated daily at noon EDT.

### **Special Note to Broadcasters**

In the 5 workdays before launch, short sound bites of astronaut interviews with the STS-31 crew will be available to broadcasters by calling 202/755-1788 between 8 a.m. and noon EDT.

### **Status Reports**

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

### **Briefings**

An STS-31 mission press briefing schedule will be issued prior to launch. During the mission, flight control personnel will be on 8-hour shifts. Change- of-shift briefings by the off-going flight director will occur at approximately 8-hour intervals.

## STS-31 QUICK LOOK

Launch Date:	April 12, 1990
Launch Window:	9:21 a.m. - 1:21 p.m. EDT
Launch Site:	Kennedy Space Center, FL
Launch Complex:	39B
Orbiter:	Discovery (OV-103)
Altitude:	330 circular
Inclination:	28.45
Duration:	5 days, 1 hour, 15 minutes
Landing Date/Time:	April 17, 1990, 10:36 a.m. EDT
Primary Landing Site:	Edwards Air Force Base, Calif.
Abort Landing Sites:	Return to Launch Site -- KSC TransAtlantic Abort - Ben Guerir, Morocco Abort Once Around - Edwards AFB, Calif.
Crew:	Loren J. Shriver - Commander Charles F. Bolden Jr. - Pilot Steven A. Hawley - MS-2 Bruce McCandless II - MS-1 and EV1 Kathryn D. Sullivan - MS-3 and EV2
Cargo Bay Payloads:	Hubble Space Telescope IMAX Cargo Bay Camera
Middeck Payloads:	Ascent Particle Monitor (APM) Investigations into Polymer Membrane Processing (IPMP) Ion Arc (Student Experiment) Protein Crystal Growth (PCG-III)

## SUMMARY OF MAJOR ACTIVITIES

### **Flight Day 1**

Ascent  
RMS checkout  
Post-insertion  
DSO  
Unstow cabin  
EMU checkout  
10.2 cabin depress  
PCG activation

### **Flight Day 2**

HST deploy  
IMAX  
DSO  
IPMP activation

### **Flight Day 3**

DSO/DTO  
Ion Arc (Student Experiment)  
IMAX  
REM Memory Module Replacement

### **Flight Day 4**

14.7 repress  
IMAX  
DSO  
RME Memory Module Replacement

### **Flight Day 5**

AMOS  
PCG deactivation  
DSO  
RCS hotfire  
FCS checkout  
RME deactivation  
IMAX  
Cabin stow

### **Flight Day 5**

DSO  
Deorbit burn  
Deorbit preparations  
Landing at EAFB



## STS-31 TRAJECTORY SEQUENCE OF EVENTS

Event	MET (d/h:m:s)	Relative Velocity (fps)	Mach	Altitude (ft)
Launch	00/00:00:00			
Begin Roll Maneuver	00/00:00:09	160	0.14	605
End Roll Maneuver	00/00:00:15	313	0.28	2,173
SSME Throttle Down to 67%	00/00:00:28	656	0.58	7,771
Max. Dyn. Pressure (Max Q)	00/00:00:51	1,155	1.07	25,972
SSME Throttle Up to 104%	00/00:00:59	1,321	1.26	33,823
SRB Staging	00/00:02:06	4,145	3.77	159,670
Negative Return	00/00:04:06	7,153	7.15	341,470
Main Engine Cutoff (MECO)	00/00:08:33	24,768	23.18	361,988
Zero Thrust	00/00:08:39	24,783	22.65	366,065
ET Separation	00/00:08:51			
OMS 2 Burn	00/00:42:38			
HST Deploy (orbit 19)	01/05:23:00			
Deorbit Burn (orbit 75)	05/00:03:00			
Landing (orbit 76)	05/01:15:00			
Apogee, Perigee at MECO: 325 x 27				
Apogee, Perigee post-OMS 2: 330 x 310				
Apogee, Perigee post deploy: 332 x 331				

## SPACE SHUTTLE ABORT MODES

Space Shuttle launch abort philosophy aims toward safe and intact recovery of the flight crew, orbiter and its payload. Abort modes include:

- Abort-To-Orbit (ATO) -- Partial loss of main engine thrust late enough to permit reaching a minimal 105-nautical mile orbit with orbital maneuvering system engines.
- Abort-Once-Around (AOA) -- Earlier main engine shutdown with the capability to allow one orbit around before landing at Edwards Air Force Base, Calif.; White Sands Space Harbor (Northrup Strip), N.M.; or the Shuttle Landing Facility (SLF) at Kennedy Space Center (KSC), Fla.
- Trans-Atlantic Abort Landing (TAL) -- Loss of two main engines midway through powered flight would force a landing at Ben Guerir, Morocco; Moron, Spain; or Banjul, The Gambia.
- Return-To-Launch-Site (RTL) -- Early shutdown of one or more engines and without enough energy to reach Ben Guerir, would result in a pitch around and thrust back toward KSC until within gliding distance of the SLF.

STS-31 contingency landing sites are Edwards AFB, White Sands, KSC, Ben Guerir, Moron and Banjul. For a contingency return of Discovery with the Hubble Space Telescope, conditioned purge air will be supplied to the payload bay within 40 minutes after landing.

## STS-31 PRELAUNCH PROCESSING

Shuttle processing activities at Kennedy Space Center for the STS-31/Hubble Space Telescope mission began on Dec. 3, following the orbiter Discovery's return to KSC after completion of the STS-33 mission of November 1989.

During its 3-month stay in the Orbiter Processing Facility, Discovery underwent some 36 modifications to its structural, flight and onboard systems. These modifications included the installation of new carbon brakes which will provide greater stopping power and control during landing. The brakes have undergone extensive preflight testing at Wright Patterson AFB in Ohio, with further testing to be conducted under actual landings conditions. The high pressure oxidizer turbo pumps on Discovery's main engines have been instrumented for the first time to provide data on bearing wear. The data provided, along with a post-flight analysis of the pumps, will help determine whether the pumps need to be rebuilt after each flight as is currently the case. The location of Discovery's main engines are the same as for the last mission: 2011 in the No. 1 position, 2031 in the No. 2 position and 2107 in the No. 3 position.

The remote manipulator system was installed in Discovery's payload bay and checked out during the first two weeks in January. The robot arm will be used to deploy the Hubble Space Telescope.

Discovery's right aft solid rocket booster was replaced with one designated for the STS-35 mission after data indicated that a critical leak test had not been performed correctly on one of the internal joints. The replacement was necessary because the location of the joint precluded retesting at KSC. The assembled vehicle, atop mobile launcher platform 2, was rolled out to Launch Pad 39B on March 15.

The Hubble Space Telescope arrived at KSC from the Lockheed Sunnyvale, Calif. facility on Oct. 4, 1989, and began prelaunch testing in the Vertical Processing Facility. It was powered up on Oct. 28 via satellite command from Lockheed's HST control facility in Sunnyvale, beginning 40 days of functional testing of its operating systems and science instruments. These tests included 11 days of on-orbit simulations via satellite link with the Space Telescope Operations Control Center (STOCC) at Goddard Space Flight Center, Greenbelt, Md.

The launch countdown is scheduled to begin 3 days prior to launch. During the countdown, the orbiter's onboard fuel storage tanks will be loaded and all orbiter systems will be configured for flight. About 9 hours before launch, the external tank will be loaded with its flight load of liquid oxygen and liquid hydrogen propellants.

Discovery is scheduled to land at Edwards AFB, Calif. KSC's landing and recovery team at NASA's Ames-Dryden Flight Research Facility will prepare the vehicle for its ferry flight back to KSC, expected to begin approximately 5 days after landing.

## PAYLOAD AND VEHICLE WEIGHTS

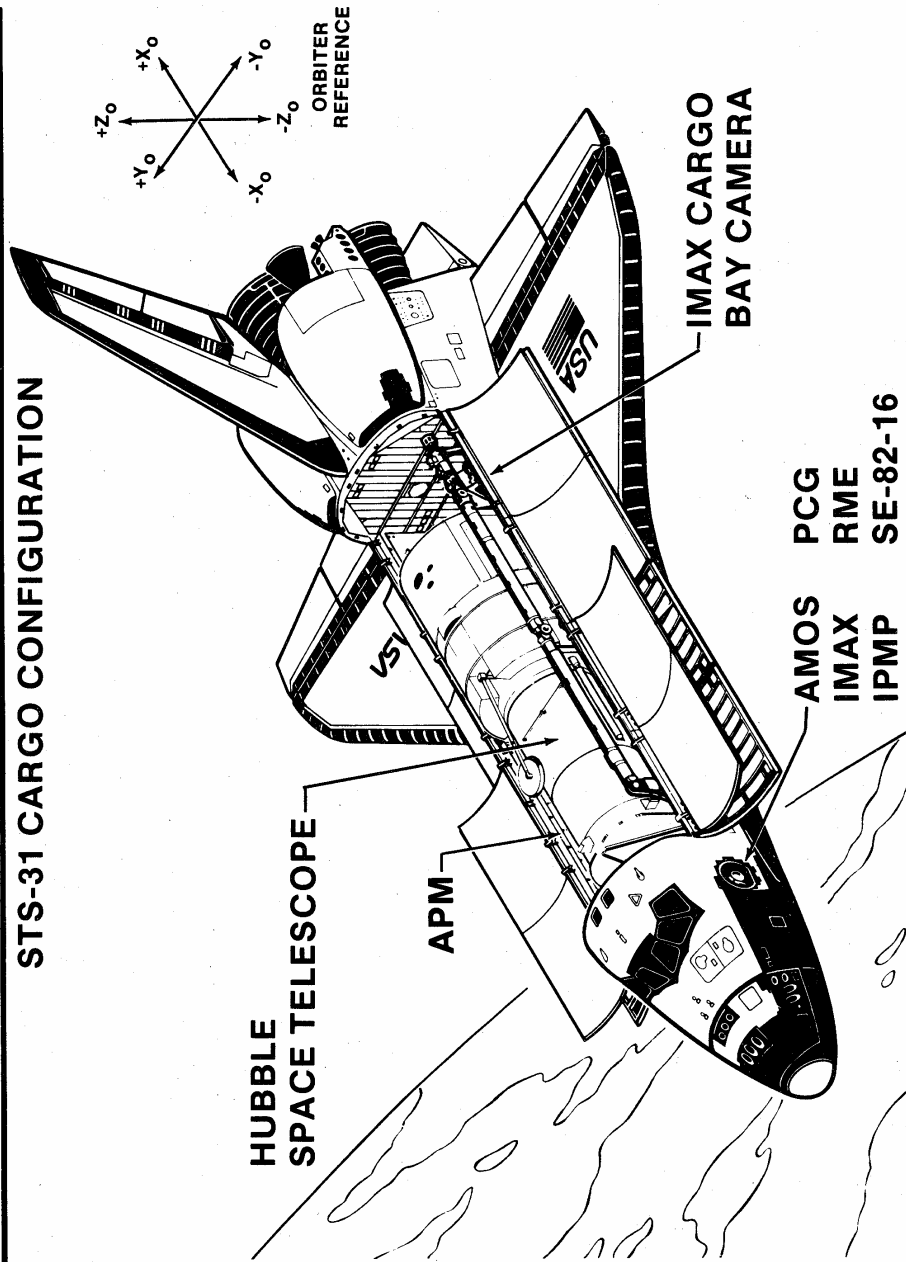
	<u>Pounds</u>
Orbiter Discovery Empty	151,314
Remote Manipulator System (payload bay)	858
Hubble Space Telescope (payload bay)	23,981
Ascent Particle Monitor (payload bay)	47
IMAX system (payload bay)	374
DSO	77
DTO	289
HST middeck equipment	127
IMAX (middeck)	271
Investigation into Polymer Membrane Processing (IPMP)	17
Ion Arc (Student Experiment)	54
Protein Crystal Growth (PCG)	85
Radiation Monitoring Experiment (RME)	7
Orbiter and Cargo at main engine cutoff	259,229
Total Vehicle at SRB Ignition	4,516,325
Orbiter Landing Weight	189,477



**NSTS** INTEGRATION  
AND OPERATIONS

# STS-31 PAYLOAD INFORMATION DOCUMENT

## STS-31 CARGO CONFIGURATION



# HUBBLE SPACE TELESCOPE

## The Hubble Space Telescope and its Elements

The HST weighs approximately 24,000 pounds, is 43 feet long, and 14 feet in diameter at its widest point. Roughly the size of a railroad tank car, it looks more like two huge cylinders joined together and wrapped in aluminum foil. Wing-like solar arrays extend horizontally from each side of these cylinders, and dish-shaped antennas stretch out on rods above and below the body of the telescope.

Many of the telescope's components are of modular design so they may be removed and replaced in orbit by astronauts. Though other spacecraft have received emergency repairs from Shuttle crews, the HST is the first specifically designed for on-orbit servicing.

The HST is made up of three major elements: the support systems module, the optical telescope assembly, and the scientific instruments.

The support systems module consists of the exterior structure of the HST and the various systems that make it possible for the optical telescope assembly and the scientific instruments to do their job.

The foil-like material with which the telescope is wrapped is actually multi-layer insulation, part of the telescope's thermal control system. The metallic silver surface reflects much of the direct sunlight which strikes the telescope to keep it from overheating. Tiny heaters are attached to many telescope components to warm them during the "eclipse" phase of orbit, when in the Earth's shadow.

Electrical power for the HST is collected from the sun by the European Space Agency's solar arrays. These two "wings" contain 48,000 solar cells. They convert the sun's energy to electricity during the portion of orbit that it is exposed to sunlight. The power is stored in six Nickel Hydrogen batteries to support the telescope during eclipse.

When conducting an observation, the space telescope is rotated into the proper orientation, then pointed to the star it is to view and locked in place, by the pointing control system. This system is made up of a complex series of gyroscopes, star trackers, reaction wheels and electromagnets. The gyroscopes and reaction wheels are used to produce a coarse pointing toward the star. That pointing is fine-tuned by star trackers called fine guidance sensors. These sensors can locate and lock on to a position in the sky to within 0.01 arc second and can hold that pointing without varying more than 0.007 arc second for as long as 24 hours.

Also included in the support systems module are the computer which controls the overall spacecraft; high-gain antennas which receive ground commands and transmit data back to Earth; the electrical power system; the structure of the telescope itself and its mechanical parts; and the safing system, designed to take over control of the telescope to protect it from damage in case of serious computer problems or loss of communication with ground controllers.

The optical telescope assembly contains the two mirrors which collect and focus light from the celestial objects being studied. The 94-inch primary mirror is located near the center of the HST. Made of precision-ground glass with an aluminum reflecting surface, it is the smoothest large mirror ever made. To reduce weight, the front and back plates are fused to a honeycomb core. The 13-inch secondary mirror is located 16 feet in front of the primary mirror. It is set far enough inside the open end of the telescope to assure that stray light does not interfere with the image being studied. In addition, three black cylinders called baffles surround the path of light to block out unwanted rays.

The two mirrors must remain in precise alignment for the images they collect to be in focus. But the space environment is a hostile one. The space telescope will experience wide variations in temperature as it passes from the sun to shade portions of its orbit. Expansion and contraction from the temperature extremes could

easily cause the mirrors to go out of focus. Therefore, the mirrors are made of a special kind of glass formulated to resist that expansion and contraction. The telescope's insulation blankets and solar-powered heaters will maintain them at 70 degrees Fahrenheit. In addition, the mirrors are held a precise distance from one another by an extremely strong but lightweight truss structure. The truss is made from graphite epoxy, a material also chosen for its resistance to expansion and contraction in temperature extremes.

During observations, light from a celestial source travels through the tube of the telescope to the large primary mirror. It is then reflected from the primary mirror back to the secondary mirror. From there, the beam narrows and intensifies, then passes through a hole in the center of the primary mirror to a focal plane where the scientific instruments are located.

The Hubble Space Telescope's scientific instruments are the Wide Field/Planetary Camera, the Faint Object Camera, the Goddard High Resolution Spectrograph, the Faint Object Spectrograph, and the High Speed Photometer. The fine guidance system, in addition to being used for pointing, also performs scientific measurements and is sometimes called the sixth scientific instrument. Mounted on a focal plane almost five feet behind the primary mirror, these scientific instruments will furnish astronomers with a wide range of information about the stars and galaxies they study. Each instrument is contained in a separate module and operates on only 110 to 150 watts of power.

### **Science Instruments**

The Wide Field/Planetary Camera (WF/PC) will be used to investigate the age of the universe and search for new planetary systems around young stars. It can compare near and far galaxies and observe comets such as Halley's comet, which we previously could only view every 75 years. As its name implies, the WF/PC can be used in two different ways. In its wide-field mode, its field of view will allow it to take pictures of dozens or even hundreds of distant galaxies at once. In the planetary mode, it will provide close-ups of all the planets in our solar system except Mercury, which is too close to the sun for safe pointing. The WF/PC can observe larger areas of the sky and more different forms of light (from far ultraviolet to near infrared) than any of the other science instruments. It will also produce a greater volume of information for analysis than any of the others.

Though its field of view is greater than that of any other Hubble instrument, the "wide field" in this camera's name may be a little misleading. Typical wide-field cameras at ground observatories have a field of view of around 5 degrees. This camera's is only 2.67 arc minutes. It would take a montage of about 100 "wide-field" images to get a picture of the full moon. However, the narrower field of view allows much better resolution of far-away objects.

Although it will focus on an even smaller area than its wide-field counterpart, the Faint Object Camera (FOC) will extend the reach of the HST to its greatest possible distance and produce its sharpest images. It will be able to photograph stars five times farther away than is possible with telescopes located on the ground. Many stars and galaxies, now barely perceptible, will appear as blazing sources of light to the FOC. The camera will intensify images to a brightness 100,000 times greater than they were when received by the telescope. Then a television camera will scan the intensified images and store them in the camera's memory for transmission to the ground.

The FOC will be used to help determine the distance scale of the universe, peer into the centers of globular star clusters, photograph phenomena so faint they cannot be detected from the ground, and study binary stars (two stars so close together they appear to be one). It is part of the European Space Agency's contribution to the HST program.

Two spectrographs are also included in the HST's group of scientific instruments. A spectrograph does not take a photograph of the image it sees. Rather, one could say it takes its chemical "fingerprint." A spectrograph separates the radiation received from an object according to wavelengths, much as a prism splits visible light into colors. Every chemical element produces its own individual pattern on a spectrogram. So when the "fingerprint" of a certain element shows up on the spectrum, scientists know that element is present in the object being viewed. Scientists use spectrographs to determine the chemical composition, temperature, pressure and density of the objects they are viewing.

The Faint Object Spectrograph (FOS) will be used to analyze the properties of extremely faint objects in both visible and ultraviolet light. It will be able to isolate individual light sources from those surrounding them at very great distances. The FOS is equipped with devices that can block out light at the center of an image so the much fainter light around a bright object can be viewed. It will study the chemical properties of comets before they get close enough to the sun for their chemistry to be altered, as well as probing to see what the mysterious quasars are made of. This instrument will offer comparisons of galaxies that are relatively near Earth with those at great distances, helping researchers determine the history of galaxies and the rate at which the universe is expanding.

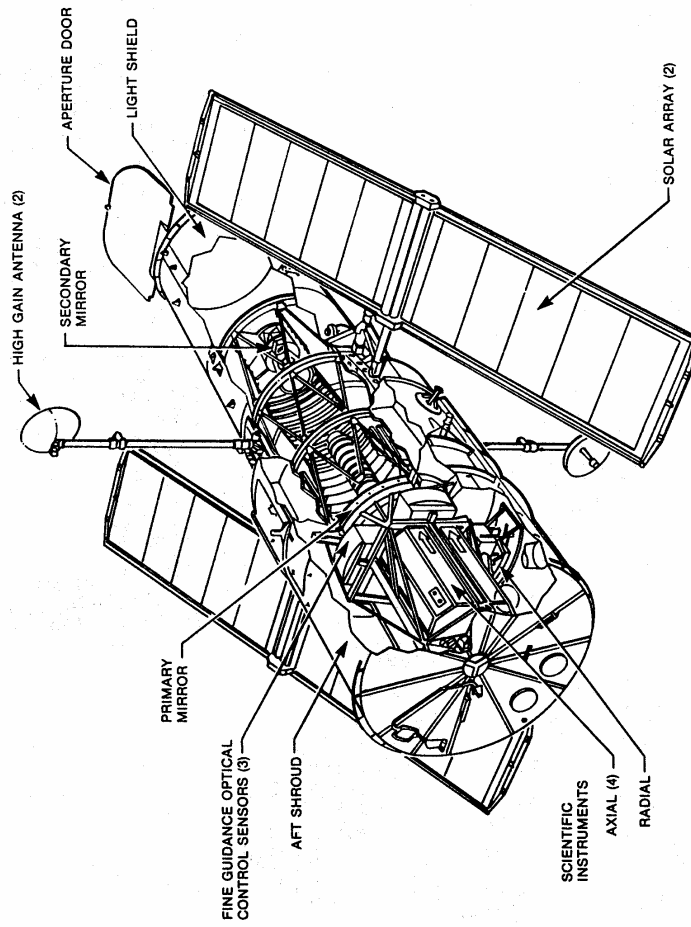
The Goddard High Resolution Spectrograph, though its work is similar to that of its faint object companion, has a specialized job. It is the only science instrument entirely devoted to studies of ultraviolet light. Its detectors are designed to be insensitive to visible light, since the ultraviolet emissions from stars are often hidden by the much brighter visible emissions. The "high resolution" in this instrument's name refers to high spectral resolution, or the ability to study the chemical fingerprints of objects in very great detail. The combination of this spectral resolution with the high spatial resolution of the cameras will allow scientists to determine the chemical nature, temperature, and density of the gas between stars. Its investigations will range from peering into the center of far-away quasars to analyzing the atmospheres of planets in our own solar system.

The High Speed Photometer, a relatively simple but precise light meter, will measure the brightness of objects being studied, as well as any variations in that brightness with time, in both the visible and ultraviolet ranges. The photometer will be able to study the smallest astronomical objects of any of the telescope's instruments. One of the photometer's tasks will be to look for clues that black holes exist in binary star systems. Variations in brightness would occur as one star revolves around the other. Irregularities in that variation might indicate that matter is being lost to a black hole--an object so dense that nothing, not even light, can escape from it. The photometer will also provide astronomers with an accurate map of the magnitude of stars.

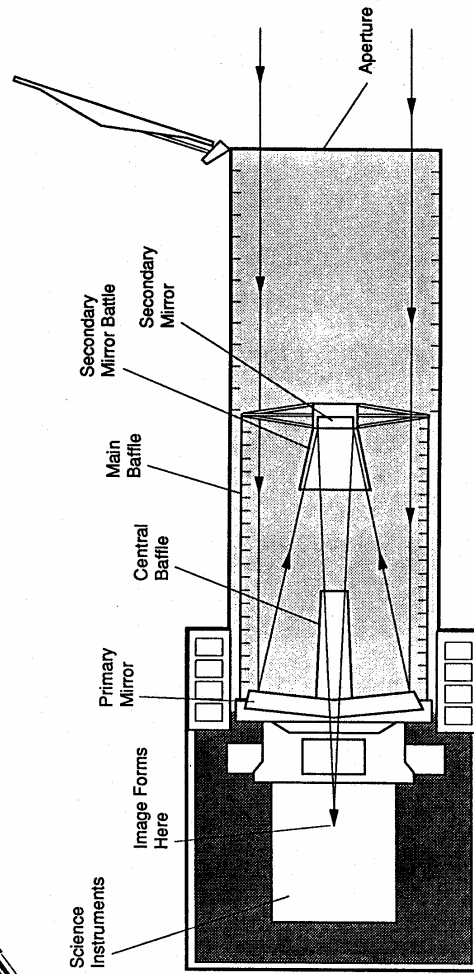
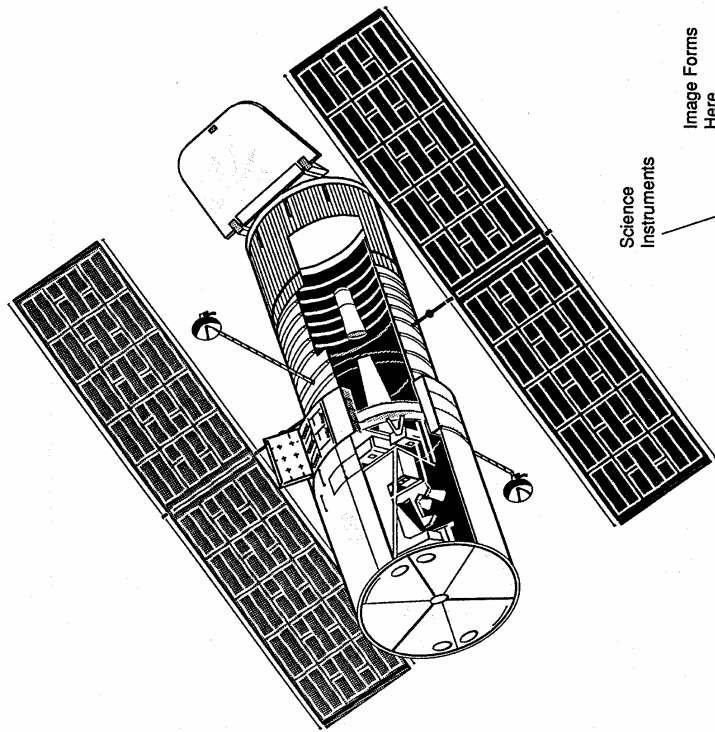
The three fine guidance sensors serve a dual purpose. Two of the sensors lock on to reference stars to point the telescope to a precise position in the sky, then hold it there with a remarkable degree of accuracy. The third sensor, in addition to serving as a backup unit, will be used for astrometry -- the science of measuring the angles between astronomical objects. These measurements will be combined with information from other instruments to prepare a more accurate distance scale of the universe.

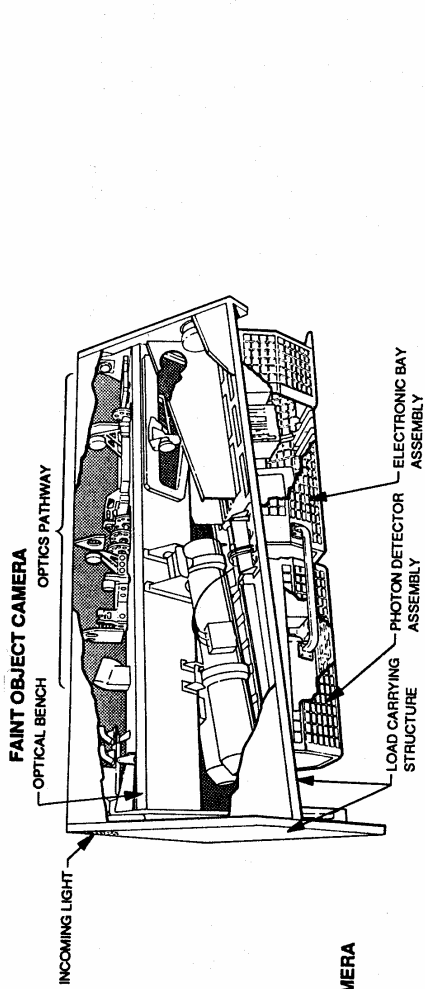


# OVERALL HUBBLE SPACE TELESCOPE CONFIGURATION

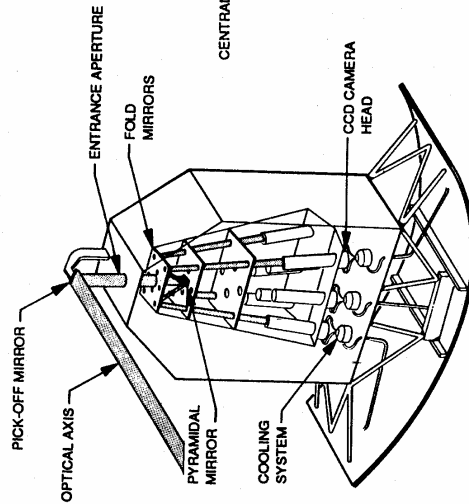


# CUTAWAY VIEWS OF HUBBLE SPACE TELESCOPE

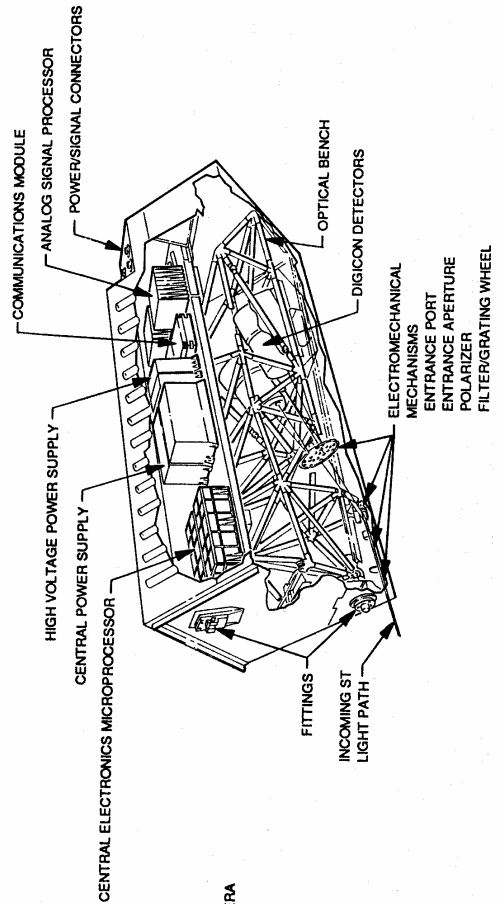




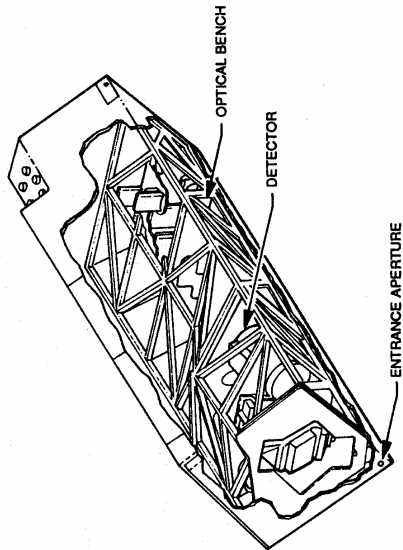
**WIDE FIELD/PLANETARY CAMERA**



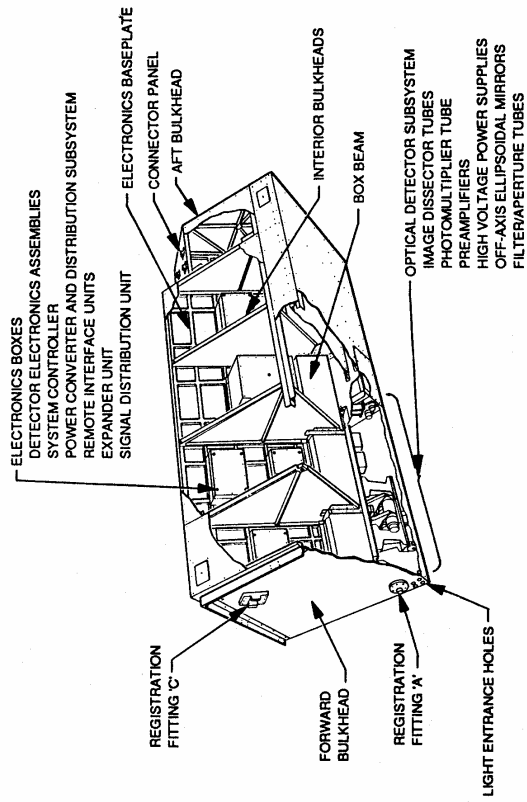
**FAINT OBJECT SPECTROGRAPH**

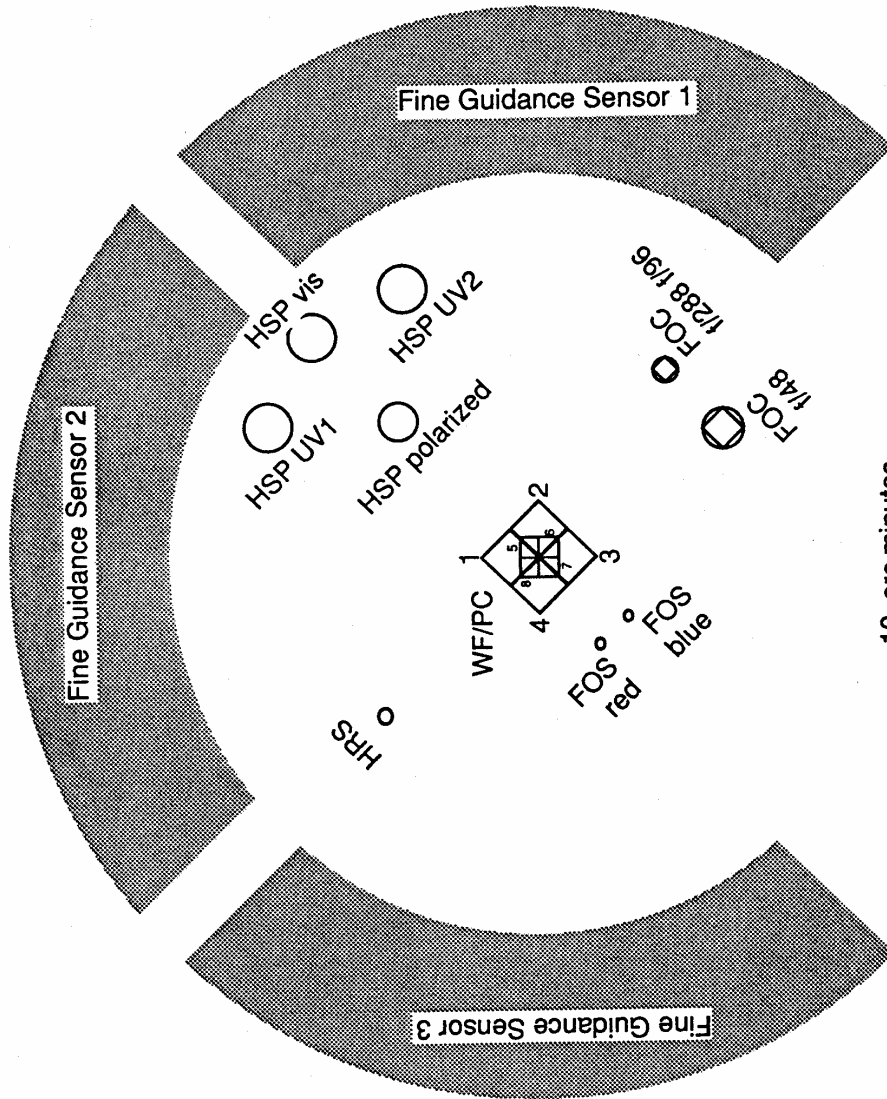


**GODDARD HIGH RESOLUTION SPECTROGRAPH**



**HIGH SPEED PHOTOMETER**





10 arc minutes

Hubble Space Telescope  
 Field of View and Focal Plane Layout  
 (as seen from the instrument point of view)

## **ORBITAL VERIFICATION**

HST's Orbital Verification (OV) program was established to verify that its subsystems are functioning properly after it has been placed in Earth orbit. As an extremely complex, precise and sensitive spacecraft, 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 thorough and methodical. It has been carefully planned to assure that the telescope systems are not damaged during activation and that the telescope itself and its ground support systems are operating properly. Engineers and scientists will control this process from the Space Telescope Operations Control Center (STOCC), at Goddard Space Flight Center, Greenbelt, Md.

Orbital verification is divided into two phases. The first includes deployment of the Hubble Space Telescope, activation of its systems, and preliminary pointing and focusing. This phase is referred to as OV/1. A team from the Marshall Space Flight Center will be stationed at the Goddard Space Flight Center to manage this portion of verification. The Marshall manager in charge of this team, referred to as the Director of Orbital Verification (DOV), will give the final go-ahead for each step of the carefully-scripted process. Another Marshall team working in Huntsville will provide technical engineering support from the Huntsville Operations Support Center (HOSC). Actual commands will be sent to the telescope by Goddard mission operations personnel.

The first stage of orbital verification, OV/1, has four major goals: fine-tuning pointing accuracy, focusing the telescope, initially activating the scientific instruments and evaluating the performance of both the telescope and ground control systems.

The second phase, referred to as OV/2, will be managed by Goddard, with continued technical support furnished by Marshall. Activation and calibration of the various science instruments, modes, as well as continued refinements in alignment and focusing, will be accomplished during this period.

The OV program is scheduled to last for about 90 days from time of HST's deployment with the time divided roughly equally between the two Orbital Verification phases.

### **HST Activation In Discovery's Cargo Bay**

The Shuttle crew will open Discovery's cargo bay doors shortly after entering orbit. Then they will wait several hours to allow the air inside the telescope to vent into space, reducing the possibility of electrical arcing in some components when the main power is supplied to HST. After the air has had time to escape, the DOV will give the go-ahead for astronauts to switch on the main power from Discovery's aft flight deck.

Orbital verification is now officially underway and from this point on, the telescope will be under direct control of the STOCC at Goddard.

Next, the DOV will authorize Goddard mission operations to send an initial series of commands to the telescope. The telescope's communication system will respond by sending information about the telescope's condition to the STOCC. Mission operations then will confirm the telescope has received the commands. Simultaneously, the technical support team in the HOSC will evaluate the data from the telescope, verify the spacecraft is responding properly to the commands, and verify that it is in the proper configuration following launch.

Next, the OV team will begin a process called "thermal safing." Spacecraft are exposed to a huge range of temperatures in orbit, from blazing heat in direct sunlight to subfreezing temperatures during the portion of their orbit when the Earth is between the craft and the sun. Multi-layer insulation protects the telescope

from the higher temperatures, but without a heating system, components left exposed to space could freeze in a

short period of time. Thermal safing activates the telescope's heaters and thermostats to assure the components do not suffer from these external temperature extremes.

Toward the end of the orbiter's first day in space, the verification team will activate HST's onboard command computer and check its memory. The system which takes automatic control of the telescope in the event of loss of communications with the ground (Safe Mode system) also will be activated. While the Shuttle crew sleeps, the night shift at the STOCC will be at work, monitoring and managing systems and preparing for removal of the telescope from the cargo bay on the second day of the mission.

### **Release of HST**

During the morning of the second day, Discovery's crew will switch on HST's internal power and deactivate the Orbiter-supplied power system. The shuttle robot arm (Remote Manipulator System) will lift the Hubble Space Telescope from the bay and suspend it above the crew cabin, with its door pointed away from the sun.

The verification team will then send the signal to unfurl HST's solar arrays almost immediately, so the telescope's six batteries can start recharging. Next, the two high gain Tracking and Data Relay Satellite System (TDRSS) antennas on the HST will be deployed.

Mission Specialists Bruce McCandless (MS1, EV1) and Kathy Sullivan (MS3, EV2) will be standing by in their spacesuits ready to go outside the spacecraft to manually provide these functions should the telescope fail to respond correctly to ground commands.

Pointing systems will be activated to control the telescope's orientation. Then, the remote manipulator arm will release its hold, and the HST will float free in orbit. Following the telescope's release, the Shuttle will back away into a parallel orbit to stand by for approximately two days in case problems occur requiring corrective action by the astronauts.

### **Aperture Door Opening Through End Of OV/1**

The telescope's aperture door must be opened next. After the OV director is confident the instruments are reading correctly and that the telescope is pointed away from the sun, Hubble's light shield door will be commanded open. Light from space will reach the telescope's precision-ground mirrors for the first time.

The OV team will gradually adjust the position of the secondary mirror until the images in the telescope's field of view become precise and sharp. Several dozen exacting adjustments in the position of the mirror may be required to further refine the focus and to compensate for the contraction of the focal plane metering truss as desorption of water vapor occurs.

All of the individual components within each instrument require specialized attention. Engineers at the STOCC will bring the instruments up to full power and make sure they are operating properly. They also will activate and evaluate the science computers which controls them. Actual fine-tuning and calibration of the instruments is part of scientific verification, but OV will not be over until the scientific instruments are fully activated and ready for use.

About 6,200 specific items of information on the telescope's status, called "telemetry points," are monitored by computer. Safe limits at any given stage of activation for each individual telemetry point have been established. Engineers from both the mission operations team at Goddard and the Marshall technical support team at Huntsville will track systems in their area of specialty. If any item does not perform within its predicted limits it will be up to the OV team to determine if the problem is in the telescope itself or in the ground system and then to decide how to resolve it. With a system as unique and complex as the HST, it is



almost inevitable that some problems will arise. The purpose of OV is to catch them before they grow into situations which could hamper telescope performance.

### **OV/2 First Week (Begins About HST Day 45)**

Engineering tests and calibrations will be performed to continue optimizing instrument settings and operations. Aperture calibrations to determine their precise locations also will be started. This set of refinements begins the process of aligning each instrument's specific aperture (a few thousandths of an arc-second field of view) within that instrument's portion of the telescope's focal-plane field-of-view. Several instruments will monitor the effects of the South Atlantic Anomaly (SAA) on instrument performance. This data will be used to decide the high voltage turn-on sequences for the science instruments and to determine if they will be able to continue data acquisition in the SAA.

The WF/PC will perform an activity to remove any contamination that has possibly formed on the Charged Coupled Devices (CCD). Power will be applied to the Thermal Electric Coolers (TEC) and the CCDs will be cooled down to the proper operating temperature for science observations.

The FOC will perform its first external target observations on a star for the purpose of aligning its apertures.

### **OV/2 Second Week**

The STOCC team will continue monitoring the effects of the SAA on the instruments. Instrument calibration and aperture alignment calibration tests will be continued. The Faint Object Spectrograph (FOS) will perform its first external target observations of a star to align its aperture. The spacecraft's ability to perform an accurate continuous scan will be assessed.

### **OV/2 Third Week**

Tests and calibrations for instrument setting and aperture alignment will continue. The WF/PC starts a series of observations that will assist in defining the sharpness of images and the ability of the camera to recognize two closely spaced images.

The Goddard High Resolution Spectrograph (GHRS) will perform its first external target observations of a star to align its apertures.

Data will be taken which will be used to remove the non-uniformities from WF/PC's images.

An HST thermal stability test will be performed to characterize the telescope to establish the capability of the Fine Guidance Sensors (FGS) to perform astrometry science.

### **OV/2 Fourth Week**

Tests and calibrations of the instruments continue. The FGS to FGS alignment will be performed to provide more precise accuracy than was achieved in OV/1. The alignment will improve the ability to establish the proper science instrument (SI) calibrations. This activity, coupled with the SI fine aperture alignment calibrations, which also are performed at this time, give the spacecraft the calibration accuracy to start the more stringent calibration activities.

These processes constitute a mid-point in what might be termed the overall boresighting activities associated with determining the telescope guidance system alignment, the telescope optical truss alignment, individual instrument alignments and finally the overall system alignment.

The first FOS spectrum will be performed during the fine aperture alignment calibration and the spiral search target acquisition capability of the GHRS will be verified.

**OV/2 Fifth Week Through End Of OV/2**

Tests and calibrations of instruments continue. The optical distortion in the FGS used most often for astrometry science will be measured to provide a baseline for this FGS and the ability to do science with FGSs at the required accuracy.

The long slit spectrographic mode of the FOC will be tested for the first time.

## SCIENCE VERIFICATION

After OV is completed, further calibration of the instruments and evaluations of the telescope's performance will be accomplished. This next effort will be carried out through the Space Telescope Science Institute. During this period, astronomers who contributed to the telescope's design will be given an opportunity to use the telescope to begin conducting their research. However, only after scientific verification is complete will the telescope be ready to begin its full-scale investigations.

Science Verification (SV) begins the phase of using the now-aligned telescope instruments to test their performance capabilities. These performance tests use specific astronomical targets for each instrument and will provide a gauge of the HST instrument's performance compared with results derived from previous, ground-based, observations of the same target.

The SV process is lengthy and is expected to last through early Fall, 1990. During this time, as specific instruments are tested and their performance capabilities recorded, some science observations will begin to be made even though the entire suite of instruments may not yet be declared operational.

### Science Operations

Once the Hubble Space Telescope and its instruments have been fully checked out and the entire system including ground data and computational systems declared operational, HST operations will be turned over to the Space Telescope Science Institute (STScI). The institute is located on the Homewood campus of the Johns Hopkins University, Baltimore, Md.

Here, the science observing program has been developed, and it will be from here that target selection and subsequent scientific observations using HST will be performed. Although it is not necessary for the investigators to be present at the STScI during their observations, space for visiting scientists is available and a great number of astronomers are expected to take up temporary residence during the time of their observations.

### Command, Control, Observation And Data Systems

The principal components of the command, control, observation and data flow for the Hubble Space Telescope are:

- HST itself with its onboard computers and data systems;
- The Tracking and Data Relay Satellites (TDRS);
- The TDRS White Sands Ground Station (WSGT);
- Domestic communications satellites;
- The Goddard Network Operations Control Center (NOCC) at GSFC;
- NASA Communications System (NASCOM) at GSFC;
- The Space Telescope Operations Control Center (STOCC) at GSFC;
- The Space Telescope Data Capture Facility (STDCE) at GSFC;
- The Space Telescope Science Institute (STScI) at Baltimore;
- The Space Telescope European Coordinating Facility (ST-ECF);
- And ultimately the astronomers and scientists who use the data.

### Tracking And Data Relay Satellite System

The conduit that connects HST to the science community is the Tracking and Data Relay Satellite System (TDRSS). There are two operational TDRS satellites, one situated over the Pacific Ocean (TDRS-W) and

one over the Atlantic (TDRS-E). Without the TDRS system, HST would not be able to conduct its observations.

HST is the first user to simultaneously require both Multiple Access (MA) and S-band Single Access (SSA) return services from TDRSS. TDRSS will continually transfer engineering data through the MA system to the STOCC at Goddard. This service will be provided for up to 85 minutes of every HST orbit that HST is in view of one of the TDRSS satellites.

TDRSS will also provide SSA forward and return services each orbit. Real-time science and readouts of the HST onboard recorders will be collected through the SSA return service. The SSA forward service will allow the 12,000 commands executed by HST daily to be packaged and transmitted to Hubble telescope's two onboard command computers controlling the spacecraft.

HST will transmit almost three billion bits of information through the TDRSS each day. This information is received at White Sands and forwarded to the Goddard Data Capture Facility where it receives initial processing.

The data is then forwarded to the Space Telescope Science Institute. There the science data is processed, calibrated and archived. Copies of the archive tapes are provided to the European Coordinating Facility at Noordwijk, the Netherlands. American and European astronomers take the data from either the Institute or the ECF back to their home institutions for detailed processing and subsequent analysis.

The White Sands Ground Terminal, located at White Sands, New Mexico, uses a pair of 16-foot (4.9 meter) diameter antennas to communicate with the TDRS-W and TDRS-E in either S- or K-bands or both. It uses separate antennas to receive and transmit the TDRSS data to other NASA controls centers using leased domestic communications satellites.

### **Space Telescope Operations Control Center**

The STOCC is located on the campus of the Goddard Space Flight Center and operates as a dedicated spacecraft control center. It directly communicates, through NASCOM and WSGT and the TDRS system, to the Hubble telescope.

The STOCC contains a large number of redundant independent computer systems. Each of the seven computer systems operates a portion of the complex scheduling, configuring and commanding system which is required to manage and run the HST. Separate systems located at the STScI work directly with STOCC systems during real-time science operations with the HST.

Within the STOCC is a separate sub-control center called the Mission Operations Center (MOC). The MOC integrates the observing schedule for each of HST's five instruments into a master schedule which includes TDRS system availability. The MOC then originates the commands which direct the movement of the HST for coverage of the various scientific targets.

### **Space Telescope Science Institute**

The Institute is both the starting point for observations and the ending point for the data from those observations. In preparing an observing calendar for HST, STScI planners arrange schedules to maximize the science gain from the telescope. In all, STScI schedulers must partition some 30,000 observations within the approximately 3,000 hours available in any given 52-week observing cycle.

To aid in this scheduling, the Institute staff developed a tool (Science Planning Interactive Knowledge Environment - SPIKE) to prepare long- range calendars. What SPIKE does is to portray graphically the various constraints imposed by HST's science instruments, the orbital parameters of the spacecraft, the

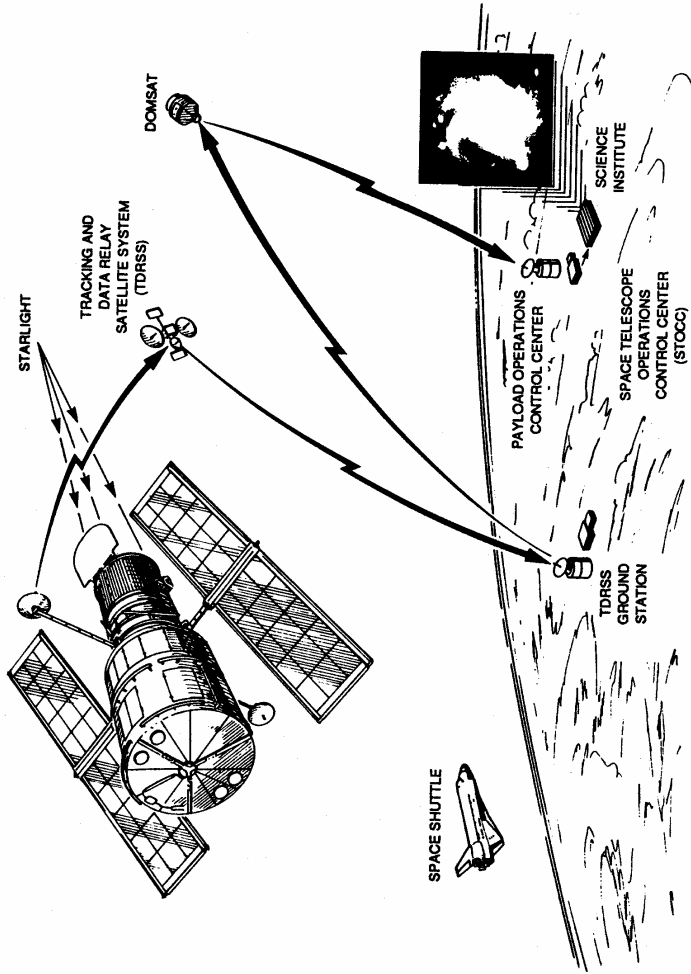
allocation of observing time for the particular observation permitted under the peer review system and any special requirements of the observer. SPIKE incorporates statistical and artificial intelligence tools which then allows a best fit for the observation and the available time.

The results of this planning are then fed into the Science Planning and Scheduling System (SPSS). Here a second-by-second timeline is computer generated to describe every detail of HST's science operation. The SPSS then assembles the requests for commands which will be executed by the telescope's onboard computer systems to carryout the observation. The product of the SPSS is called a Science Mission Specifications file. This product is then transmitted from the Institute to Goddard where it passes through yet another computer system which converts the requests into the actual binary code which will be uplinked to the spacecraft.

### **European Coordinating Facility**

Astronomers will also have access to HST data via the Data Archive and Distribution System (DADS). The basic concept for this system is similar to that used for the International Ultraviolet Explorer (IUE) and European Exosat projects. As in these other projects, all raw and calibrated HST data, upon receipt at the STScI, will be placed in the archives and will become generally available once the original observer's proprietary period of access (normally a period of one year) has expired. A copy of the HST data archives will be transmitted and kept at the European Coordinating Facility (ST-ECF) where ESA Member-State astronomers will have full access to it. The ECF is co-located at the European Southern Observatory (ESO) located near Munich, Germany.

# HST NETWORK COLLECTING DATA



## HUBBLE SPACE TELESCOPE SPECIFICATIONS

Main Mirror diameter	94.5 inches (2.4 meters)
Main Mirror weight	1,825 pounds (821 kilograms)
Main Mirror coating	aluminum with 0.025 magnesium fluoride over 70 % at hydrogen Lyman-Alpha
Main Mirror reflectivity	70 % at hydrogen Lyman-Alphawave lengths and greater than 85 % at visible wavelengths
Optical focal ratio	f/24
Spacecraft length	43.5 feet (13.3 meters)
Spacecraft diameter	(with solar array stowed) 14.0 feet (4.3 meters); (solar arrays deployed) 40.0 feet (12.0 meters)
Solar array size & power	7.9 by 39.9 feet (2.4 by 12.1 meters) each average 2,400 watts electricity production
Spacecraft weight:	24,000 pounds (11,000 kilograms)
Orbital brightness	-3 magnitude (Venus is -4.5, Jupiter is -2.3, the Moon is -12.8)
Fine Guidance	Measurement of position of a star to System Capabilities within 0.002 arc-seconds

## FUNCTIONAL DESCRIPTION OF HST OPERATIONS

Information and command flow from start to finish of an HST observation is one of the most complex and interactive activities NASA has yet undertaken in the realm of science operations.

Proposals first go to the Science Institute for review and selection. Selected proposals are then transformed into requirements against HST instrumentation and observation time. These requirements are then matched with available spacecraft capabilities and time allocations. During this process, a parallel activity matches the observation with necessary "guide stars" to serve as guidance system targets during the observation. This process matches the field of view of the observation and its target with available stars from the Guide Star Catalog (GSC). Following this process a science observation schedule is developed and sent to Goddard.

At Goddard, the science observations schedules are matched with spacecraft schedules and network tracking and data schedules. This combined schedule is then converted into HST computer commands and then sent to the Payload Operations Control Center. From there the commands travel through the NASA communications network to White Sands and then through the TDRS system to the Hubble Space Telescope.

HST's onboard computer then executes the command sequence, moving the spacecraft into position, turning on appropriate instruments and data recording equipment and executing the observations. Data from the observations is then sent back through the TDRS and NASA communications system to Goddard. At Goddard the data is first captured in an interim data storage facility and from there is transmitted to the Institute for additional processing. Following the Institute's initial processing the data is then calibrated and both archived and distributed to the scientist whose observations it represents.

In tandem with these activities, the Goddard STOC maintains an updated computer file on both the performance of the Hubble spacecraft and its exact orbital parameters. These are critical for the proper development of the command sequences and for inertial reference.



## SCIENCE QUESTIONS HST WILL HELP ANSWER

When HST is declared operational, sometime in the fall of 1990 if the verification activities are accomplished satisfactorily, the astronomy team associated with the project will be able to finally begin their full-scale attack on some of astronomy and cosmology's toughest questions.

These questions are much the same fundamental questions which the Renaissance philosophers, the Arab and before them the Egyptian and Mayan astrologer/astronomers faced. They are simple questions: How big is the universe? How old is the universe? Newer, but still simple, questions are based on our understanding of Edwin P. Hubble's pioneering work and that of the Russian mathematician Alexander Friedman and the corroborating evidence from Arno Penzias and Robert Wilson. These questions include will the universe expand forever? What is the large scale structure of the universe? And, is the universe homogeneous on a large scale. More difficult but allied questions pertain to why normal matter (baryons) exist at all. Why is matter seemingly smoothly distributed through the universe? How did structure (galaxies) arise from a smooth homogenous fireball (big bang)?

Some of these cosmological questions give rise to further, more precise, questions. What is the Hubble Constant? Today's astronomical observations give numbers which vary by a factor of two. The Hubble Constant is a calculation of the rate at which space is expanding and is expressed in kilometers per second per megaparsec (3.26 million light years). Another question facing today's astronomers is what is the age of the universe. This is calculated by taking the inverse of the Hubble Constant. Today's numbers vary from 10 to 20 billion years of age.

What is the Deceleration Parameter? This is a measure of whether the distant galaxies are receding at a slower rate than nearby (newer) galaxies and would indicate a finite universe if the total pull of the matter in the universe were sufficient to create a large Penzias - in effect slowing down the expansion and perhaps ultimately causing a recollapse.

The expansion of the universe is controlled by the amount of matter per unit volume (density). If the density is high enough, the expansion of the universe will eventually slow and reverse. If the density is not high enough then the universe will expand forever. The measure of the density therefore becomes another critical element in our understanding the evolution of the universe.

Hubble Space Telescope will contribute to answering these questions in a variety of key observations. HST will be able to directly measure Cepheid Variable stars out to 30 million light years. These stars are the mileposts by which distance is measured over vast distances. An accurate measure of Cepheid Variables out to the distance of the Virgo Supercluster (2,500 galaxies amassed together) will greatly extend reliable distance measurements more than ten times than can be routinely done from ground observations. HST will find Cepheid stars in a sample of about 50 galaxies to arrive at an accurate measurement of the Hubble Constant.

The Hubble telescope also will enable astronomers to determine the age of the universe by accurately measuring stars at distances much greater than is now possible. Current cosmology has star formation occurring at a period about one billion years (or so) after the Big Bang when the temperature of the universe cooled sufficiently to allow atomic hydrogen to form and begin condensing into stars. An accurate measurement of the ages of the oldest stars will set a minimum age for the universe and therefore help constrain the Hubble Constant.

Because HST is ideally suited for the task of resolving faint galaxies at very high red shifts (a measure of recessional velocity and therefore distance), it will also help in determining the deceleration rate of distant galaxies. Before this technique can be applied, though, HST will have to add to our knowledge about such distance galaxies since current observations of these are so limited. Because such distant galaxies formed much longer ago than nearby galaxies, their intrinsic luminosity and color are not well understood which means they cannot reliably be used at the present as a milepost. However, HST observations will contribute to the intrinsic understanding of these galaxies and subsequent observations based on new theories will allow potential use of these distant galaxies as measuring devices for studies of deceleration.

By studying the motions of galaxies within clusters out to a distance of nearly 100 million light years, HST astronomers will be able to infer the mass of galaxies - both the light matter (stellar composition) and any dark matter components. The resulting density measurements can then be scaled up to compute the mass of the universe as a whole.

Acquiring answers to cosmological questions are a major reason for the development and flight of the Hubble Space Telescope. There are, though, a great many questions in the realm of astronomy and astrophysics which HST will be addressing as well. A primary task for HST will be to trace the evolution of galaxies and clusters of galaxies. Since HST will be able to survey a volume of space nearly 100 times larger than can be surveyed with comparable resolution from the ground, HST will help give us a picture of what galaxies were like when the universe was only 35 percent of its present age.

HST's high resolution will allow a survey for extra galactic black holes. The imaging systems may be able to provide pictures of an accretion disk in nearby galaxies and HST spectrometers will enable us to measure the velocities of infalling gas thereby gauging the mass of suspected black holes.

Hubble telescope's instruments should enable a breakthrough in our understanding of synchrotron jets which extend for hundreds of thousands of light years from the center of active galactic cores. For the first time, these jets will be seen in ultraviolet light. These observations will be matched with comparable resolution views taken with radio astronomy observations.

Some of the questions pertaining to galaxies, quasi-stellar objects (quasars or QSOs) and active galactic nuclei include:

- How soon after the Big Bang did galaxies form?
- How do galaxies evolve?
- What are the dynamics of galaxies in clusters?
- Do galaxies harbor massive black holes?
- What is the dark matter in a galaxy and how is it distributed?
- How important are galactic collisions in galaxy formation?
- What is the nature of starburst phenomena?
- What is the engine which powers quasars?
- What fuels the quasar engine?
- Are there new physics to be found powering the QSO engine?
- Do quasars represent a normal stage in galactic evolution?

Stellar physics questions to be addressed by HST include studying white dwarfs. White dwarf stars are keys to our understanding the stages of late stellar evolution. HST will aid in our present understanding of this stage in a star's life and answer questions such as, can stars re-ignite after having ejected much of their mass late in their life.

At the other end of a star's life, HST will image circumstellar disks in star-forming regions to see how stellar activity affects the disks and perhaps deduce what conditions are right for planetary system formation.

Solar physics and solar system evolution are major fields of investigation for the HST astronomy team. Some of the questions HST will help answer in these fields are:

What is the precise sequence of steps in star formation? What determines the rate of star formation? How common are jets and disk structures in other stars? What is the mechanism that triggers nova-like outbursts in double stars? What are the progenitor stars to supernovas? Do circumstellar disks show evidence of planet building? Do planets exist about other stars? How abundant are other solar systems? What is the meteorology of the outer planets and how does it change over time? What is the meteorology of Mars & what triggers the global summer dust storms? How do the surface patterns of Pluto change over time?

## **HUBBLE SPACE TELESCOPE PROGRAM HISTORY**

Long before mankind had the ability to go into space, astronomers dreamed of placing a telescope above Earth's obscuring atmosphere. In the heydays of the Roaring Twenties, German rocket scientist and thinker Hermann Oberth described the advantages a telescope orbiting above Earth would have over those based in observatories on the ground.

Scientific instruments installed on early rockets, balloons and satellites beginning in the late 1940s produced enough exciting scientific revelations to hint at how much remained to be discovered. In the technology era spawned by the end of World War II, Dr. Lyman Spitzer Jr., an astronomer at Princeton University, advanced the concept of an orbiting instrument of the Mount Wilson Observatory.

The first official mention of an optical space telescope came in 1962, just four years after NASA was established, when a National Academy of Sciences study group recommended the development of a large space telescope as a logical extension of the U.S. space program.

This recommendation was repeated by another study group in 1965. Shortly afterwards the National Academy of Sciences established a committee, headed by Spitzer, to define the scientific objectives for a proposed Large Space Telescope with a primary mirror of about 10 feet (or 120 inches).

Meanwhile, the first such astronomical observatory--the Orbiting Astronomical Observatory-1, already had been launched successfully in 1968 and was providing important new information about the galaxy with its ultraviolet spectrographic instrument.

In 1969 the Spitzer group issued its report, but very little attention was paid to it by the astronomy community. At that time quasars, pulsars and other exotic cosmic phenomena were being discovered and many astronomers felt that time spent working towards a space telescope would be less productive than their existing time in ground-based observatories.

A 1972 National Academy of Sciences study reviewed the needs and priorities in astronomy for the remainder of that decade and again recommended a large orbiting optical telescope as a realistic and desirable goal. At that same time, NASA had convened a small group of astronomers to provide scientific guidance for several teams at the Goddard and Marshall Space Flight Centers who were doing feasibility studies for space telescopes. NASA also named the Marshall center as lead center for a space telescope program.

### **NASA Establishes A Telescope Office**

NASA established in 1973 a small scientific and engineering steering committee to determine which scientific objectives would be feasible for a proposed space telescope. The science team was headed by Dr. C. Robert O'Dell, University of Chicago, who viewed the project as a chance to establish not just another spacecraft but a permanent orbiting observatory.

In 1975 the European Space Agency became involved with the project. The O'Dell group continued their work through 1977, when NASA selected a larger group of 60 scientists from 38 institutions to participate in the design and development of the proposed Space Telescope. In 1978 Congress appropriated funds for the development of the Space Telescope.

NASA assigned responsibility for design, development and construction of the space telescope to the Marshall Space Flight Center in Huntsville, Ala. Goddard Space Flight Center, Greenbelt, Md., was chosen to lead the development of the scientific instruments and the ground control center.

Marshall selected two primary contractors to build the Hubble Space Telescope. Perkin-Elmer Corporation in Danbury, Connecticut, was chosen over Itek and Kodak to develop the optical system and guidance sensors. (Though Kodak was later contracted by P-E to provide a backup main mirror blank, which it did and which is now in storage at Kodak, Rochester, N.Y.) Lockheed Missiles and Space Company of Sunnyvale, California, was selected over Martin Marietta and Boeing to produce the protective outer shroud and the support systems module (basic spacecraft) for the telescope, as well as to assemble and integrate the finished product.

The European Space Agency agreed to furnish the spacecraft solar arrays, one of the scientific instruments and manpower to support the Space Telescope Science Institute in exchange for 15% of the observing time and access to the data from the other instruments. Goddard scientists were selected to develop one instrument, and scientists at the California Institute of Technology, the University of California at San Diego and the University of Wisconsin were selected to develop three other instruments.

The Goddard Space Flight Center normally exercises mission control of unmanned satellites in Earth orbit. Because the Hubble Space Telescope is so unique and complex, two new facilities were established under the direction of Goddard, dedicated exclusively to scientific and engineering operation of the telescope. The facilities are the Space Telescope Operations Control Center at Goddard and the Space Telescope Science Institute, on the grounds of the Johns Hopkins University, Baltimore, Md.

The Space Telescope Operations Control Center, or STOCC as it is called, is located in a wing of Building 14 on the Goddard campus. It was established in 1985 as the ground control facility for the telescope. The scientific observing schedule developed by the Science Institute will be translated into computer commands by the control center and relayed via the Tracking and Data Relay Satellite System to the orbiting telescope. In turn, observation data will be received at the center and translated into a format usable by the Science Institute. The control center also will maintain a constant watch over the health and safety of the satellite.

The Space Telescope Science Institute was dedicated in 1983 in a new facility near the Astronomy and Physics Departments of Hopkins. It will perform the science planning for the telescope. Scientists there will select observing proposals from various astronomers, coordinate research, and generate the telescope's observing agenda. They also will archive and distribute results of the investigations. The Institute is operated under contract to NASA by the Association of Universities for Research in Astronomy (AURA) to insure academic independence. It operates under administrative direction of the Goddard center.

### **Telescope Construction Takes Decade To Accomplish**

Construction and assembly of the space telescope was a painstaking process which spanned almost a decade. The precision-ground mirror was completed in 1981, casting and cooling of the blank by Corning Glass took nearly a year. The optical assembly (primary and secondary mirrors, optical truss and fine guidance system) was delivered for integration into the satellite in 1984. The science instruments were delivered for testing at the Goddard center in 1983. Assembly of the entire spacecraft at the Lockheed Sunnyvale facility was completed in 1985.

Launch of the Hubble Space Telescope was originally scheduled for 1986. It was delayed during the Space Shuttle redesign which followed the Challenger accident. Engineers used the interim period to subject the telescope to intensive testing and evaluation, assuring the greatest possible reliability. An exhaustive series of end-to-end tests involving the Science Institute, Goddard, the Tracking and Data Relay system and the spacecraft were performed during this time, resulting in overall improvements in system reliability.

The telescope was shipped by Air Force C5A from Lockheed, Sunnyvale, to the Kennedy Space Center, Florida in October 1989.

From 1978 through launch, the Space Telescope Program has cost \$1.5 billion for the development, design, test and integration of the Hubble Space Telescope and associated spacecraft elements, \$300 million for the science and engineering operations which have been supporting both the spacecraft development and the ground science operations at Goddard and the Space Telescope Science Institute, and \$300 million for the design, development and testing of servicing equipment to maintain the Telescope's 15-year expected lifetime.

The Hubble Space Telescope 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 down time. Some of the components such as batteries and solar arrays have a life expectancy shorter 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. Several new generation instruments are already under development. In-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 telescope back to Earth.

### **Modular Design Enhances Maintenance And Upgradability**

The modular design of many space telescope components means that units may be pulled out and a replacement plugged in without disturbing other systems. Doors on the exterior of the telescope allow astronauts access to these modular components, called Orbital Replacement Units. Handrails and portable foot restraints make it easier for them to move about in the weightless environment while working on the telescope. A special carrier has been designed to fit in the orbiter's cargo bay to hold replacement parts and tools.

Astronauts will visit the space telescope every three to five years on servicing missions. In case of an emergency, special contingency rescue missions have been partially developed and could be mounted between the scheduled visits.

On servicing missions, the Space Shuttle will rendezvous with the orbiting telescope. Astronauts will use the Shuttle's remote manipulator arm to pull in the observatory and mount it on a maintenance platform in the orbiter's payload bay. Astronauts will don space suits and go out into the bay to complete required maintenance. They may change out batteries or solar arrays, a computer, one of the scientific instruments, or any of the more than 50 units that can be replaced in orbit. The Shuttle also may be used to carry the telescope back to its original orbital altitude if atmospheric drag has caused it to descend.

Once the maintenance is finished, the telescope will be released once more as a free flyer. A ground team reactivation will then take place so the telescope again can resume its exploration tasks.

### **Program Participants Come From All Over**

The Hubble Space Telescope is the product of not just one group or agency, but a cooperative effort of many dedicated people from across the United States and around the world. Following is a brief summary of the institutions that are a part of the Hubble Space Telescope Program and their contributions:

- NASA Headquarters Astrophysics Division, Office of Space Science and Applications, Washington, D.C.: Overall direction of the Hubble Space Telescope Program.
- Marshall Space Flight Center, Huntsville, Alabama: Overall management for Hubble Space Telescope project, including supervision of design, development, assembly, pre-launch checkout and orbital verification.

- Goddard Space Flight Center, Greenbelt, Maryland: Development of the scientific instruments, day-to-day operation of the telescope through its Space Telescope Operations Control Center and oversight of the Space Telescope Science Institute on the campus of Johns Hopkins University in Baltimore, Maryland.
- Johnson Space Center, Houston, Texas: Orbiter and crew services during deployment and maintenance missions.
- Kennedy Space Center, Florida: Pre-launch processing and Space Shuttle launch support, assuring safe delivery of the telescope to orbit.
- European Space Agency: Provision of the solar arrays and Faint Object Camera, operational support at the Science Institute and maintenance of a data distribution and archive facility in Europe; in return ESA is allocated 15 percent of telescope observing time.

Universities whose staff members have made major contributions to the program include:

- California Institute of Technology, Pasadena: Wide Field/Planetary Camera, Dr. James Westphal, Principal Investigator;
- University of California at San Diego, La Jolla: Faint Object Spectrograph, Dr. Richard Harms, Principal Investigator (now with Applied Research Corp., Landover, Maryland);
- University of Colorado, Boulder: Dr. John C. Brandt, Principal Investigator for the Goddard High Resolution Spectrograph.
- University of Texas, Austin: astrometry (using the Fine Guidance System), Dr. William H. Jeffreys, Principal Investigator;
- University of Wisconsin, Madison: High Speed Photometer, Dr. Robert Bless, Principal Investigator.

## **HUNTSVILLE OPERATIONS SUPPORT CENTER**

### **HST Technical Support Team**

A team of technical experts at NASA's Marshall Space Flight Center, Huntsville, Ala., will monitor the Hubble Space Telescope's engineering performance during its deployment and activation to confirm whether ground commands sent to the telescope have had their desired result. They will help identify problems which may arise, analyze them and recommend solutions.

The Hubble Space Telescope Technical Support Team is composed of representatives of the agencies and companies which designed and built the space telescope. They will be stationed in Marshall's Huntsville Operations Support Center during orbital verification.

The data that the telescope sends back to Earth (called "telemetry") will be simultaneously monitored by engineers in the Space Telescope Operations Control Center at Goddard and by the technical support team in Huntsville. The Goddard group will use this information to track progress in implementing the verification schedule and to make short-term operational decisions. The Marshall team will track the telescope's status and engineering performance.

Support Team Responsibilities - Technical support team engineers have three major assignments:

First, they will monitor telescope telemetry, tracking several thousand engineering measurements to determine the ongoing status of the HST and to confirm whether the telescope has responded properly to ground commands sent from the control center at Goddard. With the information they receive, they can identify problems if they arise.

Second, they will use their in-depth knowledge of the telescope and its systems to analyze problems and recommend ways to resolve them. This will include problems identified at Goddard and assigned to the Huntsville team for analysis, as well as those discovered by the technical support group and reported to the orbital verification management team at the Space Telescope Operations Control Center at Goddard.

Third, they will evaluate the performance of the space telescope to determine its true capabilities and project its future performance.

Discipline Teams - Instead of being grouped by agencies and companies, the technical support team will be organized by specialty into ten discipline or subsystem teams. Team members will include civil service and contractor employees with expert knowledge of their particular Hubble Space Telescope subsystem.

Each contractor/government team will be led by a NASA engineer charged with accomplishing the three support team goals: problem analysis and resolution, evaluation of current performance and development of long-range predictions for the capabilities of the telescope system. Engineering specialists representing the companies which developed the system will also be part of the team. Each group will be assigned a conference work area where they can monitor current or past telescope telemetry and complete problem analyses.

Engineering Console Room - The "eyes and ears" of the technical support team will be provided by personnel in the engineering console room. Engineers stationed there from each discipline team will continuously monitor "real-time" telemetry (that currently being sent from the telescope). The current value of hundreds of different measurements concerning their assigned subsystem will be displayed on their computer screens. Some types of measurements to be tracked are temperature, velocity, time, position, current and voltage.

Each measurement has been assigned a safe limit for every stage of activation. For instance, at a stated time, a designated heat sensor should register a specified temperature. If the measurement begins to move outside its safe range, the screen it appears on will flash yellow to indicate the problem. If the limits are passed even

further, the screen will flash in red. About 200 measurements may be identified as critical for any point in activation or operation. When these approach the limits, a message will flash on all the terminals, regardless of discipline.

Method of Operation - Computer screens will be monitored simultaneously from the Goddard missions operations room and the Huntsville conference work areas and engineering console room. A situation requiring attention may be first detected at any of these locations.

Once a problem is identified, the discipline teams will go into action to track down its cause. First, they will determine if there is a real malfunction in the telescope or if the computer software is showing an erroneous measurement. If the problem is with the telescope itself, an approach to resolving it will be formulated between the management group at Goddard and the technical support team.

Contingency plans, designed in advance for dealing with possible problems, will be reviewed. Discipline teams will analyze current and past data from the telescope, as well as their design records. Based on that research and their in-depth knowledge of the system, the discipline teams will recommend a solution to systems engineers in the action center. The action center management group will evaluate and consolidate the recommendation and pass it on to the orbital verification management team at Goddard.

Technical Support Team Participants - The 175-member Hubble Space Telescope Technical Support Team is made up of personnel from the Marshall Space Flight Center, Lockheed Missiles and Space Company, Hughes Danbury Optical Systems (formerly Perkin-Elmer) and the European Space Agency.



## HST CONTRACTORS AND SUBCONTRACTORS

Optical Telescope Assembly and Fine Guidance Sensors	Hughes Danbury Optical Systems	Danbury, CT
Primary Mirror blank	Corning Glass Works	Corning, NY
Mirror Metering Truss	Boeing Airplane Co.	Seattle, WA
Support Systems Module (spacecraft) and Integration	Lockheed Missiles & Space Co.	Sunnyvale, CA
Solar Arrays	British Aerospace Public Ltd. Co	Bristol, England, UK
Science Instrument Command and Data Handling	Fairchild Space Co.	Germantown, MD
Wide Field & Planetary Camera	NASA Jet Propulsion Laboratory	Pasadena, CA
CCD arrays for WF/PC	Texas Instruments	Dallas, TX
Faint Object Camera	Dornier GmbH	Friedrichshafen, FRG
Faint Object Spectrograph	Martin Marietta Corp.	Denver, CO
Goddard High Resolution Spectrograph	Ball Aerospace	Boulder, CO
High Speed Photometer	University of Wisconsin	Madison, WI
Space Telescope Operations Control Center	Lockheed Missile & Space Co.	Sunnyvale, CA
	Ford Aerospace & Comm. Co.	College Park, MD
Network and Mission Operations Support	Bendix Field Engineering	Columbia, MD
Science Operations Ground Systems	TRW, Inc.	Redondo Beach, CA
Computer system software	Computer Sciences Corp.	Silver Spring, MD
Light Shade, Magnetic Torquer and Sensing System, Safemode Electronics	Bendix Corporation	Greenbelt, MD

## PROTEIN CRYSTAL GROWTH EXPERIMENT

The Protein Crystal Growth (PCG) payload aboard STS-31 is a continuing series of experiments leading toward major benefits in biomedical technology. These experiments are expected to improve food production and lead to innovative new drugs to combat cancer, AIDS, high blood pressure, organ transplant rejection, rheumatoid arthritis and many other medical conditions.

Protein crystals, like inorganic crystals such as quartz, 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 or other organisms. 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 not as particular as many of the smaller molecules and often are 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 seats.

Since the molecules have more time to find their spot, fewer mistakes are made, creating more uniform crystals.

Protein crystal growth experiments were first carried out by the investigating team during STS 51-D in April 1985. These prototype experiments were flown four times and were primarily designed to test vapor diffusion techniques and sample handling apparatus.

The STS-26 PCG was the first controlled or systematic experiment to grow useful crystals by vapor diffusion in microgravity within a thermal control enclosure -- the Refrigerator/Incubator Module (R/IM). This equipment was also flown aboard STS-29 and STS-32. Crystals were grown at cold temperatures for the first time on STS-32, demonstrating the potential for using longer flights to process certain proteins.

Results from these experiments have been encouraging, with high quality crystals developing from several of the samples flown. Generally, these crystals are of exceptional size and/or quality when compared to control samples grown in gravity.

During the STS-31 mission, 60 different PCG experiments will be conducted simultaneously using 12 different proteins. These proteins are:

- Isocitrate Lyase -- 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.
- Porcine Pancreatic Phospholipase A2 -- an enzyme associated with many human disease states including rheumatoid arthritis and septic shock. Successful structure analyses of phospholipase crystal may lead to development of drugs to treat these conditions.

- Human Gamma Interferon (GIF-D) -- an enzyme which 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 (haemmmioragic), 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 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 which 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 activation of a part of the immune system which 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 which 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.

Shortly after achieving orbit, a crewmember 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 degrees C, as on STS-26 and STS-29.

Just prior to descent, the 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 PCG experiments are sponsored by NASA's Office of Commercial Programs and the Microgravity Science and Applications Division with management provided through Marshall Space Flight Center (MSFC), Huntsville, Ala. Richard E. Valentine, is mission manager and Blair Herron is PCG experiment 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-Birmingham (UAB), is lead investigator for the PCG research team.

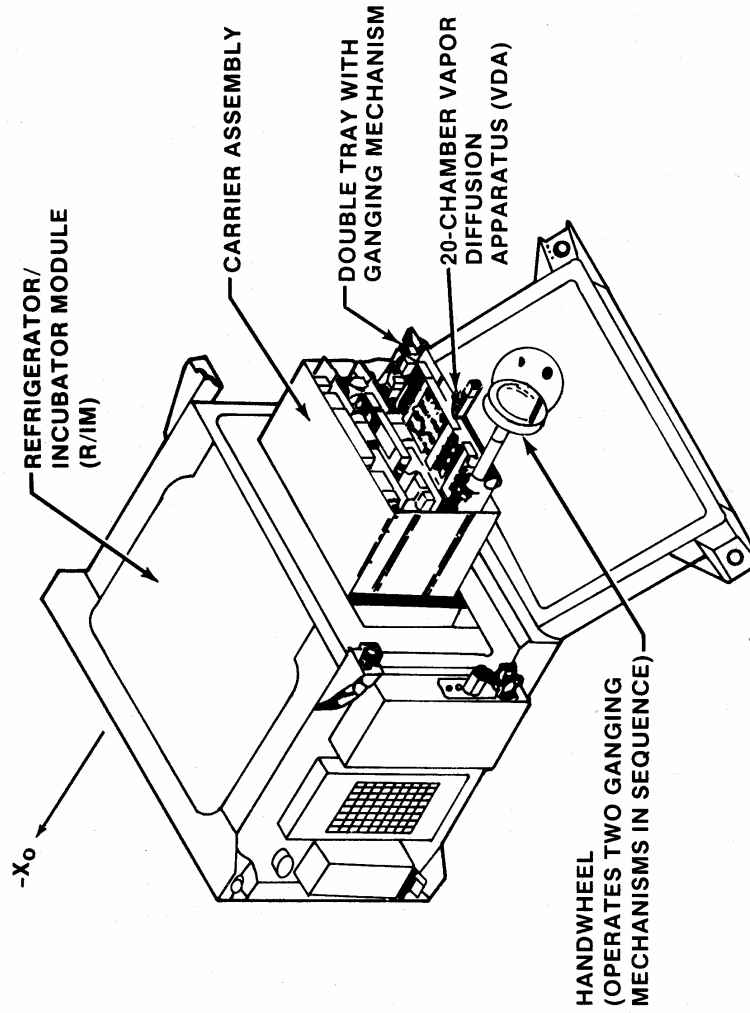
The STS-31 industry, university and government PCG research investigators include DuPont de Nemours & Co.; U.S. Naval Research Laboratory; BioCryst, Inc.; Schering Plough Corp.; Georgia Institute of Technology; Vertex Pharmaceuticals; Texas A&M University; University of California at Riverside; The Upjohn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



**NSTS** INTEGRATION  
AND OPERATIONS

# STS-31 PAYLOAD INFORMATION DOCUMENT

## PCG CONFIGURATION

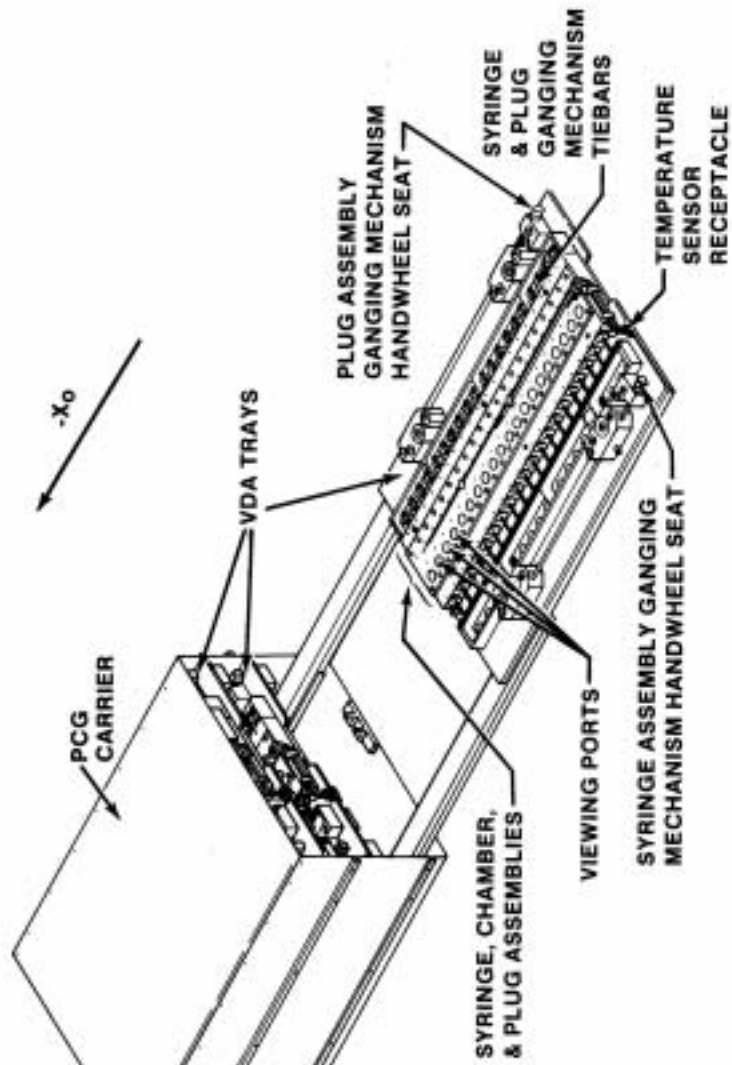




**NSTS INTEGRATION  
AND OPERATIONS**

## STS-31 PAYLOAD INFORMATION DOCUMENT

### PCG CARRIER ASSEMBLY WITH TRAYS



## INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING

The Investigations into Polymer Membrane Processing (IPMP) is a middeck payload developed by the Battelle Advanced Materials Center for the Commercial Development of Space (CCDS), 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 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 -- the solution is then evaporated 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 non-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 in. in diameter, with the smaller cylinder measuring 4.5 by 2 in. The overall dimensions of each IPMP unit are 18.6 by 3.5 by 4.41 in. The total weight of the flight hardware (both units) is approximately 17 pounds.

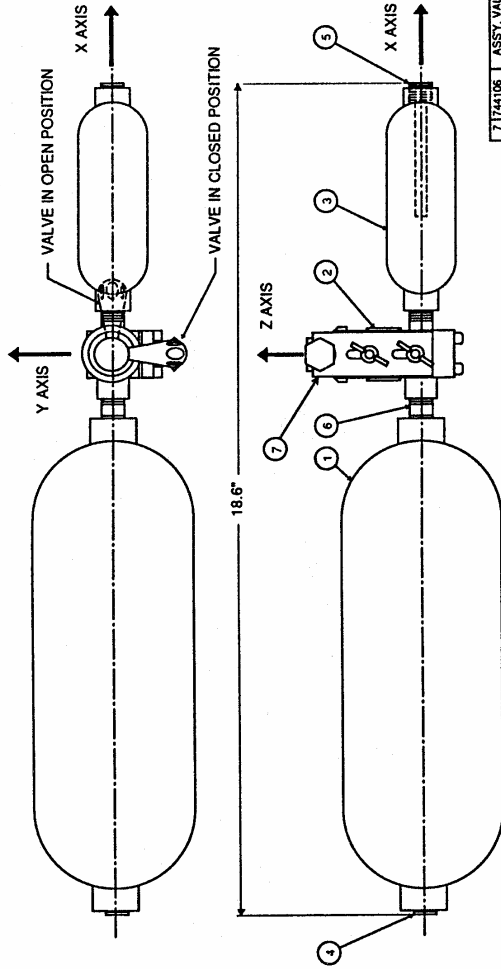
Before launch the larger cylinder, sealed on one end, is evacuated and sealed on the other end by closing the valve. The valve is then secured to preclude accidental opening during ground processing activities.

A thin-film polymer membrane is swelled in a solvent solution. (In this first flight experiment, the polymer -- polysulfone -- is swollen with a mixture of dimethylacetamide and acetone.) The resultant swollen gel (viscous fluid) is measured and inserted into a sample tube, which is inserted into the smaller of the two cylinders. This cylinder is sealed at ambient pressure (-14.7 psia) and attached to the other side of the valve. The procedure is repeated for the second unit. Once Discovery's on-orbit activities allow it, a crewmember 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 has a porosity related to the evaporation of the solution. The system reaches an equilibrium state, which is 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 (one-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 the Shuttle orbiter. Upon landing the IPMP will be returned to Battelle for analysis.

Principal investigator for the IPMP is Dr. Vince McGinniss of Battelle. Lisa A. McCauley, Associate Director of the Battelle CCDS, is program manager.

- NOTES:
- ASSEMBLE ALL PIPE FITTINGS BY WRAPPING A MINIMUM OF TWO LAYERS OF TFE TAPE ON MALE PIPE THREADS. TAPE MUST HAVE A MINIMUM DENSITY OF 1 GRAM/CC AND A MINIMUM THICKNESS OF 0.003 INCHES
  - BREAK ALL EDGES AND CORNERS 0.005 INCHES MINIMUM



7 1744106	ASSY. VALVE LOCKING
6 1744105	PIPE NIPPLE CLOSE, 1/4 IPT
5 1744104	PIPE NIPPLE, 1/4 IPT
4 1744103	PIPE NIPPLE, 1/4 IPT
3 1744102	MEMBRANE CHAMBER
2 1744101	MANUAL VALVE
1 1744101	VACUUM CHAMBER

Battelle  
 Battelle Memorial Institute  
 Columbus, Ohio 43210-1333  
 Phone: (614) 438-6424

TITLE		IPMP MICROGRAVITY EXPERIMENT	
SIZE	CODE	DWG. NO.	REV.
A	744	IPMP100	C
SCALE NONE		ACCT. G0743-7501	SHEET 1 OF 1

ENVELOPE DIMENSIONS

X: 18.6 INCHES  
 Y: 3.50 INCHES  
 Z: 4.41 INCHES  
 WEIGHT: 8.26 LBS

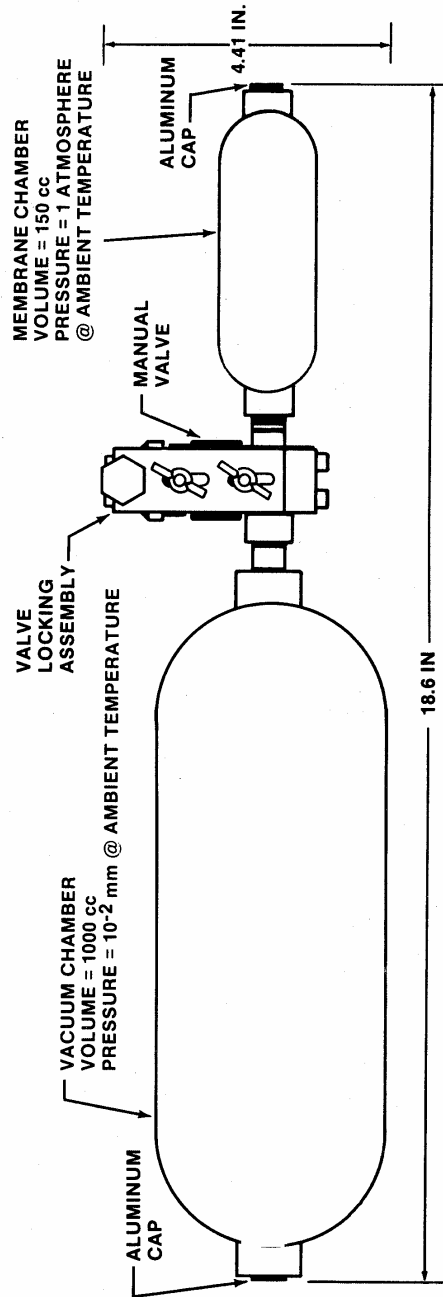




**NSTS** INTEGRATION  
AND OPERATIONS

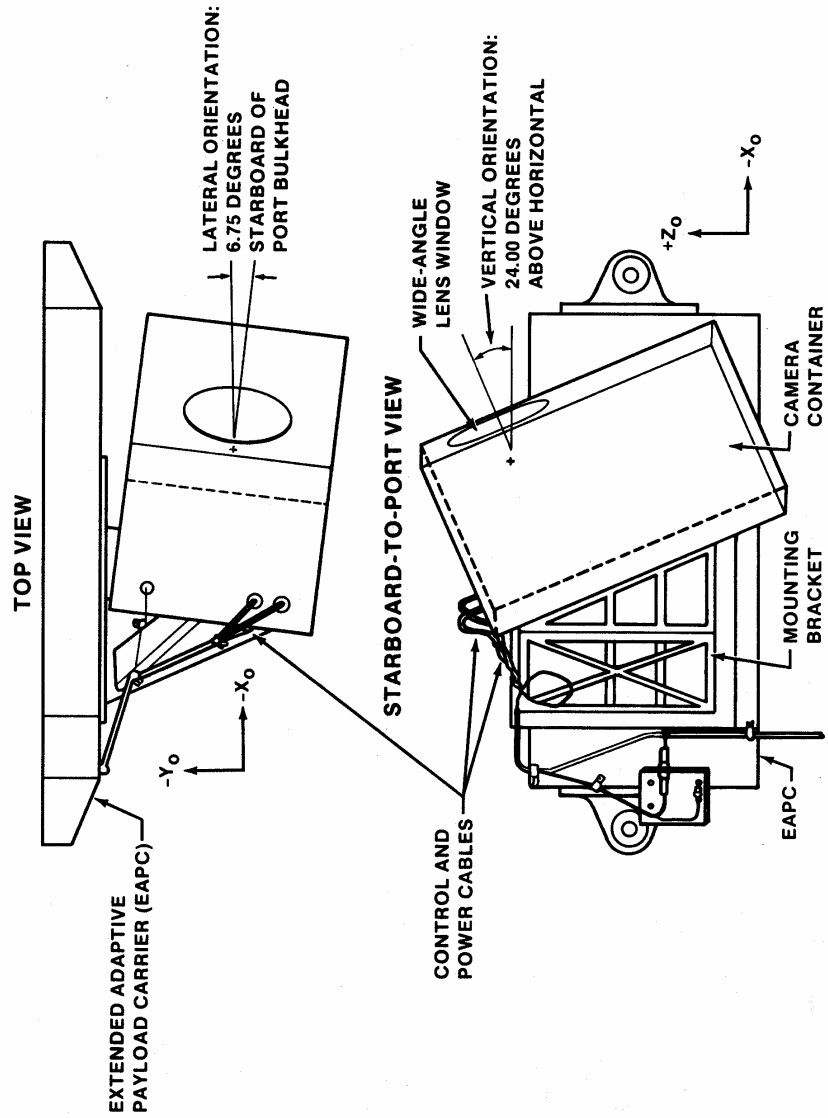
# STS-31 PAYLOAD INFORMATION DOCUMENT

## IPMP EXPERIMENT UNIT (TWO FLOWN IN HALF MIDDECK LOCKER)





ICBC MOUNTING CONFIGURATION:  
TOP AND STARBOARD VIEWS



## **ASCENT PARTICLE MONITOR**

The Ascent Particle Monitor is an automatic system mounted in Discovery's payload bay to measure particle contamination or particle detachment during the immediate prelaunch period and during ascent.

The payload consists of a small box with a fixed door and a moving door mounted in a clamshell arrangement atop an aluminum housing. Each door contains six sample coupons.

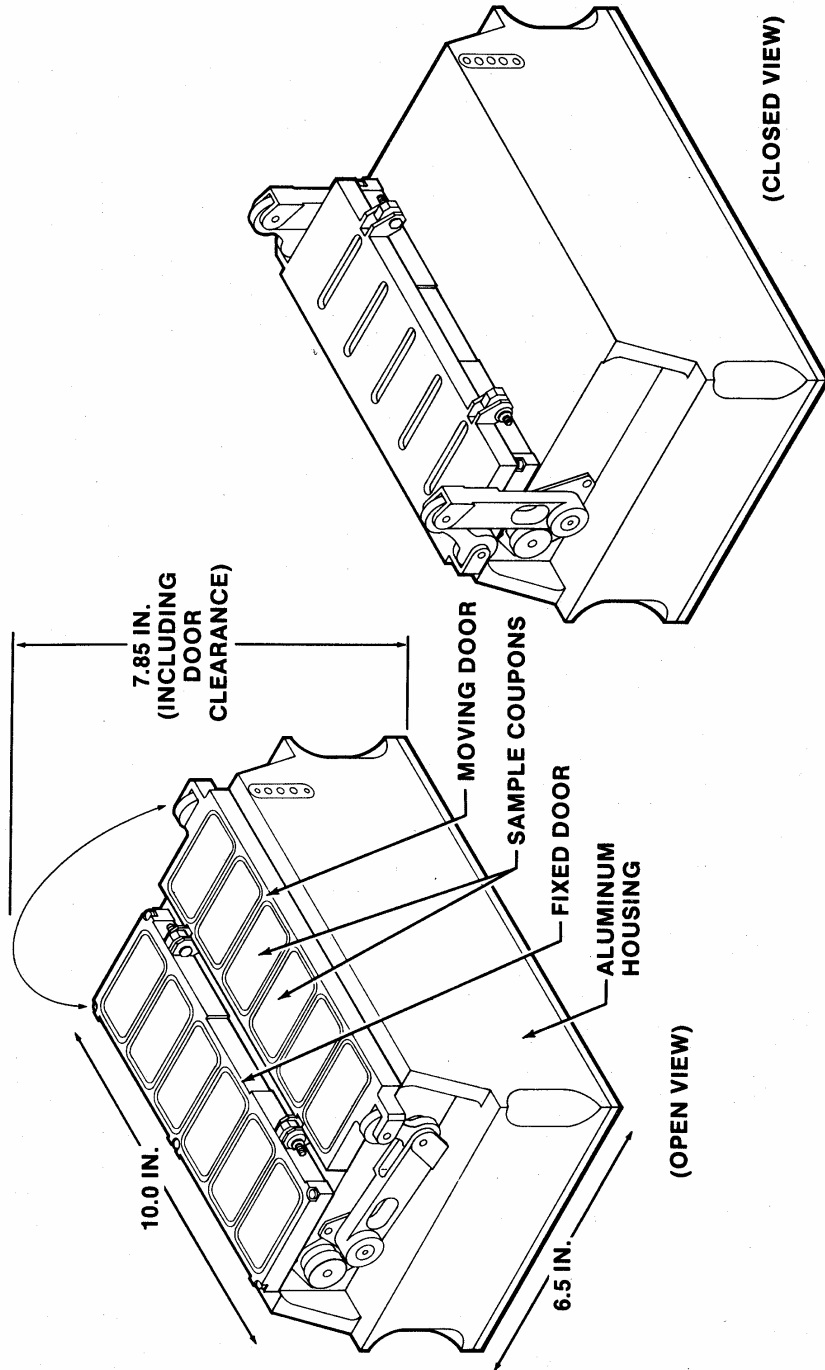
The doors are closed together preflight to protect the coupons from the environment. At a preselected time, the doors open exposing the coupons for a selected period of time. They are then closed to seal the coupons for later analysis. A motor/gearbox assembly, two battery packs and launch detection and door opening circuitry are contained within the aluminum housing.



**NSTS** INTEGRATION  
AND OPERATIONS

## STS-31 PAYLOAD INFORMATION DOCUMENT

### ASCENT PARTICLE MONITOR (APM)



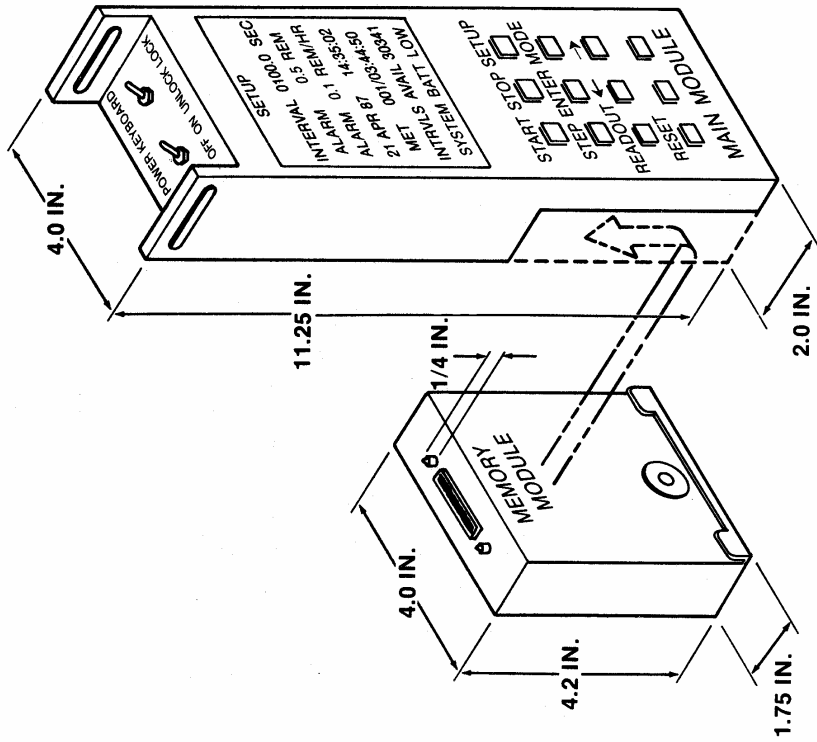
## **RADIATION MONITORING EXPERIMENT**

The Radiation Monitoring Experiment (RME) will record both the rate and total dosage of all types of ionizing radiation (gamma ray, neutron and proton radiation). The experiment consists of a single handheld instrument with replaceable memory modules. It contains a liquid crystal display for real-time data display and a keyboard for controlling its functions.

The experiment is self-contained with two zinc-air and five AA batteries contained in each memory module and two zinc-air batteries in the main module. RME-III will be activated as soon as possible after orbit is achieved and will be programmed to operate throughout the entire mission. A crew member will enter the correct mission elapsed time upon activation and change the memory module every 2 days. All data stored in the memory modules will be analyzed at the completion of the mission.



### RADIATION MONITORING EQUIPMENT CONFIGURATION



## STUDENT SCIENCE INVESTIGATION PROJECT

### "Investigation of Arc and Ion Behavior in Microgravity"

This SSIP experiment, selected in 1982, was proposed by Gregory S. Peterson, formerly of Box Elder High School, Brigham City, Utah. The experiment is designed to study the effect of weightlessness on electrical arcs.

In a normal Earth environment when electricity moves through the air between two points, air molecules become charged and form an ion path. This ion path is electrically more conductive than the surrounding air. Convective currents caused by the heating of the air around the arc tend to force the arc to rise, known as the "Jacob's ladder" effect.

In a weightless environment, convection currents cannot be created in this way, so the arc will behave differently. It is postulated that the arc shape will depend on things such as interaction between the ions, the magnetic field generated by the arc, and others. These things are not observable on Earth because the effect of convection is so much stronger than any of the other forces.

To observe the effects of free fall on an arc and to study the effects of a magnetic field on an arc without convection, Peterson's experimental apparatus consists of a sealed aluminum arc chamber box within a sealed aluminum outer box. Both boxes have a window in which a wire screen is embedded to prevent the escape of electromagnetic interference while allowing viewing and photography. Both boxes are filled with a mixture of 67% argon and 33% nitrogen to prevent the formation of ozone. Experiment results could have possible applications to materials processing in space.

Peterson is now a senior studying chemistry and biology at Utah State University. His teacher advisor is Darrel Turner, formerly with Box Elder High School. The experiment was sponsored by Thiokol Corp., with the science advice of Val King, Space Dynamics Laboratories.

## IMAX

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 IMAX Systems Corp., Toronto, Canada, uses specially designed 70 mm film cameras and projectors to record and display very high definition large-screen pictures.

During Shuttle Mission STS-31, an IMAX Cargo Bay Camera (ICBC) will be carried in the payload bay of Discovery and used to document activities associated with the deployment of the Hubble Space Telescope. The camera is mounted in the in a pressure-sealed container with a viewing window. The window has a sliding door which opens when the camera is in operation. The camera is controlled from the aft-flight deck, exposing the film through a 30 mm fisheye lens.

A second IMAX camera will be flown in the mid-deck of the orbiter and will be used by the crew to collect additional material for upcoming IMAX productions.

IMAX cameras previously have flown on Space Shuttle missions 41-C, 41-D and 41-G to document crew operations in the payload bay and the orbiter's middeck and flight deck along with spectacular views of Earth. Film from those missions form the basis for the IMAX production, *The Dream is Alive*.

The IMAX camera flew on STS-29 in March 1989, STS-34 in October 1989 and most recently STS-32 in January 1990. During those missions, the camera was used to gather material for an upcoming IMAX production entitled *The Blue Planet*.

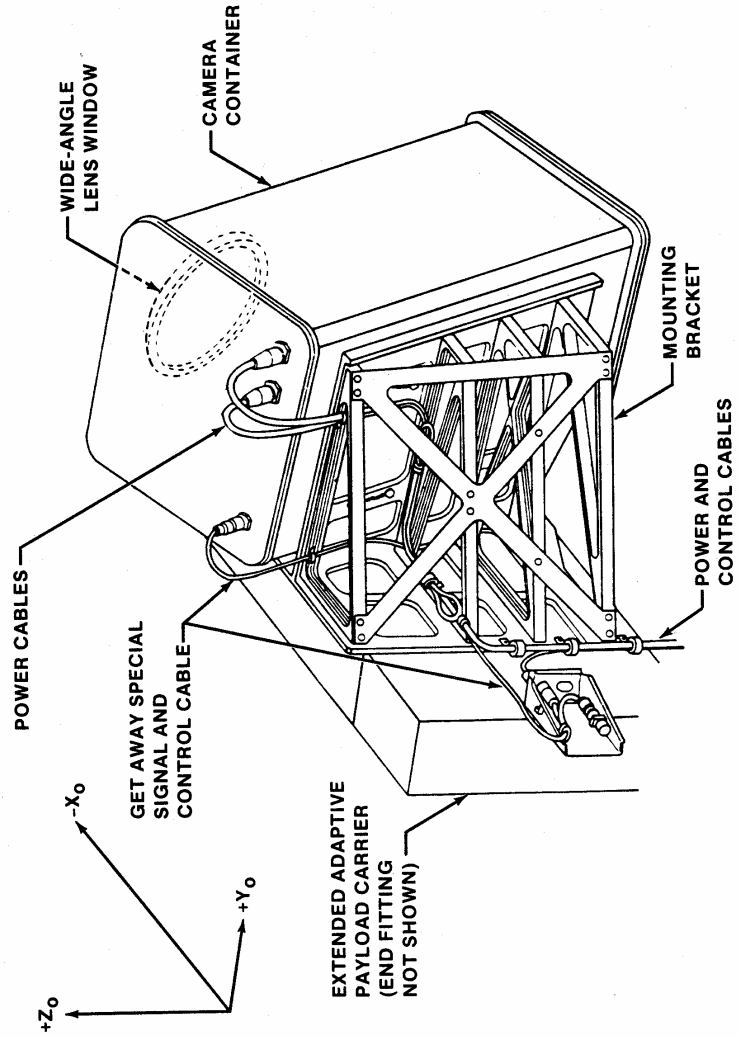




**NSTS INTEGRATION  
AND OPERATIONS**

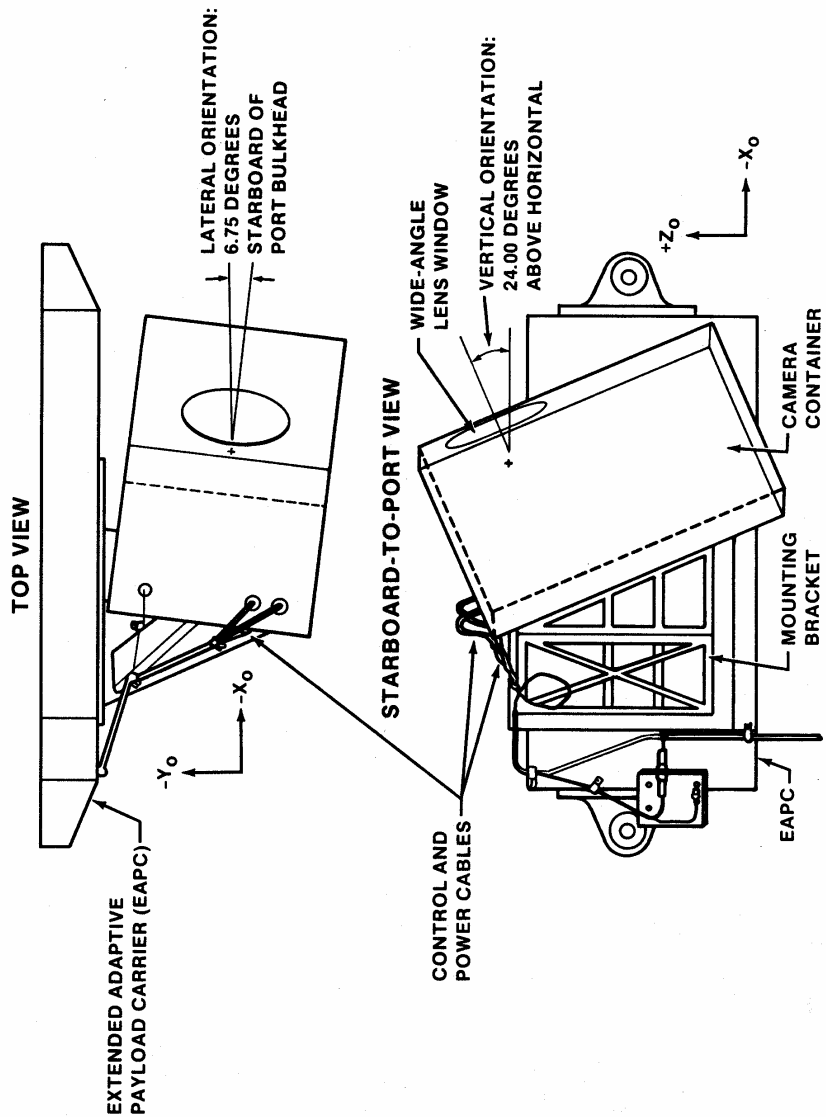
## STS-31 PAYLOAD INFORMATION DOCUMENT

### ICBC MOUNTING CONFIGURATION





ICBC MOUNTING CONFIGURATION:  
TOP AND STARBOARD VIEWS

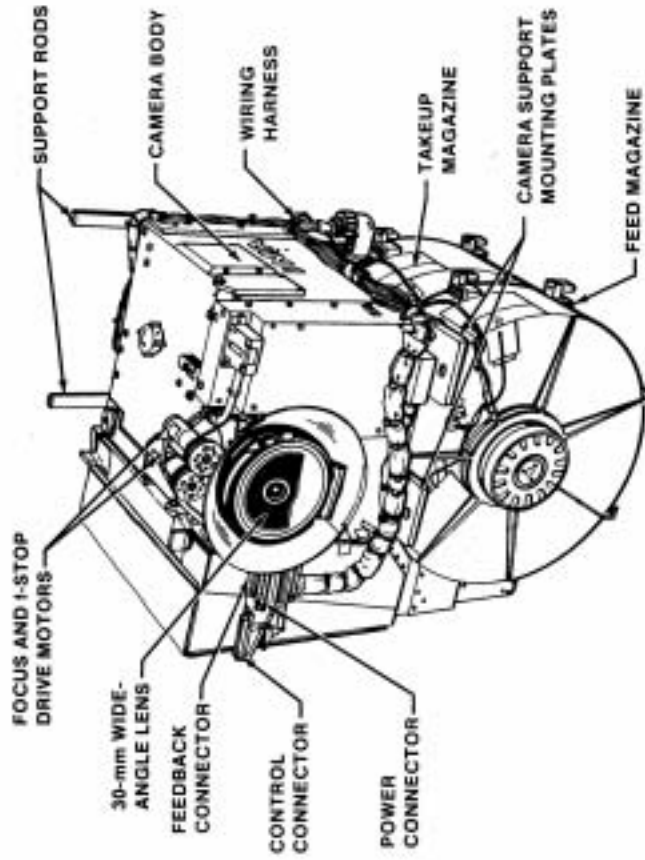




**NSTS INTEGRATION  
AND OPERATIONS**

## STS-31 PAYLOAD INFORMATION DOCUMENT

### IMAX CARGO BAY CAMERA WITHOUT CONTAINER



## STS-31 CREWMEMBERS



*STS-031-S-002 -- The five astronaut crewmembers for the STS-31 mission have chosen a busy night sky scene as a background for their portrait. Wearing mission t-shirts are (left to right) pilot Charles F. Bolden, mission specialist Steven A. Hawley, mission commander Loren J. Shriver, and mission specialists Bruce McCandless II, and Kathryn D. Sullivan. The Hubble Space Telescope (HST) depicted in the upper left of the background scene is scheduled to be deployed from the payload bay (PLB) of Discovery, Orbiter Vehicle (OV) 103, by the crew. Portrait made by NASA JSC contract photographer Jack Jacob.*

*No copyright is asserted for this photograph. If a recognizable person appears in the photo, use for commercial purposes may infringe a right of privacy or publicity. It may not be used to state or imply the endorsement by NASA or by any NASA employee of a commercial product, process or service, or used in any other manner that might mislead. Accordingly, it is requested that if this photograph is used in advertising and other commercial promotion, layout and copy be submitted to NASA prior to release.*

*PHOTO CREDIT: NASA or National Aeronautics and Space Administration.*

## BIOGRAPHICAL DATA

**LOREN J. SHRIVER**, 46, Col. USAF, will serve as Commander. Selected as an astronaut in 1978, he considers Paton, Iowa, to be his hometown and will be making his second Shuttle flight.

Shriver was Pilot for STS-51C, the eleventh shuttle flight and a DOD- dedicated mission, launched on Jan. 24, 1985. The five-member crew spent 3 days in orbit aboard Challenger.

Shriver graduated from Paton Consolidated High School in 1962 and received a bachelor of science degree in aeronautical engineering from the United States Air Force Academy in 1967. He received a master of science degree in aeronautical engineering from Purdue University in 1968.

Commissioned by the Air Force in 1967, Shriver served as a T-38 academic instructor pilot at Vance Air Force Base, Okla., from 1969-1973. He completed F-4 combat crew training in 1973 and completed a 1-year overseas assignment in Thailand in 1974. He attended the USAF Test Pilot School in 1975 and, from 1976 until his selection by NASA, served as a test pilot with the F-15 Joint Test Force at Edwards Air Force Base, Calif. Shriver has logged more than 5,000 hours in jet aircraft and flown 30 different types of single-and multi-engine aircraft.

**CHARLES F. BOLDEN JR.**, 44, Col. USMC, will serve as Pilot. Selected as an astronaut in 1980, he was born in Columbia, S.C., and will be making his second Shuttle flight.

Bolden was Pilot for STS-61C, a 6-day flight of Columbia launched Jan. 12, 1986. The crew deployed a SATCOM KU satellite and conducted experiments in astrophysics and materials processing. The flight culminated in a night landing at Edwards.

Bolden graduated from C.A. Johnson High School in Columbia in 1964. He received a bachelor of science degree in electrical science from the United States Naval Academy in 1968 and a master of science from the University of Southern California in 1978.

Bolden accepted a commission in the Marine Corps in 1968 and was designated a naval aviator in 1970. From 1972-1973, he flew more than 100 sorties in Vietnam while stationed in Thailand. In 1979, he graduated from the Naval Test Pilot School and was assigned to the Naval Air Test Center's systems engineering and strike aircraft test directorates, where he worked until his selection by NASA. Bolden has logged more than 4,800 hours flying time.

**BRUCE MCCANDLESS II**, 53, Capt. USN, will serve as Mission Specialist-1 (MS-1). Selected as an astronaut in 1966, he was born in Boston, Mass., and will be making his second Shuttle flight.

McCandless was a Mission Specialist aboard Challenger on STS-41B, the tenth Shuttle flight. During the 8-day flight, the crew deployed two Hughes 376 communications satellites and McCandless completed two spacewalks, taking the shuttle's manned maneuvering unit (MMU) on its maiden voyage. The flight ended with the first landing at Kennedy Space Center.

McCandless graduated from Woodrow Wilson Senior High School, Long Beach, Calif., and received a bachelor of science degree from the U.S. Naval Academy in 1958. He received a master of science degree in electrical engineering from Stanford University in 1965 and a master's degree in business administration from the University of Houston-Clear Lake in 1987. Designated a naval aviator in 1960, he has logged more than 5,200 hours of flying time, 5,000 of them in jet aircraft.

At NASA, McCandless was a member of the astronaut support crew for the Apollo 14 mission; backup pilot of the first manned Skylab mission; and worked with development of astronaut maneuvering units for more than 10 years.

## BIOGRAPHICAL DATA

**STEVEN A. HAWLEY**, 39, will be Mission Specialist-2 (MS-2). Selected as an astronaut in 1978, Hawley considers Salina, Kansas, to be his hometown and will be making his third Shuttle flight.

Hawley first flew on STS-41D, the twelfth Shuttle flight and the maiden flight of Discovery, launched Aug. 30, 1984. During the 7-day flight, the six-member crew deployed the SBS-D, SYNCOM IV-2 and TELSTAR satellites. His second flight was aboard Columbia on STS-61C, on which fellow STS-31 crew member Bolden served as pilot.

Hawley graduated from Salina Central High School in 1969 and received bachelor of arts degrees in physics and astronomy from University of Kansas in 1973. He received a doctor of philosophy in astronomy and astrophysics from the University of California in 1977. At NASA, Hawley now serves as deputy chief of the Astronaut Office.

**KATHRYN D. SULLIVAN**, 39, will serve as Mission Specialist-3 (MS-3). Selected as an astronaut in 1978, she considers Woodland Hills, Calif., to be her hometown and will be making her second Shuttle flight.

Sullivan flew on STS-41G, the thirteenth Shuttle flight, launched on Oct. 5, 1984. During the 8-day flight, the seven-member crew deployed Earth Radiation Budget satellite and conducted observations of Earth using the OSTA-3 flight. Sullivan conducted a 3.5-hour spacewalk to demonstrate the feasibility of refueling satellites in orbit, making her the first U.S. woman to walk in space.

Sullivan graduated from Taft High School in Woodland Hills in 1969 and received a bachelor of science degree in Earth sciences from the University of California at Santa Cruz in 1973. She received a doctorate in geology from Dalhousie University, Halifax, Nova Scotia, in 1978. At NASA, Sullivan's research interests have focused on remote sensing and planetary geology, and she made several flights in the WB-57F high-altitude research plane participating in several remote sensing projects in Alaska in 1978. She was a co-investigator on the Shuttle Imaging Radar-B experiment which flew on STS-41G.

Sullivan is an oceanography officer in the U.S. Naval Reserve and has attained the rank of Lt. Cmdr. She also is a private pilot, rated in powered and glider aircraft.

# MISSION MANAGEMENT FOR HUBBLE SPACE TELESCOPE LAUNCH

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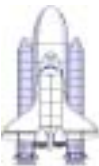



**EUROPEAN SPACE AGENCY**

Robin Lawrance	ESA Project Manager
Dr. Peter Jakobsen	FOC Project Scientist
Dr. Duccio Macchetto	Chairman FOC TDT



# SHUTTLE FLIGHTS AS OF APRIL 1990

34 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 9 SINCE RETURN TO FLIGHT

			
	STS-51L 01/28/86		
STS-32 01/09/90 - 01/20/90	STS-61A 10/30/85 - 11/06/85	STS-33 11/22/89 - 11/27/89	
STS-28 08/08/89 - 08/13/89	STS-51F 07/29/85 - 08/06/85	STS-29 03/13/89 - 03/18/89	
STS-61C 01/12/86 - 01/18/86	STS-51B 04/29/85 - 05/06/85	STS-26 09/29/88 - 10/03/88	
STS-9 11/28/83 - 12/08/83	STS-41G 10/05/84 - 10/13/84	STS-51-I 08/27/85 - 09/03/85	STS-36 02/28/90 - 03/04/90
STS-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	STS-51G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89
STS-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51A 11/08/84 - 11/16/84	STS-61B 11/26/85 - 12/03/85
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	STS-41D 08/30/84 - 09/05/84	STS-51J 10/03/85 - 10/07/85

**OV-102**  
Columbia  
(9 flights)

**OV-099**  
Challenger  
(10 flights)

**OV-103**  
Discovery  
(9 flights)

**OV-104**  
Atlantis  
(6 flights)