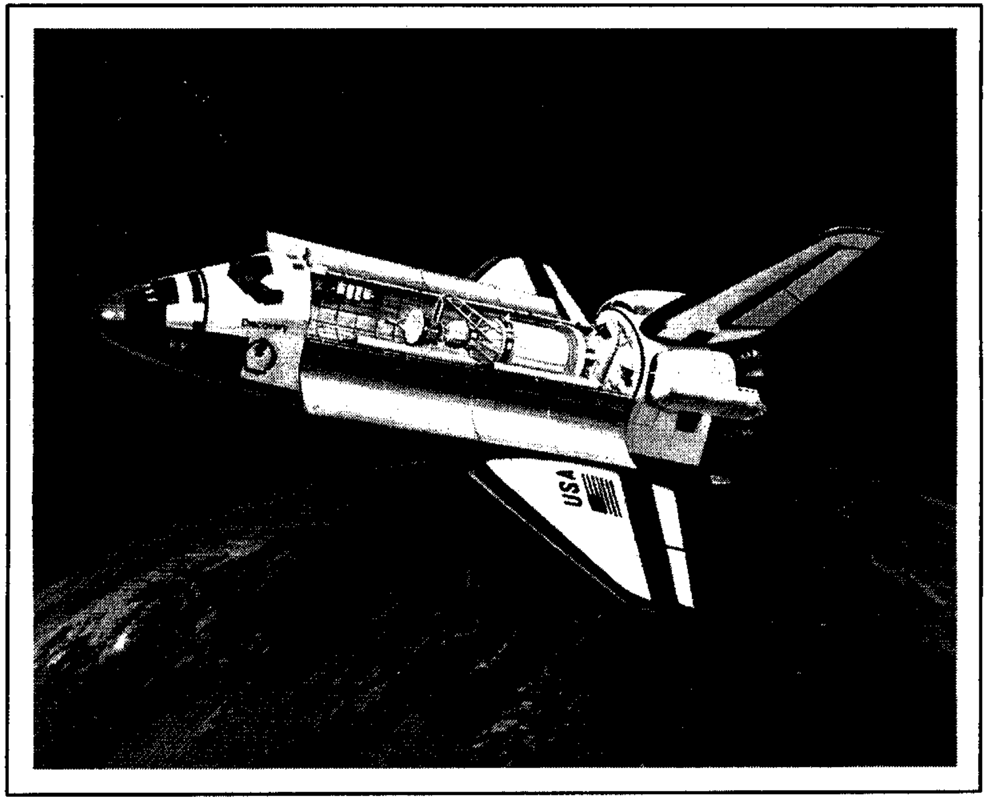


STS-41
PRESS INFORMATION

October 1990

Rockwell International
Space Systems Division

Office of Media Relations

PUB 3546-V REV 10-90

CONTENTS

MISSION OVERVIEW

This is the 11th flight of Discovery and the 36th for the space transportation system.

The flight crew for the STS-41 mission consists of commander Richard N. Richards, pilot Robert D. Cabana and mission specialists Bruce E. Melnick, William M. Sheperd and Thomas D. Akers.

The primary objective of this four-day mission is to deploy the Ulysses spacecraft, mated with an inertial upper stage and payload assist module, from Discovery's payload bay. The IUS and PAM will place Ulysses in polar regions around the sun.

The deployment of the Ulysses spacecraft with its IUS and PAM from Discovery's payload bay is scheduled to occur nominally on the fifth orbit at a mission elapsed time of six hours and one minute. Backup deployment opportunities are available on orbits 6, 7, and 15, with contingency capabilities on orbits 18 and 19.

The first stage of the IUS solid rocket motor will nominally ignite just before orbit 6, which begins approximately one hour after the IUS, PAM and Ulysses are deployed. Ignition of the IUS second stage occurs approximately four minutes after the first-stage ignition. The PAM solid rocket motor ignition occurs at approximately seven hours and 14 minutes mission elapsed time, followed by PAM separation from Ulysses at approximately seven hours and 24 minutes mission elapsed time.

Ulysses will then begin on a flight path first to Jupiter, which it will encounter in February 1992, 16 months after launch. As Ulysses flies past Jupiter at approximately 30 degrees Jovian latitude, the gravity of Jupiter will bend the spacecraft's trajectory so that Ulysses dives downward and away from ecliptic plane.

Ulysses will reach 70 degrees south solar latitude in May 1994, beginning its transit of the sun's south polar regions. Ulysses will spend about four months south of that latitude at a distance of about 200 million miles from the sun. In February 1995, Ulysses will cross the sun's equator and then make a four-month pass of the sun's northern polar region beginning in May 1995. The end of the Ulysses mission is scheduled for September 30, 1995.

Ulysses will be the first spacecraft to achieve a trajectory essentially perpendicular to the sun's equatorial plane. Throughout its five-year mission, Ulysses will study three general areas of solar physics: the sun itself, magnetic fields and streams of particles generated by the sun, and interstellar space above and below the sun.

For STS-41, Discovery will carry nine other payloads, referred to as secondary payloads. Two are located in Discovery's payload bay, and the remaining seven are in the crew compartment.

The Shuttle Solar Backscatter Ultraviolet instrument, carried in Discovery's payload bay, was developed by NASA to calibrate similar ozone-measuring instruments on the National Oceanic and Atmospheric Administration's TIROS satellites (NOAA-9 and -11).

The Intelsat Solar Array Coupon consists of solar array materials bonded to two witness plates on Discovery's remote manipulator system. The witness plates will obtain data on the interaction of atomic oxygen with the materials of the Intelsat spacecraft, now stranded in low Earth orbit. The witness plates will be exposed in the velocity vector direction for a minimum of 23 hours.

The Investigations into Polymer Membrane Processing will flash-evaporate mixed solvent systems in the absence of convection to control the porosity of the polymer membrane. With at least 24 hours remaining before entry, the flight crew will activate the experiment, which is located in Discovery's middeck.

The Physiological Systems Experiment is designed to determine the effects of proprietary protein molecules on animal physiological systems in microgravity. Sixteen rats, contained in two animal exclosure modules in Discovery's middeck, will be the subjects of the experiment.

The Chromosome and Plant Cell Division in Space Experiment (CHROMEX) is designed to determine whether the normal rate, frequency and pattern of cell division in root tips can be sustained upon exposure to microgravity. In addition, the fidelity of chromosome partitioning is investigated after cell exposure to microgravity. Day Lily and *Haplopappus gracilis* roots will be used. CHROMEX is also located in Discovery's middeck.

The Solid-Surface Combustion Experiment consists of an ashless filter paper sample internally mounted in a pressurized container. While the sample is burned, documentary photographs of the front and side are taken. In addition, chamber temperature, chamber pressure and middeck air temperature are measured. The experiment, which will be run during a period of low orbiter acceleration, is located in Discovery's middeck.

The Voice Command System is a voice recognition device designed to allow voice control of Discovery's closed-circuit television system.

Radiation Monitoring Equipment III consists of a hand-held instrument with replaceable memory modules. The equipment takes measurements of the radiation environment in the crew compartment at a specified sample rate.

The Air Force Maui Optical Site tests allow ground-based electro-optical sensors located on Mt. Haleakala on Maui, Hawaii, to collect imagery and signature data for Discovery during cooperative overflights while Discovery is performing reaction control system thruster firings, water dumps or payload light activation. The data are used to support the calibration of AMOS sensors and the validation of spacecraft contamination models.

A series of Discovery's forward reaction control system flight test maneuvers will be initiated during entry to obtain flight data showing the aerodynamic effects when the forward RCS side (yaw) firing thrusters are used to eliminate the forward RCS propellants. The flight data will be used to verify and validate existing wind tunnel data and verify the safety of performing a forward RCS dump during a return-to-launch-site or transatlantic abort. During entry, there will be three separate dumps by the yaw thrusters. The first dump will begin at Mach 13 to Mach 10, the second dump will begin at Mach 6 to 4.5, and the third dump will begin at Mach 4 to Mach 2.6.

MISSION STATISTICS

Launch: The launch window duration is two hours, 30 minutes

10/6/90 7:35 a.m. EDT
10/6/90 6:35 a.m. CDT
10/6/90 4:35 a.m. PDT

Mission Duration: 96 hours (4 days), two hours, seven minutes

Landing: Nominal end of mission on orbit 66

10/10/90 9:42 a.m. EDT
10/10/90 8:42 a.m. CDT
10/10/90 6:42 a.m. PDT

Inclination: 28.5 degrees

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

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

Altitude: 160 by 160 nautical miles (184 by 184 statute miles), 177 by 160 nautical miles (203 by 184 statute miles), 160 by 156 nautical miles (184 by 179 statute miles), and 157 by 156 nautical miles (180 by 179 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,523,894 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 293,019 pounds

Payload Weight Up: Approximately 48,812 pounds

Payload Weight Down: Approximately 10,279 pounds

Orbiter Weight at Landing: Approximately 195,890 pounds

Payloads: Ulysses with payload assist module and inertial upper stage, Shuttle Solar Backscatter Ultraviolet, Intelsat Solar Array Coupon, Solid-Surface Combustion Experiment, Investigations Into Polymer Membrane Processing, Chromosome and Plant Cell Division in Space, Physiological Systems Experiment, Voice Command System, Radiation Monitoring Equipment III and Air Force Maui Optical Site

Flight Crew Members:
Commander: Richard N. Richards, second flight
Pilot: Robert D. Cabana, first flight
Mission Specialist 1: Bruce E. Melnick, first flight
Mission Specialist 2: William M. Sheperd, second flight
Mission Specialist 3: Thomas D. Akers, second flight

Ascent Seating:
Flight deck front left seat, commander Richard Richards
Flight deck front right seat, pilot Robert Cabana
Flight deck aft center seat, mission specialist William Sheperd
Flight deck aft right seat, mission specialist Bruce Melnick
Middeck, mission specialist Thomas Akers

Entry Seating:
Flight deck aft center seat, mission specialist Thomas Akers
Middeck, mission specialist Bruce Melnick

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut 1 would be Bruce Melnick; extravehicular astronaut 2 is Thomas Akers. William Sheperd will be the intravehicular astronaut.

Entry Angle of Attack: 40 degrees

Entry: Automatic mode until subsonic, then control stick steering

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

Notes:

- The remote manipulator is installed in Discovery's payload bay for this mission. The galley is installed in the middeck.

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

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

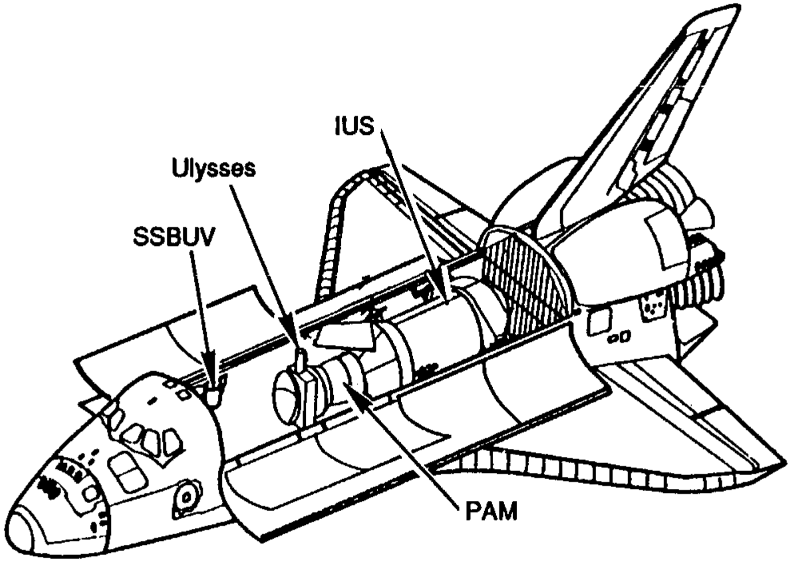
The hard copier can be powered from the ground or by the crew. Uplink operations are controlled by the Mission Control Center in Houston. Mission Control powers up the hard copier and then sends the message. In the onboard system, light-sensitive paper is exposed, cut and developed. The message is then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

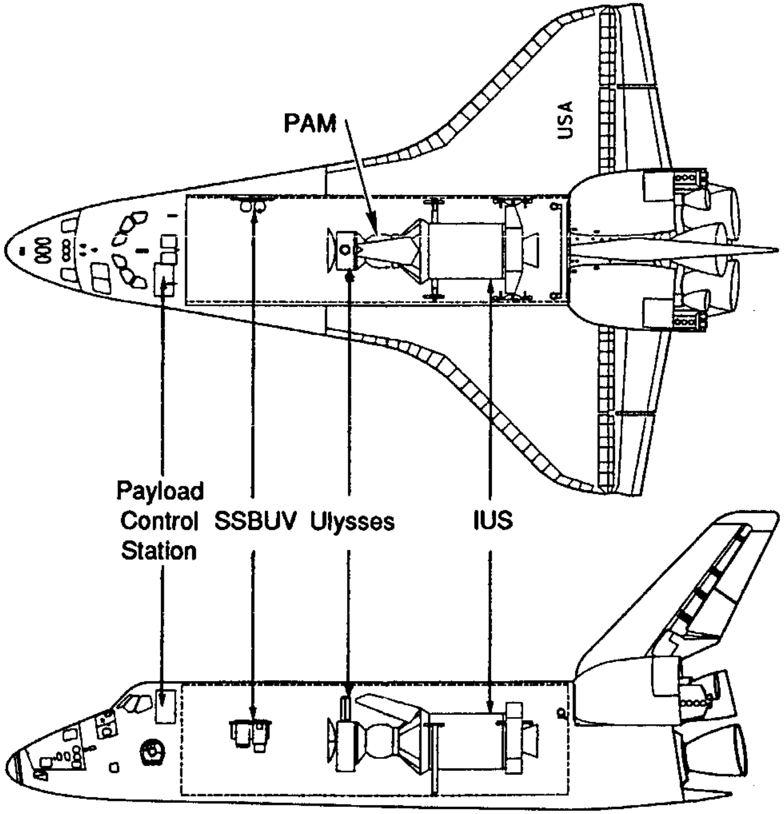
The teleprinter provides a backup on-orbit capability to receive and reproduce text-only data, such as procedures, weather reports and crew activity plan updates or changes, from the Mission Control Center in Houston. The teleprinter uses the S-band and is not dependent on the TDRS Ku-band. It is a modified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

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

PAYLOAD CONFIGURATION

Ulysses - Ulysses Spacecraft
IUS/PAM - Inertial Upper Stage/Payload Assist Module (Solid Rocket Motors)
SSBUV - Shuttle Solar Backscatter Ultraviolet





Payload Locations in Discovery's Payload Bay—Top and Side Views

DEVELOPMENT TEST OBJECTIVES

- Ascent structural capability evaluation
- Ascent compartment venting evaluation
- External tank thermal protection system performance
- Shuttle/payload low-frequency environment
- Water-dump cloud formation
- Head-up display backup to crew optical alignment sight
- Payload and general support computer electroluminescent display evaluation
- Tracking with high pitch rates
- Space station cursor control device evaluation
- Forward RCS flight test
- Entry structural evaluation
- Descent compartment venting evaluation
- Crosswind landing performance
- Carbon brake system test

DETAILED SUPPLEMENTARY OBJECTIVES

- Changes in baroreceptor reflex function
- Blood pressure variability during space flight
- Orthostatic function during entry, landing and egress
- Visual-vestibular integration as a function of adaptation
- Postural equilibrium control during landing/egress
- Intraocular pressure
- Retinal photography
- Documentary television
- Documentary motion picture photography
- Documentary still photography

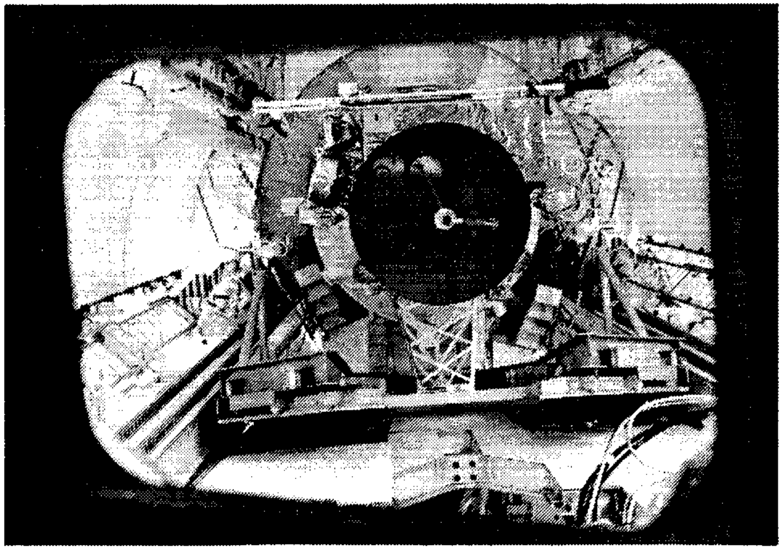
ULYSSES

Ulysses is an international project to place a spacecraft in polar regions around the sun. Until 1984, the Ulysses project was called the International Solar Polar Mission. Although the name described the mission's objectives, project officials believed it brought little romance to an undertaking they considered exciting. As a result, the officials held a contest to choose a new name.

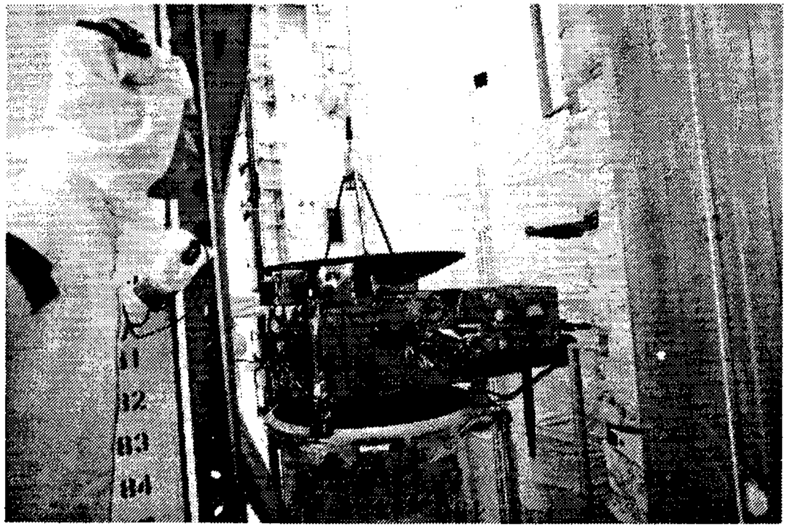
Professor Bruno Bertotti of the University of Pavia, Italy, principal investigator of the gravitational-wave experiment aboard the spacecraft, suggested "Ulysses" and cited the 26th canto of Dante's *Inferno*, referring not only to the adventurous trip of the mythological Greek hero after the Trojan War but also to a most remarkable late Medieval tradition in which the spirit and the driving motives of all human explorations of unknown regions are forcefully presented. Dante's story says that Ulysses, after his return home to his beloved wife, Penelope, and to his kingdom in Ithaca, became bored with everyday life and the troublesome duties of a king; with his old shipmates, he decided to start on a new journey to explore that part of the world which lay beyond Gibraltar, at that time completely unknown and unexplored. As Dante says, there is indeed a "mondo sanza gente," an uninhabited world beyond the sun where there are no planets, no possibility of life, no familiar features. According to Dante, Ulysses' crew mutinied out of fear and he exhorted them to continue "to follow after knowledge and excellence."

Many space missions have contributed to our understanding of the sun and its interaction with nearly interstellar matter. They have revealed that interplanetary space is not empty but filled with continuously expanding solar atmosphere—called the solar wind—as well as dust, energetic particles of both solar and galactic origin, and magnetic fields and waves. All previous studies have been restricted to the ecliptic plane (the plane in which the Earth and most other planets orbit the sun) because available launch vehicles are not energetic enough to overcome the rapid motion of the Earth around the sun.

Spacecraft navigators have found that a polar orbit of the sun can be achieved (sending the spacecraft out of the ecliptic

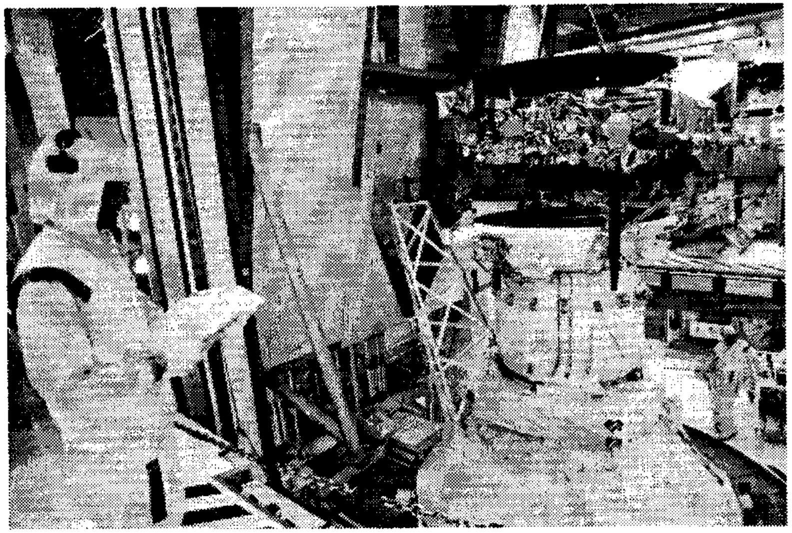


Top View of Ulysses

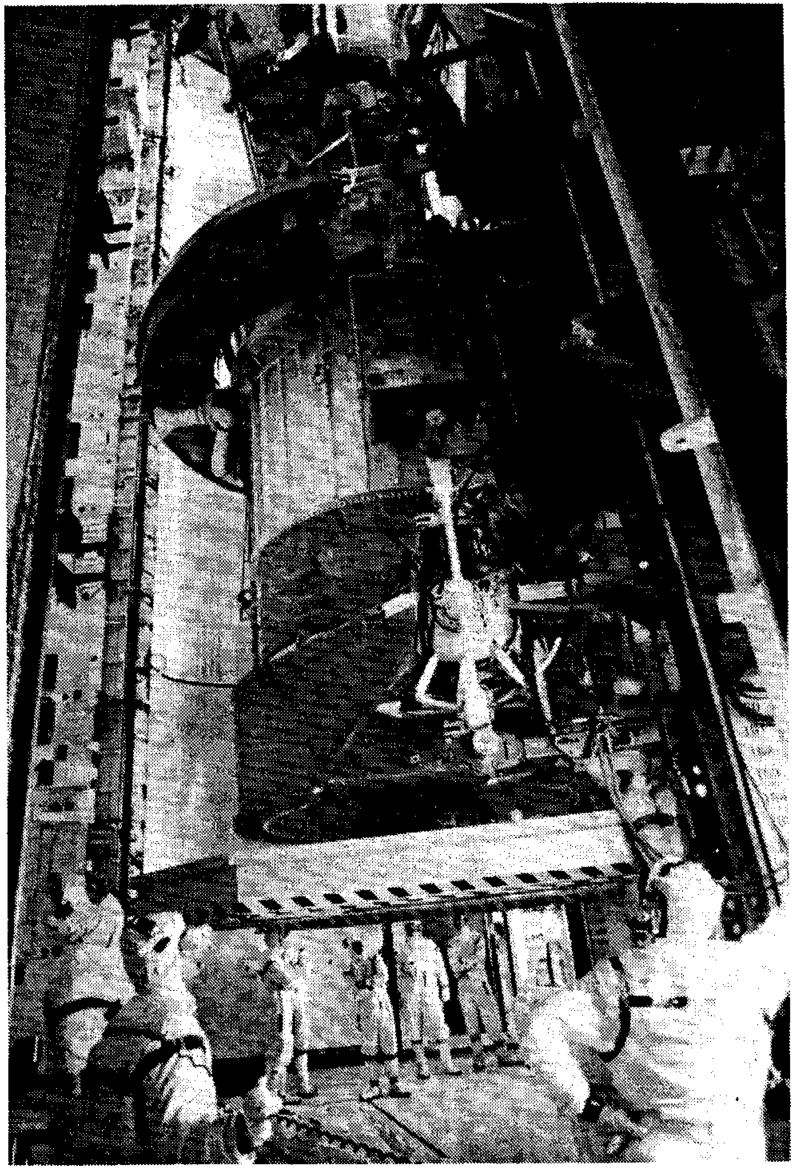


Ulysses Spacecraft Being Lowered to Payload Assist Module plane) by launching the spacecraft from Earth into its orbital plane and then using the strong gravitational field of Jupiter to reorient the spacecraft's trajectory so that it is perpendicular to its original direction. This effect, or "gravity assist," is similar to techniques used on a number of previous solar system exploration missions. Ulysses will be the first spaceraft to achieve a trajectory essentially perpendicular to the sun's equatorial plane. The spacecraft will end up traveling along a large ellipse that will bring it no closer to the sun than the distance between the sun and the Earth.

Scientists have long sought a means to explore the spacecraft environment above and below the ecliptic plane because this region is believed to be significantly different from any explored thus far. They also expect to learn more about the sun and the interstellar medium by virtue of this unique perspective. This will offer a three-dimensional perspective of the sun unglimpsed by any previous spacecraft. Throughout its five-year mission, Ulysses will study three general areas of solar physics: the sun itself, magnetic fields and streams of particles generated by the sun, and interstellar space above and below the sun.



Ulysses Spacecraft Being Lowered to Payload Assist Module



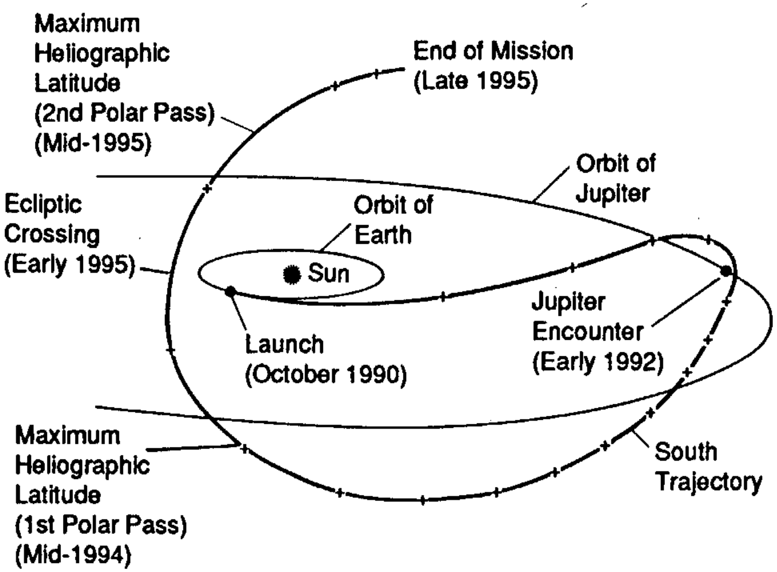
Inertial Upper Stage

The Ulysses spacecraft is provided by the European Space Agency, while launch on the space shuttle Discovery, tracking and data collection during the mission are performed by NASA and the Jet Propulsion Laboratory. The instruments aboard the spacecraft have been provided by scientific teams in both Europe and the United States.

An inertial upper stage and payload assist module (PAM-S) are attached to the Ulysses spacecraft to send it on a flight path first to Jupiter and then into orbit around the sun.

MISSION OVERVIEW

The Ulysses spacecraft will be carried in Discovery's payload bay for deployment in Earth orbit at 160 nautical miles (184 statute miles). After Ulysses is deployed, Discovery is maneuvered a safe distance away from Ulysses. The two-stage IUS attached to Ulysses is then ignited, sending the spacecraft on its initial trajectory. The IUS is then separated from Ulysses.



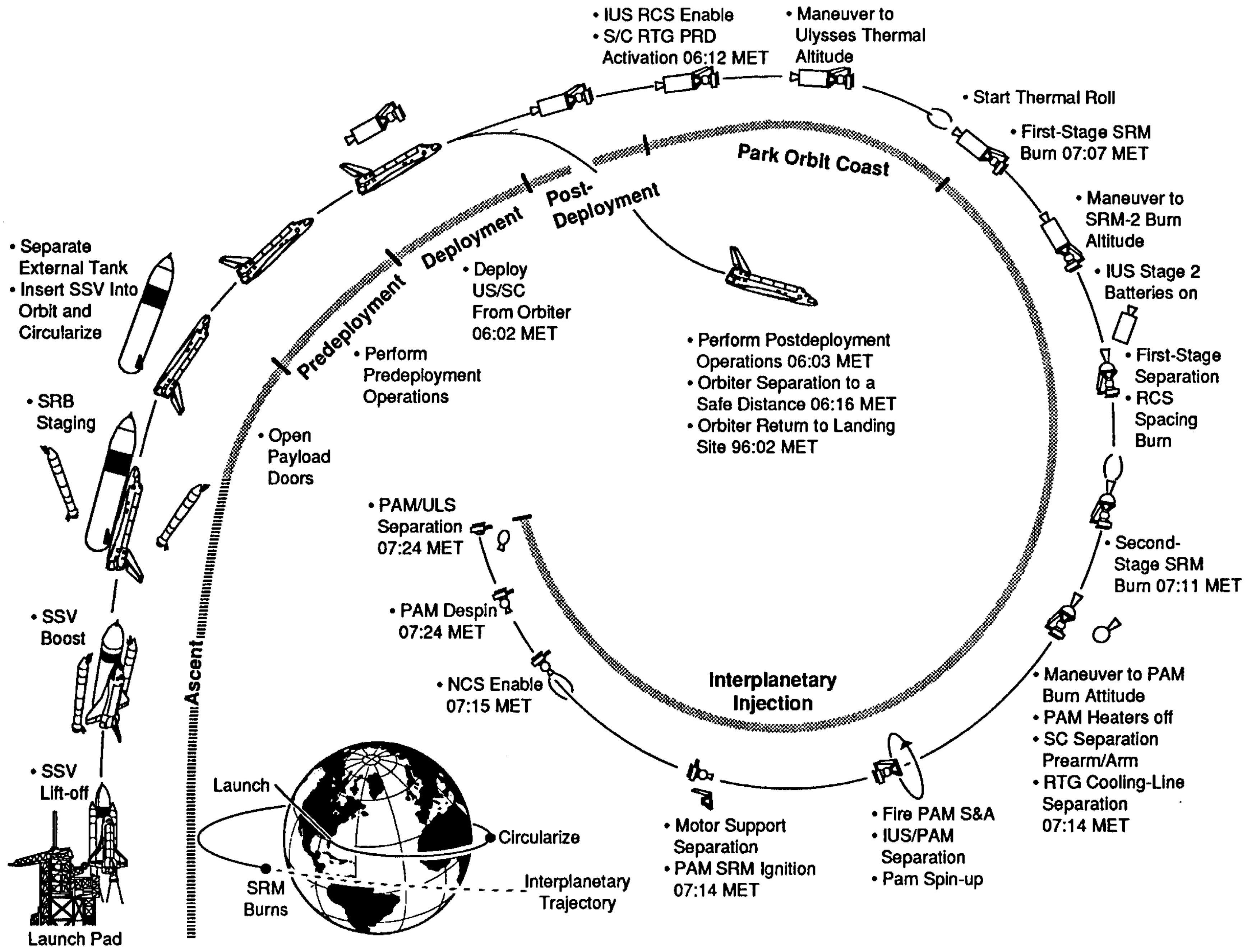
Ulysses Mission Overview

Also, on the same day of the IUS two-stage thrusting period, Ulysses will begin spinning at a rate of 70 revolutions per minute. The PAM-S will then be ignited for the final velocity increment on Ulysses' initial trajectory. The PAM-S is then separated from Ulysses. The spin rate of Ulysses will be slowed to approximately 5 rpm after the PAM-S separation and will continue at this rate throughout the remainder of the mission. Checkout of Ulysses begins two days after launch and lasts seven days.

Ulysses' flight path will encounter Jupiter in February 1992, 16 months after launch. As it flies past the planet at approximately 30 degrees Jovian latitude, the gravity of Jupiter will bend Ulysses' trajectory so that the spacecraft dives downward and away from ecliptic plane. As Ulysses continues in its orbit around the sun, its flight path will take it from a maximum distance from the sun of 5.4 astronomical units (an astronomical unit is the distance from the sun to Earth), or about 500 million miles, to a closest approach of 1.3 AU, or about 120 million miles.

Ulysses will reach 70 degrees south solar latitude in May 1994, beginning its transit of the sun's south polar regions. Ulysses will spend about four months south of that latitude at a distance of about 200 million miles from the sun. In February 1995, Ulysses will cross the sun's equator and begin a four-month pass of the sun's northern polar region in May 1995. The end of Ulysses' mission is scheduled for September 30, 1995.

During the mission, Ulysses' nine scientific instruments will collect information about the sun's poles, the heliosphere and the cosmic rays that stream into the solar system from among the stars of the Milky Way. Ulysses will study these subjects during the entire flight; however, the most intense scientific activity will begin as Ulysses approaches the sun in its first encounter at 70 degrees south solar latitude on its climb over the pole. At that latitude and more than twice the Earth's distance from the sun, the scientific instruments will sample a region of the heliosphere that has never been studied before.



Ulysses Deployment Operations

Spacecraft Characteristics

Weight: 807 Pounds

Dimensions, Boom Stowed
- Height: 7.01 Feet
- Width: 10.9 Feet
- Length: 10.6 Feet

Dimensions of Deployable Mechanisms
- Radial Boom: 18.2 Feet
- Axial Boom: 24.3 feet
- Electrical Wire-Boom Antenna: 238 Feet, Tip to Tip

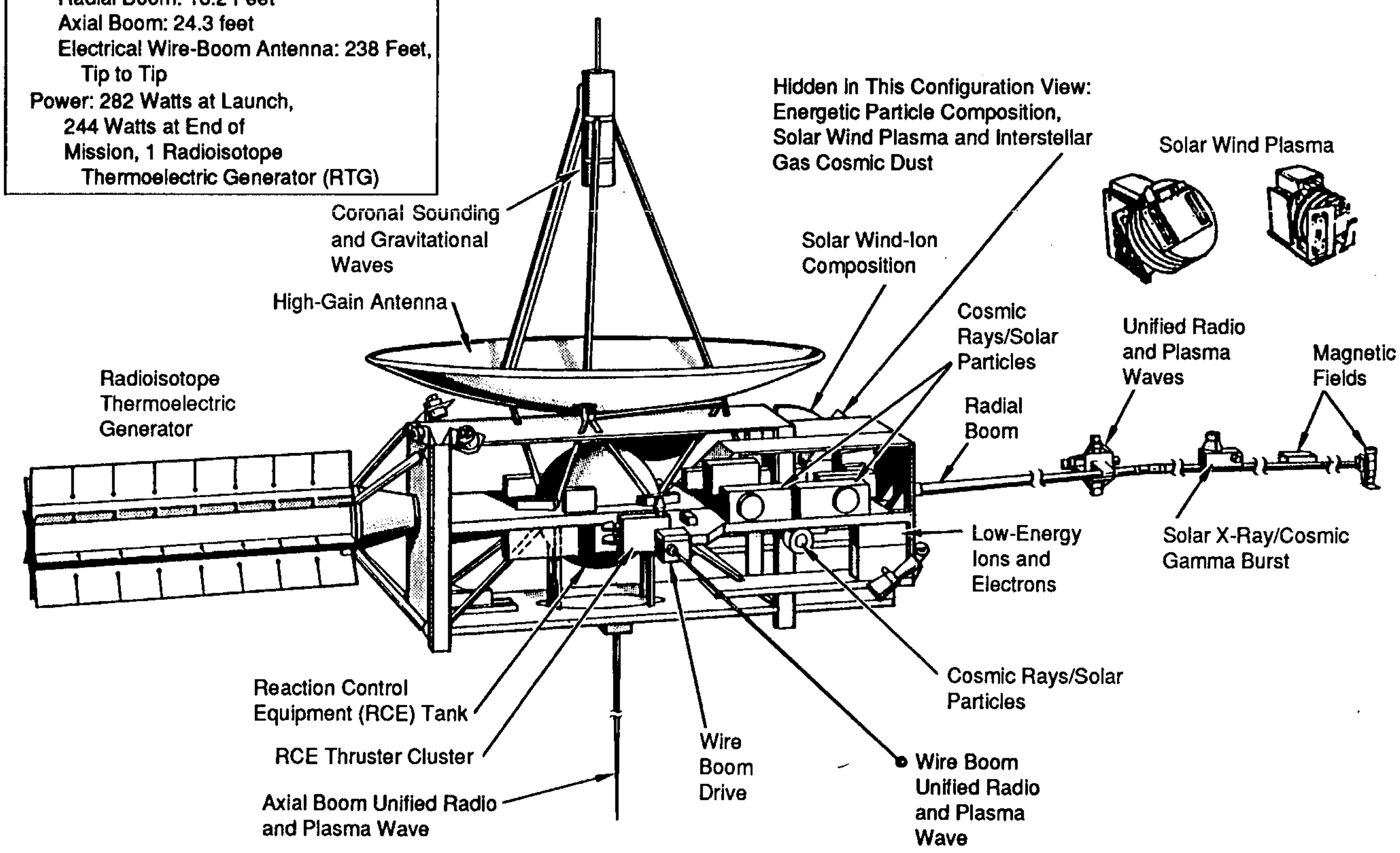
Power: 282 Watts at Launch, 244 Watts at End of Mission, 1 Radioisotope Thermoelectric Generator (RTG)

Data Storage: Two 45-Megabit Recorders at 64 to 8,192 Bits Per Second

High-Gain Antenna Diameter: 5.4 Feet

Spin Stabilized: 5 rpm

Propellant: Hydrazine, 68.7 Pounds



Ulysses Components

ULYSSES SPACECRAFT

Ulysses' systems and scientific instruments are contained within a main spacecraft bus measuring 10.5 by 10.8 by 6.9 feet. The basic spacecraft is an aluminum box-like structure with two overhanging "balconies." Mounted on the structure are most of the sensors, the hydrazine propellant tank for the trajectory and attitude control system, and all the electronic units for the scientific instruments and the spacecraft subsystems. Magnetic and gamma-ray sensors are located on an 18-foot radial boom to keep them away from interference originating in the spacecraft. Three antennas, including a 24.3-foot axial boom and two radial wire booms measuring 238 feet tip to tip, will investigate plasma waves and traveling solar radio bursts.

Communication with Earth is maintained via a 5.4-foot-diameter parabolic high-gain antenna. The spin-stabilized spacecraft will keep the centerline of this antenna pointing continuously toward Earth. Normally, NASA's Deep-Space Network will track Ulysses only about eight hours per day, which means the spacecraft must store data for later transmission interleaved with its real-time data transmissions.

The spacecraft is built to be autonomous for reconfiguration in case of failures. It is even programmed to search for and reacquire Earth if no commands are received. This provision is included because of the limited period of tracking and the long signal travel time between Earth and Ulysses. At the farthest point, radio signals need 50 minutes to reach Ulysses. The same period will be required for a confirmation signal to Earth.

The solar cells typically used on near-Earth spacecraft cannot provide enough power for Ulysses when it is out near Jupiter, where sunlight is only 4 percent as strong as it is on Earth. Thus, the spacecraft derives its power from a radioisotope thermoelectric generator. It is not a nuclear reactor but simply a quantity of safety encapsulated radioactive material that decays over a period of time. This decay releases heat, which is converted into electricity by thermocouples. The generator delivers about 290 watts of power in this manner. Similar power supplies have been used successfully on two Pioneer deep-space probes, both Voyager spacecraft and the Galileo mission to Jupiter.

The requirements met by the Ulysses spacecraft and its experiment instrumentation concerning accuracy of measurements and freedom from electromagnetic and mechanical disturbances represent a further step in the high standards of performance achieved by earlier spacecraft like GOES and ISEE-B.

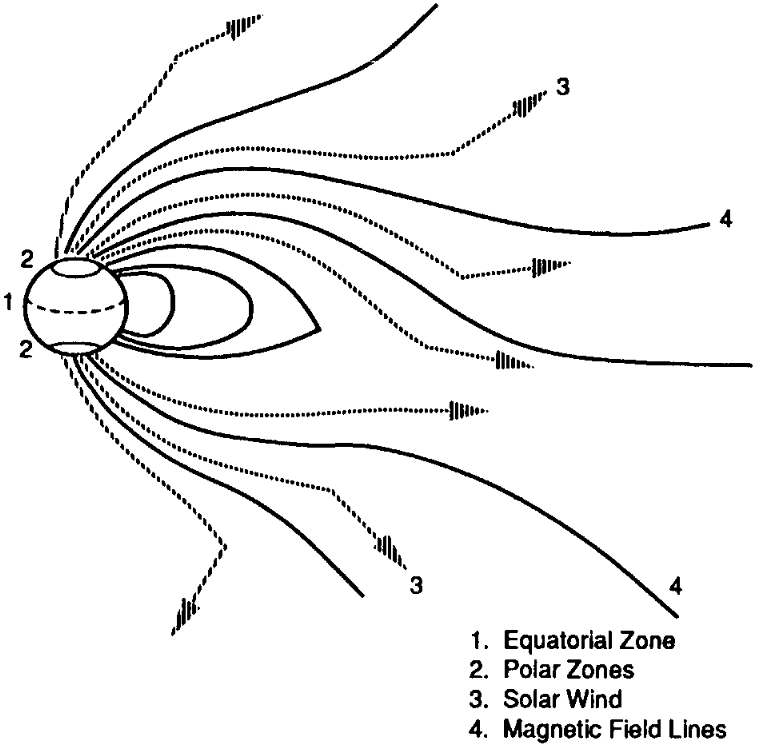
SCIENTIFIC EXPERIMENTS

Of the 807 pounds of Ulysses' total weight, some 180 pounds are devoted to nine sophisticated instrument packages. In addition, the spacecraft radio will be used to conduct a pair of experiments beyond its function of communicating with Earth, bringing the total number of experiments to 11.

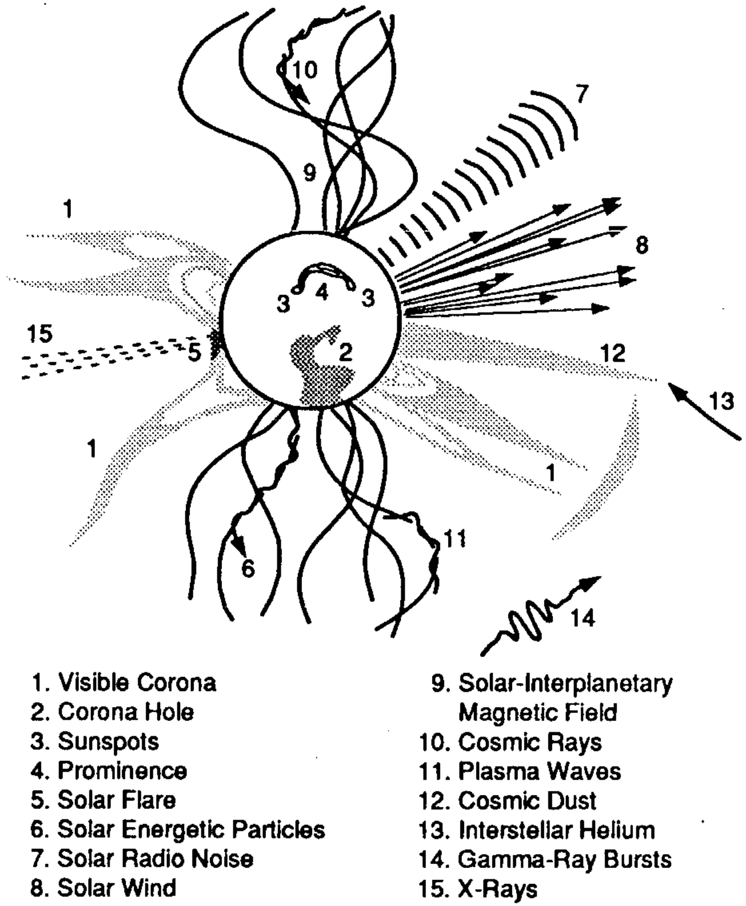
SOLAR-WIND PLASMA EXPERIMENT. A plasma experiment will detect and analyze particles in the solar wind with the goal of determining variations in the particles from the equator to the poles. The plasma experiment will determine just how the solar wind changes on two fronts: distance from the sun and distance from the ecliptic plane. The experiment, which acts like a space version of a weather station, will measure the solar wind after it leaves the corona, noting local changes in the number of particles and their energy as the solar wind blows past Ulysses while it travels along its flight path.

Scientists know little about the speed, density, direction and temperature of plasmas in the solar wind at high latitudes. If the solar wind at the poles originates from coronal holes there, then it would be free of many of the complications associated with coronal holes near the equator. Near the equator, when quiet regions of the rotating corona pass a given location, low-energy particles stream forth. When the coronal holes move past the same site, high-speed particles pour out and overtake the slower, low-energy particles. Thus, scientists who have measured the solar wind are confused by the alternating slow and fast streams. At the poles, however, effects of the collisions between slow and fast streams may be absent. The plasma instrument should be able to measure how the properties of the solar wind differ between low and high latitudes and should be able to trace the solar wind back to its place of origin more easily at the poles than at the equator. The solar-wind plasma instrument will observe particles in the energy range from 1 electron volt to 35,000 electron volts. Dr. Samuel J. Bame of the Los Alamos National Laboratory is principal investigator.

SOLAR-WIND ION-COMPOSITION SPECTROMETER. This spectrometer is expected to provide unique information on conditions and processes in the region of the corona where the solar wind is accelerated. The instrument will study composition and temperatures of heavy ions in the solar wind. The solar wind contains electrons, protons, alpha particles (the nuclei of helium atoms) and heavy ions such as oxygen, silicon and iron. The relative amounts of all those materials are not well understood but are expected to differ under differing local conditions and because of changes in the corona, where the materials formed. An important measure is their degree of ionization; differing degrees of ionization are a result of differing temperatures at the source.



While Some of the Sun's Magnetic Field Lines Are Closed, Most Are Borne Outward on the Solar Wind



This Composite of the Sun's Most Intriguing and Mysterious Phenomena Summarizes the Motivation for Research Through the Experiments Flown on the Ulysses Mission

Temperatures in the corona vary depending on the state of the magnetic fields in the photosphere beneath. High temperatures create mixtures of ions that are different at different heights. Each mixture is then locked into the solar wind; it does not change as it leaves the corona. The solar-wind ion-composition spectrometer measures the mixtures and temperatures of ions as they strike the spacecraft. Once scientists have determined those temperatures, they should be able to find the location in the corona of the coronal heating processes and the extent and causes of variations in composition of the sun's atmosphere. Dr. George Gloeckler of the University of Maryland and Dr. Johannes Geiss of the University of Bern, Switzerland, are co-principal investigators.

MAGNETOMETERS. A pair of magnetometers, each suited to a different purpose, is carried aboard Ulysses. Like a spaceborne explorer, they will map the heliospheric magnetic field as the spacecraft travels through it. Use of the magnetometers will allow the investigators to monitor changes in the magnetic field at the spacecraft. A vector-helium magnetometer will measure slight fields; near Jupiter, a flux-gate magnetometer will measure the planet's intense magnetic field. Still more important, the two magnetometers will measure the magnetic fields above the sun's poles.

Since the magnetic field lines are borne outward across space on the wings of the solar wind, knowledge of the shape and structure of the field lines at high latitudes is important to those who are studying the solar wind and the energetic, charged particles. If the soar wind is simple above the poles, it should be possible to infer the character of the magnetic fields at the sun's polar caps. Very little is known about the fields there (such as their strength) because it is nearly impossible to observe them from the lower latitudes where all earlier spacecraft have flown.

The magnetometer team is interested in particle streams riding the solar wind outward from the sun. Do the magnetic field lines near the poles cause clouds of plasma to act differently from those nearer the equator? For example, the field lines at the poles are expected to arrange themselves nearly parallel to the flow of the solar wind; thus, the plasma clouds are not kept distinct and separate as they are at the equator, where the field lines are perpendicular to the flow.

Dr. Andre Balogh of Imperial College, London, is the principal investigator on the magnetometer experiment and has provided the flux-gate magnetometer. Dr. Edward J. Smith of Jet Propulsion Laboratory, the U.S. project scientist and a co-investigator on the magnetic-fields team, provided the vector-helium magnetometer.

ENERGETIC-PARTICLE-COMPOSITION EXPERIMENT. This instrument has two tasks: to detect and measure ions in the solar wind that are in the medium-energy range and to detect helium atoms entering the solar system from interstellar space. While the high temperatures in the sun's corona accelerate the solar wind's low-energy particles, the medium- and high-energy particles achieve energies that are much too great to have been caused by such relatively simple heating processes. No one knows what processes cause the acceleration of the medium- and high-energy particles. In addition, once the particles with medium and high energy are accelerated, they appear to be stored temporarily in the corona, to be released sometime later along the magnetic field lines. (Physicists observe solar flares where the particles originate but they do not always see the particles arrive at Earth at the time they should.) The structures in the corona where the storage and acceleration processes are believed to occur are likely to extend to high solar latitudes during the period of maximum solar activity—just as Ulysses is flying over the sun's poles. The energetic-particle instrument will detect the particles of medium energy in an effort to understand the processes of the coronal-storage phenomenon and how that storage depends on the particles' energy. The instrument will also study how solar latitude affects the paths along which the particles move through the heliosphere.

The other experiment allied with the energetic-particle detector will search for neutral helium—atoms that have no net electric charge—coming from the Milky Way. Interstellar hydrogen and helium gas exists throughout the Milky Way, perhaps as both a remnant and a source of the star-formation process. The solar system moves through that gas as it orbits the center of the galaxy. Neutral helium is extremely difficult to detect. However, the hydrogen is even more difficult to see in the inner heliosphere, since a helium atom is four times more massive and holds onto its electrons with a stronger force. Since it has no electric charge to trap it in the sun's magnetic field lines, the helium falls directly in toward the sun, drawn by gravity. The helium atoms, therefore, penetrate deeper into the solar system (to about the Erath's distance) than the hydrogen atoms before they are ionized and carried outward again by the solar wind. The interstellar helium can't be detected until the sun's gravity gives it enough speed, and that doesn't occur until it is between 1.2 and 1 astronomical units from the sun. Therefore, the helium-detection portion of the experiment will operate only during the first 70 to 100 days of the flight.

Dr. Erhardt Keppler of the Max-Planck-Institut fur Aeronomie in West Germany is principal investigator of the energetic-particle detection experiment. Dr. Helmut Rosenbauer, also of the Max-Planck-Institut fur Aeronomie, is principal investigator of the interstellar neutral helium experiment.

HI-SCALE. An instrument called HI-SCALE will study interplanetary ions and electrons with a wide range of energies, from high-energy particles in the solar wind to particles with extremely high energies—the sun's equivalent to cosmic rays. Scientists hope to understand the mechanisms that release solar-flare particles and the dynamic phenomena that are associated with the solar cycle's maximum activity. The instrument will use the flow of high-energy particles from eruptive processes on the sun to study structural changes in the corona and in the magnetic field lines. (They can do this because the sun's high-energy particles travel paths that reveal the field lines carried by the solar wind.) The structures are expected to change as the spacecraft files ever farther from the ecliptic plane. Interactions between the particles and waves that move through the solar wind also may be responsible for the energy imparted to particles in the solar wind and, therefore, could explain their speeds.

Scientists on the HI-SCALE team will also try to measure the composition of low-energy nuclei from the sun, both in the ecliptic plane and at high solar latitudes, since these nuclei should give information on the sun's composition. The instrument should also provide clues about how the masses of individual particles influence the acceleration caused by electromagnetic forces. HI-SCALE is an acronym for heliospheric instrument for spectral composition and anisotropy at low energies. Dr. Louis Lanzerotti of Bell Laboratories is principal investigator.

INVESTIGATION OF COSMIC RAYS AND SOLAR PARTICLES. A cosmic-ray and solar-particle investigation will search for particles in the Milky Way Galaxy. Team members hope to sample these objects in near-pristine condition, unaltered by the sun's magnetic field lines near the ecliptic plane. Specific goals include an understanding of acceleration and movement of charged particles in interplanetary space—primarily the cosmic rays that originate beyond the solar system. Most important, what are cosmic rays like before they enter the solar system? How do galactic cosmic rays change? And from measurements of particles not accessible in the plane of the ecliptic, we hope to determine how and where cosmic rays originate, what forces act on them, and how they travel through the Milky Way.

The experiment can distinguish between the different elements present in cosmic rays. It can identify such heavy particles as hydrogen nuclei, helium nuclei, oxygen and nitrogen. The physicists on this team also hope to determine individual isotopes of each element, which would tell them about how the cosmic rays were created. Dr. John Simpson of the University of Chicago's Enrico Fermi Institute is principal investigator.

UNIFIED RADIO AND PLASMA-WAVE EXPERIMENT. The sun is a mighty broadcaster of radio signals that move across the solar system at the speed of light. High-energy electrons that move outward as the result of solar eruptions also produce low-frequency waves of energy. Ulysses' unified radio and plasma-wave experiment has two objectives: the first is to determine the direction and polarization of radio sources flowing outward from the sun, and the second is a detailed study of waves in the solar wind—waves associated with local variations in the properties of clouds of plasma that move through the interplanetary medium.

The unified radio and plasma-wave experiment is both a remote-sensing and a local-measurement instrument. It senses the longer radio frequencies that originate at great distances and the shorter plasma-wave frequencies as they move past the spacecraft. Scientists on this team, along with colleagues on others, are seeking to understand the basic physics of plasmas—clouds of particles that have lost one or more of their electrons and thus have been electrically charged. Electrons that move with the plasma cloud follow magnetic field lines of the heliosphere, emitting electromagnetic waves. Both ions and electrons in streams of plasma interact with the solar wind to create plasma waves. Scientists want to know three things about the waves: What is their source? How do they interact with the solar wind? And how do various kinds of waves depend on the medium through which they move? Dr. R.G. Stone of NASA's Goddard Space Flight Center is principal investigator.

SOLAR X-RAY AND COSMIC GAMMA-RAY BURSTS. Almost all solar flares produce high-energy charged particles that, for the most part, are protons or electrons. The electrons are constrained to spiral in the strong magnetic fields of the flare region, and the "braking" they experience gives rise to the so-called "Bremsstrahlung" radiation in the X-ray region of the electromagnetic spectrum. The division between the X-ray region and the gamma-ray region is somewhat arbitrary and, indeed, the same instrumentation is capable of measuring in both regions. (A rough guide might be to consider X-rays as arising from relatively low energy atomic processes, while gamma rays come mainly from high-energy reactions involving nuclei.)

A single device on Ulysses, the solar X-ray and cosmic gamma-ray bursts experiment, will detect these particles in two rather different investigations. The first, the solar-flare X-ray portion of the experiment, will work in conjunction with other spacecraft in the ecliptic plane, such as Galileo, which will be en route to Jupiter. It will measure the directionality of X-rays from solar flares; this information could be used to determine how the electrons that produced the X-rays were moving in the magnetic fields of the parent flare.

The second investigation will also require observation by other spacecraft. In 1973, mysterious short bursts of gamma radiation were detected arriving from interstellar space. The origin of these high-energy gamma rays is still unknown, and their discovery has given rise to much exciting speculation about a birthplace in neutron stars, in black holes or in supernova explosions. When a gamma ray is detected at the Ulysses spacecraft and almost simultaneously at another spacecraft, the small difference in arrival times will be used to pinpoint the source of the radiation. Dr. Kevin Hurley of the Centre d'Etude Spatiale des Rayonnements, France, and the University of California, Berkeley, and Dr. Michael Sommer of the Max-Planck-Institut für Extraterrestrische Physik, West Germany, are co-principal investigators.

DUST-PARTICLE EXPERIMENT. One Ulysses experiment will measure the dust particles that move through the solar system. The dust probably originated in several different ways: Some may be left over from the creation of the solar system. Some has undoubtedly been left behind by comets streaking past the sun. Still other dust may have come from collisions of great boulders in the asteroid belt. Finally, some probably comes into the solar system from interstellar space.

Dust particles in space are extremely tiny, about the size of the particles in cigarette smoke. Two basic forces act on the dust particles at the same time: gravity and solar radiation. Depending on their sizes, the individual particles can be drawn inward toward the sun by gravity or forced outward by the pressure of solar radiation. Still other dust particles are just passing through, on their way from interstellar space through the solar system and out again.

The Ulysses dust experiment aims to measure the speed and flight direction of particles. It will measure the electric charges they acquire as they fly through the solar wind and it will attempt to determine if the dust exists in greater amounts at higher latitudes than in the ecliptic plane. Dr. Eberhard Grün of the Max-Planck-Institut für Kernphysik in West Germany is the principal investigator.

MEASUREMENT OF RADIO SIGNALS. Twice during the Ulysses mission, the spacecraft and the Earth will be on opposite sides of the sun. The first such orientation will occur about 10 months after launch and the second will be about one year later. During these opportunities, scientists will use radio signals going to and from Ulysses to measure the density of electrons along the path the radio signals take from Earth to the spacecraft and back as they pass the sun.

Since interplanetary space is not a perfect vacuum, the radio signals' speed will be slightly affected by the material they pass through. Therefore, the frequency of the signals will change slightly as they pass through the sun's corona. Part of that shift is caused by realtive motions of the spacecraft and Earth. Yet another part is caused by the electrons in the signals' path. In addition, irregularities in electron density make the radio waves scintillate, or twinkle, just as starlight does, and that scintillation is a measure of the number of electrons near the corona. The unique thing about Ulysses' measurements is that they will count the electrons as they stream from a region of the sun that has never been seen before—the high solar lattitudes. Dr. Hans Volland of Bonn University is the principal investigator.

TESTING EINSTEIN'S THEORY. Ulysses may provide evidence in support of Albert Einstein's theory of gravitation (the Theory of General Relativity). Relativity predicts the presence of gravitational waves. They are ripples in Einstein's space-time caused by matter or mass in motion. Particularly strong waves could be produced by cataclysmic events involving vast amounts of matter in quasars and the centers of exploding galaxies. An example of such an event would be the collapse into a black hole of matter equivalent to 100 million times the sun's mass. Current astronomical observations appear to lend credence to the existence of such objects in the centers of galaxies. Gravitational waves would travel out from such events through space at the speed of light and disturb the position of any object that they pass.

Thus, gravitational waves are similar in many ways to radio waves: an essential difference is that radio waves are created by moving electrical charges, while gravitational waves are created by moving masses. And radio waves are many times stronger than gravitational waves. Gravitational waves would cause extremely tiny changes in a local gravity field and would be extraordinarily difficult to detect. Although experiments are under way to search for them, the consensus is that none has been detected as yet. If a gravitational wave were to pass through the solar system while Ulysses is out at the distance of Jupiter, the wave would alter the distance between Ulysses and the Deep-Space Network antenna that is tracking it by less than 1 centimeter across 746 million kilometers. Thus, those changes in distance cannot be measured directly.

However, by using the Deep-Space Network's hydrogen-maser clocks, scientists can measure tiny changes—called Doppler shifts—in the frequency of radio signals making the round trip between Earth antennas and the spacecraft. Those minute changes are measured against the network's extremely accurate clocks. Einstein's theory of gravitation predicts that a tiny fractional frequency shift will occur if a gravitational wave passes through the solar system while Ulysses is near Jupiter. Such a minute change, a decimal followed by 14 zeroes and a 3, would be detectable by the Deep-Space Network's hydrogen-maser clocks. Professor Bruno Bertotti of the University of Pavia, Italy, is principal investigator.

EXPERIMENT RESULTS. An interdisciplinary team of scientists who are not attached to any of the experiment teams has perhaps the most challenging task of all: they will work to construct a complete and coherent model of the heliosphere from the data furnished by the instruments.

ULYSSES ORGANIZATION AND PERSONNEL

The Ulysses spacecraft was built for ESA by Dornier Systems of Germany. Subcontractors included firms in Austria, Belgium, Denmark, France, Italy, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States. In addition to providing the spacecraft, ESA is responsible for mission operations. Scientific instruments for the Ulysses spacecraft were provided by each science team.

Launch on space shuttle Discovery is provided by NASA. In addition, NASA is responsible for the inertial upper stage built for the U.S. Air Force by Boeing Aerospace & Electronics Co. and the

PAM-S upper stage built by McDonnell Douglas Space Systems Co. NASA also provides the radioisotope thermoelectric generator, which was built for the U.S. Department of Energy by the General Electric Co. Tracking through the Deep-Space Network and ground operations facilities in Pasadena, Calif., is managed for NASA by JPL.

Willis Meeks of JPL is the U.S. project manager. Dr. Edward J. Smith of JPL is the U.S. project scientist. The U.S. program manager is Robert Murray of NASA Headquarters, and the U.S. program scientist is Dr. J. David Bohlin, also of NASA Headquarters. The U.S. portion of the Ulysses mission is managed by JPL for NASA's Office of Space Science and Applications.

Derek Eaton is ESA project manager. Dr. Klaus-Peter Wenzel is ESA project scientist. EASA's share of the Ulysses project is headquartered at Noorduijk, the Netherlands, at the European Space Technology and Research Center.

INERTIAL UPPER STAGE

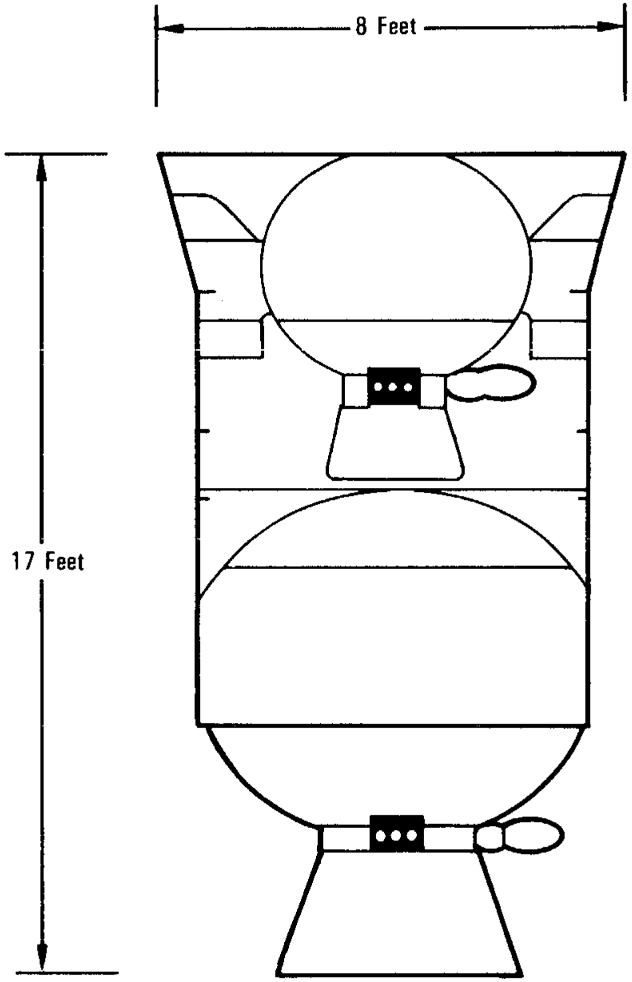
The inertial upper stage will be used with the space shuttle to transport NASA's Tracking and Data Relay satellites to geosynchronous orbit, 22,300 statute miles from Earth. The IUS was also selected by NASA for the Magellan, Galileo and Ulysses planetary missions.

The IUS was originally designed as a temporary stand-in for a reusable space tug and was called the interim upper stage. Its name was changed to inertial upper stage (signifying the satellite's guidance technique) when it was realized that the IUS would be needed through the mid-1990s.

The IUS was developed and built under contract to the Air Force Systems Command's Space Division. The Space Division is executive agent for all Department of Defense activities pertaining to the space shuttle system and provides the IUS to NASA for space shuttle use. In August 1976, after 2.5 years of competition, Boeing Aerospace Company, Seattle, Wash., was selected to begin preliminary design of the IUS.

The IUS is a two-stage vehicle weighing approximately 32,500 pounds. Each stage is a solid rocket motor. This design was selected over those with liquid-fueled engines because of its relative simplicity, high reliability, low cost and safety.

The IUS is 17 feet long and 9.5 feet in diameter. It consists of an aft skirt, an aft stage SRM with 21,400 pounds of propellant generating 45,600 pounds of thrust, an interstage, a forward stage SRM with 6,000 pounds of propellant generating 18,500 pounds of thrust and using an extendable exit cone, and an equipment support section. The equipment support section contains the avionics that provide guidance, navigation, telemetry, command and data management, reaction control and electrical power. All mission-critical components of the avionics system and thrust vector actuators, reaction control thrusters, motor igniter and pyrotechnic stage separation equipment are redundant to ensure better than 98-percent reliability.



Inertial Upper Stage

FLIGHT SEQUENCE

After the orbiter's payload bay doors are opened in Earth orbit, the orbiter maintains a preselected attitude to fulfill payload thermal requirements and constraints except during those operations that require special attitudes (e.g., orbiter inertial measurement unit alignments, RF communications and deployment operations).

On-orbit predeployment checkout is followed by an IUS command link check and spacecraft RF command check, if required. The state vector is uplinked to the orbiter for trim maneuvers the orbiter performs. The state vector is transferred to the IUS.

The forward airborne support equipment payload retention latch actuator is released, and the aft frame ASE electromechanical tilt actuator tilts the IUS and spacecraft combination to 29 degrees. This extends the spacecraft into space just outside the orbiter payload bay, which allows direct communication with Earth during systems checkout. The orbiter is then maneuvered to the deployment attitude. If a problem develops within the spacecraft or IUS, they can be restowed.

Before deployment, the flight crew switches the spacecraft's electrical power source from orbiter power to IUS internal power. Verification that the spacecraft is on IUS internal power and that all IUS and spacecraft predeployment operations have been successfully completed is ascertained by evaluating data contained in the IUS and spacecraft telemetry. IUS telemetry data are evaluated by the IUS Mission Control Center at Sunnyvale, Calif., and the spacecraft data by the spacecraft control center. Analysis of the telemetry results in a go/no-go decision for IUS and spacecraft deployment from the orbiter.

When the orbiter flight crew is given a go decision, the orbiter flight crew activates the ordnance that separates the IUS and spacecraft's umbilical cables. The flight crew then commands the electromechanical tilt actuator to raise the tilt table to a 58-degree deployment position. The orbiter's reaction control system thrusters are inhibited, and the Super*zip ordnance separation device physically separates the IUS and spacecraft combination from the tilt table. Compressed springs provide the force to jettison the IUS and spacecraft from the orbiter payload bay at approximately 0.4 foot per second. The IUS and spacecraft are deployed in the shadow of the orbiter or in Earth eclipse. The tilt table is lowered to minus 6 degrees after deployment. Approximately 15 minutes after deployment, the orbiter's orbital maneuvering system engines are ignited to separate the orbiter from the IUS and spacecraft.

The IUS and spacecraft are now controlled by computers on board the IUS. Approximately 10 minutes after the IUS and spacecraft are ejected from the orbiter, the IUS onboard computers send out discrete signals that are used by the IUS or spacecraft to begin mission sequence events. All subsequent operations are sequenced by the IUS computer from transfer orbit injection through spacecraft separation and IUS deactivation. Following RCS activation, the IUS maneuvers to the required thermal attitude and performs any required spacecraft thermal control maneuver.

Approximately 39 minutes after IUS and spacecraft ejection from the orbiter, the SRM-1 ordnance inhibits are removed. At this time, the bottom of the orbiter is oriented toward the IUS and spacecraft to protect the orbiter windows from the IUS SRM-1 plume. The IUS then recomputes SRM-1 ignition time and maneuvers to the proper attitude for the SRM-1 thrusting period. When the transfer orbit or planetary trajectory injection opportunity is reached, the IUS computer enables and applies ordnance power, arms the safe and arm devices and ignites the first-stage SRM. The IUS second-stage SRM is ignited approximately two minutes after SRM first-stage cutoff to provide sufficient thrust for the predetermined contribution of thrust for planetary trajectory for planetary missions.

The IUS then supports spacecraft separation and performs a final collision and contamination avoidance maneuver before deactivating its subsystems.

Boeing's propulsion team member, Chemical Systems Division of United Technologies, designed and tests the two solid rocket motors. Supporting Boeing in the avionics area are TRW, Cubic and the Hamilton Standard Division of United Technologies. TRW and Cubic provide IUS telemetry, tracking and command subsystem hardware. Hamilton Standard provides guidance system hardware support. Delco, under subcontract to Hamilton Standard, provides the avionics computer.

In addition to the actual flight vehicles, Boeing is responsible for the development of ground support equipment and software for the checkout and handling of the IUS vehicles from factory to launch pad.

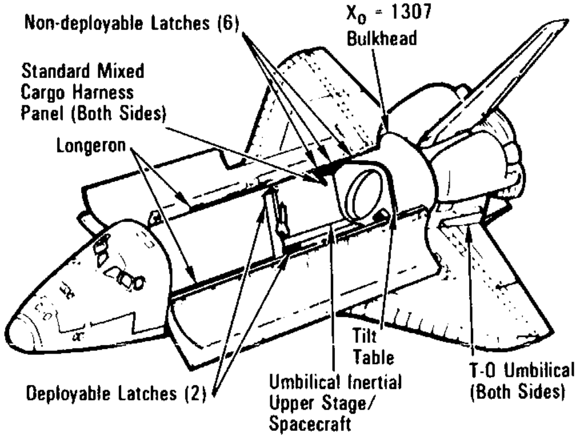
Boeing also integrates the IUS with various satellites and joins the satellite with the IUS, checks out the configuration and supports launch and mission control operations for both the Air Force and NASA. Boeing also develops airborne support equipment to support the IUS in the space shuttle and monitors it while it is in the orbiter payload bay.

The IUS, without the two SRMs, is fabricated and tested at the Boeing Space Center, Kent, Wash. SRMs are shipped directly from Chemical Systems Division in California to the eastern launch site at Cape Canaveral, Fla. Similarly, the Boeing-manufactured IUS subsystems are shipped from Washington to the eastern launch site. IUS/SRM buildup is done in the Solid Motor Assembly Building and the IUS and spacecraft are mated in the Vertical Processing Facility at the Kennedy Space Center. The combined IUS and spacecraft payload is installed in the orbiter at the launch pad. Boeing is building 22 IUS vehicles under its contract with the Air Force.

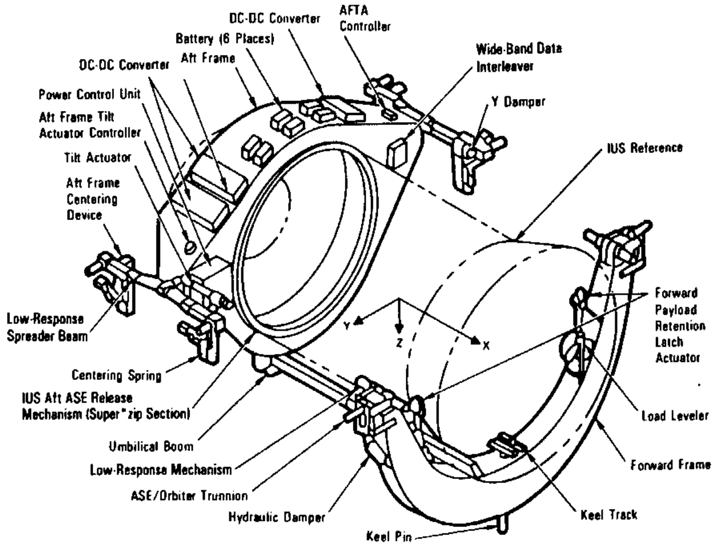
AIRBORNE SUPPORT EQUIPMENT

The IUS ASE is the mechanical, avionics and structural equipment located in the orbiter. The ASE supports and provides services to the IUS and the spacecraft in the orbiter payload bay and positions the IUS/spacecraft in an elevated position for final checkout before deployment from the orbiter.

The IUS ASE consists of the structure, batteries, electronics and cabling to support the IUS and spacecraft combination. These ASE subsystems enable the deployment of the combined vehicle and provide or distribute and control electrical power to the IUS and spacecraft and provide communication paths between the IUS, spacecraft and the orbiter.



Inertial Upper Stage Airborne Support Equipment



Inertial Upper Stage Airborne Support Equipment

The ASE incorporates a low-response spreader beam and torsion bar mechanism that reduces spacecraft dynamic loads to less than one-third what they would be without this system. In addition, the forward ASE frame includes a hydraulic load leveler system to provide balanced loading at the forward trunnion fittings.

The ASE data subsystem allows data and commands to be transferred between the IUS and spacecraft and the appropriate orbiter interface. Telemetry data include spacecraft data received over dedicated circuits via the IUS and spacecraft telemetry streams. An interleaved stream is provided to the orbiter to transmit to the ground or transfer to ground support equipment.

The structural interfaces in the orbiter payload bay consist of six standard non-deployable attach fittings on each longeron that mate with the ASE aft and forward support frame trunnions and two payload retention latch actuators at the forward ASE support frame. The IUS has a self-contained, spring-actuated deployment system that imparts a velocity to the IUS at release from the raised deployment attitude. Ducting from the orbiter purge system interfaces with the IUS at the forward ASE.

IUS STRUCTURE

The IUS structure is capable of transmitting all of the loads generated internally and also those generated by the cantilevered spacecraft during orbiter operations and IUS free flight. In addition, the structure supports all of the equipment and solid rocket motors within the IUS and provides the mechanisms for IUS stage separation. The major structural assemblies of the two-stage IUS are the equipment support section, interstage and aft skirt. The basic structure is aluminum skin-stringer construction with six longerons and ring frames.

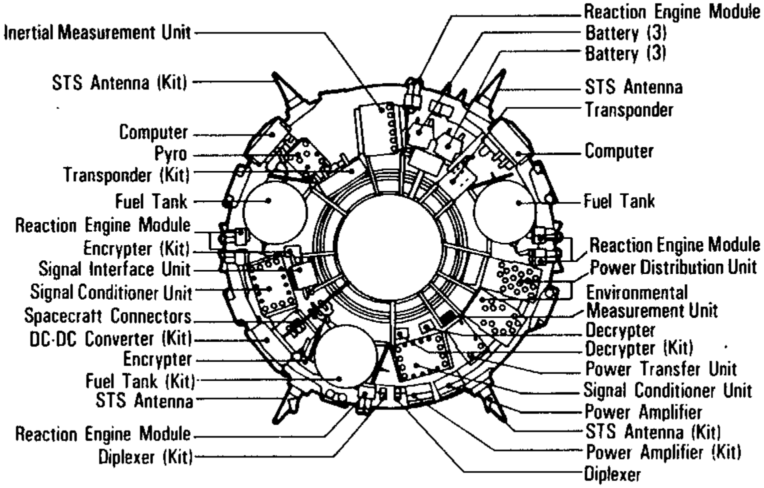
EQUIPMENT SUPPORT SECTION

The ESS houses the majority of the IUS avionics and control subsystems. The top of the ESS contains the 10-foot-diameter interface mounting ring and electrical interface connector segment for mating and integrating the spacecraft with the IUS. Thermal isolation is provided by a multilayer insulation blanket across the interface between the IUS and spacecraft. All line replaceable units mounted in the ESS can be removed and replaced via access doors even when the IUS is mated with the spacecraft.

IUS AVIONICS SUBSYSTEM

The avionics subsystem consists of the telemetry, tracking and command; guidance and navigation; data management; thrust vector control; and electrical power subsystems. This includes all of the electronic and electrical hardware used to perform all computations, signal conditioning, data processing and software formatting associated with navigation, guidance, control, data management and redundancy management. The IUS avionics subsystem also provides the communications between the orbiter and ground stations and electrical power distribution.

Data management performs the computation, data processing and signal conditioning associated with guidance, navigation and control; safing and arming and ignition of the IUS two-stage solid rocket motors and electroexplosive devices; command decod-



Inertial Upper Stage Equipment Support Section ing and telemetry formatting; and redundancy management and issues spacecraft discretes. The data management subsystem consists of two computers, two signal conditioner units and a signal interface unit.

Modular general-purpose computers use operational flight software to perform in-flight calculations and to initiate the vehicle thrust and attitude control functions necessary to guide the IUS and spacecraft through a flight path determined on board to a final orbit or planned trajectory. A stored program, including data known as the onboard digital data load, is loaded into the IUS flight computer memory from magnetic tape through the memory load unit during prelaunch operations. Memory capacity is 65,536 (64K) 16-bit words.

The SCU provides the interface for commands and measurements between the IUS avionics computers and the IUS pyrotechnics, power, reaction control system, thrust vector control, TT&C and the spacecraft. The SCU consists of two channels of signal conditioning and distribution for command and measurement functions. The two channels are designated A and B. Channel B is redundant to channel A for each measurement and command function.

The signal interface unit performs buffering, switching, formatting and filtering of TT&C interface signals.

Communications and power control equipment is mounted at the orbiter aft flight deck payload station and operated in flight by the orbiter flight crew mission specialists. Electrical power and signal interfaces to the orbiter are located at the IUS equipment connectors. Cabling to the orbiter equipment is provided by the orbiter. In addition, the IUS provides dedicated hardwires from the spacecraft through the IUS to an orbiter multiplexer/demultiplexer for subsequent display on the orbiter cathode-ray tube of parameters requiring observation and correction by the orbiter flight crew. This capability is provided until IUS ASE umbilical separation.

To support spacecraft checkout or other IUS-initiated functions, the IUS can issue a maximum of eight discretes. These discretes may be initiated either manually by the orbiter flight crew before the IUS is deployed from the orbiter or automatically by the IUS mission-sequencing flight software after deployment. The discrete commands are generated in the IUS computer either as an event-scheduling function (part of normal onboard automatic sequencing) or a command-processing function initiated from an uplink command from the orbiter or Air Force Consolidated Satellite Test Center to alter the onboard event-sequencing function and permit the discrete commands to be issued at any time in the mission.

During the ascent phase of the mission, the spacecraft's telemetry is interleaved with IUS telemetry, and ascent data are provided to ground stations in real time via orbiter downlink. Telemetry transmission on the IUS RF link begins after the IUS and spacecraft are tilted for deployment from the orbiter. Spacecraft data may be transmitted directly to the ground when the spacecraft is in the orbiter payload bay with the payload bay doors open or during IUS and spacecraft free flight.

IUS guidance and navigation consist of strapped-down redundant inertial measurement units. The redundant IMUs consist of five rate-integrating gyros, five accelerometers and associated electronics. The IUS inertial guidance and navigation subsystem provides measurements of angular rates, linear accelerations and other sensor data to data management for appropriate processing by software resident in the computers. The electronics provides conditioned power, digital control, thermal control, synchronization and the necessary computer interfaces for the inertial sensors. The electronics are configured to provide three fully independent channels of data to the computers. Two channels each support two sets of sensors and the third channel supports one set. Data from all five gyro and accelerometer sets are sent simultaneously to both computers.

The guidance and navigation subsystem is calibrated and aligned on the launch pad. The navigation function is initialized at lift-off, and data from the redundant IMUs are integrated in the navigation software to determine the current state vector. Before vehicle deployment, an attitude update maneuver may be performed by the orbiter.

If for any reason the computer is powered down before deployment, the navigation function is reinitialized by transferring orbiter position, velocity and attitude data to the IUS vehicle. Attitude updates are then performed as described above.

The IUS vehicle uses an explicit guidance algorithm (gamma guidance) to generate thrust steering commands, SRM ignition time and RCS vernier thrust cutoff time. Before each SRM ignition and each RCS vernier, the vehicle is oriented to a thrust attitude based on nominal performance of the remaining propulsion stages. During SRM burn, the current state vector determined from the navigation function is compared to the desired state vector, and the commanded attitude is adjusted to compensate for the buildup of position and velocity errors caused by off-nominal SRM performance (thrust, specific impulse).

Vernier thrust compensates for velocity errors resulting from SRM impulse and cutoff time dispersions. Residual position errors from the SRM thrusting and position errors introduced by impulse and cutoff time dispersions are also removed by the RCS.

Attitude control in response to guidance commands is provided by thrust vector control during powered flight and by reaction control thrusters during coast. Measured attitude from the guidance and navigation subsystem is compared with guidance commands to generate error signals. During solid motor thrusting, these error signals drive the motor nozzle actuator electronics in the TVC subsystem. The resulting nozzle deflections produce the desired attitude control torques in pitch and yaw. Roll control is maintained by the RCS roll-axis thrusters. During coast flight, the error signals are processed in the computer to generate RCS thruster commands to maintain vehicle attitude or to maneuver the vehicle. For attitude maneuvers, quarternion rotations are used.

TVC provides the interface between IUS guidance and navigation and the SRM gimbaled nozzle to accomplish powered-flight attitude control. Two complete electrically redundant channels minimize single-point failure. The TVC subsystem consists of two controllers, two actuators and four potentiometers for each IUS SRM. Power is supplied through the SCU to the TVC controller that controls the actuators. The controller receives analog pitch and yaw commands that are proportioned to the desired nozzle angle and converts them to pulsewidth-modulated voltages to power the actuator motors. The motor drives a ball screw that extends or retracts the actuator to position the SRM nozzle. Potentiometers provide servoloop closure and position instrumentation. A staging command from the SCU allows switching of the controller outputs from IUS first-stage actuators to the IUS second-stage actuators.

The IUS's electrical power subsystem consists of avionics batteries, IUS power distribution units, power transfer unit, utility batteries, pyrotechnic switching unit, IUS wiring harness and umbilical, and staging connectors. The IUS avionics subsystem distributes electrical power to the IUS and spacecraft interface connector for all mission phases from prelaunch to spacecraft separation. The IUS system distributes orbiter power to the spacecraft during ascent and on-orbit phases. ASE batteries supply power to the spacecraft if orbiter power is interrupted. Dedicated IUS and spacecraft batteries ensure uninterrupted power to the spacecraft after deployment from the orbiter. The IUS will also accomplish an automatic power-down if high-temperature limits are experienced before the orbiter payload bay doors are opened. Dual buses ensure that no single power system failure can disable both A and B channels of avionics. For the IUS two-stage vehicle, four batteries (three avionics and one spacecraft) are carried in the IUS first stage. Five batteries (two avionics, two utility and one spacecraft) supply power to the IUS second stage after staging. The IUS battery complement can be changed to adapt to mission-unique requirements and to provide special spacecraft requirements. Redundant IUS switches transfer the power input among spacecraft, ground support equipment, ASE and IUS battery sources.

Stage 1 to stage 2 IUS separation is accomplished via redundant low-shock ordnance devices that minimize the shock environment on the spacecraft. The IUS provides and distributes ordnance power to the IUS/spacecraft interface for firing spacecraft ordnance devices in two groups of eight initiators: a prime group and a backup group. Four separation switches or breakwires provided by the spacecraft are monitored by the IUS telemetry system to verify spacecraft separation.

IUS SOLID ROCKET MOTORS

The two-stage IUS vehicle incorporates a large SRM and a small SRM. These motors employ movable nozzles for thrust vector control. The nozzles are positioned by redundant electromechanical actuators permitting up to 4 degrees of steering on the large motor and 7 degrees on the small motor. Kevlar filament-wound cases provide high strength at minimum weight. The large motor's 145-second thrusting period is the longest ever developed for space. Variations in user mission requirements are met by tailored propellant off-loading or on-loading. The small motor can be flown either with or without its extendible exit cone, which provides an increase of 14.5 seconds in the delivered specific impulse of the small motor.

IUS REACTION CONTROL SYSTEM

The IUS RCS is a hydrazine monopropellant positive-expulsion system that controls the attitude of the IUS and spacecraft during IUS coast periods, roll during SRM thrustings and delta velocity impulses for accurate orbit injection. Valves and thrusters are redundant, which permits continued operation with a minimum of one failure.

The IUS baseline includes two RCS tanks with a capacity of 120 pounds of hydrazine each. Production options are available to add a third tank or remove one tank if required. To avoid spacecraft contamination, the IUS has no forward-facing thrusters. The system is also used to provide the velocities for spacing between multiple spacecraft deployments and for a collision/contamination avoidance maneuver after spacecraft separation.

The RCS is a sealed system that is serviced before spacecraft mating. Propellant is isolated in the tanks with pyrotechnic squib-operated valves that are not activated until 10 minutes after IUS deployment from the orbiter. The tank and manifold safety factors are such that no safety constraints are imposed on operations in the vicinity of the serviced tanks.

IUS-TO-SPACECRAFT INTERFACES

The spacecraft is attached to the IUS at a maximum of eight attachment points. They provide substantial load-carrying capability while minimizing thermal transfer across the interface.

Power and data transmission to the spacecraft are provided by several IUS interface connectors. Access to these connectors can be provided on the spacecraft side of the interface plane or through the access door on the IUS equipment bay.

The IUS/PAM-S interface is covered by a multilayer insulation blanket of aluminized Kapton with polyester net spacers and an aluminized beta cloth outer layer. All IUS thermal blankets are vented toward and into the IUS cavity. All gases within the IUS cavity are vented to the orbiter payload bay. There is no gas flow between the PAM-S and the IUS. The thermal blankets are grounded to the IUS structure to prevent electrostatic charge buildup.

PAYLOAD ASSIST MODULE

The payload assist module (PAM-S), used in conjunction with the inertial upper stage for the Ulysses mission, was developed by McDonnell Douglas Space Systems Co. of Huntington Beach, Calif. The IUS and PAM-S will provide the extremely high energy required for Ulysses' journey to the sun. The PAM-S was specifically developed for the Ulysses mission by McDonnell Douglas Space Systems Co., which also developed the original PAM—the world's first commercial space launch vehicle. PAMs have successfully placed over 40 satellites in orbit.

The PAM consists of a spin-stabilized stage with a solid-fuel rocket motor, a payload attach fitting to mate with Ulysses, and the necessary timing, sequencing, power and control assemblies. The PAF structure is a machined forging that provides the subsystem mounting installations and mounts on the forward ring of the motor case. The forward interface of the PAF contains the Ulysses mounting and separation system. The PAF also provides the impetus to separate the PAM from Ulysses. The electrical interface connectors between PAM and Ulysses are mounted on the PAF.

SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET INSTRUMENT

The SSBUV instrument was developed by NASA to calibrate similar ozone-measuring space-based instruments on the National Oceanic and Atmospheric Administration's TIROS satellites (NOAA-9 and -11). The SSBUV was also flown aboard Atlantis in the STS-34 mission.

The SSBUV data will help scientists solve the problem of data reliability caused by calibration drift of solar backscatter ultraviolet instruments on orbiting spacecraft. The SSBUV instrument assesses instrument performance by directly comparing its data with data from identical instruments aboard the TIROS spacecraft as the shuttle and the satellite pass over the same Earth location within a one-hour window. These orbital coincidences can occur 17 times a day.

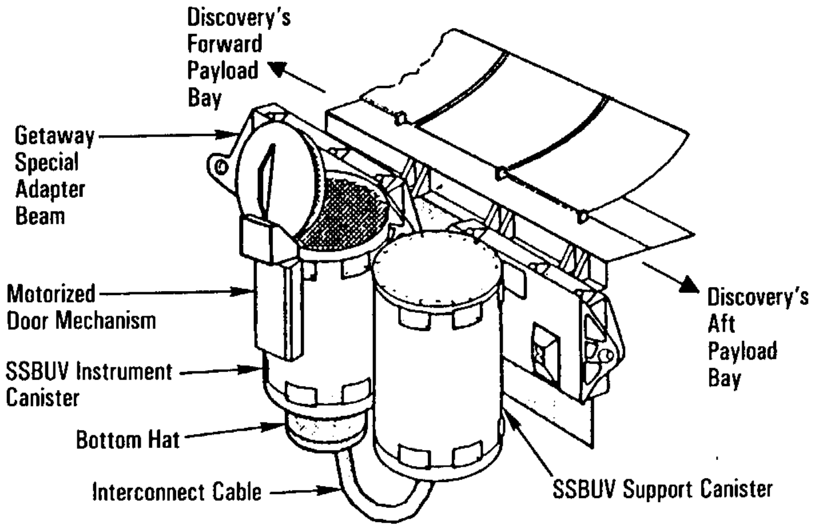
Solar backscatter ultraviolet instruments measure the amount and height distribution of ozone in the upper atmosphere by measuring incident solar ultraviolet radiation and ultraviolet radiation backscattered from the Earth's atmosphere. These parameters are measured in 12 discrete wavelength channels in the ultraviolet. Because ozone is absorbed in the ultraviolet, an ozone measurement can be derived from the ratio of backscatter radiation at different wavelengths, providing an index of the vertical distribution of ozone in the atmosphere.

Global concern over the depletion of the ozone layer has sparked increased emphasis on developing and improving ozone measurement methods and instruments. Accurate, reliable measurements from space are critical for detecting ozone trends and assessing the potential effects of ozone depletion and developing corrective measures.

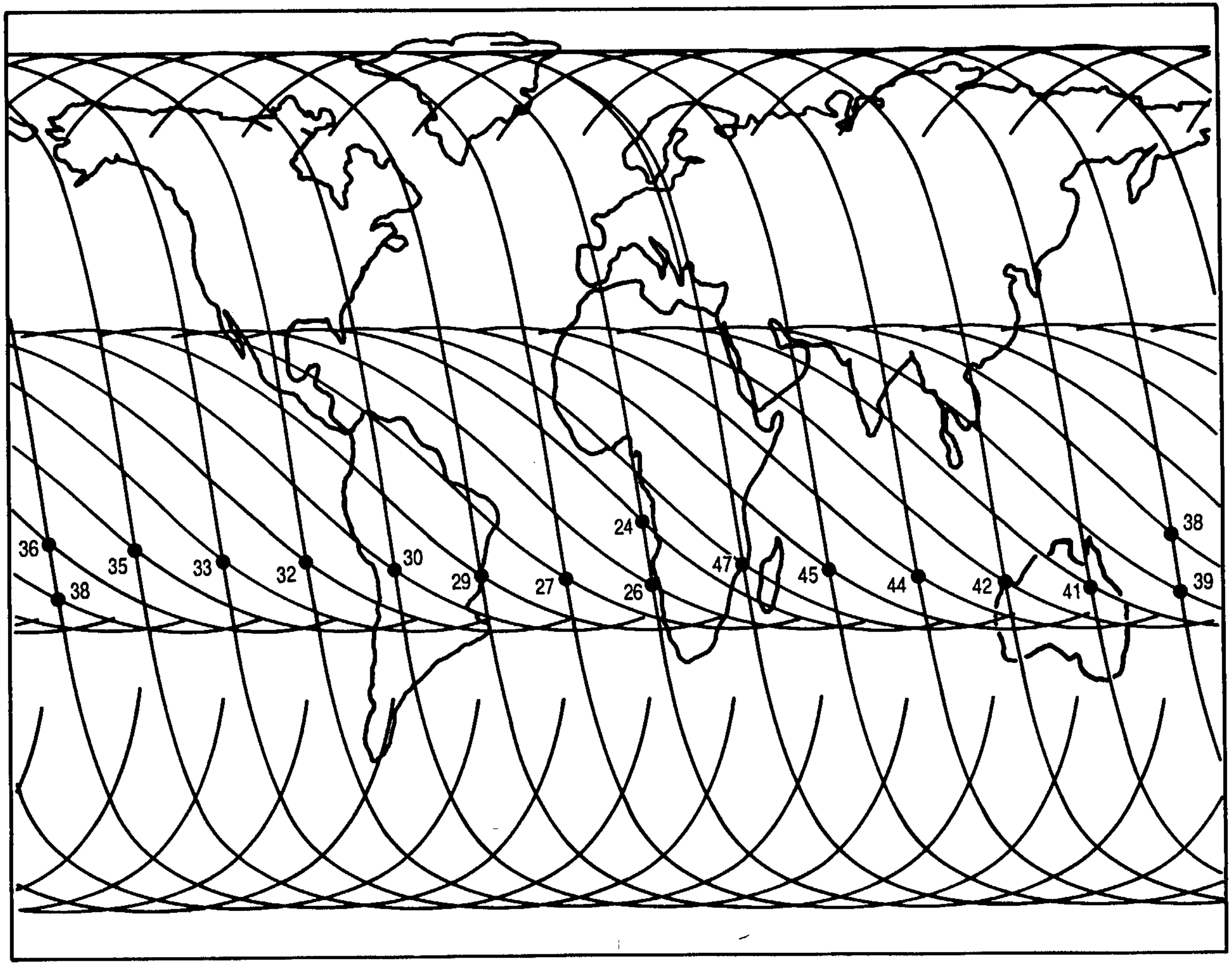
The SSBUV missions are so important to the support of Earth science that six additional missions have been added to the shuttle manifest to calibrate ozone instruments on future TIROS satellites. In addition, the four previously manifested SSBUV flights have been moved up.

The payload configuration consists of two canisters interconnected by cables mounted on a getaway special adapter beam on the starboard side of Discovery's payload bay. The canister containing the SSBUV spectrometer is equipped with a motorized door assembly. The adjacent support canister contains data, command and power systems. Together, they weigh approximately 1,200 pounds. The flight crew interface is through a GAS autonomous payload controller on the aft flight deck. After an outgassing period, the instrument will be operated in three modes: Earth viewing, solar viewing and calibration.

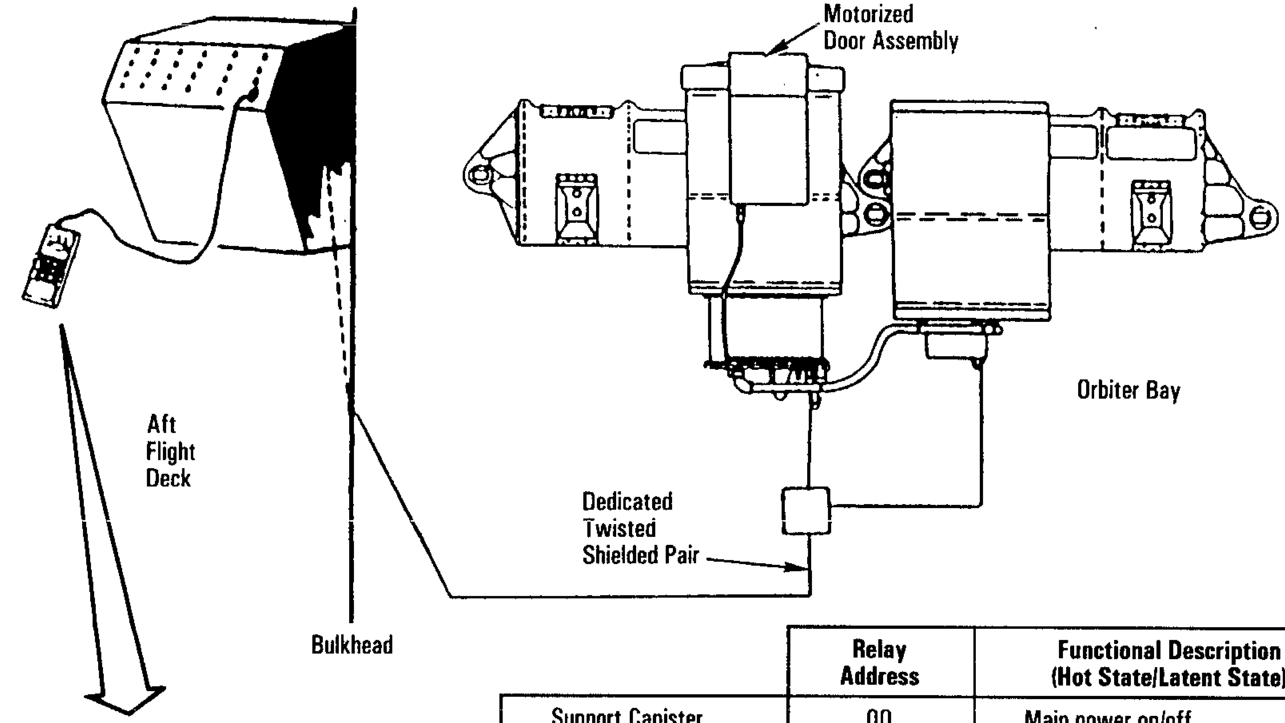
The SSBUV project is managed by NASA's Goddard Space Flight Center, Greenbelt, Md. Ernest Hilsenrath is the principal investigator.

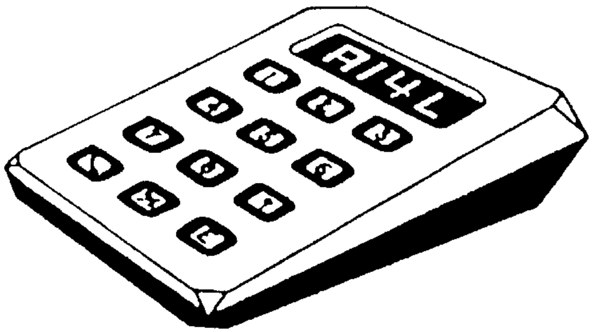


Shuttle Solar Backscatter Ultraviolet Experiment Configuration



An Analysis of Discovery and NOAA's TIROS Satellite Orbits Demonstrates That 17 SSBUV Coincidences on Discovery and SBUV/2 Coincidences on TIROS (1-Hour Window) Can Be Achieved per Day





	Relay Address	Functional Description (Hot State/Latent State)
Support Canister	00	Main power on/off
	01	Main power (backup) on/off
	02	Power circuit initialization on/off
Instrument Canister	03	Door enable/disable
	04	Earth view mode on/off
	05	Solar view mode on/off
	06	Door motor inhibit on/off
	07	Door open/close
	08	Calibration mode on/off
SRU in Instrument Canister	60	Base go/no-go address
	61	Diffuser plate position go/no-go
	62	PMT high-voltage go/no-go
	63	Door position go/no-go
	64	Experiment pressure go/no-go
	65	Experiment power go/no-go
	66	Not used
	68	Not used
	67	Not used

Shuttle Solar Backscatter Ultraviolet Experiment Command and Status Monitoring

INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING

Investigations into Polymer Membrane Processing will make its second space shuttle flight for the Office of Commercial Programs-sponsored Battelle Advanced Materials Center for the Commercial Development of Space in Columbus, Ohio. The objective of the IPMP research program is to gain a fundamental understanding of the role of convection-driven currents in the transport processes that occur during the evaporation casting of polymer membranes and, in particular, to investigate how these transport processes influence membrane morphology.

Polymer membranes have been used in the separation industry for many years for such applications as desalination of water, filtration during the processing of food products, atmospheric purification, purification of medicines and dialysis of kidneys and blood. The IPMP payload uses the evaporation casting method to produce polymer membranes. In this process, a polymer 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 listed above.

The IPMP investigation on STS-41 will seek to determine the importance of the evaporation step in the formation of thin-film membranes by controlling the convective flows. 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 research into polymer membrane casting in a convection-free environment. This program will increase the existing knowledge base regarding the effects of convection in the evaporation process. In turn, industry will use this understanding to improve commercial processing techniques on Earth with the ultimate goal of optimizing membrane properties.

The IPMP payload on STS-41 consists of two experimental units that occupy a single small stowage tray (half of a middeck locker) that weighs less than 20 pounds. Early in flight day 1, a crew member will turn the valve to the first stop to activate the evaporation process. Turning the valve opens the pathway between the large and sample cylinders, causing the solvents in the sample to evaporate into the evacuated larger cylinder. Both flight units are activated at the same time.

The STS-41 experiment will investigate the effects of evaporation time on the resulting membranes by deactivating the two units at different times. A crew member will terminate the evaporation process in the first unit after five minutes by turning the valve to its final position. This ends the process by flushing the sample with water vapor, which sets the membrane structure. After the process is terminated, the resulting membrane then will not be affected by gravitational forces experienced during reentry, landing and post-flight operations. The second unit will be deactivated after seven hours.

In IPMP's initial flight on STS-31, mixed solvent systems were evaporated in the absence of convection to control the porosity of the polymer membrane. Ground-based control experiments also were performed. Results from STS-31 strongly correlated with previous KC-135 aircraft testing and with a similar experiment flown on the Consort 3 sounding rocket flight in May 1990. The morphology of polymer membranes processed in reduced gravity showed noticeable differences from that of membranes processed on Earth.

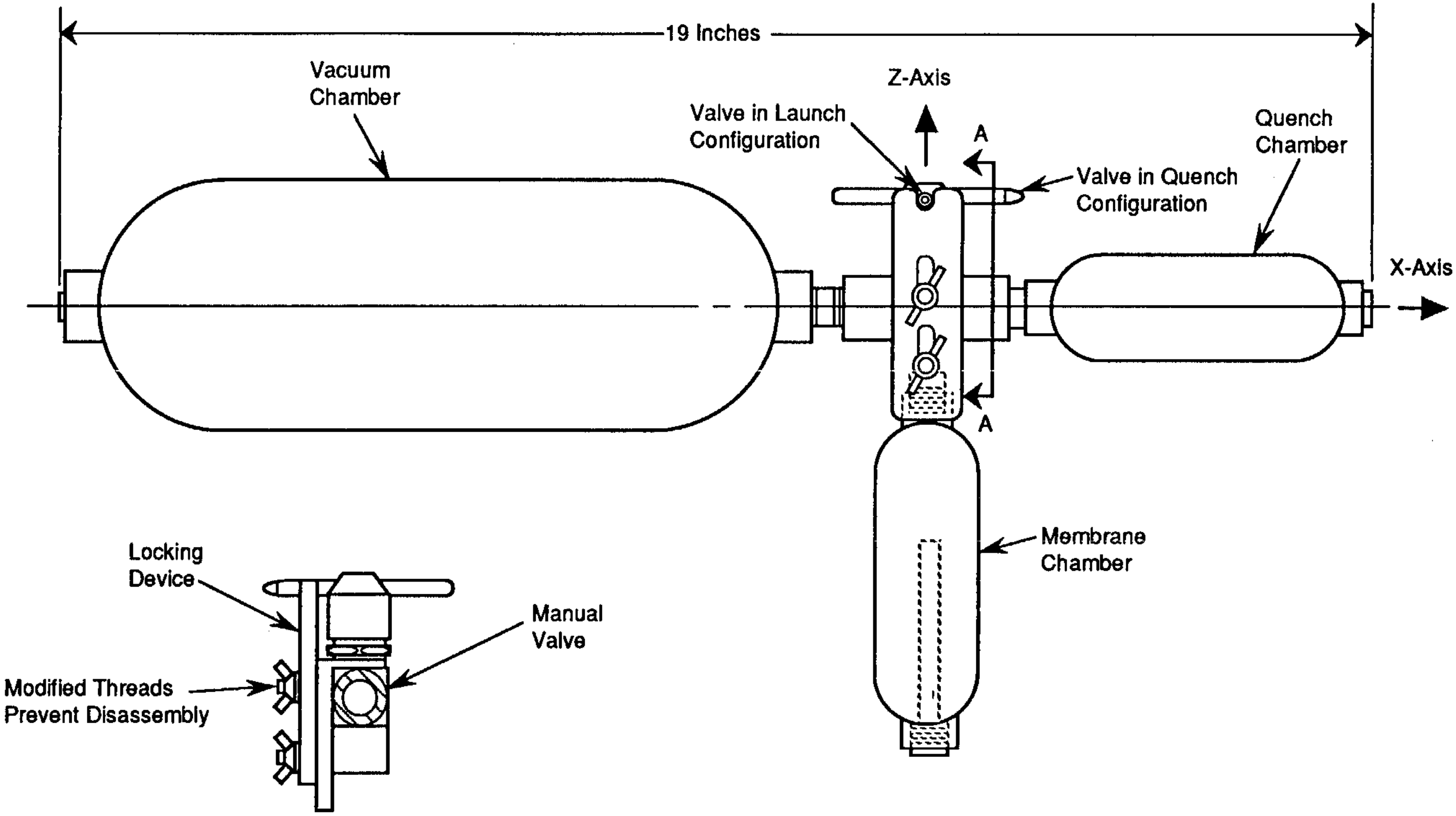
However, following post-flight analyses of the STS-31 experiment, a minor modification was made in the hardware to improve confidence in the analysis by increasing insight into the problem. The modification also would further remove remaining variables from the experiment.

The two most significant variables remaining in the experiment as originally configured are the time factor and the gravitational forces affecting the samples before the payload is retrieved. With the addition of a 75-cc cylinder containing a small quantity of distilled water pressurized with compressed air to greater than

14 psig, flight crew members will be able to terminate (or "quench") the vacuum evaporation process abruptly by flushing the sample with water vapor. After the process is terminated, the resulting membrane will not be further affected by gravity variations. The planned modifications will not alter the experimental objectives and, in fact, will contribute to a better understanding of the transport mechanisms involved in the evaporation casting process.

Subsequent flights of the IPMP payload will use different polymers, solvents and polymer-to-solvent ratios. However, because of the hardware modifications, the polymer/solvent combination used on this flight will be the same as that used on the first flight. The polymer, polysulfone, is swollen with a mixture of dimethylacetamide and acetone in the IPMP units. Combinations of polymers and solvents for later experiments will be selected and/or adjusted on the basis of these first flights results.

Principal investigator for the IPMP is Dr. Vince McGinness of Battelle. Lisa A. McCauley, associate director of the Battelle CCDS, is program manager.



Section A-A

Locking Device in Launch Configuration

PHYSIOLOGICAL SYSTEMS EXPERIMENT

The Physiological Systems Experiment is sponsored by the Pennsylvania State University's Center for Cell Research, a NASA Office of Commercial Programs Center for the Commercial Development of Space. The corporate affiliate leading the PSE investigation is Genentech Inc., South San Francisco, Calif., with NASA's Ames Research Center, Mountain View, Calif., providing payload and mission integration support.

The goal of the PSE is to investigate whether biological changes caused by near weightlessness mimic Earth-based medical conditions closely enough to facilitate pharmacological evaluation of potential new therapies. Research previously conducted by investigators at NASA, Penn State and other institutions has revealed that in the process of adapting to near weightlessness, or microgravity, animals and humans experience a variety of physiological changes including loss of bone and lean body tissue, some decreased immune cell function, change in hormone secretion and cardiac deconditioning, among others. These changes occur in space-bound animals and people soon after leaving Earth's gravitational field. Therefore, exposure to conditions of microgravity during the course of a space flight might serve as a useful and expedient means of testing potential therapies for bone and muscle wasting, organ tissue regeneration and immune system disorders.

Genentech is a biotechnology company engaged in the research, development, manufacture and marketing of recombinant DNA-based pharmaceuticals. The company replicates natural proteins and evaluates their pharmacological potential to treat a range of medical disorders. In this experiment, eight healthy rats will receive one of the natural proteins Genentech has developed. An identical group will accompany them during the flight but will not receive the protein, thereby providing a standard of comparison for the treated group. Both groups will be housed in self-contained animal enclosure modules that provide sophisticated environmental controls and plenty of food and water throughout the flight. The experiment's design and intent have been reviewed and approved by the Animal Care and Use Committees from both NASA and Genentech. Laboratory animal veterinarians will oversee selection, care and handling of the animals.

Following the flight, the rat tissues will be thoroughly evaluated by teams of scientists from Genentech and the Center for Cell Research in a series of studies that will require several months. Dr. Wesley Hymer is director of the Center for Cell Research at Penn State and co-investigator for the PSE. Dr. Michael Cronin of Genetech is principal investigator.

CHROMOSOME AND PLANT CELL DIVISION IN SPACE EXPERIMENT

Roots of the monocot *Hemerocallis* and the dicot *Haplopappus gracilis* were initiated under space-flight conditions aboard Discovery during a five-day flight (STS-29) in March 1989. The two species were cultivated in NASA's plant growth unit equipped with a newly designed air exchange system. Asepsis was maintained throughout the experiment. A comparison of root formation between tissue-culture-generated plantlets and comparably sized seedling clone individuals of *H. gracilis* (both of which had their roots trimmed on Earth) revealed that overall root tissue produced was 40 to 50 percent greater under space-flight conditions than during ground control tests. Production of new roots appeared to slow down toward the end of the flight, a result that did not occur in the ground control experiment. Even so, damage and aberrations were found in 3 to 30 percent of the chromosomes of dividing cells within root tips fixed at recovery before the first cell division on Earth was completed. Ground controls were damage-free. Numbers of cells in division within the root tips were uniformly higher in ground controls.

The exact causes of chromosomal aberrations are not known, but dosimetry data suggest that radiation alone was not responsible. An interaction of microgravity and radiation could conceivably be responsible. Whatever the precise nature of the mechanism of damage, it now seems clear that under space-flight conditions the precision of the processes associated with cell division and chromosome partitioning can be adversely affected.

This experiment (CHROMEX) is a repeat and extension of the CHROMEX flown March 3, 1989, on STS-29. In this flight CHROMEX has been designed with both broad and specific objectives in mind. From the broad perspective, the intent is to repeat the performance of the CHROMEX flown on March 3, 1989. The experiment will be carried out with the upgraded plant growth unit on aseptic tissue or cell-culture-derived, cloned plant specimens. Again, the broad aim is to demonstrate that asepsis can be maintained throughout an entire space biology experiment. If successful, the repetition of the experiment is expected to place on firmer footing the new stage set by the March 3, 1989, CHROMEX for future implementation of both basic plant biology and biotechnology research in space with PGU-type hardware.

The more narrowly focused objectives are, among other things, to verify the hypothesis that g-unloading or micro-g does affect the frequency, rate and pattern of cell division in higher plant roots as they regrow from shoots of trimmed roots, to prove that the fidelity of cell division can be affected in space-grown materials and to affirm that microgravity has measurable effects on growth and differentiation of cells, especially in root- and shoot-growing zones.

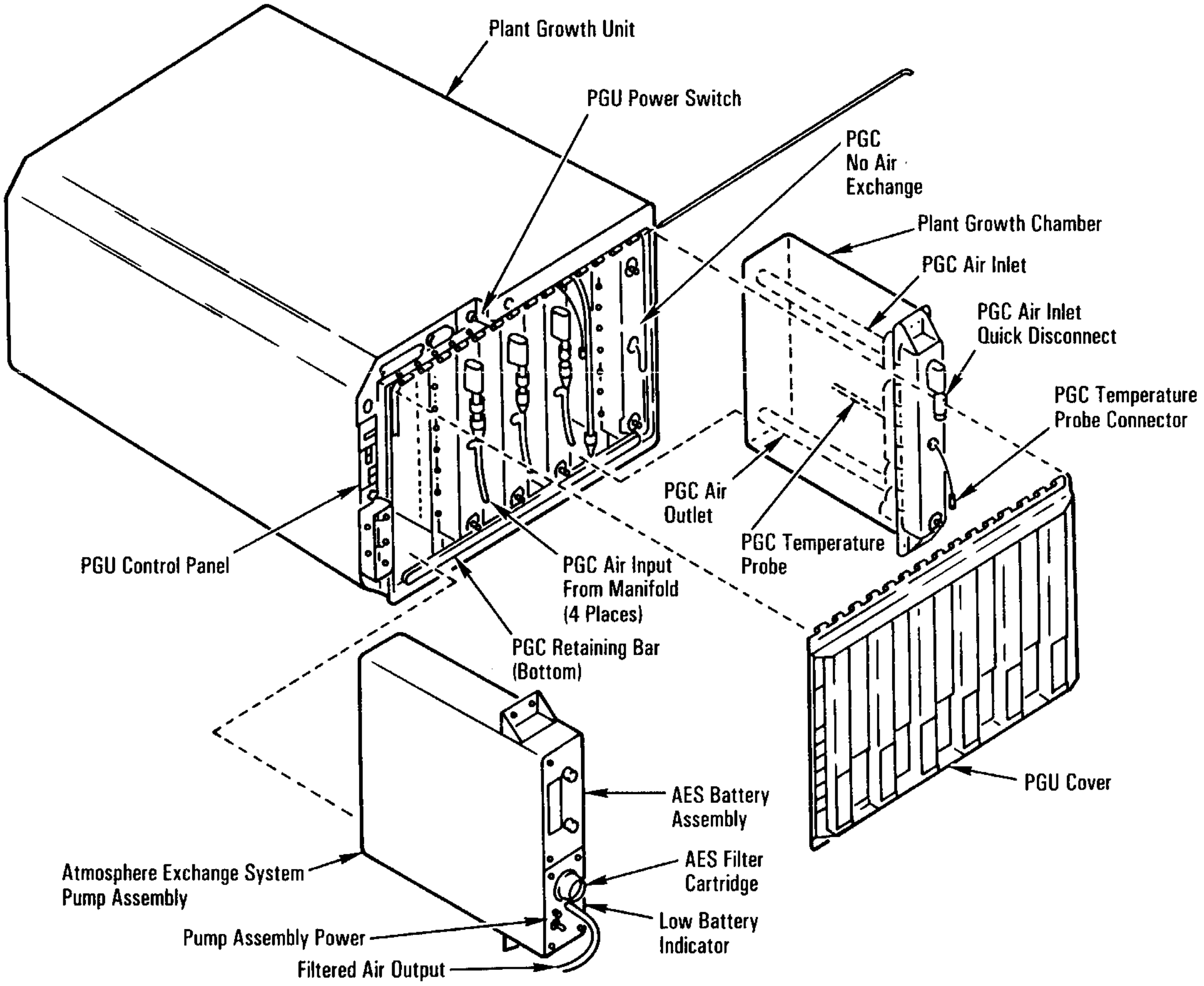
The rationale for the March 3, 1989, CHROMEX derived from past observations that some space-grown plants show a substantially lowered level of cell division in primary and lateral root tips and accumulate a range of significant chromosomal abnormalities such as breakage and fusion. Also, the influence of the asymmetric force of gravity on differentiation and growth of plant tissues that are themselves asymmetric is still largely unexplored—certainly under space conditions. The field of gravitational plant biology is in its infancy.

By testing whether new roots can develop and grow in space on shoots that have been critically trimmed of preformed roots prior to lift-off, the experiment also addressed a key component of futuristic cloning operations: namely, will roots form on propagules predominantly composed of shoots? It goes without saying that reliable and high-performance biological activity such as regeneration and cell division in test materials is crucial to implementing any kind of plant biology research program in space.

A particulary novel and positive feature of the March 3, 1989, CHROMEX design was that it utilized a newly designed air exchange system that freed cabin air of trace contaminants (including ethylene and a variety of organic compounds represented in the testing by acetaldehyde, ethanol, acetone, Freon 113 and toluene) and adjusted the CO_2 content to be passed aseptically through the plant growth containers that are inserted into the plant growth unit. Also, a dosimetry package designed by Dr. Eugene Benton, Physics Department, University of San Francisco, to measure radiation was included in the March 3, 1989, CHROMEX. This was expected to resolve any outstanding questions involving radiation effects on the test materials. Moreover, an accelerometer was used for selected periods (a total of some 19 hours) during flight to obtain direct measurement of g-levels.

Root-free shoots of the Day Lily and *Haplopappus* plants will be used in this mission also. The criteria for comparison include the number of roots formed and their length, weight and quality based on a subjective appraisal as well as quantitative morphological and histological examination. Cells from root tips will be analyzed after the flight for their karyotype and the configuration of their chromosomes. *Haplopappus* is a unique flowering plant that has four chromosomes in its diploid cells ($2n = 4$). Day Lily monocotyledon is also of interest because of the specific features of its karyotype ($2n = 22$).

Day Lily and *Haplopappus gracilis* will be flown in the plant growth unit located in Discovery's middeck. The PGU can hold up to six plant growth chambers. One PGC will be replaced by the atmosphere exchange system, which will filter cabin air before pumping it through the remaining PCGs. The experiment is to collect and treat roots after the flight before the first cell division cycle is completed.



Plant Growth Unit With Atmosphere Exchange System

INTELSAT SOLAR ARRAY COUPON

The Intelsat Solar Array Coupon consists of solar array material samples bonded to two witness plates and mounted on Discovery's remote manipulator system. The purpose is to obtain data on the interaction of atomic oxygen with the solar-array silver interconnects and other materials of the Intelsat spacecraft, now stranded in low Earth orbit. The witness plates will be exposed in the velocity vector direction for a minimum of 23 hours.

SOLID-SURFACE COMBUSTION EXPERIMENT

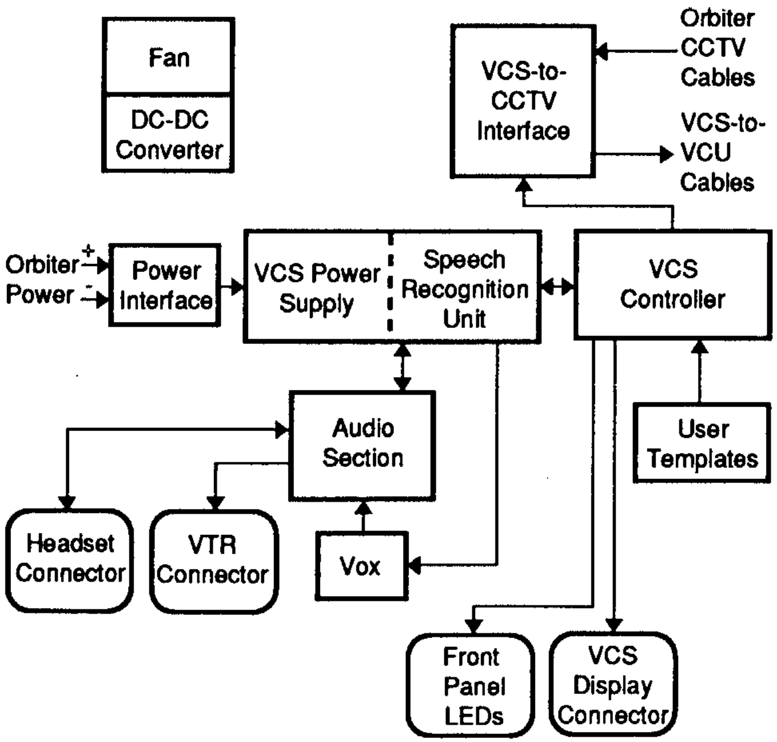
This experiment consists of an ashless filter paper sample internally mounted in a pressurized chamber. While the sample is burned, documentary photography of the front and side of the sample is taken. In addition, chamber temperature, chamber pressure and middeck air temperature are measured. The experiment must be conducted during a period of low orbiter accelerations. The purpose of the experiment is to improve fire safety aspects of space travel.

VOICE COMMAND SYSTEM

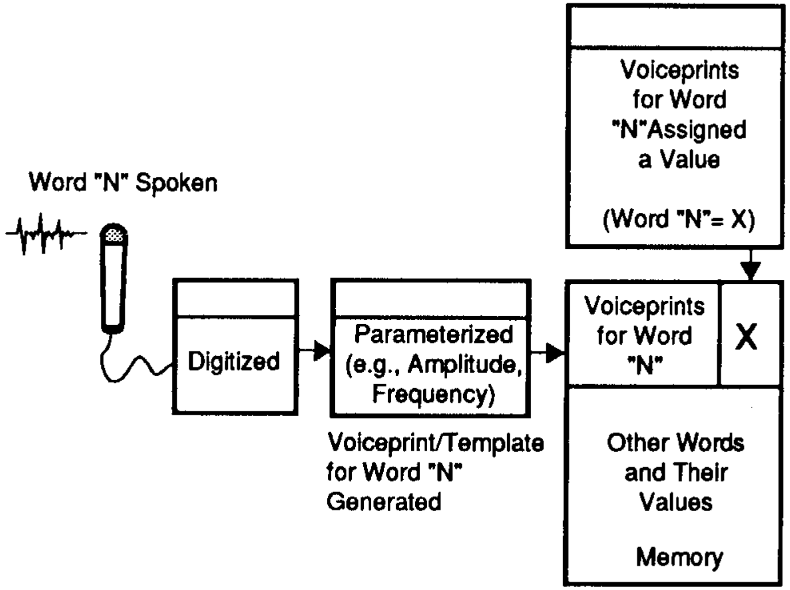
The Voice Command System is a voice recognition device to allow voice control of Discovery's closed-circuit television system during the mission. When powered off, the VCS does not affect the normal operation of the CCTV system. The flight crew members were required to create a personalized voiceprint template prior to the flight. In flight, the VCS test will be performed three times at approximately the same time of day.

The purpose of the VCS in this mission is to collect baseline data on the effects the space environment has on the speech process and voice recognition, to observe the accuracy of voice recognition in microgravity with the use of ground-based voice templates, to assess the potential time-saving and/or convenience of using voice recognition, to evaluate human performance in using voice recognition to control a spacecraft system in an actual space environment/mission operation, and to explore the potential use of voice recognition for shuttle applications and future space programs.

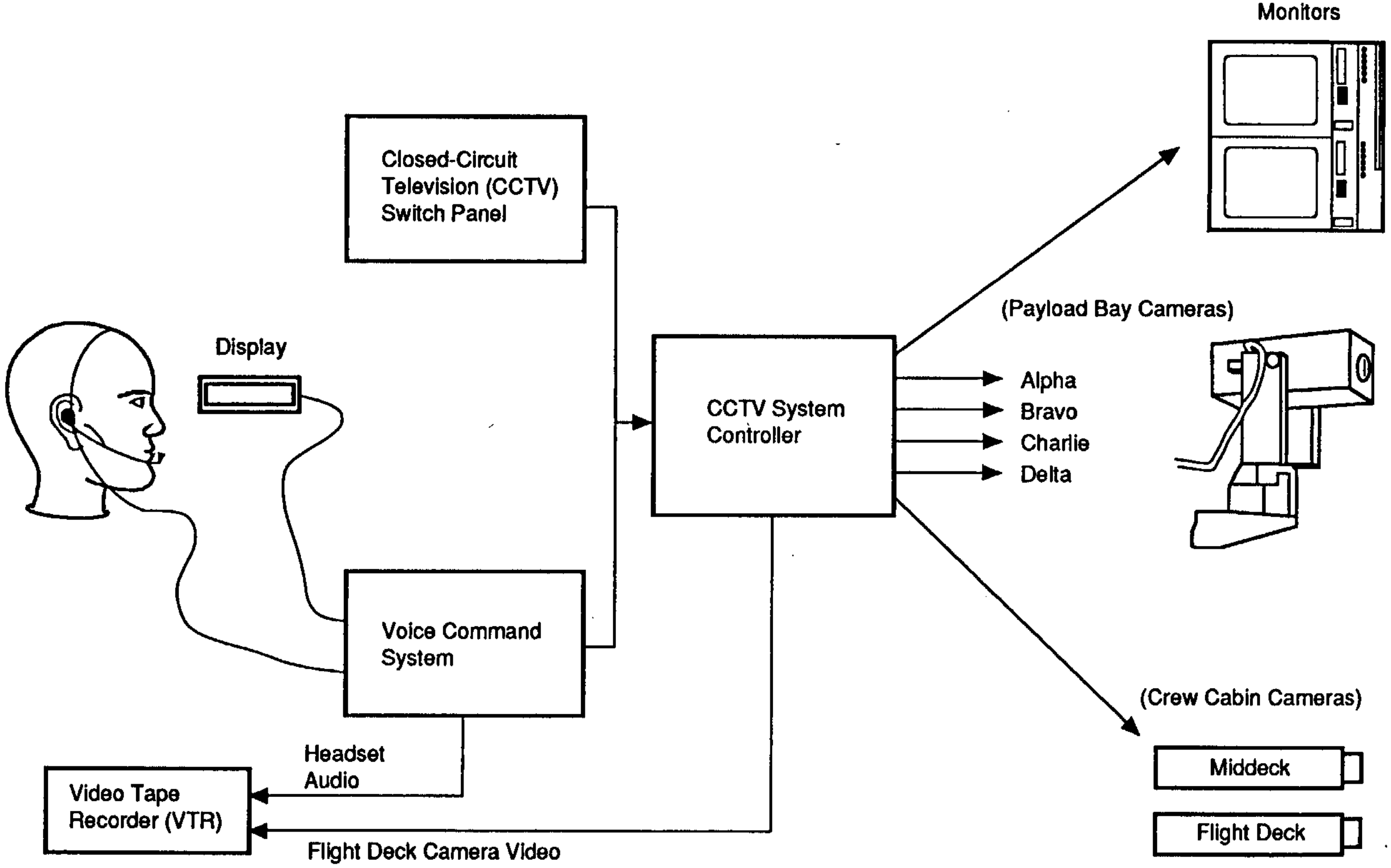
Features of the VCS include parallel operations with the existing CCTV switch panel, non-conflicting multiaction camera commanding, VCS-unique fine-tuning camera-action commands, stowage of payload bay cameras, on-orbit voiceprint/template enrollment (volatile memory), manual or voice control activation/ deactivation of listening (once user is logged in), system feedback (audio and visual), selectable astronaut headset mode (push to talk, push to disable and hot microphone), four-node command word structure, 35 command words (23 CCTV switch-panel-related commands) and nonvolatile memory templates for six users.



Voice Command System Block Diagram

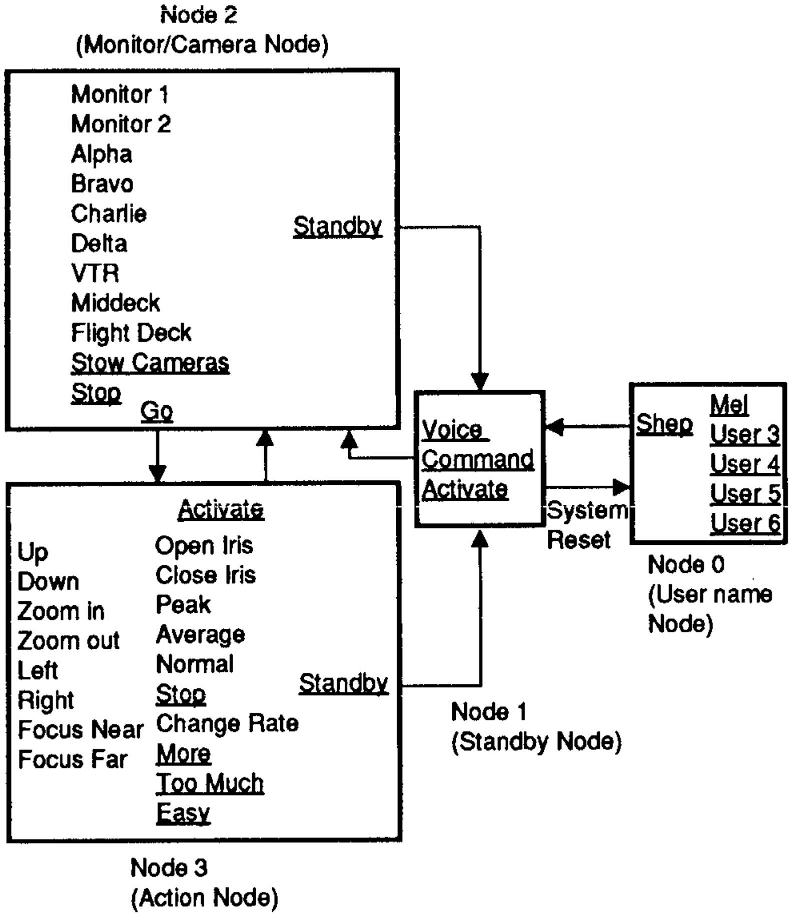


Voice Command System Voiceprint/Template Generation



Voice Command System Overview

In orbit, the VCS items will be unstowed from a middeck locker. The flight deck camera and video tape recorder will be set up. The VCS will be configured for exercise. The VCS is powered up with the VTR in the record mode, and the flight deck camera is configured for recording onto the VTR. One of six tasks will be performed: camera alignment, payload bay views, SSBUV inspection, Earth-looking views, mimic deployment views of Ulysses or payload bay bulkhead latch inspection.



Voice Command System Node Structure

AIR FORCE MAUI OPTICAL SITE

The Air Force Maui optical site tests allow ground-based electro-optical sensors located on Mt. Haleakala, Maui, Hawaii, to collect imagery and signature data of Discovery during cooperative overflights. This experiment is a continuation of tests made on the STS-29, -30, -34, -32 and -31 missions. The scientific observations made of Discovery while it performs reaction control system thruster firings and water dumps or activates payload bay lights are used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models. The AMOS tests involve no payload-unique flight hardware and require only that Discovery perform certain operations in predefined attitudes and be in predefined lighting conditions.

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

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

RADIATION MONITORING EQUIPMENT

RME-III consists of a hand-held instrument with replaceable memory modules. The equipment contains a liquid crystal display for real-time data presentation and a keyboard for controlling its functions. The experiment is self-contained with two zinc-air and five AA batteries in each memory module and a zinc-air battery in the main module. The equipment measures the crew's exposure to ionizing radiation in Discovery's crew compartment.

DEVELOPMENT TEST OBJECTIVES

WATER-DUMP CLOUD FORMATION

This development test is designed to define water-dump plume formation and angular extent with respect to orbiter coordinate system and trajectory. The intent is to dump the water in a retrograde direction. Ground observation sites are determined on a flight-by-flight basis. Preferred sites are Houston, Texas, Orlando, Fla., or Hilo, Hawaii. The ground site must be in darkness at the time of the observation.

HEAD-UP DISPLAY BACKUP TO CREWMAN OPTICAL ALIGNMENT SIGHT

This test will verify the suitability of the head-up display as a star-sighting device for inertial measurement unit alignments.

PAYLOAD GENERAL SPACECRAFT COMPUTER ELECTROLUMINESCENT DISPLAY EVALUATION

The purpose of this test is to evaluate a new payload general support computer configuration with an electroluminescent display that is brighter and has a wider viewing angle than those previously flown.

TRACKING WITH HIGH PITCH RATES

This operation will test the ability of the orbiter to maneuver efficiently at high pitch rates with tight attitude and rate deadbands. The data from this test will support planning for the star lab mission.

SPACE STATION CURSOR CONTROL DEVICE EVALUATION

This test will evaluate human performance in space with cursor control devices similar to those being considered for the space station.

INTRAOCULAR PRESSURE

Pressure measurements 20 to 25 percent above normal or preflight levels were observed in bed-rest studies during zero-g on the KC-135 and on the German D-1 shuttle mission. The possible deleterious effects of sustained deviations in intraocular pressure are difficult to predict, since no statistically valid in-flight data exist. Even though a few days or weeks of elevated intraocular pressure would be harmless, months or years of sustained pressure, caused by microgravity, could cause ocular disturbances. Significant baseline data are needed to define normal intraocular pressure ranges in microgravity and to determine the magnitude of pressure rises to be expected in crew members. A tono pen is used to measure intraocular pressure.

RETINAL PHOTOGRAPHY

This detailed supplementary objective is to collect retinal photographs in flight to determine if microgravity-induced cephalid international pressure fluid shifts elevate intracranial pressure. Evidence of increased ICP and the development of SAS will be correlated. Two crew members will collect retinal photographs during the scheduled presleep periods.

VARIABILITY OF BLOOD PRESSURE AND HEART RATE DURING SPACE FLIGHT

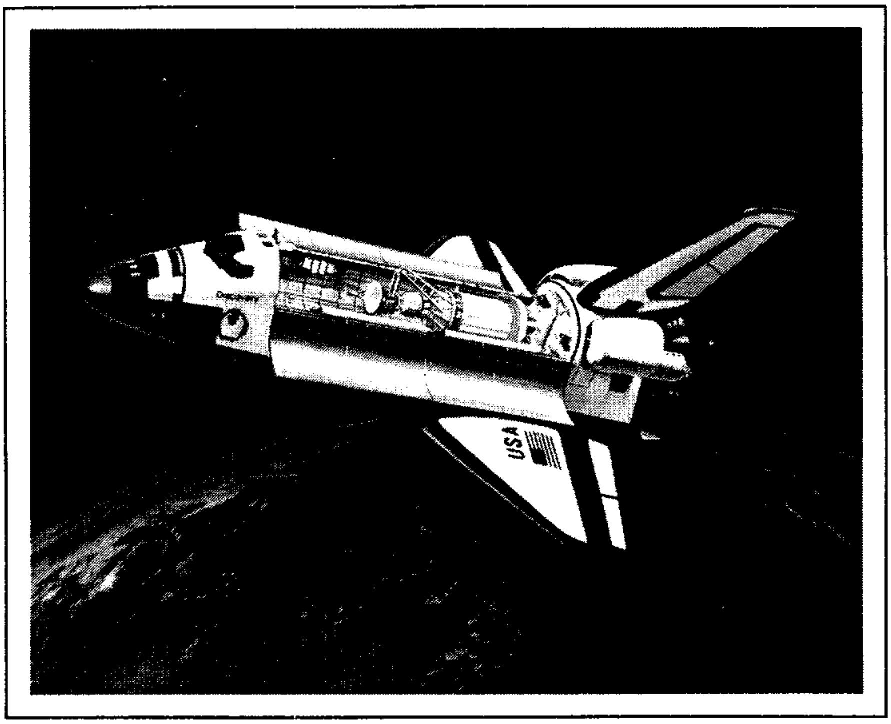
This objective is to determine whether arterial blood pressure and heart rate exhibit less variability in a microgravity environment than on Earth. The data will be used to investigate whether reduced blood pressure variability in flight, if any, is correlated with the extent of baroreflex attentuation that has been measured after space flight. Integrity of the baroreceptor function is required for the appropriate blood pressure responses to the orthostatic stresses imposed by entry, landing and egress. The crew member will wear blood pressure and electrocardiograph equipment for two flight days in orbit.

ORTHOSTATIC FUNCTION DURING ENTRY, LANDING AND EGRESS

This objective is to measure the changes in orthostatic function of crew members during the actual stresses of orbiter entry, landing and egress. Crew members will don equipment before donning the LES during deorbit preparation. Equipment consists of a blood pressure monitor, accelerometers, an impedance cardiograph and transcranial Doppler hardware. The crew member wears the equipment and records verbal comments through entry.

VISUAL VESTIBULAR INTEGRATION AS A FUNCTION OF ADAPTION

This objective is to investigate visual vestibular and perceptual adaptive responses as a function of mission duration. The operational impact of these responses on the crew members' ability to conduct entry, landing and egress procedures will also be investigated. For STS-41, four sessions will be scheduled in which the crew member performs slow head movements while verbally recording self and surrounding motion sensations. The sessions are scheduled early and late in the flight, during entry and immediately after landing.



STS-41

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

October 1990

Rockwell International
Space Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the 11th flight of Discovery and the 36th for the space transportation system.

The flight crew for the STS-41 mission consists of commander Richard N. Richards, pilot Robert D. Cabana and mission specialists Bruce E. Melnick, William M. Sheperd and Thomas D. Akers.

The primary objective of this four-day mission is to deploy the Ulysses spacecraft, mated with an inertial upper stage and payload assist module, from Discovery's payload bay. The IUS and PAM will place Ulysses in polar regions around the sun.

The deployment of the Ulysses spacecraft with its IUS and PAM from Discovery's payload bay is scheduled to occur nominally on the fifth orbit at a mission elapsed time of six hours and one minute. Backup deployment opportunities are available on orbits 6, 7, and 15, with contingency capabilities on orbits 18 and 19.

The first stage of the IUS solid rocket motor will nominally ignite just before orbit 6, which begins approximately one hour after the IUS, PAM and Ulysses are deployed. Ignition of the IUS second stage occurs approximately four minutes after the first-stage ignition. The PAM solid rocket motor ignition occurs at approximately seven hours and 14 minutes mission elapsed time, followed by PAM separation from Ulysses at approximately seven hours and 24 minutes mission elapsed time.

Ulysses will then begin on a flight path first to Jupiter, which it will encounter in February 1992, 16 months after launch. As Ulysses flies past Jupiter at approximately 30 degrees Jovian latitude, the gravity of Jupiter will bend the spacecraft's trajectory so that Ulysses dives downward and away from ecliptic plane.

Ulysses will reach 70 degrees south solar latitude in May 1994, beginning its transit of the sun's south polar regions. Ulysses will spend about four months south of that latitude at a distance of about 200 million miles from the sun. In February 1995, Ulysses will cross the sun's equator and then make a four-month pass of the sun's northern polar region beginning in May 1995. The end of the Ulysses mission is scheduled for September 30, 1995.

Ulysses will be the first spacecraft to achieve a trajectory essentially perpendicular to the sun's equatorial plane. Throughout its five-year mission, Ulysses will study three general areas of solar physics: the sun itself, magnetic fields and streams of particles generated by the sun, and interstellar space above and below the sun.

For STS-41, Discovery will carry nine other payloads, referred to as secondary payloads. Two are located in Discovery's payload bay, and the remaining seven are in the crew compartment.

The Shuttle Solar Backscatter Ultraviolet instrument, carried in Discovery's payload bay, was developed by NASA to calibrate similar ozone-measuring instruments on the National Oceanic and Atmospheric Administration's TIROS satellites (NOAA-9 and -11).

The Intelsat Solar Array Coupon consists of solar array materials bonded to two witness plates on Discovery's remote manipulator system. The witness plates will obtain data on the interaction of atomic oxygen with the materials of the Intelsat spacecraft, now stranded in low Earth orbit. The witness plates will be exposed in the velocity vector direction for a minimum of 23 hours.

The Investigations into Polymer Membrane Processing will flash-evaporate mixed solvent systems in the absence of convection to control the porosity of the polymer membrane. With at least 24 hours remaining before entry, the flight crew will activate the experiment, which is located in Discovery's middeck.

The Physiological Systems Experiment is designed to determine the effects of proprietary protein molecules on animal physiological systems in microgravity. Sixteen rats, contained in two animal exclosure modules in Discovery's middeck, will be the subjects of the experiment.

The Chromosome and Plant Cell Division in Space Experiment (CHROMEX) is designed to determine whether the normal rate, frequency and pattern of cell division in root tips can be sustained upon exposure to microgravity. In addition, the fidelity of chromosome partitioning is investigated after cell exposure to microgravity. Day Lily and *Haplopappis gracilis* roots will be used. CHROMEX is also located in Discovery's middeck.

The Solid-Surface Combustion Experiment consists of an ashless filter paper sample internally mounted in a pressurized container. While the sample is burned, documentary photographs of the front and side are taken. In addition, chamber temperature, chamber pressure and middeck air temperature are measured. The experiment, which will be run during a period of low orbiter acceleration, is located in Discovery's middeck.

The Voice Command System is a voice recognition device designed to allow voice control of Discovery's closed-circuit television system.

Radiation Monitoring Equipment III consists of a hand-held instrument with replaceable memory modules. The equipment takes measurements of the radiation environment in the crew compartment at a specified sample rate.

The Air Force Maui Optical Site tests allow ground-based electro-optical sensors located on Mt. Haleakala on Maui, Hawaii, to collect imagery and signature data for Discovery during cooperative overflights while Discovery is performing reaction control system thruster firings, water dumps or payload light activation. The data are used to support the calibration of AMOS sensors and the validation of spacecraft contamination models.

A series of Discovery's forward reaction control system flight test maneuvers will be initiated during entry to obtain flight data showing the aerodynamic effects when the forward RCS side (yaw) firing thrusters are used to eliminate the forward RCS propellants. The flight data will be used to verify and validate existing wind tunnel data and verify the safety of performing a forward RCS dump during a return-to-launch-site or transatlantic abort. During entry, there will be three separate dumps by the yaw thrusters. The first dump will begin at Mach 13 to Mach 10, the second dump will begin at Mach 6 to 4.5, and the third dump will begin at Mach 4 to Mach 2.6.

MISSION STATISTICS

Launch: The launch window duration is two hours, 30 minutes

10/6/90 7:35 a.m. EDT
10/6/90 6:35 a.m. CDT
10/6/90 4:35 a.m. PDT

Mission Duration: 96 hours (4 days), two hours, seven minutes

Landing: Nominal end of mission on orbit 66

10/10/90 9:42 a.m. EDT
10/10/90 8:42 a.m. CDT
10/10/90 6:42 a.m. PDT

Inclination: 28.5 degrees

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

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

Altitude: 160 by 160 nautical miles (184 by 184 statute miles), 177 by 160 nautical miles (203 by 184 statute miles), 160 by 156 nautical miles (184 by 179 statute miles), and 157 by 156 nautical miles (180 by 179 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,523,894 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 293,019 pounds

Payload Weight Up: Approximately 48,812 pounds

Payload Weight Down: Approximately 10,279 pounds

Orbiter Weight at Landing: Approximately 195,890 pounds

Payloads: Ulysses with payload assist module and inertial upper stage, Shuttle Solar Backscatter Ultraviolet, Intelsat Solar Array Coupon, Solid-Surface Combustion Experiment, Investigations Into Polymer Membrane Processing, Chromosome and Plant Cell Division in Space, Physiological Systems Experiment, Voice Command System, Radiation Monitoring Equipment III and Air Force Maui Optical Site

Flight Crew Members:
Commander: Richard N. Richards, second flight
Pilot: Robert D. Cabana, first flight
Mission Specialist 1: Bruce E. Melnick, first flight
Mission Specialist 2: William M. Sheperd, second flight
Mission Specialist 3: Thomas D. Akers, second flight

Ascent Seating:
Flight deck front left seat, commander Richard Richards
Flight deck front right seat, pilot Robert Cabana
Flight deck aft center seat, mission specialist William Sheperd
Flight deck aft right seat, mission specialist Bruce Melnick
Middeck, mission specialist Thomas Akers

Entry Seating:
Flight deck aft center seat, mission specialist Thomas Akers
Middeck, mission specialist Bruce Melnick

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut 1 would be Bruce Melnick; extravehicular astronaut 2 is Thomas Akers. William Sheperd will be the intravehicular astronaut.

Entry Angle of Attack: 40 degrees

Entry: Automatic mode until subsonic, then control stick steering

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

Notes:

- The remote manipulator is installed in Discovery's payload bay for this mission. The galley is installed in the middeck.

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

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

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

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

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

DEVELOPMENT TEST OBJECTIVES

- Ascent structural capability evaluation
- Ascent compartment venting evaluation
- External tank thermal protection system performance
- Shuttle/payload low-frequency environment
- Water-dump cloud formation
- Head-up display backup to crew optical alignment sight
- Payload and general support computer electroluminescent display evaluation
- Tracking with high pitch rates
- Space station cursor control device evaluation
- Forward RCS flight test
- Entry structural evaluation
- Descent compartment venting evaluation
- Crosswind landing performance
- Carbon brake system test

DETAILED SUPPLEMENTARY OBJECTIVES

- Changes in baroreceptor reflex function
- Blood pressure variability during space flight
- Orthostatic function during entry, landing and egress
- Visual-vestibular integration as a function of adaptation
- Postural equilibrium control during landing/egress
- Intraocular pressure
- Retinal photography
- Documentary television
- Documentary motion picture photography
- Documentary still photography

PRELAUNCH COUNTDOWN

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

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

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

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

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

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

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

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

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

MISSION TIMELINE

DAY ZERO

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:00:06.8	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:09	Positive roll maneuver (right-clockwise) is started. Pitch profile is heads down (astronauts), wings level.
0/00:00:15	Roll maneuver ends.
0/00:00:27	All three SSMEs throttle down from 104 to 67 percent for maximum aerodynamic load (max q).
0/00:00:52	Max q occurs.
0/00:00:58	All three SSMEs throttle to 104 percent.
0/00:02:04	SRBs separate.
	When chamber pressure (P_C) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse in another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:03:58	Negative return. The vehicle is no longer capable of return-to-launch-site abort at Kennedy Space Center runway.
0/00:07:04	Single engine to main engine cutoff.
0/00:07:33	All three SSMEs throttle down from 104 percent—vehicle acceleration capability no greater than 3g's.
0/00:08:32	All three SSMEs throttle down to 65 percent for MECO.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:08:30	MECO occurs at approximate velocity 25,871 feet per second, 156 by 35 nautical miles (179 by 40 statute miles).
0/00:08:48	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	ET liquid oxygen valve is opened at separation to induce ET tumble for Pacific Ocean impact area footprint.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	5-fps RCS maneuver, 11 seconds in duration, facilitates the MPS dump.
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs.
	— Remaining residual propellants are vented to space vacuum, inerting the MPS.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	— Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads.
	— MPS vacuum inerting terminates.
0/00:42	OMS-2 thrusting maneuver is performed, approximately 2 minutes in duration, at 221 fps, 160 by 160 nautical miles (184 by 184 statute miles).
0/00:52	Commander closes circuit breakers for signal conditioner humidity separator and IMU fan on Panel L4.
0/00:54	Mission specialist (MS) seat egress occurs.
0/00:55	Commander and pilot configure general-purpose computers (GPCs) for OPS-2.
0/00:57	MS configures middeck.
0/01:00	MS configures aft flight station.
0/01:00	Payload and general-support computer (PGSC) is unstowed, set up, and activated.
0/01:07	Pilot verifies payload (PL) bus, PL PRIMARY MAIN C ON, talkback ON, CAB, MNA, MNB and AUX ON.
0/01:10	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive X velocity vector attitude.
0/01:13	Orbit 2 begins.
0/01:17	Commander activates radiators.
0/01:19	MS configures for payload bay door operations.
0/01:28	Pilot opens payload bay doors in AUTO mode.
0/01:35	Commander turns star tracker power 2, to ON on Panel 06.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:36	Mission Control Center (MCC) and flight crew are given command “go for orbit operations.”
0/01:37	Commander and pilot egress seats.
0/01:38	Commander and pilot configure clothing.
0/01:39	MS configures clothing.
0/01:50	Pilot purge fuel cells in AUTO mode.
0/01:51	MS activates teleprinter.
0/01:52	Commander configure post payload bay door radiators.
0/01:55	MS removes and stows seat.
0/01:56	Commander performs star tracker (ST) self test and opens door.
0/01:57	MS configures middeck.
0/01:58	Pilot closes MNB supply H_2O dump isolation circuit breaker on Panel ML86B and A on Panel R12L; opens supply H_2O dump isolation valve, tank C inlet and outlet.
0/02:00	MS performs IUS and PAM checkout.
0/02:00	Pilot activates APU steam vent heater, boiler controller/heater, 3, to A and power, 3, to ON, on Panel R2.
0/02:02	MS reconfigures CHROMEX ascent cable.
0/02:03	MS performs radioisotope thermoelectric generator (RTG) checks.
0/02:09	MS engages IUS activator.
0/02:10	Commander configures vernier reaction control system (RCS).
0/02:12	Commander and pilot configure controls for on orbit.
0/02:19	MS configures remote manipulator system at aft flight station.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/02:21	Pilot enable hydraulic thermal conditioning.
0/02:24	MS resets aft caution/warning (C/W).
0/02:26	MS unstows and installs treadmill in middeck.
0/02:27	Pilot switches APU coolant system, APU fuel pump/valve cool A to OFF and B to AUTO on Panel R2.
0/02:29	Pilot plots fuel cell performance.
	EZ ACTIVITIES
	— Launch entry suit (LES) cleaning and drying, 25 minutes.
	— Pressure control system (PCS), environmental control life support system (ECLSS) to system 1, 5 minutes (2 crewmen).
	— Lamp and fire suppression test, 10 minutes.
	— Food preparation, 45 minutes.
0/02:30	All unstow cabin equipment.
0/02:30	Systems management (SM) cockpit initiation occurs.
0/02:30	Photo/TV are activated for satellite deployment.
0/02:35	Ku-band antenna is deployed.
0/02:40	IUS predeploy checkout is performed, tracking data relay satellite (TDRS) west (W).
0/02:43	Orbit 3 begins.
0/02:46	Ku-band is activated.
0/03:00	Photo/TV cameras are assembled.
0/03:00	IUS check and predeploy checks are performed.
0/03:05	PGSC liquid crystal display (LCD) temperature test, development test objective (DTO) is performed.
0/03:12	Payload interleaver (PI) is checked.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:20	Power reactant storage distribution system (PRSD) cryo oxygen (O_2) tank heater sensor is checked.
0/03:21	Aft controller checkout is performed.
0/03:23	CHROMEX experiment status is reported.
0/03:31	State vector (SV) is transferred to TDRS east (E).
0/03:41	APU steam vent heater deactivation, boiler power, 3, to OFF.
0/03:44	Attitude match update (AMU)/IUS sequence is performed.
0/03:46	Photo/TV are set up for satellite deployment.
0/03:46	Vehicle is maneuvered to AMU 1 attitude.
0/03:50	AMU data take 1 is performed.
0/03:53	Physiological systems experiment (PSE) is performed.
0/03:53	Vehicle is maneuvered to AMU 2 attitude.
0/04:01	APU cool off occurs, APU fuel pump/valve cool B to OFF.
0/04:03	AMU data take 2 is performed.
0/04:06	Payload assist module (PAM)-S checkout and pre-deployment check are performed.
0/04:06	Vehicle is maneuvered to AMU 3/IMU align attitude.
0/04:13	Orbit 4 begins.
0/04:15	Crew members eat meal.
0/04:16	AMU data take 3 occurs.
0/04:21	IMU alignment occurs.
0/04:26	AMU data take 4 is performed.
0/04:29	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/05:00	APU heater gas generator/fuel pump, 3 is turned to AUTO, Panel A12.
0/05:05	Vehicle is maneuvered to deployment attitude.
0/05:11	IUS/PI lock occurs.
0/05:16	Photo/TV are activated for satellite deployment.
0/05:21	SV transfers to TDRE; predeploy checks are performed.
0/05:21	Crew elevates Ulysses tilt table to 29 degrees; transfers to internal power.
0/05:31	Ulysses deployment countdown begins.
0/05:41	Ulysses umbilicals are released; tilt table to 58 degrees.
0/05:43	Orbit 5 begins.
0/05:49	RTG purge starts.
0/05:52	RTG purge stops.
0/06:01	Ulysses is deployed with PAM-S and IUS from Discovery.
0/06:01	Vehicle is maneuvered to separation from Ulysses.
0/06:07	Crew lowers tilt table to minus 6 degrees.
0/06:12	IUS RCS are enabled for Ulysses. RTG activation is followed by maneuver of Ulysses to external attitude and start of thermal roll.
0/06:16	OMS separation maneuver occurs, 31 fps, 16 seconds in duration, 177 by 160 nautical miles (203 by 184 statute miles).
0/06:17	Vehicle is maneuvered to Ulysses viewing attitude.
0/06:40	Vehicle is maneuvered to window protection attitude.
0/06:51	Post IUS deployment closeout is performed.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/07:00	Radiation monitoring equipment (RME)-III is activated and checked out.
0/07:07	IUS solid rocket motor (SRM) Stage 1 ignition occurs and is followed by maneuver to SRM Stage 2 lower attitude after SRM burnout, IUS Stage 2 batteries are ON. First stage separation and RCS spacing burn occur.
0/07:11	IUS SRM Stage 2 ignites.
0/07:13	Discovery digital autopilot (DAP) A is changed to A1, configured to DAP A/AUTO/VERNIER.
0/07:14	Ulysses is maneuvered to PAM burn attitude, PAM heaters turned to OFF, spacecraft prearm/arm and RTG cooling line separate.
0/07:14	Motor support separates and PAM SRM ignites.
0/07:14	Orbit 6 begins.
0/07:16	Video tape recorder (VTR) is set up for Ulysses deployment scenes.
0/07:17	Ulysses nutation control system (NCS) is enabled.
0/07:20	Discovery is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
0/07:20	Discovery's pulse code modulation master unit (PCMMU) format is loaded.
0/07:24	PAM despin occurs.
0/07:24	PAM/Ulysses separate.
0/07:30	VTR playback of Ulysses deployment occurs at TDRS-W at 0/07:30 to 0/07:45.
0/07:35	PGCS chassis temperature test is performed.
0/07:51	Photo/TV are set up for shuttle solar backscatter ultraviolet (SSBUV) experiment.
0/07:51	APC setup is unstowed for SSBUV.
0/08:00	Private medical conference occurs.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/08:00	Crew begins presleep activity.
0/08:00	Photo/TV are set up for SSBUV scenes.
0/08:25	Vehicle is maneuvered to IMU align attitude.
0/08:30	Crew does not perform supply water dump.
0/08:32	Crew checks humidity separator for water accumulation.
0/08:41	IMU is aligned using ST.
0/08:44	Orbit 7 begins.
0/08:45	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.
0/08:51	SSBUV system is verified.
0/09:01	SSBUV outgas initiation occurs.
0/10:15	Orbit 8 begins.
0/10:05	Retinal photo medical detailed supplementary objective (DSO) occurs.
0/10:45	Intraocular pressure (IOP) medical DSO occurs.
0/11:00	Crew begins 8-hour sleep period.
0/11:46	Orbit 9 begins.
0/13:16	Orbit 10 begins.
0/14:47	Orbit 11 begins.
0/16:17	Orbit 12 begins.
0/17:48	Orbit 13 begins.
0/19:00	Crew ends 8-hour sleep period.
0/19:00	Crew perform postsleep activity.
	EZ ACTIVITIES
	— Exercise for 1 hour (all).
	— Food preparation, 30 minutes.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/19:19	Orbit 14 begins.
0/20:20	COAS power is turned to OFF, Panel 019; COAS is mounted aft.
0/20:20	SSBUV outgas terminates.
0/20:45	IMU is aligned using ST.
0/20:49	Orbit 15 begins.
0/20:50	COAS calibration occurs.
0/20:52	Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude.
0/21:10	Crew changes DAP B to B1.
0/21:15	Photo/TV are set up for middeck scenes.
0/21:15	Crew changes COAS power to OFF, Panel 019, stows COAS.
0/21:45	Photo/TV are activated for middeck scenes.
0/21:45	Variability of blood pressure and heart rate during space flight (BP) medical DSO is measured.
0/22:05	Cursor control device is tested.
0/22:05	PSE experiment is performed.
0/22:20	Orbit 16 begins.
0/22:56	OMS on-orbit thrusting maneuver occurs, one engine, 35 fps, 160 by 156 nautical miles (184 by 179 statute miles).
0/23:05	Photo/TV are set up for voice command system (VCS).
0/23:05	VCS is unstowed.
0/23:35	Photo/TV are activated for VCS.
0/23:38	On-orbit RCS thrusting period occurs, 6.6 fps, 157 by 156 nautical miles (180 by 179 statute miles).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/23:40	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
0/23:50	Orbit 17 begins.
0/23:55	VCS configuration occurs.

DAY ONE

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:05	Cursor control device is used.
1/00:15	VCS Exercise 1, payload operations, occurs.
1/01:05	VCS is deactivated.
1/01:15	Photo/TV are set up for middeck scenes.
1/01:20	Orbit 18 begins.
1/01:32	Air Force Maui optical site (AMOS) RCS test occurs.
1/01:40	Photo/TV are activated for middeck scenes.
1/01:45	Investigations into polymer membrane processing (IPMP) experiment is activated, Unit A and B.
1/01:50	IPMP is deactivated, Unit A and B.
1/01:50	Crew turns port RMS heater, 2 to AUTO, Panel A8L.
1/01:50	Crew members eat meal.
1/02:51	Orbit 19 begins.
1/03:00	Gravity gradient free drift occurs.
1/03:00	CHROMEX status is checked.
1/03:00	Photo/TV are activated for middeck scenes.
1/03:20	RMS is powered up.
1/03:25	Solid surface combustion experiment (SSCE) is activated.
1/03:35	RMS is checked out.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/03:45	SSBUV is activated.
1/04:20	Intelsat solar array coupon is checked.
1/04:21	Orbit 20 begins.
1/04:45	SSBUV calibration is initiated.
1/05:45	SSBUV calibration is terminated.
1/05:51	Orbit 21 begins.
1/05:55	Vehicle is maneuvered to negative Z solar inertial attitude.
1/06:15	SSBUV solar phase is initiated.
1/06:25	Schedule inflight maintenance occurs, filter cleaning.
1/06:55	COAS power is turned to OFF, Panel 01, crew mounts COAS forward.
1/07:00	Begin presleep activity.
1/07:00	SSBUV solar phase terminated.
1/07:05	Vehicle is maneuvered to IMU alignment/COAS calibration attitude.
1/07:15	IMU is aligned using ST.
1/07:15	COAS calibration occurs.
1/07:19	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
1/07:21	Orbit 22 begins.
1/07:25	SSBUV earth phase is initiated.
1/07:45	COAS power is turned to OFF, Panel 01, COAS is stowed.
1/07:45	Visual/vestibular medical DSO is performed.
1/08:05	Private medical conference occurs.
1/08:35	IPMP is deactivated.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/08:51	Orbit 23 begins.
1/09:00	Retinal photo medical DSO is performed.
1/09:50	IOP medical DSO is performed.
1/10:00	Crew begins 8-hour sleep period.
1/10:21	Orbit 24 begins.
1/11:51	Orbit 25 begins.
1/13:22	Orbit 26 begins.
1/14:52	Orbit 27 begins.
1/16:22	Orbit 28 begins.
1/17:52	Orbit 29 begins.
1/18:00	Crew ends 8-hour sleep period.
1/18:00	Crew begins postsleep activity.
	EZ ACTIVITIES
	— Exercise, 1 hour (all).
	— Food preparation, 30 minutes.
1/18:55	COAS power is turned OFF, crew mounts COAS forward Panel 01.
1/19:05	SSBUV earth phase is terminated.
1/19:07	Vehicle is maneuvered to IMU alignment/COAS calibration attitude.
1/19:15	IMU is aligned using ST.
1/19:20	COAS calibration occurs.
1/19:23	Orbit 30 begins.
1/19:30	HUD backup to COAS is performed.
1/19:40	Crew performs manual fuel cell purge.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/19:43	Vehicle is maneuvered to positive X solar inertial attitude.
1/20:00	HUD backup to COAS is performed.
1/20:00	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.
1/20:45	COAS power is turned to OFF, Panel 01, COAS is stowed.
1/20:45	RCS regulator is reconfigured; helium pressure A, 3 to OPEN, B, 3 to OPEN, then GPC, A, 3 to CLOSE.
1/20:45	Vehicle is maneuvered to negative Z solar inertial attitude.
1/20:52	Orbit 31 begins.
1/21:00	Cabin temperature controller is reconfigured, Panel MD44F, cabin temp controller actuator linkage to secondary actuator, Panel L1 cabin temp controller to 2.
1/21:05	PSE experiment is activated.
1/21:13	SSBUV solar view occurs.
1/21:20	ECLSS redundant component is checked out.
1/21:30	Electrical power system (EPS) heater is reconfigured to B.
1/21:45	Humidity separator is reconfigured, humidity SEP B to OFF, A to ON, Panel L1.
1/21:55	PCS is configured to 1.
1/22:00	SSBUV solar view is terminated.
1/22:05	Cursor control device is used.
1/22:23	Orbit 32 begins.
1/22:30	Vehicle is maneuvered and set up for high pitch rate.
1/22:30	High pitch rate occurs.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/23:05	Crew changes DAP A, B to A1, B1.
1/23:10	Photo/TV are set up for VCS.
1/23:15	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
1/23:30	Waste water dump occurs.
1/23:40	Photo/TV are activated for VCS.
1/23:53	Orbit 33 begins.
1/23:55	Humidity separator is checked for water accumulation.

DAY TWO

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/00:00	VCS is configured.
2/00:30	VCS exercise 2 occurs.
2/00:35	Waste water dump occurs.
2/00:55	COAS is turned to OFF, crew mounts COAS forward, Panel 01.
2/01:00	Vehicle is maneuvered to IMU alignment/COAS calibration attitude.
2/01:10	VCS is deactivated.
2/01:15	IMU is aligned using ST.
2/01:15	COAS calibration occurs.
2/01:20	SSBUV calibration is initiated.
2/01:23	Orbit 34 begins.
2/01:25	HUD backup to COAS occurs.
2/01:35	Photo/TV are set up for crew conference.
2/01:44	Vehicle is maneuvered to negative Z solar inertial attitude.
2/02:00	Crew members eat meal.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/02:20	SSBUV calibration is terminated.
2/02:53	Orbit 35 begins.
2/03:05	PGSC electroluminescent display evaluation occurs.
2/03:05	Photo/TV are activated for crew conference.
2/03:05	CHROMEX status is checked.
2/03:14	SSBUV solar view is initiated.
2/03:20	Crew conference audio/TV check is performed, TDRS-E from 2/03:20 to 2/03:35.
2/04:05	SSBUV solar view is terminated.
2/04:05	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.
2/04:23	Orbit 36 begins.
2/04:30	SSBUV earth view is initiated.
2/05:00	Crew conference occurs.
2/05:00	Photo/TV are activated for crew conference; TDRS-E from 2/05:00 to 2/05:15.
2/05:53	Orbit 37 begins.
2/06:00	Cursor control device is used.
2/07:00	Crew begins presleep activity.
2/07:00	COAS power is turned to OFF, COAS is mounted forward, Panel 01.
2/07:09	Vehicle is maneuvered to IMU alignment/COAS calibration attitude.
2/07:15	SSBUV outgas phase is terminated.
2/07:15	Humidity separator is reconfigured, humidity SEP A to OFF, B to ON, Panel L1.
2/07:23	Orbit 38 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/07:25	IMU Is aligned using ST.
2/07:25	COAS calibration occurs.
2/07:30	HUD backup to COAS occurs.
2/07:35	Crew changes DAP A, B to A1, B1.
2/07:39	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.
2/07:50	SSBUV outgas phase is initiated.
2/08:54	Orbit 39 begins.
2/10:00	Crew begins 8-hour sleep period.
2/10:24	Orbit 40 begins.
2/11:54	Orbit 41 begins.
2/13:24	Orbit 42 begins.
2/14:54	Orbit 43 begins.
2/16:24	Orbit 44 begins.
2/17:54	Orbit 45 begins.
2/18:00	Crew ends 8-hour sleep period.
2/18:00	Postsleep activity is performed.
2/19:25	Orbit 46 begins.
	EZ ACTIVITIES
	— Exercise, 1 hour (all).
	— Food preparation, 30 minutes.
2/20:40	SSBUV earth view is terminated.
2/20:40	COAS is turned to OFF, COAS is mounted forward Panel 01.
2/20:40	Vehicle is maneuvered to IMU alignment/COAS calibration attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/20:55	Orbit 47 begins.
2/21:00	IMU is aligned using ST.
2/21:00	COAS calibration occurs.
2/21:05	RMS is powered down.
2/21:05	PSE experiment is performed.
2/21:10	HUD backup to COAS occurs.
2/21:15	Crew changes DAP A, B TO A1, B1.
2/21:17	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
2/21:45	APU steam vent heater is activated, boiler controller/heater, 3 to B, power 3, to ON.
2/21:50	RCS hot fire test occurs.
2/22:00	COAS is turned to OFF, COAS is stowed, Panel 01.
2/22:00	Flight control system (FCS) is checked out.
2/22:25	Orbit 48 begins.
2/22:35	SSBUV earth view is initiated.
2/23:20	BP variability medical DSO occurs.
2/23:35	Photo/TV are set up for VCS.
2/23:55	Orbit 49 begins.
DAY THREE	
3/00:05	APU cool off is performed, APU fuel pump/VLV cool A to OFF, Panel R2.
3/00:05	Photo/TV are activated for VCS.
3/00:05	VCS is configured.
3/00:15	APU heater is reconfigured.
3/00:25	VCS Exercise 3 occurs.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/01:15	Photo/TV are setup for middeck scene.
3/01:15	VCS is deactivated.
3/01:25	VCS is stowed.
3/01:25	Orbit 50 begins.
3/01:45	Crew members eat meal.
3/02:50	Cursor control device is used.
3/02:50	Photo/TV are activated for middeck scenes.
3/02:55	Orbit 51 begins.
3/03:05	CHROMEX status is checked.
3/03:25	CHROMEX gas sampling occurs.
3/03:50	Cursor control device is used.
3/04:00	Cabin configuration and stowage occur.
3/04:05	Memory module replacement, RME-III, occurs.
3/04:25	Orbit 52 begins.
3/05:45	Vehicle is maneuvered to negative Z solar inertial attitude.
3/05:50	SSBUV earth view is terminated.
3/05:56	Orbit 53 begins.
3/06:25	SSBUV solar view is initiated.
3/06:35	Photo/TV are set up for SSBUV.
3/06:55	Ku-band antenna is stowed.
3/07:00	Crew begins presleep activity.
3/07:10	COAS power is turned to OFF, COAS is mounted forward, Panel 01.
3/07:10	SSBUV solar view is terminated.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/07:10	Vehicle is maneuvered to IMU alignment/COAS calibration altitude.
3/07:20	SSBUV calibration is initiated.
3/07:26	Orbit 54 begins.
3/07:30	IMU is aligned using ST.
3/07:30	COAS calibration occurs.
3/07:35	HUD backup to COAS is performed.
3/07:45	Crew changes DAP A, B, to A1, B1.
3/07:45	COAS power is turned to OFF, COAS is stowed, Panel 01.
3/07:49	Vehicle is maneuvered to biased negative Z local vertical, positive X velocity vector attitude.
3/08:20	SSBUV calibration is terminated.
3/08:56	Orbit 55 begins.
3/09:05	Retinal photo medical DSO occurs.
3/09:10	SSBUV earth view is initiated.
3/09:50	IOP medical DSO occurs.
3/10:00	Crew begins 8-hour sleep period.
3/10:26	Orbit 56 begins.
3/11:56	Orbit 57 begins.
3/13:26	Orbit 58 begins.
3/14:56	Orbit 59 begins.
3/16:27	Orbit 60 begins.
3/17:57	Orbit 61 begins.
3/18:00	Crew ends 8-hour sleep period.
3/18:00	Crew begins postsleep activity.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	EZ ACTIVITIES
	— Air sample.
	— Fluid loading preparation, fill six drink containers with eight ounces H_2O each per person.
	— Visual vestibular medical DSO performed during entry or postlanding.
3/18:50	Photo/TV are activated for SSBUV.
3/19:05	SSBUV earth view is terminated.
3/19:15	SSBUV calibration is initiated.
3/19:15	Vehicle is maneuvered to IMU alignment altitude.
3/19:27	Orbit 62 begins.
3/19:30	IMU is aligned using ST.
3/19:35	Vehicle is maneuvered to negative X solar inertial attitude.
3/20:05	CHROMEX status is checked.
3/20:10	SSBUV calibration is terminated.
3/20:20	PSE experiment is performed.
3/20:20	SSBUV data transfer occurs.
3/20:40	SSBUV is deactivated.
3/20:50	Crew deactivates and stows RME-III.
3/20:50	APC is stowed.
3/20:57	Orbit 63 begins.
3/21:08	Pilot sets up cathode ray tube (CRT) timer.
3/21:09	Crew changes DAP, B set to B1.
3/21:11	Commander initiates coldsoak; flash evaparator controller primary A, B, secondary to OFF, radiator controller outlet temp to HI, when evap out temp equals 50 plus or minus 2 degrees, flash evap primary B (A) to ON, HI load duct heater to B.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/21:17	MS entry stowage card.
3/21:22	Crew stows radiators, if required.
3/21:32	MS installs specialist seats.
3/21:40	Commander configures data processing system (DPS) for deorbit preparation.
3/21:42	MCC updates deorbit IMU star pads, if required.
3/22:08	Commander maneuvers vehicle to IMU attitude.
3/22:18	MCC gives "GO/NO GO" command for payload bay door closure.
3/22:23	Commander aligns IMU.
3/22:27	Pilot closes payload bay doors.
3/22:27	Orbit 64 begins.
3/22:37	Commander performs preliminary deorbit update/ uplink.
3/22:40	Pilot terminates hydraulic thermal conditioning.
3/22:43	Pilot activates APU steam vent heater, boiler controller heater, 3 to A, power 3 to Panel R2.
3/22:47	Commander and pilot configure dedicated display.
3/22:50	Commander turns H_2O pump loop, two to OFF, Panel L1.
3/22:51	MCC gives "GO/NO GO" command for OPS-3.
3/22:57	Pilot performs SSME hydraulic repressurization preparation.
3/23:00	Pilot computes nitrogen quantity.
3/23:02	Commander and pilot configure DPS entry.
3/23:10	MS deactivates ST and closes doors.
3/23:17	Entry switch list verification occurs.
3/23:27	MS resets C/W.
3/23:42	Commander and pilot don LES.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/23:57	MS dons LES.
3/23:57	Orbit 65 begins.

DAY FOUR

4/00:04	Crew proceeds to major mode (MM)-302.
4/00:07	Commander and pilot ingress seat.
4/00:09	Commander and pilot set up HUD.
4/00:15	Commander and pilot perform LES pressure integrity check.
4/00:17	MS stows wireless.
4/00:18	MS deactivates waste collection system.
4/01:02	First APU is started.
4/01:07	Deorbit thrusting period occurs, 278 fps, 2 minutes in duration.
4/01:10	Crew proceeds to MM303.
4/01:11	Post deorbit attitude maneuver is initiated.
4/01:16	Post deorbit attitude maneuver is terminated.
4/01:24	Remaining APUs start.
4/01:27	Orbit 66 begins.
4/01:32	Crew proceeds to entry guidance MM304.
4/01:37	Entry interface (EI) occurs, 400,000 feet altitude.
4/01:41	RCS roll thrusters are deactivated.
4/01:44	RCS pitch thrusters are deactivated.
4/01:54	First roll reversal occurs.
4/01:55	Preprogrammed test input (PTI)-1 is initiated.
4/01:55.14	Terminate PTI-1.
4/01:57	Second roll reversal occurs.
4/01:58	PTI-2 is initiated.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/01:58.37	PTI-2 is terminated.
4/02:00	Air data system (ADS) probes are deployed.
4/02:00	PTI-3 is initiated.
4/02:00.15	PTI-3 is terminated.
4/02:00.24	Third roll reversal occurs.
4/02:01	Entry/terminal area energy management (TAEM) occurs.
4/02:03	RCS yaw thrusters are deactivated.
4/02:06	TAEM/approach landing (AIL) interface occurs.
4/02:07	Weight is on main landing gear.
4/02:07.54	Weight is on nose landing gear.
4/02:08	Main landing gear brakes are initiated.
4/02:08.28	Wheels stop.
4/02:22	Flight crew safes OMS/RCS.
4/02:25	Sniff checks are performed.
4/02:27	Aft vehicles are positioned.
4/02:37	Ground purge unit (transport) is connected to right-hand (starboard) T-O orbiter umbilical, and ground cooling unit (transporter) is connected to left-hand (port) T-O orbiter umbilical.
4/02:37	Crew compartment side hatch access vehicle is positioned.

GLOSSARY

AA	accelerometer assembly
ADSF	automatic directional solidification furnace
AES	atmosphere exchange system
A/L	approach and landing
AMOS	Air Force Maui Optical Site
AMU	attitude match update
AOA	abort once around
APC	autonomous payload controller
APU	auxiliary power unit
ARC	Aggregation of Red Blood Cells Experiment
ARS	attitude reference system
ASE	airborne support equipment
ASTRO	astronomy
BBXRT	Broad-Band X-Ray Telescope
CAP	crew activity plan
CAPS	crew altitude protection suit
CBSA	cargo bay stowage assembly
CCTV	closed-circuit television
CDMS	command and data management system
CEC	control electronics container
CFES	continuous flow electrophoresis system
CHROMEX	Chromosones and Plant Cell Division in Space
CIU	communications interface unit
COAS	crewman optical alignment sight
CRT	cathode-ray tube
CSS	control stick steering
DAP	digital autopilot
DDS	data display system
DEX	dextroamphetamine
DMOS	diffusive mixing of organic solutions
DPS	data processing system
DSO	detailed supplementary objective
DTO	detailed test objective
EAFB	Edwards Air Force Base
EAC	experiment apparatus container
ECLSS	environmental control and life support system
EEP	electronics equipment package
ELRAD	Earth Limb Radiance Experiment
EMU	extravehicular mobility unit
EPS	electrical power system
ESA	European Space Agency
ET	external tank
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FES	flash evaporator system
fps	feet per second

FSS	flight support structure
FSS	flight support system

GAS	getaway special
GEM	generic electronics module
GHCD	Growth Hormone Concentration and Distribution
GLS	ground launch sequencer
GPC	general-purpose computer
GSFC	Goddard Space Flight Center

HDRS	high data rate system
HGAS	high-gain antenna system
HRA	helmet-retention assembly
HRM	high rate multiplexer
HRM	hand-held radiation meter
HST	Hubble Space Telescope
HUD	head-up display
HUT	Hopkins Ultraviolet Telescope

ICBC	IMAX cargo bay camera
IEF	Isoelectric Focusing Experiment
IFM	inflight maintenance
IMCS	image motion compensation system
IMU	inertial measurement unit
IPMP	investigation into polymer membrane processing
IPS	instrument pointing system
IRCFE	Infrared Communications Flight Experiment
ISAC	Intelsat Solar Array Coupon
IUS	inertial upper stage
IV	intravehicular

JEA	joint endeavor agreement
JSC	Johnson Space Center

kbps	kilobits per second
KSC	Kennedy Space Center

LDEF	long-duration exposure facility
LEASAT	leased communication satellite
LES	launch entry suit
LPS	launch processing system
LRU	line replaceable unit

MC	midcourse correction maneuver
MCC-H	Mission Control Center-Houston
MDM	multiplexer/demultiplexer
MEB	main electronics box
MECO	main engine cutoff
MEM	middeck electronics module
MET	mission elapsed time
MFR	manipulator foot restraint
MILA	Merritt Island antenna
MLE	Mesoscale Lightning Experiment
MLR	monodisperse latex reactor

MM	major mode
MMU	manned maneuvering unit
MPESS	mission-peculiar equipment support structure
MPM	manipulator positioning mechanisms
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NC	normal corrective maneuver
NCC	normal corrective combination maneuver
NH	normal height adjust maneuver
nmi	nautical mile
NPC	normal plane change maneuver
NSR	normal slow rate maneuver
O&C	operations and checkout
OCP	Office of Commercial Programs
OASIS	Orbiter Experiment Autonomous Supporting Instrumentation System
OEX	orbiter experiment
OAST	Office of Aeronautics and Space Technology
OMS	orbital maneuvering system
OSSA	Office of Space Sciences and Applications
OSTA	Office of Space and Terrestrial Applications
PALAPA	Indonesian communication satellite
PAM	payload assist module
PCP	payload control panel
PCS	pressure control system
PCG	protein crystal growth
PDI	payload data interleaver
PFR	portable foot restraint
PGC	plant growth chamber
PGU	plant growth unit
PI	payload interrogator
PIC	pyro initiator controller
PL	payload
PM	polymer morphology
POCC	Payload Operations Control Center
PPE	Phase Partitioning Experiment
PRCS	primary reaction control system
PRLA	payload retention latch assembly
PRM	pocket radiation meter
PS	payload specialist
PSE	Physiological Systems Experiment
PTI	preprogrammed test input
PVTOS	Physical Vapor Transport Organic Solids Experiment
RAHF-VT	research animal holding facility-verification test
RCC	reinforced carbon-carbon
RCS	reaction control system
RGA	rate gyro assembly
RME	radiation monitoring equipment
RMS	remote manipulator system

RTGS	radioisotope thermoelectric generators
RTLS	return to launch site
S&A	safe and arm
SAREX	Shuttle Amateur Radio Experiment
SAS	space adaption syndrome
SCOP	scopolamine
SESA	special equipment stowage assembly
SHARE	Space Station Heat Pipe Radiator Element Experiment
SL	Spacelab
sm	statute mile
SM	systems management
SMS	space motion sickness
SRB	solid rocket booster
SRSS	shuttle range safety system
SSBUV	Shutter Solar Backscatter Ultraviolet
SSCE	Solid Surface Combustion Experiment
SSIP	shuttle student involvement project
SSME	space shuttle main engine
ST	star tracker
STEX	Sensor Technology Experiment
STS	space transportation system
SYNCOM	synchronous communication satellite
TACAN	tactical air navigation
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TAPS	two-axis pointing system
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite system
TI	terminal phase initiation
TIG	time of ignition
TLD	thermoluminescent dosimeter
TPAD	trunnion pin acquisition device
TPF	terminal phase final maneuver
TPI	terminal phase initiation maneuver
TPS	thermal protection system
TV	television
UIT	Ultraviolet Imaging Telescope
VCGS	vapor crystal growth system
VCS	voice command system
VRCS	vernier reaction control system
VTR	video tape recorder
VWFC	very wide field camera
WCS	waste collection system
WUPPE	Wisconsin Ultraviolet Photo Polarimeter