STS-34
PRESS INFORMATION

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Rockwell International

Space Transportation
Systems Division

Office of Media Relations

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CONTENTS

MISSION OVERVIEW

This is the fifth flight of Atlantis and the 30th in the space transportation system

The flight crew for the STS-34 mission consists of commander Donald E. Williams; pilot Michael J. McCulley; and mission specialists Shannon W. Lucid, Ellen S. Baker and Franklin R. Chang-Diaz.

The primary objective of this five-day mission is to deploy the Galileo spacecraft mated with an inertial upper stage. After the deployment of the Galileo spacecraft with its IUS from Atlantis' payload bay, the IUS will insert Galileo into a Venus-Earth-Earth gravity assist (VEEGA) trajectory to Jupiter.

The deployment of the Galileo spacecraft and IUS from Atlantis' payload bay is scheduled to nominally occur on the fifth orbit at a mission elapsed time of six hours and 22 minutes. 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 6A (the ascending node) begins approximately one hour after the IUS and Galileo spacecraft are deployed. (Each orbit begins after Atlantis crosses the equator on its ascending node.) Ignition of the second-stage SRM of the IUS occurs approximately two minutes after the first stage cuts off. After the boost out of Earth orbit, the IUS separates from Galileo, and Galileo will fly past Venus and twice by the Earth in gravity assist maneuvers to pick up enough speed to reach Jupiter. Travel time from launch to Jupiter is a little more than six years.

Galileo is a NASA mission designed to study Jupiter's atmosphere, satellites and surrounding magnetosphere. It was named for the Italian Renaissance scientist who discovered Jupiter's major moons with the first astronomical telescope.

This mission will be the first to make direct measurements from an instrumented probe within Jupiter's atmosphere and the first to conduct long-term observations of the planet and its magnetosphere and satellites from orbit around Jupiter. It will be the first orbiter and atmospheric probe sent to any of the outer planets.

On the way to Jupiter, Galileo will also observe Venus, the Earth-moon system, one or two asteroids and various phenomena in interplanetary space.

The Galileo spacecraft was prepared by the Jet Propulsion Laboratory, Pasadena, Calif.

Eight other payloads, referred to as secondary payloads, will be carried aboard Atlantis on this mission.

The Shuttle Solar Backscatter Ultraviolet instrument in Atlantis' 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 Polymer Morphology Experiment is a 3M-developed organic material-processing experiment designed to explore the effects of microgravity on polymeric materials as they are processed in space. The samples of polymeric materials being studied in this experiment are thin films (25 microns or less) approximately 25 millimeters in diameter. The experiment is contained in two separate, hermetically sealed containers mounted in Atlantis' middeck.

The IMAX camera project is a collaboration between NASA and the Smithsonian Institution's National Air and Space Museum to document significant space activities using the IMAX film medium. This system, developed by IMAX Systems Corporation, Toronto, Canada, uses specially designed 70mm cameras and projectors to record and display very high definition, large-screen motion pictures. IMAX will be used on this mission to cover the deployment of Galileo and gather material on Earth observations from space for IMAX films to succeed "The Dream Is Alive." IMAX is located in Atlantis on this mission.

The Mesoscale Lightning Experiment for this mission is designed to obtain nighttime images of lightning in order to better understand the global distribution of lightning, the interrelationships of lightning events in storms that are close together, and the relationships of lightning, convective storms and precipitation. Cameras in Atlantis' payload bay will record lightning directly below Atlantis, and, if time permits, the flight crew will also use handheld 35mm cameras to photograph lightning in storm systems not directly below Atlantis' ground track.

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 Atlantis during cooperative overflights while Atlantis 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.

The Growth Hormone Concentration and Distribution in Plants Experiment is designed to determine the effects of microgravity on the concentration, turnover properties and behavior of the plant growth hormone, auxin, in the tissue of shoots of corn (*Zea mays*). Mounted in foam blocks inside two standard middeck lockers, the equipment consists of four plant canisters, two gaseous nitrogen freezers and two temperature recorders. A total of 228 seeds will have been "planted" in special filter paper-Teflon tube holders no more than 56 hours before the flight. The lockers will be installed during the last 14 hours before the launch. The seeds will remain in total darkness throughout the mission.

The Sensor Technology Experiment is a radiation detection experiment designed to measure the natural radiation background. It is a self-contained experiment with its own power, sensor, computer control and data storage. It is stowed in a standard middeck locker, where it will remain throughout the flight.

The zero-gravity growth of ice crystals student experiment will observe the geometric ice crystal shapes formed at supercooled temperatures below zero degrees Celsius without the influence of gravity. The experiment is located in Atlantis' middeck.

STS-34 MISSION STATISTICS

Launch: Launch window duration increases from a minimum of nine minutes to a maximum of 47 minutes in the middle, then decreases to nine minutes at the end of the launch window on Nov. 21.

10/12/89 1:29 p.m. EDT
12:29 p.m. CDT
10:29 a.m. PDT

Mission Duration: 120 hours (five days), two hours, 45 minutes

Landing: Nominal end of mission is on orbit 82.

10/17/89 4:14 p.m. EDT
3:14 p.m. CDT
1:14 p.m. PDT

Inclination: 34.30 degrees, first flight at this inclination

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 lifts 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 nautical miles (184 statute miles) by 161 nautical miles (185 statute miles), then 161 nautical miles (185 statute miles) by 178 nautical miles (204 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,523,129 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 257,012 pounds

Payload Weight Up: Approximately 49,013 pounds

Payload Weight Down: Approximately 10,625 pounds

Orbiter Weight at Landing: Approximately 194,938 pounds

Payloads: Galileo/IUS-2, SSBUV-01, IMAX-02, PM-01, GHCD, STEX, MLE-03, AMOS-03, and student experiment SE 82-15

Flight Crew Members:
Commander: Donald E. Williams, second space shuttle flight
Pilot: Michael J. McCulley, first space shuttle flight
Mission Specialist 1: Shannon W. Lucid, second space shuttle flight
Mission Specialist 3: Ellen S. Baker, first space shuttle flight
Mission Specialist 2: Franklin R. Chang-Diaz, second space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Donald Williams
Flight deck front right seat, pilot Michael McCulley
Flight deck aft center seat, MS-2, Franklin Chang-Diaz
Flight deck aft right seat, MS-1, Shannon Lucid
Middeck, MS-3, Ellen Baker

Entry Seating:
Flight deck aft right seat, MS-3, Ellen Baker
Middeck, MS-1, Shannon Lucid

Extravehicular Activity Crew Members, If Required:
EV-1 would be Franklin Chang-Diaz and EV-2 would be Ellen Baker.

Angle of Attack, Entry: 40 degrees

Entry: Automatic mode will be used until subsonic; then control stick steering (CSS) mode will be used.

Runway: Nominal end-of-mission landing will be on dry lake bed Runway 17 at Edwards Air Force Base, Calif.

Notes:

- The remote manipulator system is not installed in Atlantis' payload bay for this flight. The galley is installed in the middeck of Atlantis for this flight.

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

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

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

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

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

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

MISSION OBJECTIVES

- Deployment of Galileo spacecraft with IUS
- Secondary payloads
  - SSBUV-01
  - IMAX-02
  - PM-01
  - GHCD
  - STEX
  - MLE-03
  - AMOS-03
  - SE 82-15

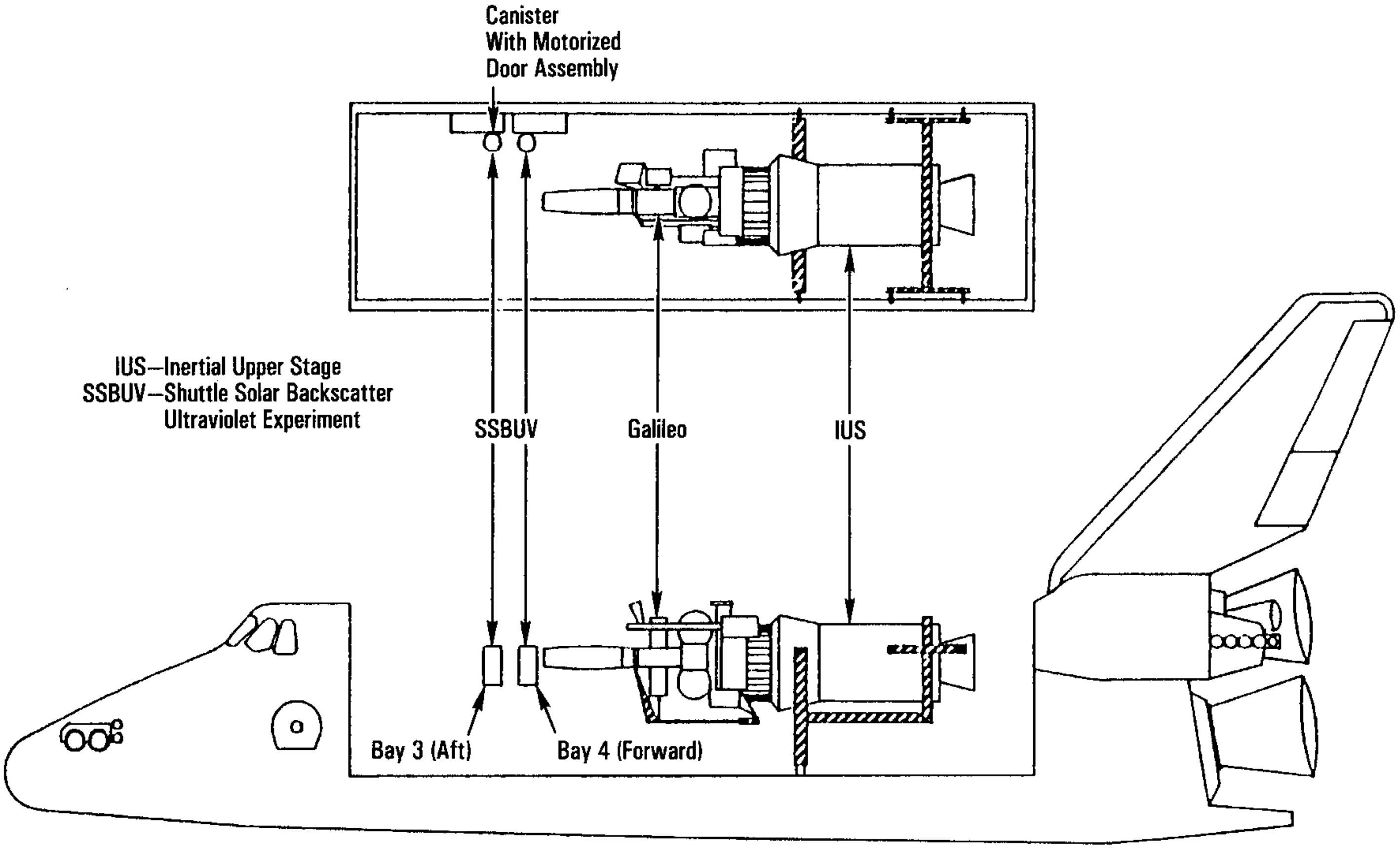
DEVELOPMENT TEST OBJECTIVES

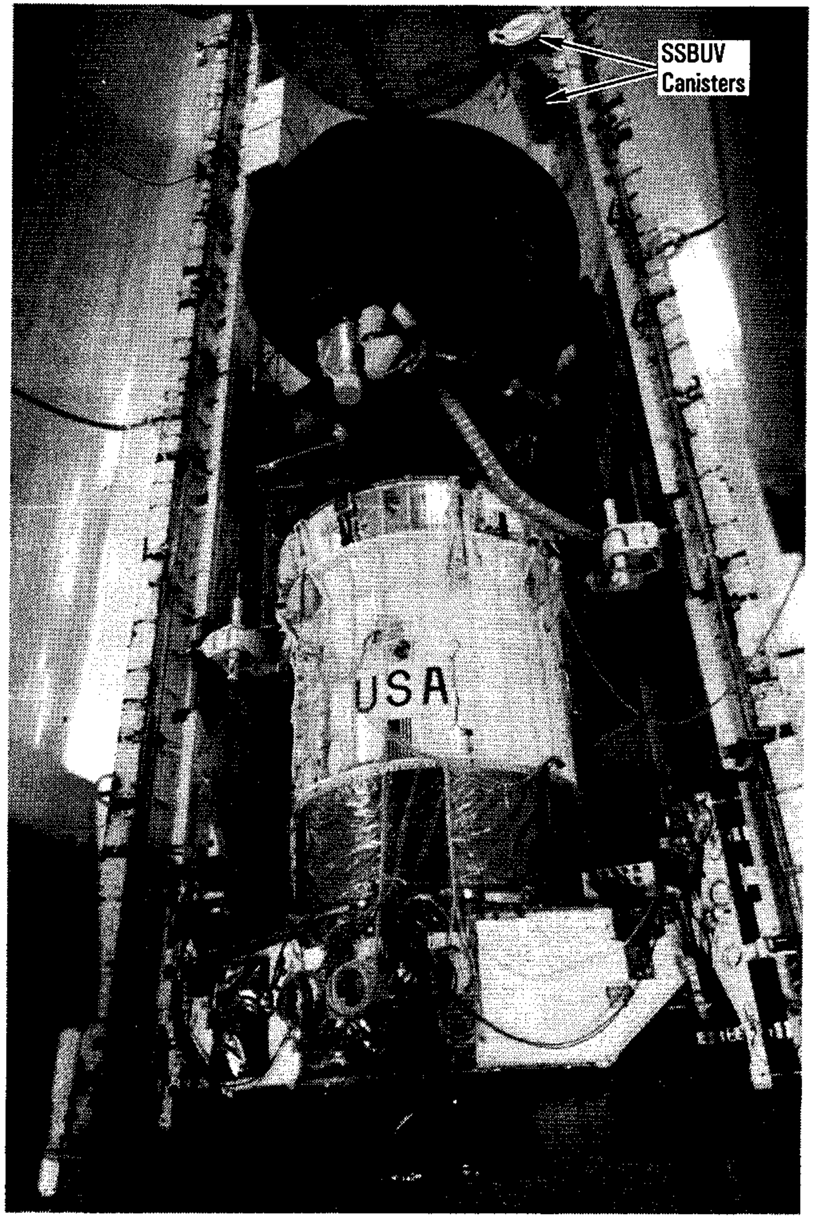
- Ascent structural capability evaluation
- Entry structural capability
- Ascent flutter boundary evaluation (data collection only; no change to ascent design)
- Pogo stability performance
- External tank thermal protection system performance (flight crew maneuvers Atlantis to photograph external tank after separation)
- Shuttle/payload low frequency
- Hot nose wheel steering runway evaluation (if no crosswind, go for nose wheel steering between 120 to 140 knots, left and right of runway centerline 30 degrees)
- Camcorder demonstration
- TDRS-to-TDRS handover demonstration
- Text and graphics system
- Crosswind landing performance
- Gravity gradient attitude control

DETAILED SUPPLEMENTARY OBJECTIVES

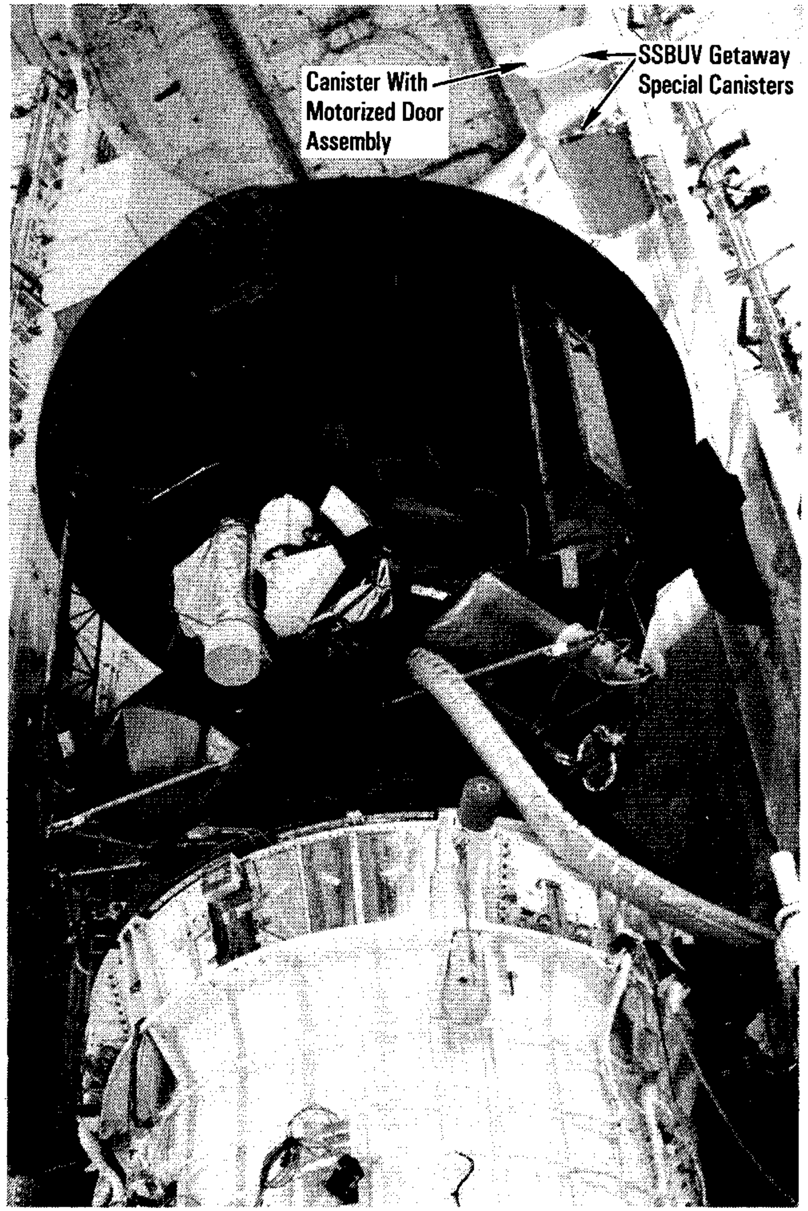
- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Variations in supine and standing heart rate, blood pressure and size of heart as a function of spaceflight and time after flight
- The relationship of space adaptation syndrome to velocity of middle cerebral artery blood, measured during flight by Doppler
- Delayed-type hypersensitivity
- Retinal photography
- Muscle biopsy (pre- and postflight)
- Muscle performance
- Documentary television
- Documentary motion picture photography
- Documentary still photography

STS-34 PAYLOAD CONFIGURATION





Shuttle Solar Backscatter Ultraviolet Canisters and Galileo Spacecraft With Inertial Upper Stage in Atlantis' Payload Bay



Shuttle Solar Backscatter Ultraviolet Canisters and Galileo With Inertial Upper Stage in Atlantis' Payload Bay

INERTIAL UPPER STAGE

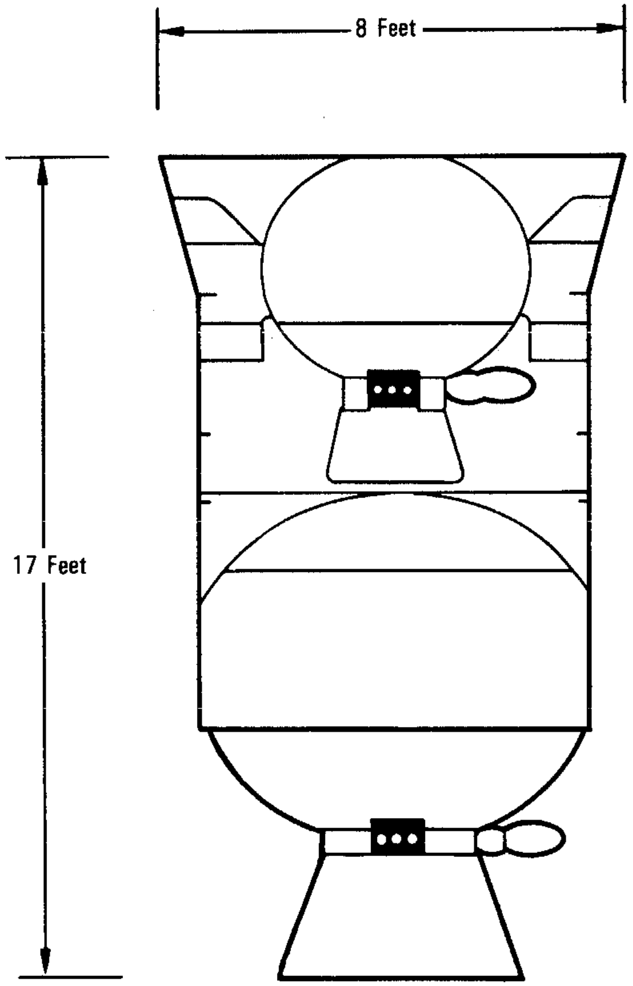
The inertial upper stage will be used with the space shuttle to transport NASA's Tracking and Data Relay satellites to geosynchronous orbit, 22,300 statute miles from Earth. The IUS was also selected by NASA for the Magellan, Galileo and Ulysses planetary missions.

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.



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.

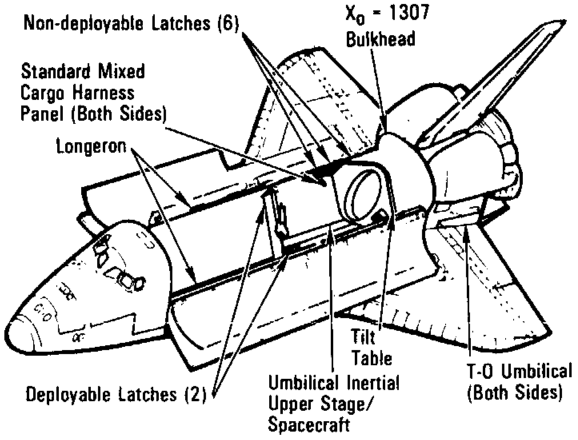
Boeing also integrates the IUS with various satellites and joins the satellite with the IUS, checks out the configuration and supports launch and mission control operations for both the Air Force and NASA. Boeing also develops airborne support equipment to support the IUS in the space shuttle and monitors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

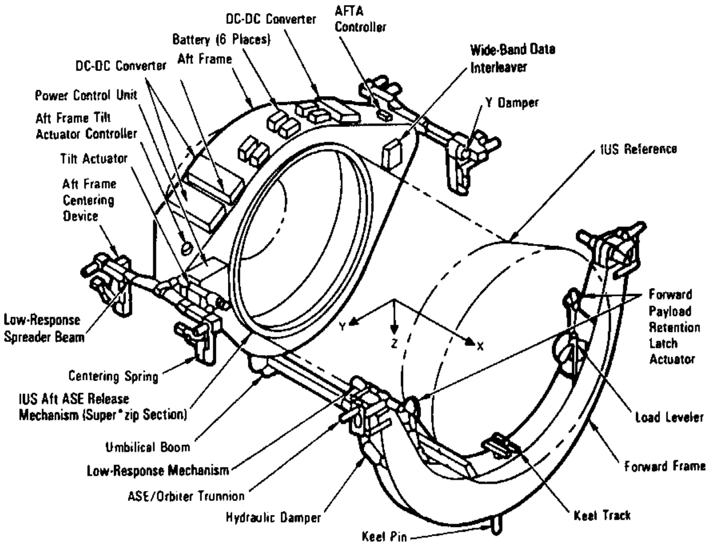
The IUS, without the two SRMs, is fabricated and tested at the Boeing Space Center, Kent, Wash. SRMs are shipped directly from Chemical Systems Division in California to the eastern launch site at Cape Canaveral, Fla. Similarly, the Boeing-manufactured IUS subsystems are shipped from Washington to the 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.





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.

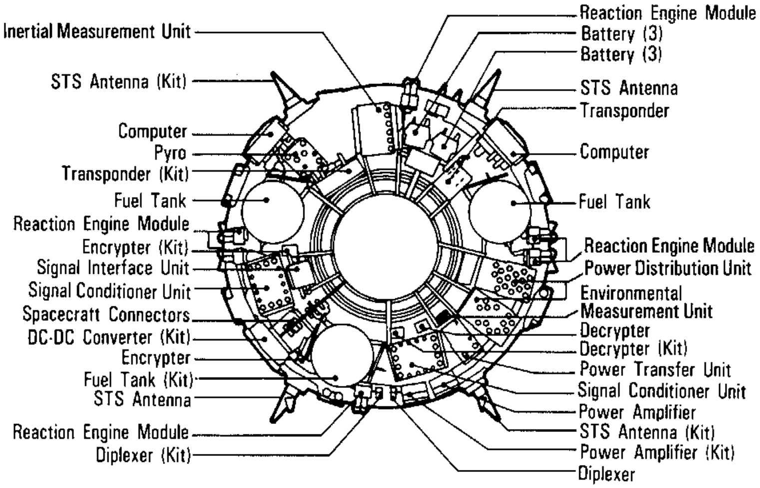
EQUIPMENT SUPPORT SECTION

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-



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 extendable 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 provides a multilayer insulation blanket of aluminized Kapton with polyester net spacers and an aluminized beta cloth outer layer across the IUS and spacecraft interface. 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 spacecraft and the IUS. The thermal blankets are grounded to the IUS structure to prevent electrostatic charge buildup.

GALILEO

Galileo is a NASA spacecraft mission to Jupiter that is designed to study the planet's atmosphere, satellites and surrounding magnetosphere. It was named for the Italian Renaissance scientist who discovered Jupiter's major moons with the first astronomical telescope.

The Galileo mission will be the first to make direct measurements from an instrumented probe within Jupiter's atmosphere and the first to conduct long-term observations of the planet, its magnetosphere and satellites from orbit around Jupiter. Galileo will also be the first orbiter and atmosphere probe to be sent to any of the outer planets. On the way to Jupiter, Galileo will also observe Venus, the Earth-moon system, one or two asteroids and various phenomena in interplanetary space.

The Galileo spacecraft, with its attached inertial upper stage, is carried into Earth orbit in Atlantis' payload bay. From the payload bay, Galileo and its IUS are nominally deployed at a mission elapsed time of six hours and 22 minutes. Approximately one hour later, the first-stage solid rocket motor of the IUS is ignited to provide Galileo's initial escape velocity out of Earth orbit. Ignition of the second-stage SRM occurs approximately two minutes after the IUS first-stage cutoff. The second-stage SRM provides Galileo with the final velocity increment for its trip to Venus. The IUS is separated from Galileo shortly after second-stage cutoff. Galileo then flies past Venus once and Earth twice—using gravity assist maneuvers to gain enough velocity to reach Jupiter. Travel time from Galileo's launch to its arrival in Jupiter's atmosphere is a little more than six years.

In December 1995, the Galileo atmosphere probe will conduct a brief, direct examination of Jupiter's gigantic atmosphere while the larger part of the craft, the orbiter, begins a 22-month, ten-orbit tour of the major satellites, during which it will also examine the planet's magnetosphere and conduct long-term observations of Jupiter itself.

The 2.5-ton Galileo orbiter carries ten scientific instruments; there are six more on the 750-pound probe. The spacecraft's radio link to Earth serves as an instrument for additional scientific measurements. The probe's scientific data will be relayed to Earth by the orbiter during the 75-minute period when the probe is descending into Jupiter's atmosphere.

Galileo will communicate with its controllers and scientists through the Deep Space Network, which uses tracking stations at Goldstone, Calif.; Madrid, Spain; and Canberra, Australia.

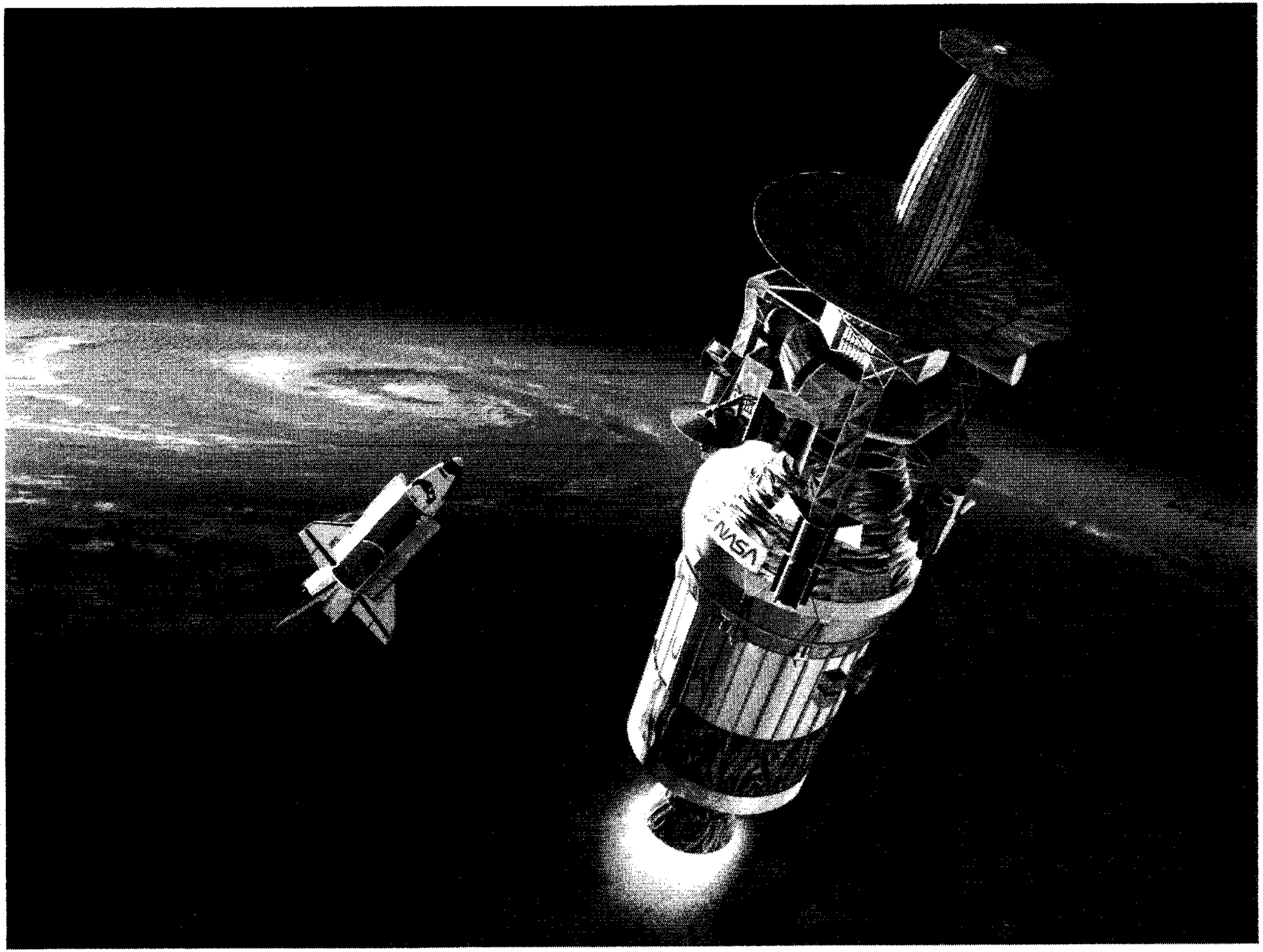
The Galileo mission was originally designed as a direct, 2.5-year flight to Jupiter. Later, however, the IUS replaced the Centaur upper-stage rocket, precluding the short flight. Trajectory engineers designed a new interplanetary flight path using gravity assists, once with Venus and twice with Earth, to increase Galileo's speed so it will reach Jupiter in just over six years. This is called the Venus-Earth-Earth gravity assist (or VEEGA) trajectory.

Galileo will make three planetary encounters in the course of its gravity-assisted flight to Jupiter. These encounters provide opportunities for the scientific observation and measurement of Venus and the Earth-moon system. The mission may also include close flybys of one or two asteroids, bodies which have never been observed up close, and opportunities to obtain data on other phenomena of interplanetary space.

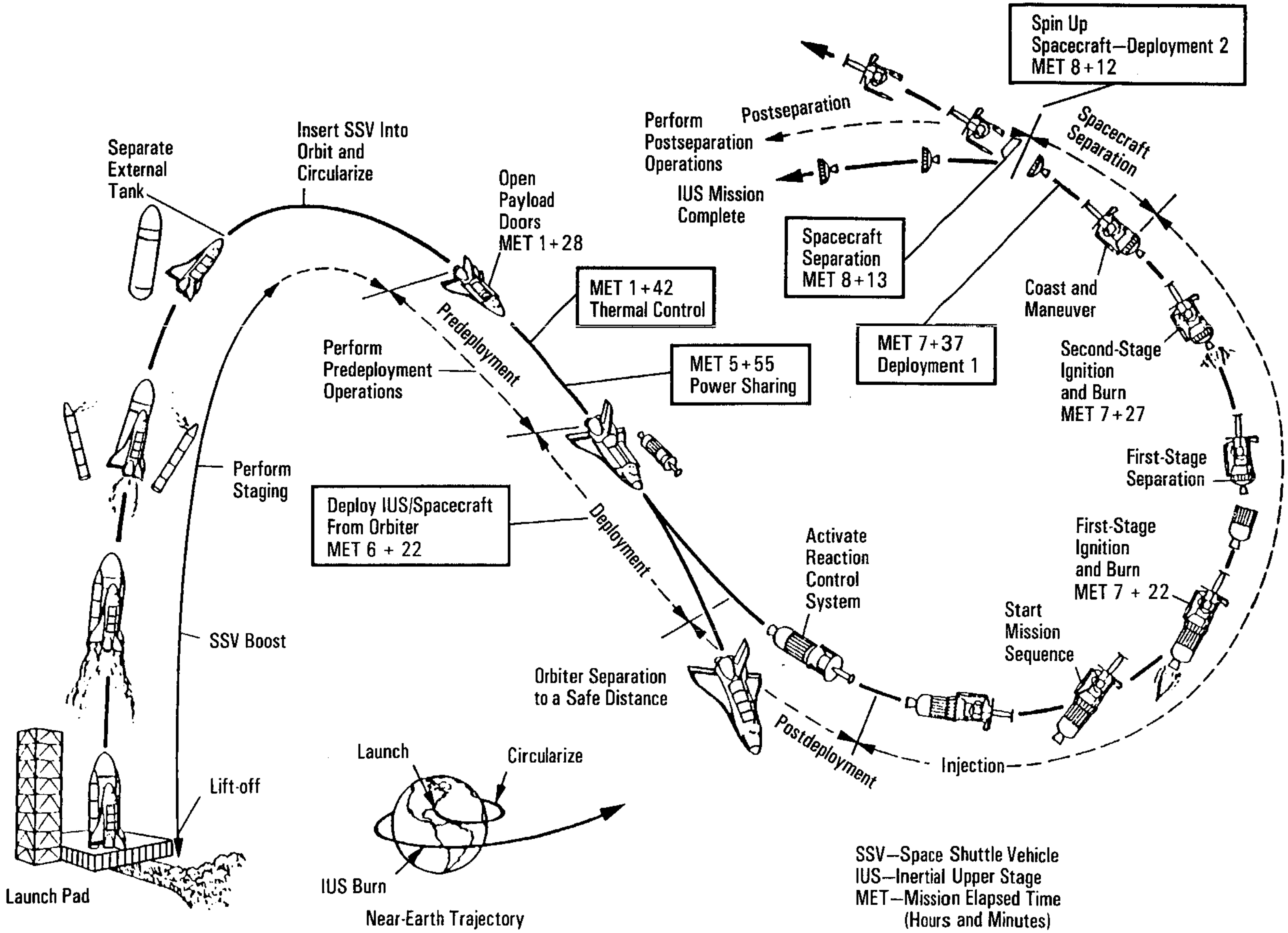
GALILEO SPACECRAFT

The Galileo mission and systems were designed to investigate three broad aspects of the Jovian system: the planet's atmosphere, the satellites and the magnetosphere. The spacecraft is divided into three segments to focus on these areas: the probe; a non-spinning section of the orbiter carrying cameras and other remote sensors; and the spinning main section of the orbiter that includes the propulsion module, communications antennas, main computers and most support systems. The third section also carries the field and particle instruments, which directly sense and measure the environment the spacecraft is flying through.

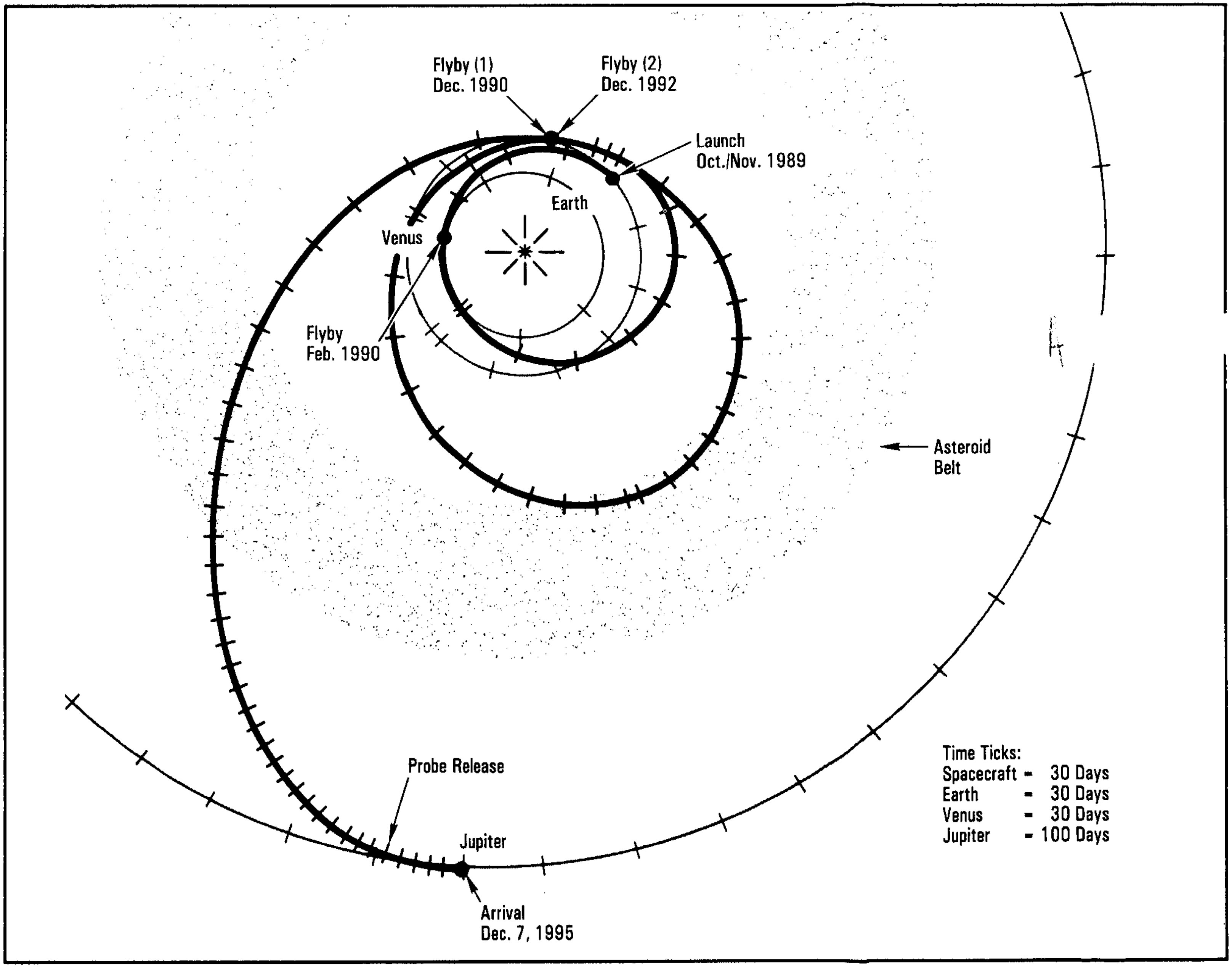
The probe weighs just under 750 pounds and includes a



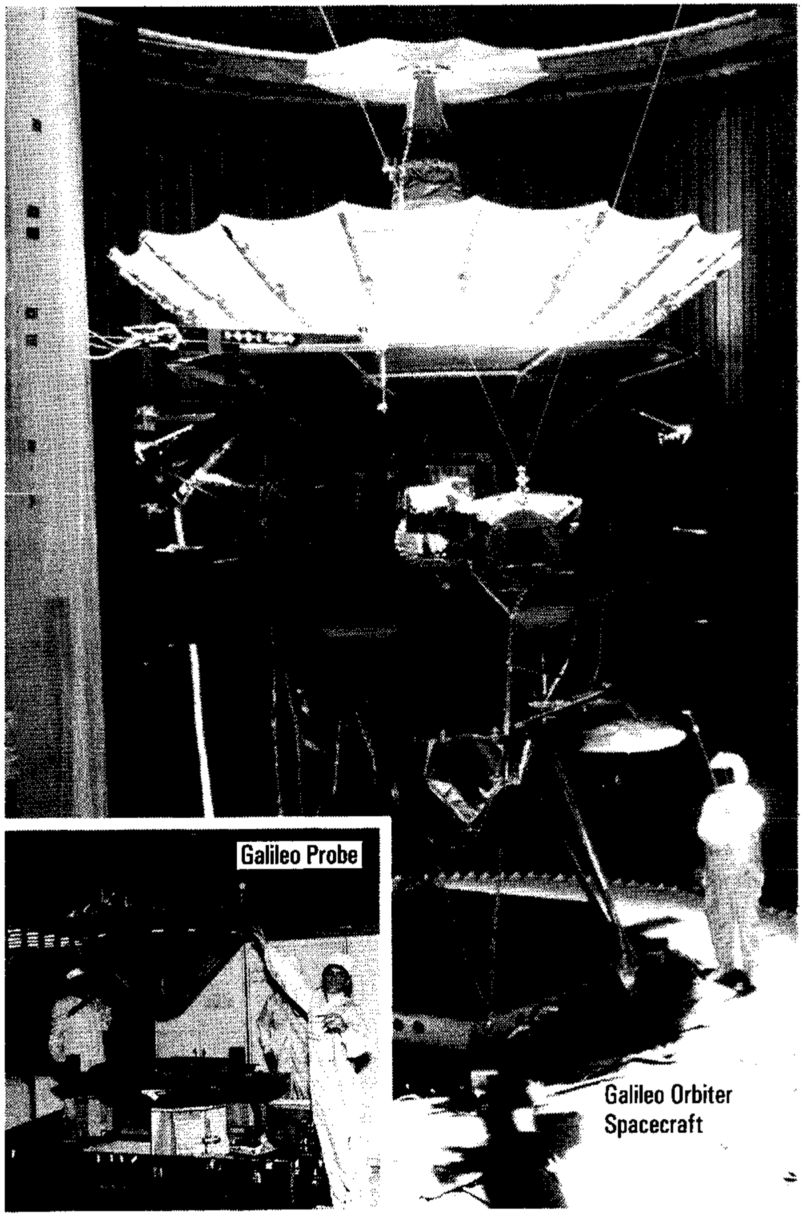
Galileo Deployment From Atlantis



SSV—Space Shuttle Vehicle
IUS—Inertial Upper Stage
MET—Mission Elapsed Time
(Hours and Minutes)



Galileo Mission



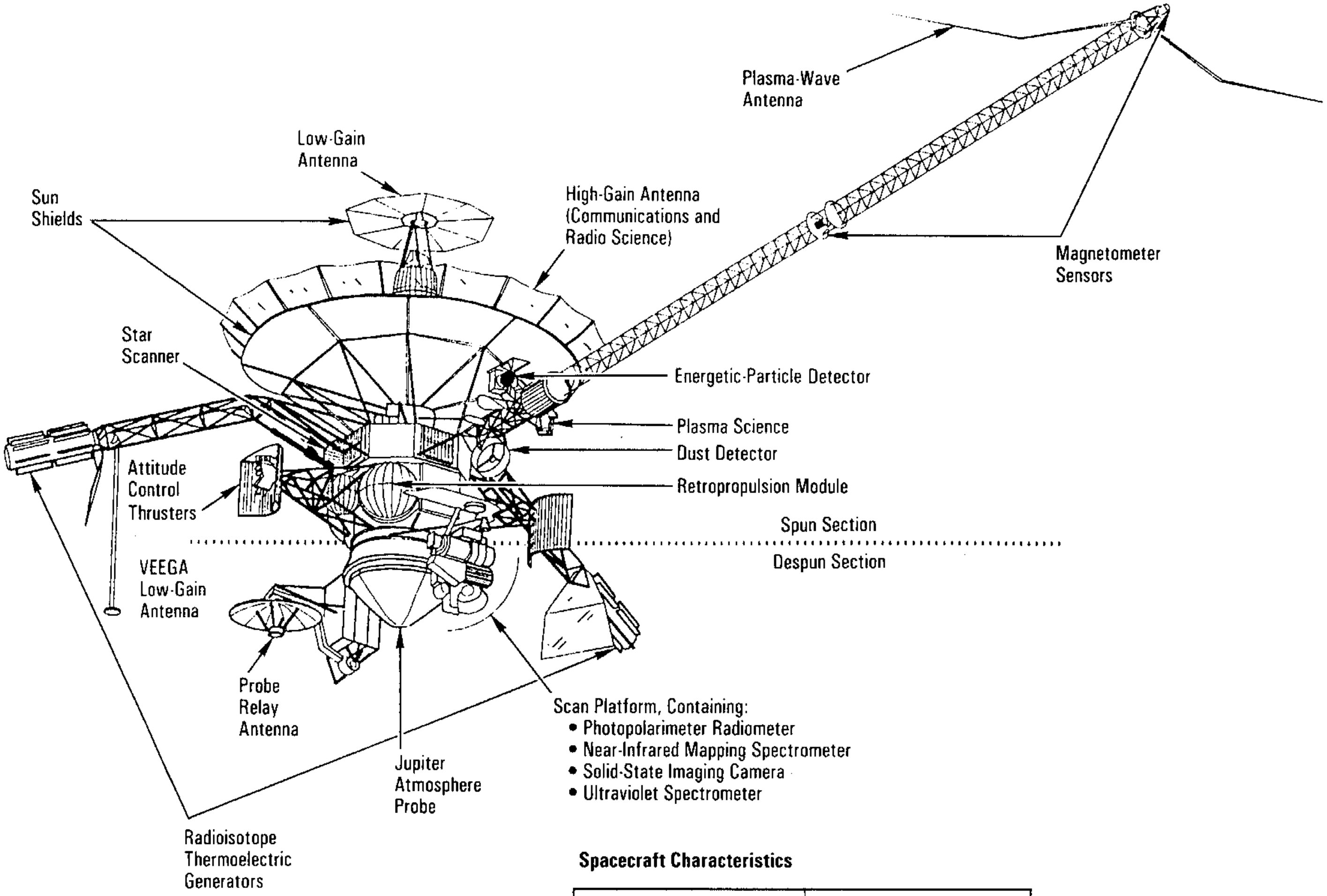
deceleration module that slows and protects the descent module, which carries out the scientific mission. The deceleration module consists of an aeroshell and an aft cover, designed to block the heat generated as the probe's arrival speed of about 100,000 mph is slowed—in less than two minutes—to subsonic speed.

After the covers are released, the descent module deploys its 8-foot parachute; then its six instruments, the control and data system, and the radio-relay transmitter go to work. Operating at 128 bits per second, the dual L-band transmitters send nearly identical streams of scientific data to the orbiter. The probe's electronics are powered by long-life batteries with an estimated capacity of 18 amp-hours upon arrival at Jupiter.

The probe's instruments include an atmospheric structure instrument group that measures temperature, pressure and deceleration; a neutral mass spectrometer and a helium-abundance interferometer that support atmospheric composition studies; a nephelometer for cloud and cloud particle observation; a net-flux radiometer that measures the difference (upward versus downward) in radiant energy flux at each altitude; and a lightning/radio-emission instrument (with an energetic-particle detector) that measures electromagnetic waves (including light and radio frequency) associated with lightning and energetic particles associated with the radiation belts of Jupiter.

The orbiter, in addition to delivering the probe to Jupiter and relaying the probe's data to Earth, will support all the scientific investigations of Venus, the Earth and its moon, asteroids and the interplanetary medium, Jupiter's satellites and magnetosphere, and remote-sensing observation of the giant planet itself.

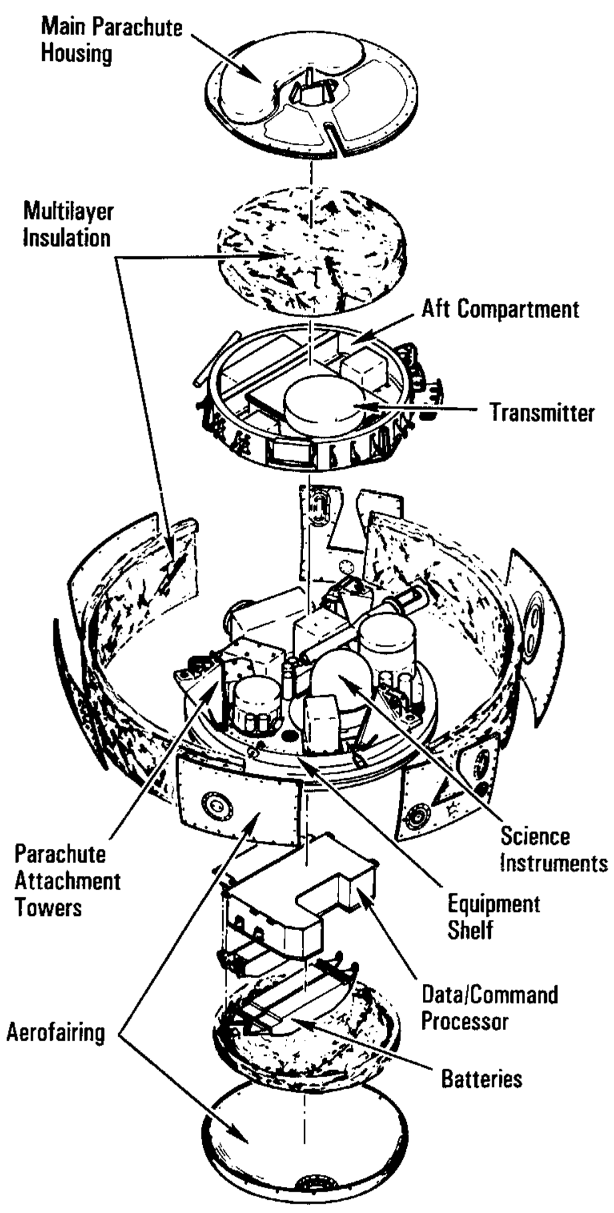
The orbiter, which weighs about 5,200 pounds, carries about 2,400 pounds of rocket propellant that will be used for 30 relatively small maneuvers during the long gravity-assisted flight to Jupiter, the large thrust maneuver that puts the craft into its Jupiter orbit and approximately 30 trim maneuvers during the satellite tour phase.



Spacecraft Characteristics

	Orbiter	Probe
Mass	5,242 pounds	744 pounds
Height	15 feet	34 inches
In-flight span (excluding magnetometer boom)	30 feet	
Instrument payload	10 instruments	6 instruments
Payload mass	260 pounds	66 pounds
Electric power	RTGs, 570-480 watts	Lithium-sulfur battery, 730 W-h
Propellant carried	2,400 pounds	

Galileo Spacecraft Configuration



Galileo Descent Module Configuration

The retropropulsion module consists of 12 44-pound thrust engines, a single 1,777-pound thrust engine, the fuel and oxidizer tanks, pressurizing gas tanks, tubing, valves and control equipment.

The orbiter's maximum communication rate is 134 kilobits per second (the equivalent of about one black-and-white image per minute); there are other data rates, down to 10 bits per second, for transmitting some engineering data under poor conditions. The spacecraft transmitters operate at S-band and X-band (2,295- and 8,415-megahertz) frequencies. The high-gain antenna is a 16-foot, umbrellalike reflector that is unfurled after the first Earth flyby. Two low-gain antennas (one mounted forward and one aft on the spinning section) support communications during the Earth-Venus-Earth leg of the flight and during moments when the main antenna is not pointed at Earth. The despun section of the orbiter carries a radio relay antenna for receiving the probe's data transmissions.

Electrical power is provided to Galileo's equipment by two radioisotope thermoelectric generators. Heat produced by the natural radioactive decay of plutonium is converted to approximately 500 watts of electricity (570 watts at launch and 480 watts at the end of the mission) to operate the orbiter equipment during its eight-year active period. This is the same type of power source used by the Voyager and Pioneer Jupiter spacecraft in their long outer-planet missions.

Most spacecraft are stabilized in flight either by spinning around a major axis or by maintaining a "fixed" orientation in space, referenced to the sun and another star. Galileo represents a hybrid of these techniques, with a spinning section rotating ordinarily at 3 rpm and a despun section, which counterrotates to provide a fixed orientation for cameras and other remote sensors.

Instruments that measure fields and particles—together with the main antenna, the power supply, the propulsion module and most of the computers and control electronics—are mounted on the spinning section. The instruments include magnetometer sensors mounted on a 36-foot boom to escape interference from the spacecraft, a plasma instrument to detect low-energy charged particles, a plasma-wave detector to study waves generated in magnetospheres and by lightning discharges, a high-energy particle detector and a detector of cosmic and Jovian dust.

The despun section carries instruments and other equipment whose operation depends on a fixed orientation in space. The instruments include the camera system, the near-infrared mapping spectrometer (to make multispectral images for atmosphere and surface chemical analysis), the ultraviolet spectrometer (to study gases and ionized gases) and the photopolarimeter radiometer (to measure radiant and reflected energy). The camera system is expected to obtain images of Jupiter's satellites at resolutions that exceed Voyager's best images by 20 to 1,000 times.

The despun section also carries the probe and a dish antenna, which will track the probe in Jupiter's atmosphere and pick up its signals for relay to Earth. Before the probe is released, the whole spacecraft has to be spun up briefly to 10 rpm in order to spin-stabilize the probe.

MANAGEMENT

The Galileo project is managed for NASA's Office of Space Science and Applications by the Jet Propulsion Laboratory. This responsibility includes designing, building, testing, operating and tracking Galileo. Richard J. Spehalski is project manager, Dr.

Salient Features

Orbiter	Probe
• Dual-spin • RTG-powered • Federal Republic of Germany propulsion • Distributed data system • S-X-band communication (134 kbps maximum data rate) • Four remote-sensing instruments • Five field and particle instruments • Probe data relay • 22-month orbital mission	• Spin-stabilized • Battery-powered • Entry trajectory and attitude established by orbiter • No uplink after separation • Aeroshell entry • Parachute descent • Six science instruments • L-band downlink to orbiter (128 bps maximum data rate) • Prime mission to 10 bars within 48 minutes

Orbiter Science Investigations

Investigations	Purpose
Imaging	Map satellite at resolution of approximately 1 km. Obtain color "motion pictures" of atmosphere over 22 months
Near-infrared mapping spectrometer	Obtain infrared pictures of Jupiter and satellites to detect satellite surface composition, Jupiter atmospheric composition and temperature profile
Ultraviolet spectrometer	Measure atmospheric composition; detect aerosols and measure gases
Photopolarimeter radiometer	Determine distribution and character of particulates in Jupiter's atmosphere; measure solar and thermal radiation
Plasma	Measure distribution of electrons and positive ions establish sources and interactions of Jovian plasm
Energetic-particle detector	Measure energetic electrons, protons and heavy ions
Plasma wave spectrometer	Measure electric and magnetic fields to analyze wave-particle interactions affecting magnetosphere dynamics
Magnetometer	Measure magnetic field continuously to obtain time and spatial variation
Dust detector	Measure mass and velocity of dust particles measuring approximately 1 micron
Radio science—celestial mechanics	Determine mass distributions of Jupiter and satellites
Radio science—propagation	Measure atmospheric structure and radii

Probe Science Investigations

Investigations	Purpose
Atmospheric structure	Determine temperature, pressure, density and molecular weight versus altitude
Nephelometer	Detect clouds and infer liquid or solid particle states
Net flux radiometer	Determine net solar energy flux versus altitude
Neutral mass spectrometer	Determine chemical composition
Helium abundance detector	Determine relative abundance of helium
Lightning/energetic particles	Verify existence of lightning; measure energetic particles

Torrence V. Johnson is project scientist, William J. O'Neil is science and mission design manager, Dr. Clayne M. Yeates is deputy science and mission design manager, and Neal E. Ausman Jr. is mission operations and engineering manager. Orbiter spacecraft manager is A. Earl Cherniack, Matthew R. Landano is the deputy manager, and William G. Fawcett is orbiter science payload manager. The Federal Republic of Germany has furnished the orbiter's retropropulsion module and is participating in the scientific investigations. The propulsion system was developed and built by Messerschmitt-Bolklow-Blohm. The radioisotope thermoelectric generators were designed and built by the General Electric Company for the U.S. Department of Energy.

NASA's Ames Research Center (Moffett Field, Calif.) is responsible for the atmosphere probe, which was built by Hughes Aircraft Company (El Segundo, Calif.). At Ames, the probe manager is Benny Chin and the probe scientists are Lawrence Colin and Richard E. Young.

GROUND SYSTEMS

Galileo communicates with Earth via NASA's Deep Space Network, which has a complex of large antennas with receivers and transmitters located at Goldstone, Calif.; Canberra, Australia; and Madrid, Spain. All three locations are linked to the network control center at JPL in Pasadena, Calif. The spacecraft receives commands, sends science and engineering data, and is tracked by Doppler and ranging measurements through this network.

At JPL, mission controllers—including about 275 scientists, engineers and technicians—will support the mission at launch. There will be nearly 400 of them on hand for Jupiter operations. Their responsibilities include commanding the spacecraft, interpreting the engineering data it sends (in order to understand how it is performing and responding) and analyzing navigation data obtained by the DSN. The controllers use a set of complex computer programs to help them control the spacecraft and interpret the data.

Because the time delay in transmitting radio signals from Earth to Jupiter and back is more than an hour, the Galileo spacecraft was designed to operate from programs sent in advance and stored in the spacecraft's memory. A single master sequence program can cover four weeks of quiet operations between planetary and satellite encounters; during busy Jupiter operations, one program covers only a few days. Spacecraft tasks are carried out by several subsystems and scientific instruments, many of which work from their own computers controlled by the main sequence program.

Designing these sequences was a complex process that balanced the desire to make certain scientific observations with the need to safeguard the spacecraft and mission. The sequence design process itself is supported by other programs. For example, one program contains maps that show scientists the area covered by their instruments on the surface of an approaching Jovian satellite for a given spacecraft orientation and trajectory. These aids notwithstanding, it may have taken many months of effort to design, check and recheck the sequence for a typical three-day encounter with a Jovian satellite. The controllers also use software designed to check the command sequence further against flight rules and constraints.

The spacecraft regularly reports its status and health through an extensive set of engineering measurements. Interpreting these data into trends and averting or working around equipment failures are major tasks for the mission operations team. Conclusions from this activity become an important input (along with scientific plans) to the sequence design process. This, too, is supported by computer programs written and used in the mission support area.

Navigation is the process of estimating, from radio range and Doppler measurements, the position and velocity of the spacecraft in order to predict its flight path and design course-correcting maneuvers. These calculations must be done with computer support. The Galileo mission, with its complex gravity assist flight to Jupiter and ten gravity assist satellite encounters in the Jovian system, is extremely dependent on consistently accurate navigation.

In addition to the programs that directly operate the spacecraft and are periodically transmitted to it, the mission operations team uses software amounting to 650,000 lines of programming code in the sequence design process, 1,615,000 lines in the telemetry interpretation and 550,000 lines in navigation.

Science investigators, linked by computer, are located at JPL or at other laboratories. They are involved in developing the sequences affecting their experiments and, in some cases, will help to change preplanned sequences in order to follow up on unexpected discoveries with second looks and confirming observations.

Galileo's scientific experiments will be carried out by more than 100 scientists from six nations. Except for the radio science investigation, the experiments are supported by dedicated instruments on the Galileo orbiter and probe. NASA has appointed 15 interdisciplinary scientists whose studies span more than one Galileo instrument data set to the project.

VENUS

The Galileo spacecraft will approach Venus early in 1990 from the night side and will pass across the sunlit hemisphere, observing the clouds and atmosphere. Both infrared and ultraviolet spectral observations are planned, as well as several images and other remote measurements.

The search for deep cloud patterns (and possibly also for lightning storms) will be limited by the fact that all the Venusian data must be tape-recorded on the spacecraft for playback eight months later. The spacecraft was originally designed to operate between Earth and Jupiter, where sunlight is 25 times weaker than on Earth and temperatures are much lower, but the VEEGA maneuver will expose the spacecraft to a hotter environment during the trip from Earth to Venus and back to Earth. Therefore, spacecraft engineers have devised a set of sunshades to protect the craft. For this system to work, the front of the spacecraft must be aimed precisely at the sun, with the main antenna furled to protect it from the sun's rays until after the first Earth flyby in December 1990. Scientists, therefore, must wait until the spacecraft is close to Earth to receive the recorded Venusian data, transmitted through a low-gain antenna.

EARTH

Approaching Earth for the first time about 14 months after launch, the Galileo spacecraft will observe the night side of Earth and parts of both the dark and bright sides of the moon from a distance. After passing Earth, Galileo will observe its sunlit side. At this short range, scientific data will be transmitted at high rate using only the low-gain antennas. The high-gain antenna will be unfurled like an umbrella and its high-power transmitter turned on and checked out about five months after the first Earth encounter.

FIRST ASTEROID

Nine months after the Earth passage, Galileo will enter the asteroid belt and two months later will have its first asteroid encounter. Gaspra is believed to be a fairly representative main-belt asteroid, about 10 miles across and probably similar in composition to stony meteorites.

The spacecraft will pass about 620 miles from Gaspra at a relative speed of about 18,000 mph. It will collect several pictures of the asteroid and take measurements to determine its composition and physical properties.

EARTH AGAIN

Thirteen months after the Gaspra encounter, the spacecraft will have completed a two-year elliptical orbit around the sun and will arrive at Earth. The second flyby of Earth will increase Galileo's orbit to the much longer ellipse (with a six-year period) it will need to reach Jupiter.

Passing nearly 185 miles above the Earth's surface, close to the altitude at which it had been deployed from Atlantis almost three years earlier, Galileo will use Earth's gravitation to change its flight direction and increase its speed about 8,000 mph.

Each gravity-assisted flyby requires about three rocket-thrusting sessions—using Galileo's onboard retropropulsion module—to fine tune the flight path. (Asteroid encounters require similar maneuvers to obtain the best observing conditions.)

As the spacecraft passes Earth for the last time, its scientific equipment will make thorough observations of the planet, both for comparison with observations of Venus and Jupiter and to aid in Earth studies.

SECOND ASTEROID

Nine months later, Galileo may have a second opportunity to observe an asteroid, in this case Ida, which is about 20 miles across. While there are believed to be differences between Ida and Gaspra, they are both believed to represent the majority of main-belt asteroids in composition.

Relative velocity for the Ida flyby will be nearly 28,000 mph, and the planned approach will be 600 miles.

APPROACHING JUPITER

Nearly 2.5 years after leaving Earth for the third time and five months before reaching Jupiter, Galileo's probe must separate from the orbiter, which will have been carrying it since before launch.

The spacecraft turns to aim the probe precisely toward its entry point in the atmosphere; it then spins up to 10 rpm and releases the spin-stabilized probe. Then the Galileo orbiter maneuvers again in order to aim for its own Jupiter encounter and resumes its scientific measurements of the interplanetary environment, which have been going on since the launch more than five years earlier.

JUPITER

Jupiter is the largest and fastest-spinning planet in the solar system. Its radius is more than 11 times Earth's and its mass is 318 times that of our planet. It is made mostly of light elements, principally hydrogen and helium. Its atmosphere and clouds are deep and dense, and a significant amount of energy is emitted from its interior. The earliest Earth-based telescopic observations detected bands and spots in Jupiter's atmosphere; one of these spots, known as the Red Spot, is a storm system that has persisted for over three centuries. Atmospheric forms and dynamics were observed in increasing detail by the Pioneer and Voyager flyby spacecraft, and Earth-based astronomers using infrared astronomy have recently studied the nature and vertical dynamics of deeper clouds.

Sixteen satellites are known. The four largest, discovered by the Italian scientist Galileo in 1610, are about the size of small planets. The innermost of these, Io, has active sulfurous volcanoes, discovered by Voyager 1 and further observed by Voyager 2 and Earth-based infrared astronomy. Io and Europa are about the size and density of the Earth's moon (three to four times the density of water) and are probably mostly rocky inside. Ganymede and Callisto, farther out from Jupiter, are the size of Mercury but less than twice as dense as water. Their cratered surfaces look icy in Voyager images, and they may be composed partly of ice or water.

Of the others, eight (probably captured asteroids) orbit irregularly far from the planet, and four (three discovered by the Voyager mission in 1979) are close to the planet. Voyager also discovered a thin ring system at Jupiter in 1979.

Jupiter has the strongest planetary magnetic field known; the resulting magnetosphere is a huge teardrop-shaped, plasma-filled cavity in the solar wind that points away from the sun. The inner part of the magnetic field is doughnut-shaped, but farther out it flattens into a disk. The magnetic poles are offset and tilted relative to Jupiter's axis of rotation, so the field appears to wobble with Jupiter's rotation (just under ten hours), sweeping up and down across the inner satellites and making waves throughout the magnetosphere.

AT JUPITER

Early in December 1995, the Galileo orbiter and probe will approach Jupiter separately. They will have traveled about 2.5 billion miles in a complex, multiple-looping path for more than six years. For the last 60 days of the approach, the orbiter will have carried out a comprehensive program of observations of Jupiter and measurements of its environment in space.

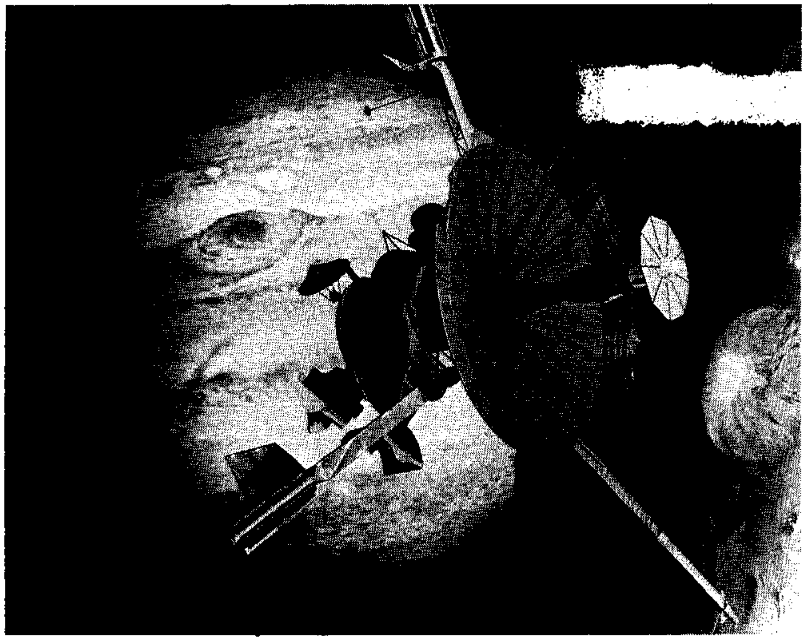
The probe will enter the atmosphere about 6 degrees north of the equator to make direct measurements. The orbiter will fly close to Io, receive the probe's signals for relay to Earth and go into orbit around Jupiter, all in a period of about seven hours.

While the probe is still approaching Jupiter, the orbiter will have its first two satellite encounters. After passing within 22,000 miles of Europa, it will fly about 600 miles above Io's volcanic surface (about one-twentieth of the closest approach of Voyager in 1979).

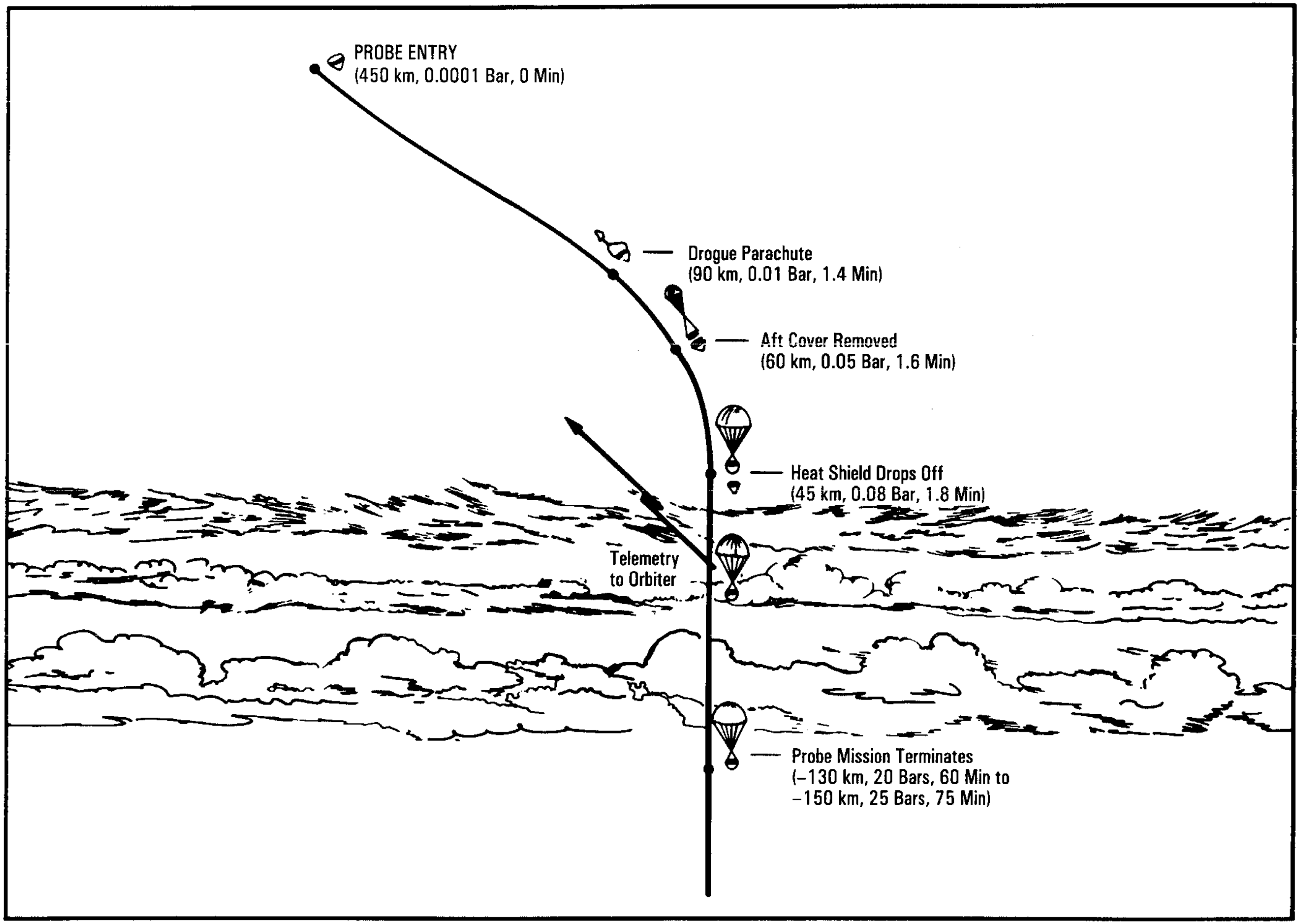
A few hours later, the probe will enter the upper atmosphere at nearly 100,000 mph. Aerodynamic braking will slow its descent, and in about two minutes it will drop its heat shields and deploy its parachute. This will allow it to float down about 125 miles through the clouds, passing from a pressure one-tenth that on Earth's surface to about 25 Earth atmospheres in 75 minutes. The probe's batteries are not expected to last beyond this point, and the relaying orbiter will move out of reach.

About 133,000 miles above the probe, the orbiter will receive, store and transmit the probe's scientific data. Then the orbiter must thrust its main engine to go into orbit around Jupiter. Throughout the 22-month orbital phase, Galileo will continue to observe the planet and its satellites and gather data on the magnetosphere environment.

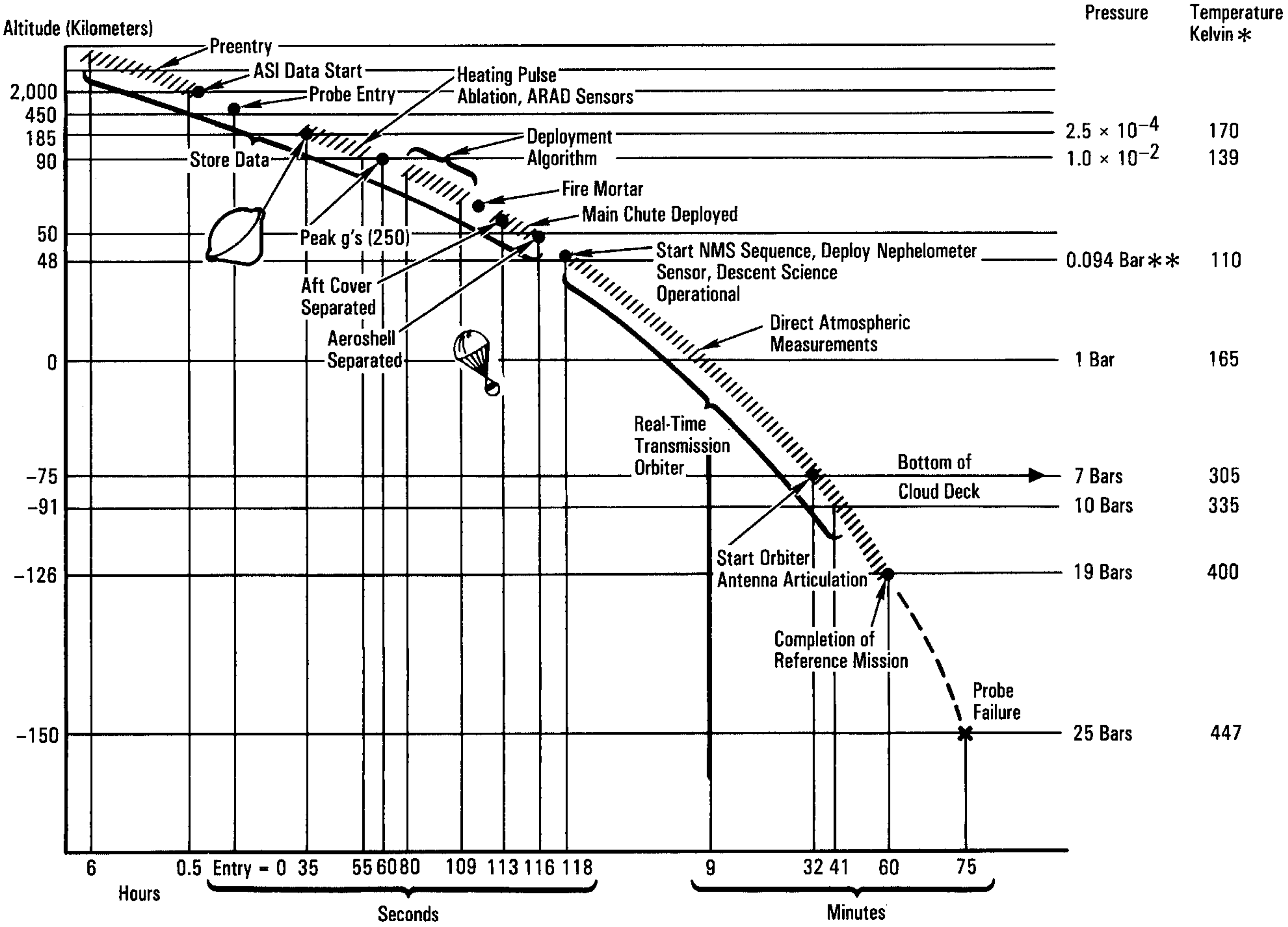
The first of ten planned orbits will have an eight-month period. A close flyby of Ganymede in July 1996 will shorten the orbit, and each time the orbiter returns to the inner zone of satellites it will make a gravity-assisted close pass over one or another of them to change its orbit and make close observations. These encounters will be at altitudes of as little as 125 miles.



Galileo Orbiter Passing Io on Its Way Into Its First Orbit Around Jupiter in December 1995



Galileo Probe Entry to Jupiter



✱ Kelvin—Temperature Measured in Degrees Celsius From Absolute Zero (Minus 273.15 C)

✱✱ Bar—A Metric Unit of Pressure

Galileo Entry/Descent Events

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 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.

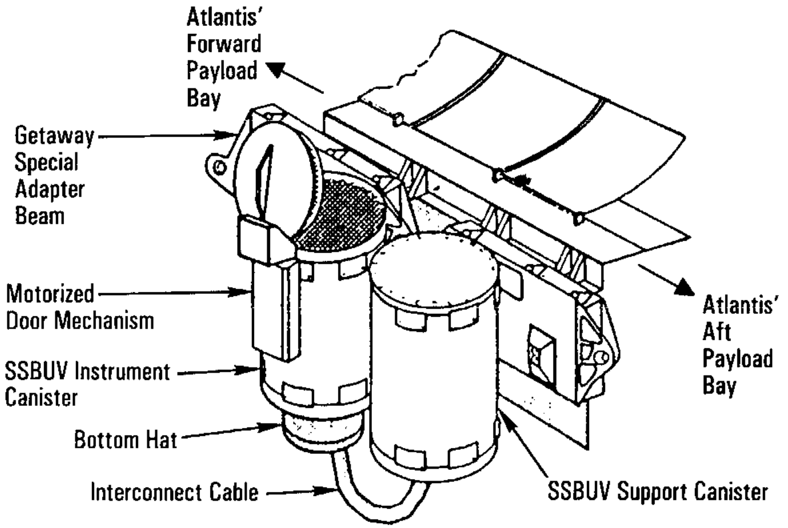
Solar backscatter ultraviolet instruments measure the amount and height distribution of ozone in the upper atmosphere by measuring incident solar ultraviolet radiation and ultraviolet radiation backscattered from the Earth's atmosphere. These parameters are measured in 12 discrete wavelength channels 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.

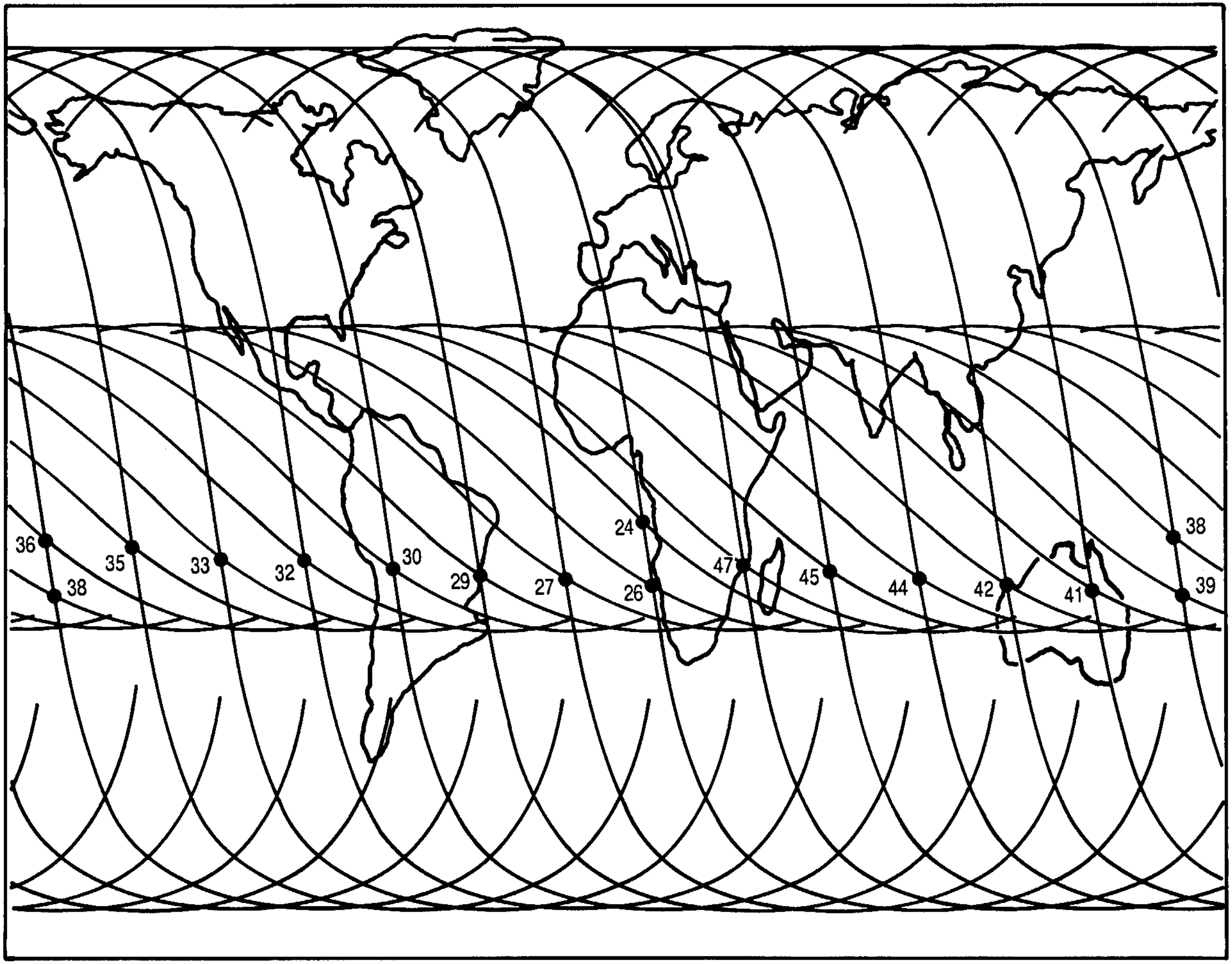
The SSBUV missions are so important to the support of Earth science that six additional missions have been added to the shuttle manifest to calibrate ozone instruments on future TIROS satellites. In addition, the four previously manifested SSBUV flights have been moved up.

The payload configuration consists of two canisters interconnected by cables mounted on a getaway special adapter beam on the starboard side of Atlantis' 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.

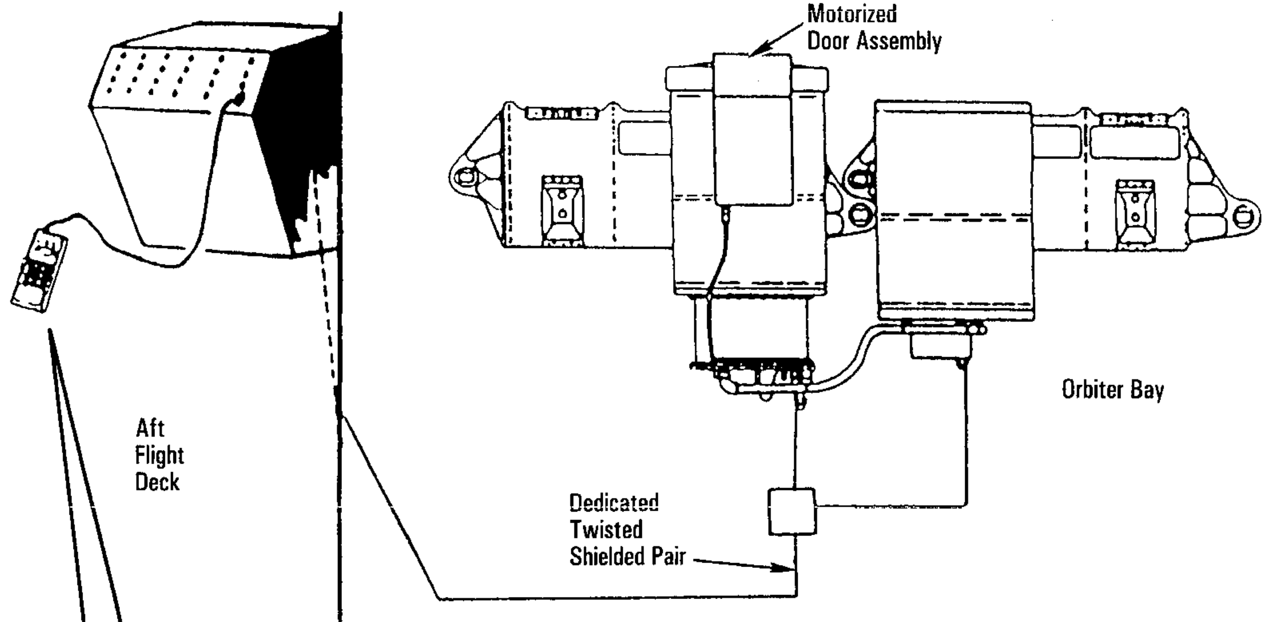
The SSBUV project is managed by NASA's Goddard Space Flight Center, Greenbelt, Md. Ernest Hilsenrath is the principal investigator.

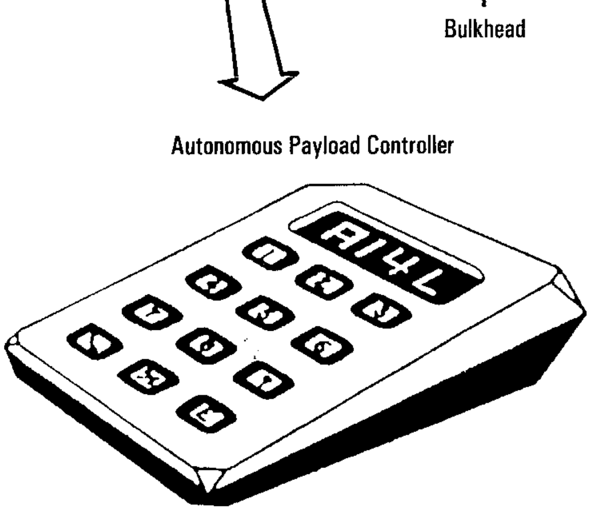


Shuttle Solar Backscatter Ultraviolet Experiment Configuration



An Analysis of Atlantis and NOAA's TIROS Satellite Orbits Demonstrates That 17 SSBUV Coincidences on Atlantis 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

POLYMER MORPHOLOGY EXPERIMENT

The Polymer Morphology Experiment is a 3M-developed organic material-processing experiment designed to explore the effects of microgravity on polymeric materials as they are processed in space.

Since melt processing is one of the more industrially significant methods of making products from polymers, it has been chosen for study in the PM Experiment. Key aspects of melt processing include polymerization, crystallization and phase separation. Each aspect will be examined in the PM Experiment. The polymeric systems for the first flight of the experiment include polyethelyne, nylon-6 and polymer blends.

The apparatus for the experiment includes a Fournier transform infrared (FTIR) spectrometer, an automatic sample-manipulating system, and a process control and data acquisition computer known as the generic electronics module. The experiment is contained in two separate, hermetically sealed containers that are mounted in the middeck of Atlantis' crew compartment. Each container includes an integral heat exchanger that transfers heat from the interior of the containers to the orbiter's environment. All sample materials are triply contained for the safety of the astronauts.

The samples of polymeric materials being studied in the PM Experiment are thin films (25 microns or less) approximately 25 millimeters in diameter. The samples are mounted between two infrared transparent windows in a specially designed infrared cell that provides the capability of thermally processing the samples to 200 C with a high degree of thermal control. The samples are mounted on a carousel that allows them to be positioned, one at a time, in the infrared beam where spectra may be acquired. The GEM provides all carousel and sample cell control. On this flight, the PM Experiment will process 17 samples.

The PM Experiment is unique among material-processing experiments in that measurements characterizing the effects of microgravity will be made in real time, as the materials are processed in space.

In most material-processing experiments in space, little or no measurements have been made during on-orbit processing and the effects of microgravity were determined later.

In the PM Experiment, infrared spectra (400 to 5,000 cm-1) will be acquired from the FTIR spectrometer by the GEM computer once every 3.2 seconds as the materials are processed. During 100 hours of processing time, approximately 2 gigabytes of data will be collected. After the flight, 3M scientists will process the data to clearly reveal the effects of microgravity on the samples processed in space.

The PM Experiment weighs approximately 200 pounds, occupies three standard middeck locker spaces in the orbiter (6 cubic feet total) and requires 240 watts to operate. This innovative apparatus was designed, developed and fabricated by 3M scientists and engineers.

Mission specialists Franklin Chang-Diaz and Shannon Lucid are responsible for the operation of the experiment on orbit. Their interface with the PM Experiment is through a small, NASA-supplied laptop computer that is used as an input and output device for the main PM computer. This interface has been programmed by 3M engineers to manage and display the large quantity of data available to the crew.

The PM Experiment is being conducted by 3M's Space Research and Applications Laboratory. Dr. Earl L. Cook is 3M's payload representative and mission coordinator. Dr. Debra L. Wilfong is PM's science coordinator and James E. Steffen is the hardware coordinator.

The PM Experiment, a commercial-development payload, is sponsored by NASA's Office of Commercial Programs. The PM

Experiment will be 3M's fifth space experiment and the first under the company's 10-year Joint Endeavor Agreement with NASA for 62 flight experiment opportunities. Previous 3M space experiments have studied organic crystal growth from solution (Diffusive Mixing of Organic Solutions on missions STS 51-A and STS 61-B) and organic thin-film growth (Physical Vapor Transport Organic Solids on STS 51-I and STS-26).

IMAX CAMERA

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

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

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

The IMAX camera, last carried on STS-29, will be used on this mission to cover the deployment of the Galileo spacecraft and to gather material on the use of observations of the Earth from space for IMAX films to succeed "The Dream Is Alive."

MESOSCALE LIGHTNING EXPERIMENT

The Mesoscale Lightning Experiment will be conducted on the STS-34 mission. The MLE is designed to obtain nighttime images of lightning in order to better understand the global distribution of lightning, the interrelationships of lightning events in storms that are close together, and the relationships of lightning, convective storms and precipitation.

A better understanding of the relationships of lightning and thunderstorm characteristics can lead to the development of applications for severe-storm warning and forecasting and early warning systems for lightning threats to life and property.

In recent years, NASA has used the STS-26 and STS-30 missions and high-altitude U-2 aircraft to observe lightning from above convective storms. The objectives of these observations have been to determine some of the baseline design requirements for an optical lightning mapper sensor on satellites; study the overall optical and electrical characteristics of lightning as viewed from above the cloud tops; and investigate the relationship between the electrical development of storms and the structure, dynamics and evolution of thunderstorms and thunderstorm systems.

The MLE began as an experiment to demonstrate that meaningful, qualitative observations of lightning could be made from the space shuttle orbiters. Having accomplished this, the experiment is now focused on obtaining quantitative measurements of lightning's characteristics and simulating observations for future spaceborne lightning sensors.

Data from the MLE will provide information for use in the development of observation simulations for an upcoming polar platform and space station instrument, the lightning imaging sensor. The lightning experiment also will be helpful for designing procedures for using the lightning mapper sensor planned for several geostationary platforms.

Atlantis' payload bay cameras will be pointed directly below Atlantis to observe nighttime lightning in large, or mesoscale, storm systems to gather global estimates of lightning as observed from Atlantis' altitudes. Scientists on the ground will analyze the imagery for the frequency of lightning flashes in active storm clouds within the camera's field of view, the length of lightning discharges and cloud brightness when the cloud is illuminated by the lightning discharge within it.

If time permits during the mission, the flight crew will also use a handheld 35mm camera to photograph lightning activity in storm systems not directly below Atlantis' orbital track.

Data from the MLE will be combined with data from observations of lightning made at several locations on the ground, including the Marshall Space Flight Center, Huntsville, Ala.; the Kennedy Space Center, Fla.; and the NOAA Severe Storms Laboratory, Norman, Okla. Other ground-based lightning detection systems in Australia, South America and Africa will be integrated when possible.

The MLE is managed by NASA's Marshall Space Flight Center. Otha H. Vaughn Jr. is coordinating the experiment. Dr. Hugh Christian is the project scientist and Dr. James Arnold is the project manager.

AIR FORCE MAUI OPTICAL SITE CALIBRATION TEST

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 Atlantis during cooperative overflights. This experiment is a continuation of tests made on the STS-29 and STS-30 missions. The scientific observations made of Atlantis while it performs reaction control system thruster firings, water dumps or payload bay light activation are used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models. The AMOS tests involve no payload-unique flight hardware and only require that Atlantis 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.

GROWTH HORMONE CONCENTRATIONS AND DISTRIBUTION IN PLANTS EXPERIMENT

The Growth Hormone Concentrations and Distribution in Plants Experiment is designed to determine the effects of microgravity on the concentration, turnover properties and behavior of the plant growth hormone, auxin, in the tissue of shoots of corn *(Zea mays)*.

Mounted in foam blocks inside two standard middeck lockers, the equipment consists of four plant canisters, two gaseous nitrogen freezers and two temperature recorders. Equipment for the experiment, excluding the lockers, weighs 97.5 pounds.

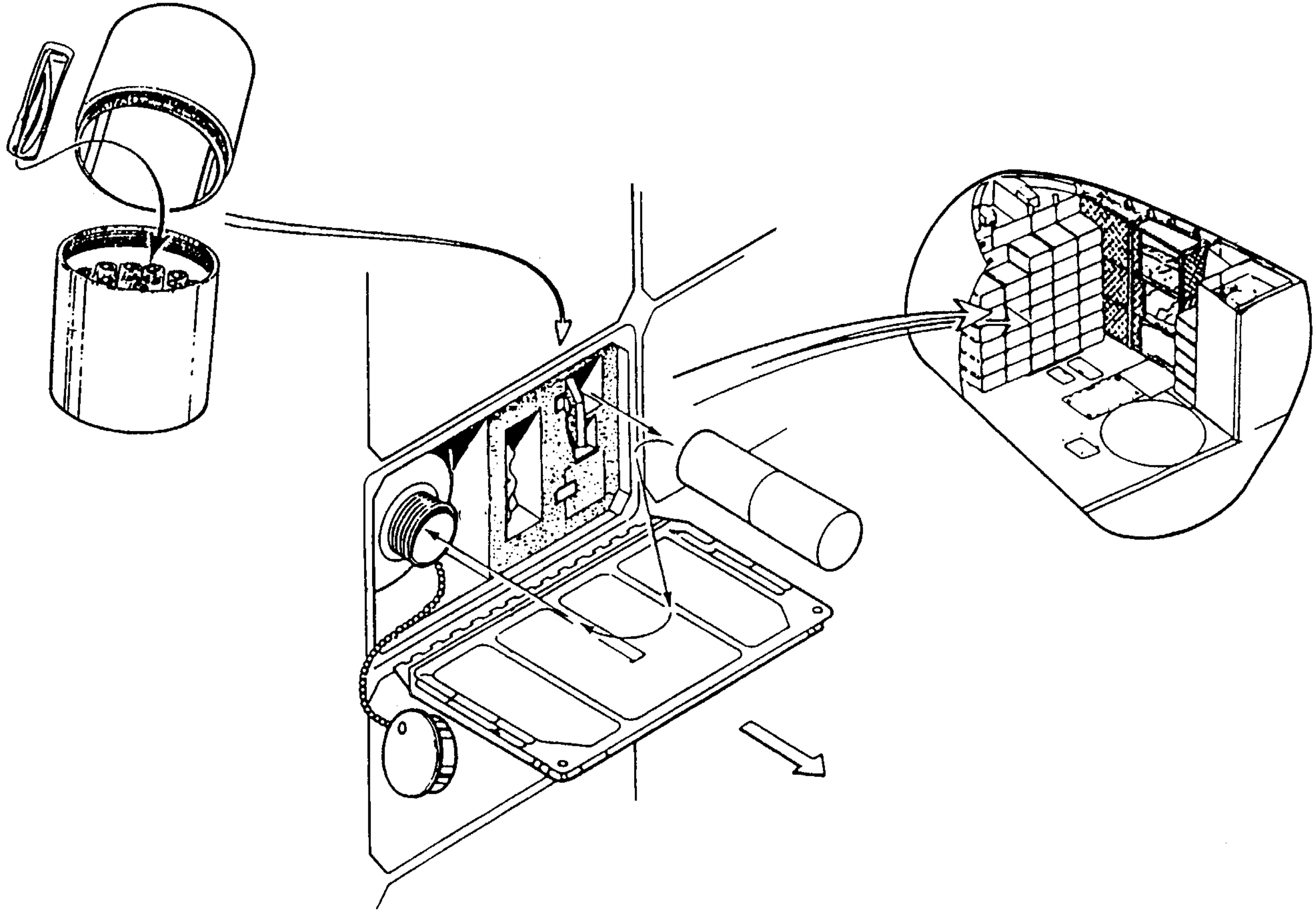
A total of 228 seeds will be "planted" in special filter paper-Teflon tube holders no more than 56 hours before the flight. The seeds will remain in total darkness throughout the mission.

The GHCD experiment equipment and specimens will be prepared in a payload-processing facility at KSC and placed in the middeck lockers. The GHCD lockers will be installed in the orbiter during the last 14 hours before the launch.

No sooner than 72 hours after the launch, mission specialist Ellen Baker will place two of the plant canisters in the gaseous nitrogen freezers to arrest plant growth and to preserve the specimens. The payload will be restowed in the lockers for the remainder of the mission.

After the landing, the payload must be removed from the orbiter within two hours and will be returned to customer representatives at the landing site. The specimens will then be examined for microgravity effects.

The experiment is sponsored by NASA Headquarters, the Johnson Space Center and Michigan State University.



Growth Hormone Concentrations and Distribution
in Plants Experiment Payload

SENSOR TECHNOLOGY EXPERIMENT

The Sensor Technology Experiment is a radiation detection experiment designed to measure the natural radiation background. It is a self-contained experiment with its own power, sensor, computer control and data storage. A calibration pack composed of a small number of passive threshold reaction monitors is attached to the outside of the STEX package.

The STEX package weighs approximately 50 pounds and will be stowed in a standard middeck locker throughout the flight. The experiment is sponsored by the Strategic Defense Initiative Organization.

SHUTTLE STUDENT INVOLVEMENT PROJECT EXPERIMENT

The SSIP was created in 1980 to stimulate interest in science and technology by directly involving intermediate and secondary school students in space research.

Originally, the program was designed to develop payload experiments that could fly on the space shuttle. In 1986, the program was redesigned to allow students to design aerospace science experiments that could theoretically be conducted on the space station, in a wind tunnel or in a zero-gravity research facility. The program also was expanded to include students interested in space, but not necessarily in scientific research. These students participate in Mars settlement illustration or school newspaper promotion competitions, for example.

Since 1980, NASA's Educational Affairs Division, in coordination with the National Science Teachers Association, has introduced the SSIP to approximately 6 million students and their teachers. To date, over 15,000 students have submitted proposals for aerospace science experiments.

SE 82-15, ZERO-GRAVITY GROWTH OF ICE CRYSTALS FROM SUPERCOOLED WATER WITH RELATION TO TEMPERATURE

This experiment, proposed by Tracy L. Peters, formerly of Ygnacio High School in Concord, Calif., will observe the geometric ice crystal shapes formed at supercooled temperatures (below zero degrees Celsius) without the influence of gravity. This experiment was developed in 1983.

Liquid water has been discovered at temperatures far below water's freezing point. This phenomenon occurs because liquid water does not have a nucleus, or core, around which to form the crystal. When the ice freezes at supercold temperatures, the ice takes on many geometric shapes based on the hexagon. The shape of the crystal depends primarily on the supercooled temperature and saturation of water vapor. The shapes of the crystals vary from simple plates to complex prisms.

Many scientists have tried to determine the relation between temperature and geometry; but gravity has deformed crystals, caused convection currents in temperature-controlled apparatus and caused faults in crystalline structures. These all affect crystal growth through either rapid fluctuations in temperature or the gravitational influence of crystal geometry.

The results of this experiment could aid in the design of radiator cooling and cryogenic systems and in the understanding of high-altitude meteorology and planetary ring structure theories.

The experiment is located in the middeck of Atlantis' crew compartment.

Peters is now a physics student at the University of California, Berkeley. His teacher advisor is James R. Cobb, Ygnacio High School; his sponsor is Boeing Aerospace Corporation, Seattle; and his science advisor is Vernon Klockzien of Boeing.

ON-ORBIT DEVELOPMENT TEST OBJECTIVES

TDRS-TO-TDRS HANDOVER DEMONSTRATION

The purpose of this on-orbit development test objective is to demonstrate S-band and Ku-band and TDRS-to-TDRS handover capabilities. The handovers are ground commanded. Following each handover, the flight crew will record any changes in voice quality.

TEXT AND GRAPHICS SYSTEM TEST

This DTO is designed to test and evaluate TAGS under zero-g to increase confidence in the system significantly and to generate data for comparison with data from 1-g test conditions. Approximately 400 images will be sent.

GRAVITY GRADIENT ATTITUDE CONTROL

Data collected during this DTO will help researchers refine the computer models used to predict stable gravity gradient attitudes. On STS-34, only long-duration tests (eight to 12 hours) will be done. The long-duration tests will help researchers determine the amplitude of steady-state attitude oscillations and the sensitivity of these oscillations to attitude and rate errors at attitude initiation.

CAMCORDER DEMONSTRATION

The DTO will evaluate the unique hardware aspects of a camcorder as well as crew use of and interaction with it. Various factors that affect camera performance will be evaluated, including low light level, macrozoom capability and fiber optics accessories.

IN-FLIGHT SALIVARY PHARMACOKINETICS OF SCOPOLAMINE AND DEXTROAMPHETAMINE

The purpose of this detailed supplementary objective is to investigate the pharmacokinetics of anti-motion sickness agents during spaceflight and predict the resultant therapeutic consequences. A crew member will take the drug after an eight-hour fast and take salivary samples at required intervals during the flight day.

THE RELATIONSHIP OF SPACE ADAPTION SYNDROME TO MIDDLE CEREBAL ARTERY BLOOD VELOCITY MEASURED IN-FLIGHT BY DOPPLER

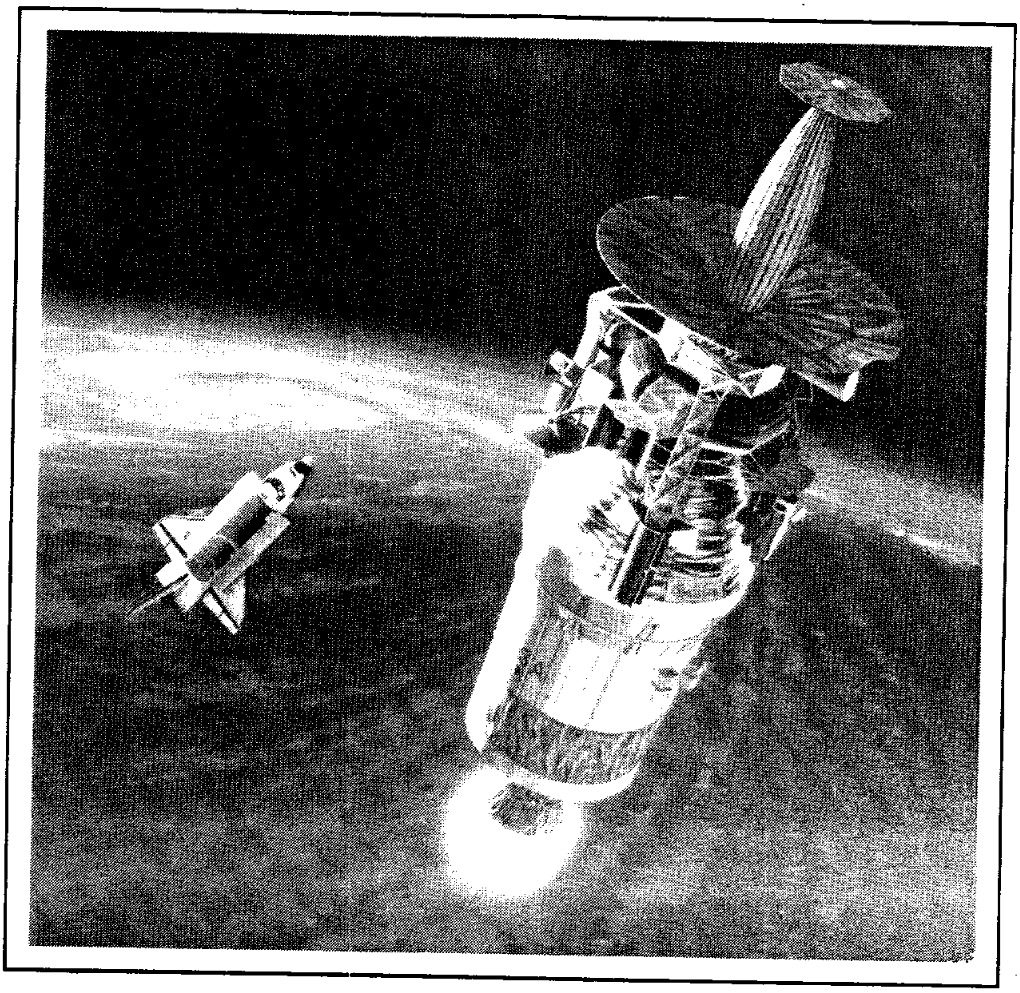
The objectives of this DSO are to explore the in-flight use of a small, lightweight, portable instrument capable of measuring blood flows in the microgravity environment and correlate changes in blood flow with the onset and severity of space adaptation syndrome. The measurement sessions will be performed on flight day 1 and after sleep on flight day 2.

DELAYED-TYPE HYPERSENSITIVITY

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

RETINAL PHOTOGRAPHY

The objectives of this DSO are to analyze retinal photographs obtained during the flight and determine if microgravity-induced cephalad fluid shifts elevate intracranial pressure. Evidence of increased intracranial pressure and the development of space adaptation syndrome will be sought.



STS-34

MISSION STATISTICS
PRELAUNCH COUNTDOWN TIMELINE
MISSION TIMELINE

October 1989

Rockwell International
Space Transportation
Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the fifth flight of Atlantis and the 30th in the space transportation system.

The flight crew for the STS-34 mission consists of commander Donald E. Williams; pilot Michael J. McCulley; and mission specialists Shannon W. Lucid, Ellen S. Baker and Franklin R. Chang-Diaz.

The primary objective of this five-day mission is to deploy the Galileo spacecraft mated with an inertial upper stage. After deployment of the Galileo spacecraft with its IUS from Atlantis' payload bay, the IUS will insert Galileo into a Venus-Earth-Earth gravity assist (VEEGA) trajectory to Jupiter.

Deployment of the Galileo spacecraft and IUS from Atlantis' payload bay is scheduled nominally to occur on the fifth orbit at a mission elapsed time of six hours and 22 minutes. 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 nominally will be ignited just prior to the beginning of orbit 6A (ascending node), approximately one hour after deployment of the IUS and Galileo spacecraft. (Each orbit begins when Atlantis has crossed the equator on its ascending node.) Ignition of the second-stage SRM of the IUS occurs approximately two minutes after IUS first-stage SRM cutoff. After being boosted out of earth orbit by the IUS, Galileo is separated from the IUS; Galileo will fly past Venus and twice by Earth in gravity-assist maneuvers to pick up enough speed to reach Jupiter. Travel time from launch to Jupiter is a little more than six years.

Galileo is a NASA spacecraft mission to Jupiter, designed to study the planet's atmosphere, satellites and surrounding magnetosphere. It was named for the Italian Renaissance scientist who discovered Jupiter's major moons with the first astronomical telescope.

This mission will be the first to make direct measurements from an instrumented probe within Jupiter's atmosphere, and the first to conduct long-term observations of the planet and its magnetosphere and satellites from orbit around Jupiter. It will be the first orbiter and atmospheric probe for any of the outer planets.

On the way to Jupiter, Galileo will also observe Venus, the Earth-moon system, one or two asteroids and various phenomena in interplanetary space.

The Galileo spacecraft was prepared by the Jet Propulsion Laboratory, Pasadena, California.

Eight other payloads, referred to as secondary payloads, are carried aboard Atlantis in the mission.

The Shuttle Solar Backscatter Ultraviolet instrument in Atlantis' payload bay 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 Polymer Morphology Experiment is a 3M-developed organic materials processing experiment designed to explore the effects of microgravity on polymeric materials as they are processed in space. The samples of polymeric materials being studied in this experiment are thin films (25 microns or less) approximately 25 millimeters in diameter. The experiment is contained in two separate hermetically sealed containers mounted in Atlantis' middeck.

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The Sensor Technology Experiment is a radiation detection experiment designed to measure the natural radiation background. STEX is a self-contained experiment with its own power, sensor, computer control and data storage, stowed in a standard middeck locker throughout the flight.

Zero Gravity Growth of Ice Crystals Student Experiment will observe the geometric ice crystal shapes formed at super-cooled temperatures, below zero degrees Celsius without the influence of gravity. The experiment is located in Atlantis' middeck.

MISSION STATISTICS

Launch: Launch window duration increases from a minimum of 9 minutes to a maximum of 47 minutes in the middle, then decreases to 9 minutes at the end of the launch window on Nov. 21.

10/12/89 1:29 p.m. EDT
12:29 p.m. CDT
10:29 a.m. PDT

Mission Duration: 120 hours (5 days), 2 hours, 45 minutes

Landing: Nominal end of mission is on orbit 82.

10/17/89 4:14 p.m. EDT
3:14 p.m. CDT
1:14 p.m. PDT

Inclination: 34.30 degrees; first flight at this inclination

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 161 nautical miles (184 by 185 statute miles), then 161 by 178 nautical miles (185 by 204 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,523,129 pounds

Orbiter Weight, Including Cargo at Lift-off: Approximately 257,012 pounds

Payload Weight Up: Approximately 49,013 pounds

Payload Weight Down: Approximately 10,625 pounds

Orbiter Weight at Landing: Approximately 194,938 pounds

Payloads: Galileo/IUS-2; SSBUV-01, IMAX-02, PM-01, GHCD, STEX, MLE-03, AMOS-03, and student experiment SE 82-15

Flight Crew Members:
Commander: Donald E. Williams, second space shuttle flight
Pilot: Michael J. McCulley, first space shuttle flight
Mission Specialist 1: Shannon W. Lucid, second space shuttle flight
Mission Specialist 2: Franklin R. Chang-Diaz, second space shuttle flight
Mission Specialist 3: Ellen S. Baker, first space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Donald Williams
Flight deck front right seat, pilot Michael McCulley
Flight deck aft center seat, MS-2 Franklin Chang-Diaz
Flight deck aft right seat, MS-1 Shannon Lucid
Middeck, MS-3 Ellen Baker

Entry Seating:
Flight deck aft right seat, MS-3 Ellen Baker
Middeck, MS-1 Shannon Lucid

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut (EV-1) would be Franklin Chang-Diaz and EV-2 would be Ellen Baker.

Angle of Attack, Entry: 40 degrees

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

Runway: Nominal end-of-mission landing will be on dry lake bed Runway 17 at Edwards Air Force Base, California.

Notes:

- The remote manipulator system is not installed in Atlantis' payload bay for this flight. The galley is installed in the middeck of Atlantis for this flight.

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

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

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

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

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

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

MISSION OBJECTIVES

- Deployment of Galileo spacecraft with IUS
- Secondary payloads
  - SSBUV-01
  - IMAX-02
  - PM-01
  - GHCD
  - STEX
  - MLE-03
  - AMOS-03
  - SE 82-15

DEVELOPMENT TEST OBJECTIVES

- Ascent structural capability evaluation
- Entry structural capability
- Ascent flutter boundary evaluation (data collection only; no change to ascent design)
- Pogo stability performance
- External tank thermal protection system performance (flight crew maneuvers Atlantis to photograph external tank after separation)
- Shuttle/payload low frequency
- Hot nose wheel steering runway evaluation (if no crosswind, go for nose wheel steering between 120 to 140 knots, left and right of runway centerline 30 degrees)
- Camcorder demonstration
- TDRS-to-TDRS handover demonstration
- Text and graphics system
- Crosswind landing performance
- Gravity gradient attitude control

DETAILED SUPPLEMENTARY OBJECTIVES

- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Variations in supine and standing heart rate, blood pressure, and cardiac size as a function of space flight and time postflight
- The relationship of space adaptation syndrome to middle cerebral artery blood velocity measured in flight by Doppler
- Delayed-type hypersensitivity
- Retinal photography
- Muscle biopsy (pre- and postflight)
- Muscle performance
- Documentary television
- Documentary motion picture photography
- Documentary still photography

PRELAUNCH COUNTDOWN

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

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

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

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

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:09:00 Hold 40 Minutes	A planned 40-minute hold starts.
	NASA and contractor project managers will be formally polled by the deputy director of NASA, National Space Transportation System (NSTS) Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records.
	All test support team members verify that they are "go for launch."
	Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins.
	The chase aircraft are launched.
	From this point the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the onboard orbiter PASS redundant-set computers.
00:09:00	Operations recorders are on. MCC-H, Johnson Space Center, sends a command to turn these recorders on. They record shuttle system performance during ascent and are dumped to the ground once orbit is achieved.
00:08:00	Payload and stored prelaunch commands proceed.
00:07:30	The orbiter access arm (OAA) connecting the access tower and the orbiter side hatch is retracted. If an emergency arises requiring flight crew activation, the arm can be extended either manually or by GLS computer control in approximately 30 seconds or less.
00:05:00	Orbiter APUs start. The orbiter APUs provide pressure to the three orbiter hydraulic systems. These systems are used to move the SSME engine nozzles and aerosurfaces.
00:05:00	ET/SRB range safety system (RSS) is armed. At this point, the firing circuit for SRB ignition and destruct devices is mechanically enabled by a motor-driven switch called a safe and arm device (S&A).

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

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

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

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

MISSION TIMELINE

DAY ZERO

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:00:06.8	Tower is cleared (SRBs above lightning rod tower).
0/00:00:08	120-degree roll maneuver positive roll (right-clockwise) is started. Pitch profile is heads down (astronauts) wings level.
0/00:00:20	Roll maneuver ends.
0/00:00:28	All three SSMEs throttle from 104 to 65 percent for maximum aerodynamic load (max q).
0/00:00:55	Max q occurs.
0/00:00:58	All three SSMEs throttle to 104 percent.
0/00:02:05	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 they are recovered for reuse in another mission. Flight control system switchover from SRB to orbiter RGAs occurs.
0/00:04:01	Negative return. The vehicle is no longer capable of return-to-launch-site (RTLS) abort to Kennedy Space Center runway.
0/00:06:56	Single engine to main engine cutoff (MECO).
0/00:07:30	All three SSMEs throttle from 104 percent for vehicle no greater than 3-g acceleration capability.
0/00:08:23	All three SSMEs throttle down to 65 percent for MECO.
0/00:08:33	MECO, approximate velocity 25,873 feet per second (fps), 156 by 39 nautical miles (nmi) (179 by 44 statute miles [sm]).

T + (PLUS)
DAY/
HR:MIN:SEC

EVENT

0/00:08:51 ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).

The orbiter forward and aft reaction control systems (RCSs), which provide altitude hold and negative Z translation of 11 fps to the orbiter for separation of ET from orbiter, are first used.

ET liquid oxygen valve is opened at separation to induce a tumble to ET 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 on 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 SSMEs' combustion chamber nozzles and the liquid hydrogen is dumped out through the right-hand side T minus zero (T-0) 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.
- 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.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— MPS vacuum inerting terminates.
0/00:42	OMS-2 thrusting maneuver is performed, 2 minutes 15 seconds in duration, 218.3 fps, 160 by 161 nmi (184 by 185 sm).
0/00:53	MS seat egress occurs.
0/00:54	Commander and pilot configure general-purpose computers (GPCs) for OPS-2.
0/00:57	MS configures middeck.
0/00:59	MS configures aft station.
0/01:08	Pilot activates payload bus.
0/01:10	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers to payload bay door opening attitude, negative Z local vertical biased negative Y velocity vector.
0/01:16	Commander activates radiators.
0/01:18	MS configures for payload bay door operations.
0/01:20	Commander loads payload data interleaver (PDI).
0/01:21	Orbit 2 begins.
0/01:28	Pilot opens payload bay doors.
0/01:30	Commander powers the star trackers (STs) ON.
0/01:36	MCC-H gives flight crew "go for orbit operations."
0/01:37	Commander and pilot egress seats.
0/01:38	Commander and pilot doff launch entry suits (LESs).
0/01:39	MSs doff LESs.
0/01:50	Pilot activates AUTO fuel cell purge.
0/01:51	MS activates teleprinter, if flown.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:52	Commander configures radiators for postpayload bay door opening operations.
0/01:55	MS removes and stows seat.
0/01:56	Commander opens ST doors and performs self-test.
0/01:57	Pilot closes MNB supply H_2O dump isolation circuit breaker, ML86, and activates supply H_2O dump isolation valve open (OP) on R12L.
0/02:00	Pilot activates auxiliary power unit (APU) steam vent heater boiler control power heater (3) to A, controller (3) power to ON.
0/02:05	MS performs radioisotope thermoelectric generator (RTG) panel checks.
0/02:09	MS engages inertial upper stage (IUS) actuator.
0/02:10	Commander configures RCS vernier control.
0/02:11	Commander and pilot configure controls for on orbit and unstow and install head-up display (HUD) covers.
0/02:14	MS assembles photo/TV camera.
0/02:21	Pilot enables hydraulic systems thermal conditioning.
0/02:24	MS resets caution and warning (C/W) system.
0/02:26	MS unstows and installs treadmill in middeck.
0/02:27	Pilot switches APU fuel pump/valve cool from A-OFF to B-AUTO.
0/02:29	Pilot plots fuel cell performance.
	EZ ACTIVITIES
	— LES cleaning and drying, 25 minutes
	— Pressure control system (PCS) configure system 1, 5 minutes, 2 crewmen
	— Lamp and fire suppression test, 10 minutes

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— Food preparation, 30 minutes
	— Iodine samples.
0/02:30	Flight crew unstows cabin equipment.
0/02:36	Ku-band antenna deployment.
0/02:41	Photo/TV are activated for satellite deployment scenes.
0/02:46	Ku-band activated in communication mode.
0/02:46	IUS predeployment checkout is performed.
0/02:51	Orbit 3 begins.
0/02:56	IUS direct check and predeployment checks are performed.
0/03:00	Checkout of aft controller is performed.
0/03:06	IUS predeployment checks occur.
0/03:11	Attitude match update (AMU)/inertial measurement unit (IMU) sequence is initiated.
0/03:12	AMU data take No. 1 occurs.
0/03:15	Crew maneuvers vehicle to AMU No. 2 attitude.
0/03:15	Sensor Technology Experiment (STEX) is activated.
0/03:21	Cryogenic O_2 tank heater sensor check is performed.
0/03:25	AMU data take No. 2 occurs.
0/03:27	Crew maneuvers vehicle to AMU No. 3 attitude.
0/03:31	Polymer Morphology (PM) Experiment is set up.
0/03:35	Videotape recorder (VTR) is played back from 0/03:35 to 0/03:45.
0/03:37	AMU data take No. 3 occurs.
0/03:39	Crew maneuvers vehicle to star pair (A2) attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:41	APU steam vent heater is deactivated; boiler power switches (3) are turned to OFF.
0/03:51	AMU data take No. 4 occurs.
0/03:55	Crew maneuvers vehicle to plus Z solar inertial attitude.
0/04:01	AMU/IMU sequence is performed.
0/04:06	APU cool-off occurs; APU fuel pump/valve cool B is turned to OFF.
0/04:11	STEX is calibrated.
0/04:15	Crew mealtime.
0/04:21	Orbit 4 begins.
0/04:36	Vehicle transfers state vector for IUS deployment; predeployment checks are performed.
0/05:15	Crew maneuvers vehicle to deployment attitude.
0/05:15	APU heater gas generator/fuel pumps (3) are turned to AUTO.
0/05:27	IUS payload interleaver (PI) locks.
0/05:30	Photo/TV are activated for satellite deployment scenes.
0/05:37	Tilt table is elevated to 29 degrees.
0/05:51	Orbit 5 begins.
0/05:52	Flight crew is informed "go for deploy." Crew begins deployment countdown, releases umbilicals and elevates tilt table to 58 degrees.
0/06:14	Purge of Galileo's RTGs starts.
0/06:19	Purge of RTGs stops.
0/06:22	Galileo/IUS is deployed.
0/06:22	Crew maneuvers Atlantis to postdeployment attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/06:30	Tilt table is lowered to minus 6 degrees.
0/06:37	OMS separation thrusting maneuver occurs, 16 seconds in duration, 32 fps, 161 by 178 nmi (185 by 204 sm).
0/06:37	Crew maneuvers Atlantis to IUS viewing attitude.
0/07:07	Crew maneuvers Atlantis to window protection attitude.
0/07:07	Closeout and postdeployment operations are performed.
0/07:16	VTR is set up for satellite deployment.
0/07:22	IUS solid rocket motor (SRM) 1 is ignited.
0/07:22	Orbit 6 begins.
0/07:25	Payload interleaver is turned to OFF.
0/07:30	VTR playback of the satellite deployment occurs at TDRS-West, 0/07:30 to 0/07:45.
0/07:31	Pulse code modulation master unit (PCMMU) format is loaded.
0/07:31	STEX is calibrated.
0/07:46	Blood velocity is measured in flight (medical DSO).
0/08:00	Crew maneuvers vehicle to IMU alignment attitude.
0/08:11	Retinal photos are taken (medical DSO).
0/08:16	Crew aligns IMU using ST.
0/08:20	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
0/08:21	Photo/TV are set up for flight deck scenes.
0/08:36	Autonomous payload controller (APC) is unstowed and set up for Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment.
0/08:46	SSBUV system verification is performed.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/08:51	Photo/TV are activated for flight deck scenes.
0/08:51	SSBUV Experiment outgas occurs, Step 1.
0/08:53	Orbit 7 begins.
0/08:55	Crew begins presleep activity.
0/09:26	Flash evaporator controller primary A (B) is turned to OFF.
0/09:51	PM Experiment is initiated for samples 1, 2, 3 and 4; sample status is checked.
0/10:23	Orbit 8 begins.
0/11:00	Crew begins 8-hour sleep period.
0/11:54	Orbit 9 begins.
0/13:25	Orbit 10 begins.
0/14:55	Orbit 11 begins.
0/16:26	Orbit 12 begins.
0/17:57	Orbit 13 begins.
0/19:00	Crew ends 8-hour sleep period and begins postsleep activity.
	EZ ACTIVITIES
	— Exercise, 1 hour, all.
	— Food preparation, 30 minutes.
	— Iodine samples.
0/19:05	Salivary pharmacokinetics for scopolamine and dextroamphetamine is performed (medical DSO).
0/19:27	Orbit 14 begins.
0/19:35	Salivary SCOP/DEX is performed (medical DSO).
0/20:05	Salivary SCOP/DEX is performed (medical DSO).
0/20:58	Orbit 15 begins.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/21:05	Salivary SCOP/DEX is performed (medical DSO).
0/21:10	SSBUV Experiment outgas is performed.
0/21:15	Blood velocity is measured (medical DSO).
0/21:20	SSBUV Experiment is activated.
0/21:25	Crewman optical alignment sight (COAS) power is turned to OFF. COAS is mounted aft.
0/21:35	Crew maneuvers vehicle to IMU alignment attitude.
0/21:55	IMU is aligned using ST.
0/21:55	COAS is calibrated.
0/22:00	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
0/22:20	Photo/TV are set up for IMAX scenes.
0/22:20	SSBUV Experiment is calibrated, Step 1.
0/22:29	Orbit 16 begins.
0/23:05	Salivary SCOP/DEX is performed (medical DSO).
0/23:15	PM Experiment sample 4 is checked, sample status is recorded.
0/23:20	SSBUV Experiment is calibrated, Step 2.
0/23:30	Crew maneuvers vehicle to negative Z solar inertial attitude.
0/23:30	SSBUV Experiment is set up for solar view at sunrise, 0/23:42.
0/23:59	Orbit 17 begins.

DAY ONE

1/00:20	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
1/00:25	Crew performs scheduled in-flight maintenance and filter cleaning.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:35	Photo/TV are set up for flight deck scenes and camcorder.
1/00:50	PM Experiment is initiated for samples 5 and 6; sample status is checked.
1/01:05	Salivary SCOP/DEX is performed (medical DSO).
1/01:05	Photo/TV are activated for flight deck scenes and camcorder
1/01:05	SSBUV Experiment is set up for earth view, Step 1, at sunrise, 1/01:13:03.
1/01:30	Orbit 18 begins.
1/01:40	Photo/TV are activated for IMAX scenes of Dallas and Ft. Worth, oil fields, Ouashita Mountains and Chesapeake Bay.
1/01:55	PM Experiment sample 5 is checked; sample status is checked.
1/02:00	Student ice crystal experiment is activated.
1/02:15	Crew mealtime.
1/03:00	Salivary SCOP/DEX is performed (medical DSO).
1/03:01	Orbit 19 starts.
1/03:16	Text and graphics system paper roll is unloaded and reloaded.
1/03:20	Photo/TV are activated for IMAX scenes of Los Angeles.
1/04:31	Orbit 20 begins.
1/04:35	PM Experiment sample 6 is checked; sample status is checked.
1/04:45	Photo/TV are activated for Grand Canyon and oil fields.
1/05:05	Salivary SCOP/DEX is performed (medical DSO).
1/05:50	Photo/TV are activated for Indonesian volcanoes.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/06:00	Photo/TV are set up for middeck scenes, camcorder and student ice crystal experiment.
1/06:02	Orbit 21 begins.
1/06:30	Photo/TV are activated for middeck scenes, camcorder and student ice crystal experiment.
1/06:35	Ice crystal experiment recycles.
1/06:50	PM Experiment is initiated for samples 7, 8 and 9; sample status is checked.
1/07:05	Salivary SCOP/DEX is performed (medical DSO).
1/07:35	Photo/TV are activated for middeck scenes and retinal photography.
1/07:32	Orbit 22 begins.
1/07:45	Retinal photos are taken (medical DSO).
1/08:00	Flight crew begins presleep activity.
1/08:05	Photo/TV are activated for middeck scenes and retinal photography.
1/08:10	Crew maneuvers vehicle to IMU alignment attitude.
1/08:30	IMU is aligned using ST.
1/08:30	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
1/08:35	Ice crystals experiment is deactivated.
1/08:55	PM Experiment sample 7 is checked; sample status is recorded.
1/09:00	Flash evaporator controller primary A (B) is turned to ON
1/09:03	Orbit 23 begins.
1/09:20	Photo/TV are set up, crew's choice.
1/09:50	Photo/TV are activated, crew's choice.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/10:34	Orbit 24 begins.
1/11:00	Flight crew begins 8-hour sleep period.
1/12:04	Orbit 25 begins.
1/13:35	Orbit 26 begins.
1/15:06	Orbit 27 begins.
1/16:36	Orbit 28 begins.
1/18:07	Orbit 29 begins.
1/19:00	Flight crew ends 8-hour sleep period and begins postsleep activity.
1/19:05	Salivary SCOP/DEX is performed (medical DSO).
	EZ ACTIVITIES
	— Exercise, 1 hour, all.
	— Food preparation, 30 minutes.
	— Retinal photography, space adaptation syndrome (SAS) medical detailed supplementary objective (DSO), 5 minutes, MS-2 and MS-3.
	— Iodine samples.
1/19:38	Orbit 30 begins.
1/20:05	COAS power is turned to OFF. Crew mounts COAS forward.
1/20:15	Crew maneuvers vehicle to IMU alignment attitude.
1/20:35	IMU is aligned using ST.
1/20:40	COAS is calibrated.
1/20:40	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
1/20:45	Manual fuel cell purge is performed.
1/21:05	COAS power is turned OFF. Crew stows COAS.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/21:05	TDRS-to-TDRS handover is performed. Voice quality is recorded during S-band handover.
1/21:08	Orbit 31 begins.
1/21:45	Photo/TV are set up for middeck scenes.
1/22:05	PM Experiment sample 10 is checked; sample status is recorded.
1/22:05	RCS regulator is reconfigured. Helium pressure A(3) is turned to CL (close); B (3) to GPC, OP (open).
1/22:15	Photo/TV are activated for middeck scenes, set up for IMAX scenes.
1/22:20	Electrical power system (EPS) heater is reconfigured to B
1/22:25	Environmental control and life support system (ECLSS) redundant component is checked out.
1/22:35	Two crewmen configure ECLSS pressure control system from 1 to 2.
1/22:39	Orbit 32 begins.
1/22:40	Cabin temperature controller is reconfigured. Pin cabin temperature controller actuator linkage to actuator 2 and cabin temperature controller is changed to 2.
1/22:50	Humidity separator is reconfigured; humidity separator B is turned to OFF, A to ON.
1/22:55	Photo/TV are set up for Mesoscale Lightning Experiment (MLE) and camcorder.
1/22:55	Photo/TV are activated for IMAX scenes of Canary Islands.
1/23:15	PM Experiment is initiated for sample 14; sample status is checked.
1/23:25	Photo/TV are activated for MLE scenes and camcorder.

DAY TWO

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/00:05	Photo/TV are activated for camcorder and Earth views.
2/00:10	Orbit 33 begins.
2/00:35	PM Experiment sample 14 is checked; sample status is verified.
2/00:35	Photo/TV are activated for IMAX scenes of Chesapeake Bay.
2/00:50	SSBUV Experiment is set for Earth view, Step 2.
2/00:55	Photo/TV are activated for MLE scenes and camcorder.
2/01:00	SSBUV Experiment is calibrated, Step 1.
2/01:30	Crew maneuvers vehicle to negative Z local vertical, positive Y velocity vector attitude.
2/01:40	Orbit 34 begins.
2/01:45	Waste water is dumped.
2/02:00	SSBUV Experiment is calibrated.
2/02:00	Photo/TV are activated for scenes of Ouashita Mountains and Chesapeake Bay.
2/02:15	Crew mealtime.
2/03:11	Orbit 35 begins.
2/03:15	Crew maneuvers vehicle to IMAX landmark track of Los Angeles.
2/03:25	Photo/TV are activated for IMAX scenes of Los Angeles.
2/03:40	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
2/04:05	PM Experiment is initiated for sample 11; sample status is checked.
2/04:10	Crew maneuvers vehicle to negative Z solar inertial attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/04:10	SSBUV Experiment is set for solar view at sunrise, 2/04:27:01.
2/04:42	Orbit 36 begins.
2/05:00	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
2/05:45	SSBUV Experiment is set for Earth view, Step 1, at sunrise, 2/05:57.
2/06:12	Orbit 37 begins.
2/06:20	PM Experiment sample 11 is checked; sample status is verified.
2/07:05	Salivary SCOP/DEX is performed (medical DSO).
2/07:30	Flight crew begins presleep activity.
2/07:43	Orbit 38 begins.
2/07:55	Photo/TV are set up for scenes of crew's choice.
2/08:20	Photo/TV are activated for scenes of crew's choice.
2/08:25	Crew maneuvers vehicle to IMU alignment attitude.
2/08:45	IMU is aligned using ST.
2/08:45	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
2/09:13	Orbit 39 begins.
2/10:30	Flight crew begins 8-hour sleep period.
2/10:44	Orbit 40 begins.
2/12:15	Orbit 41 begins.
2/13:45	Orbit 42 begins.
2/15:16	Orbit 43 begins.
2/16:47	Orbit 44 begins.
2/18:17	Orbit 45 begins.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/18:30	Flight crew ends 8-hour sleep period and begins postsleep activity.
2/18:35	Salivary SCOP/DEX is performed (medical DSO).
	EZ ACTIVITIES
	— Exercise, 1 hour, all.
	— Food preparation, 30 minutes.
	— Retinal photo, SAS check, 5 minutes, MS-2 and MS-3.
	— Iodine samples.
2/19:05	Salivary SCOP/DEX is performed (medical DSO).
2/19:35	Salivary SCOP/DEX is performed (medical DSO).
2/19:48	Orbit 46 begins.
2/20:30	Crew maneuvers vehicle to IMU alignment attitude.
2/20:35	Salivary SCOP/DEX is performed (medical DSO).
2/20:50	IMU is aligned using ST.
2/20:50	Crew maneuvers vehicle to negative Z local vertical, positive X velocity vector attitude.
2/21:19	Orbit 47 begins.
2/21:35	Photo/TV are set up for IMAX scenes.
2/21:50	PM Experiment sample 11 is checked; sample status is recorded.
2/22:05	Photo/TV are activated for flight deck scenes recreating Galileo deployment.
2/22:35	Salivary SCOP/DEX is performed (medical DSO).
2/22:49	Orbit 48 begins.
2/23:05	Photo/TV are set up for MLE scenes and camcorder.
2/23:10	Photo/TV are activated for IMAX scenes of Canary Islands.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/23:35	Photo/TV are actuated for MLE scenes and camcorder.
DAY THREE	
3/00:20	Orbit 49 begins.
3/00:35	Photo/TV are activated for IMAX scenes of Dallas and Ft. Worth, oil fields, Ouashita Mountains and Chesapeake Bay.
3/00:35	PM Experiment sequence initiates samples 12, 15, 16 and 17.
3/00:45	Salivary SCOP/DEX is performed (medical DSO).
3/01:05	Photo/TV are activated for MLE scenes and camcorder.
3/01:51	Orbit 50 begins.
3/02:05	Photo/TV are activated for IMAX scenes of Los Angeles, Grand Canyon and Ouashita Mountains.
3/02:35	Salivary SCOP/DEX is performed (medical DSO).
3/03:00	Crew mealtime.
3/03:21	Orbit 51 begins.
3/04:00	PM Experiment sample 12 is checked; sample status is verified.
3/04:35	Salivary SCOP/DEX is performed (medical DSO).
3/04:45	Hypersensitivity tests are performed (medical DSO).
3/04:52	Orbit 52 begins.
3/05:45	SSBUV Experiment is set for Earth view, Step 2.
3/05:55	Crew maneuvers vehicle to negative Z solar inertial attitude.
3/05:55	SSBUV Experiment is set for solar view at sunrise, 3/06:10:16.
3/06:05	Photo/TV are set up for flight deck scenes and camcorder.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/06:22	Orbit 53 begins.
3/06:35	Salivary SCOP/DEX is performed (medical DSO).
3/06:35	Photo/TV are activated for flight deck scenes and camcorder.
3/06:45	Crew maneuvers vehicle to negative Z local vertical, positive Y velocity vector attitude.
3/06:50	SSBUV Experiment is calibrated for Step 1.
3/07:00	PM Experiment initiates samples 15 and 17; sample status is recorded.
3/07:30	Flight crew begins presleep activity.
3/07:35	Photo/TV are set up, crew's choice.
3/07:50	SSBUV Experiment is calibrated for Step 2.
3/07:53	Orbit 54 begins.
3/07:55	Photo/TV are activated for IMAX scenes of Taiwan, Taipei and southwest Japan.
3/08:00	Photo/TV are activated for scenes of crew's choice.
3/08:20	SSBUV Experiment is deactivated.
3/08:30	APC is stowed.
3/08:40	Crew maneuvers vehicle to IMU alignment attitude.
3/08:40	PM Experiment sample 15 is checked; sample status is recorded.
3/09:00	IMU is aligned using ST.
3/09:00	Crew maneuvers vehicle to negative Z local vertical, positive Y velocity vector attitude.
3/09:24	Orbit 55 begins.
3/10:30	Flight crew begins 8-hour sleep period.
3/10:54	Orbit 56 begins.
3/12:25	Orbit 57 begins.

T + (PLUS) DAY/ HR:MIN:SEC.	EVENT
3/13:56	Orbit 58 begins.
3/15:26	Orbit 59 begins.
3/16:57	Orbit 60 begins.
3/18:27	Orbit 61 begins.
3/18:30	Flight crew ends 8-hour sleep period and begins postsleep activity.
3/18:35	Salivary SCOP/DEX is performed (medical DSO).
	EZ ACTIVITIES
	— Exercise, 1 hour, all.
	— Food preparation, 30 minutes.
	— Iodine samples.
3/19:15	Crew maneuvers vehicle to IMU alignment attitude.
3/19:35	IMU is aligned using ST.
3/19:35	Crew maneuvers vehicle to TDRS attitude.
3/19:50	PM Experiment sample 16 is checked.
3/19:50	TDRS-to-TDRS handover is performed. Voice quality is recorded during Ku-band handover.
3/19:58	Orbit 62 begins.
3/21:05	Photo/TV are set up for crew conference.
3/21:29	Orbit 63 begins.
3/31:30	Crew conference is held.
3/21:35	Photo/TV are activated for crew conference scenes.
3/22:05	Crew maneuvers vehicle to negative Z local vertical, positive Y velocity vector attitude.
3/22:05	APU steam vent heater is activated, boiler controller/heater (3) is turned to B, power (3) is turned ON.
3/22:05	PM Experiment sample 17 is checked.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/22:20	Flight control system (FCS) is checked out by 2 crewmen.
3/22:59	Orbit 64 begins.
3/23:45	Two crewmen perform RCS hot-fire test.
DAY FOUR	
4/00:00	Vehicle is in gravity gradient free drift, Steps 1 and 2.
4/00:05	PM Experiment sample 13 is initiated; sample status is recorded.
4/00:30	Orbit 65 begins.
4/00:35	APU cool-off occurs; APU fuel pump/valve cool A is turned to OFF.
4/00:50	APU heater is reconfigured.
4/01:05	Crew performs scheduled in-flight maintenance and filter cleaning.
4/01:35	Photo/TV are set up for middeck scenes and PM Experiment.
4/02:01	Orbit 66 begins.
4/02:05	Photo/TV are activated for middeck scenes and PM Experiment.
4/02:05	Growth Hormone Concentration and Distribution (GHCD) in Plants Experiment is operated.
4/03:00	Crew mealtime.
4/04:00	Photo/TV are set up for scenes of crew's choice.
4/04:15	STEX is deactivated.
4/04:15	Photo/TV are activated for scenes chosen by crew.
4/04:30	PM Experiment sample 13 is checked; sample status is recorded.
4/04:30	Flight crew configures the cabin for stowage.
4/04:31	Orbit 67 begins.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/05:02	Orbit 68 begins.
4/05:35	TDRS early Ku-band handover occurs; voice quality is recorded.
4/06:33	Orbit 69 begins.
4/06:35	Salivary SCOP/DEX is performed (medical DSO).
4/07:30	Flight crew begins presleep activity.
4/07:35	Retinal photos are taken (medical DSO).
4/08:03	Orbit 70 begins.
4/08:25	Vehicle is in gravity gradient drift, Step 3.
4/08:35	Crew maneuvers vehicle to IMU alignment attitude.
4/08:55	IMU is aligned using ST.
4/08:55	Crew maneuvers vehicle to negative Z local vertical, positive Y velocity vector attitude.
4/09:34	Orbit 71 begins.
4/10:30	Flight crew begins 8-hour sleep period.
4/11:04	Orbit 72 begins.
4/12:35	Orbit 73 begins.
4/14:06	Orbit 74 begins.
4/15:36	Orbit 75 begins.
4/17:07	Orbit 76 begins.
4/18:30	Flight crew ends 8-hour sleep period and begins postsleep activity.
	EZ ACTIVITIES
	— Air sample.
	— Fluid loading preparation, fill 4 drink containers with 8 ounces of water each (per person).
	— Iodine samples.
4/18:38	Orbit 77 begins.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/20:08	Orbit 78 begins.
4/20:55	Crew maneuvers vehicle to IMU alignment attitude.
4/21:15	IMU is aligned using ST.
4/21:15	Crew maneuvers vehicle to negative X solar inertial attitude.
4/21:35	PM Experiment is stowed.
4/21:39	Orbit 79 begins.
4/21:45	Cathode-ray tube (CRT) timer is set up.
4/21:50	Coldsoak attitude is initiated.
4/22:00	Crew stows radiators, if required.
4/22:17	Crew configures data processing system (DPS) for deorbit preparation.
4/22:20	Mission Control Center (MCC) updates IMU pad, if required.
4/22:30	Crew configures for payload bay door closure.
4/22:40	Crew stows Ku-band antenna, if required.
4/22:46	Vehicle is maneuvered to IMU alignment attitude.
4/22:53	Digital autopilot (DAP) is set to B/AUTO/NORMAL.
4/22:54	Radiator is set to BYPASS and flash evaporator system (FES) is checked out.
4/22:56	MCC issues "go for payload bay door closure" command.
4/23:00	IMU is aligned with ST.
4/23:05	Payload bay doors are closed.
4/23:09	Orbit 80 begins.
4/23:15	Preliminary deorbit update/uplink.
4/23:24	Crew configures dedicated displays.
4/23:28	MCC issues "go for OPS 3" command.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/23:31	Vehicle is maneuver to deorbit burn attitude.
4/23:40	Crew configures DPS for entry.
4/23:50	All crew members verify entry switch list.

DAY FIVE

5/00:05	All crew members perform entry review.
5/00:20	Commander and pilot don LES clothing.
5/00:35	MSs don LES clothing.
5/00:40	Orbit 81 begins.
5/00:45	Commander and pilot ingress seats.
5/00:58	Deorbit update is performed.
5/01:02	Flight crew performs OMS gimbal check.
5/01:23	MCC issues "go for deorbit thrusting maneuver" command.
5/01:29	Crew maneuvers vehicle to deorbit ignition attitude.
5/01:30	Crew terminates vehicle maneuver to deorbit ignition attitude.
5/01:30	MSs ingress seats.
5/01:39	First APU is activated.
5/01:44:54	Deorbit thrusting maneuver is performed, 2 minutes 46 seconds in duration, 307 fps.
5/01:48:40	Crew proceeds to major mode (MM) 303.
5/01:49:40	Crew maneuvers vehicle to postdeorbit thrusting attitude.
5/01:54	Crew terminates vehicle postdeorbit thrusting attitude.
5/02:02	Crew starts two remaining APUs.
5/02:10	MM 304 is selected and SSME hydraulic systems are repressurized.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/02:11	Orbit 82 begins.
5/02:15:18	Vehicle achieves entry interface (EI), 400,000 feet altitude.
5/02:17:52	Vehicle enters S-band blackout through ground station.
5/02:20:02	RCS roll thrusters are deactivated automatically.
5/02:26:34	First roll reversal is initiated.
5/02:27:53	RCS pitch thrusters are deactivated automatically.
5/02:32:57	Vehicle exits S-band blackout through ground station.
5/02:33:48	Vehicle performs second roll reversal.
5/02:37:40	Third roll reversal is initiated.
5/02:38:20	Air data system (ADS) is deployed.
5/02:39:37	Fourth roll reversal is initiated.
5/02:39:45	Entry/terminal area energy management (TAEM) is achieved.
5/02:39:50	Vent doors open.
5/02:41:56	RCS yaw thrusters are deactivated automatically.
5/02:41:59	Vehicle is at 50,000 feet altitude.
5/02:44:48	TAEM-approach and landing (A/L) interface is achieved.
5/02:45:45	Landing gear deployment is initiated.
5/02:46:07	Vehicle has weight on main landing gear wheels.
5/02:46:16	Vehicle has weight on nose landing gear wheels.
5/02:46:23	Braking is initiated.
5/02:46:49	Wheels stop.
5/03:00	Flight crew safes OMS/RCS.
5/03:03	Sniff checks are performed.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/03:05	Aft vehicles are positioned.
5/03:15	Ground purge unit (transporter) is connected to right-hand (starboard) T-O orbiter umbilical and ground cooling unit (transporter) to left-hand (port) T-O orbiter umbilical.
5/03:15	Crew compartment side hatch access vehicle is positioned.
5/03:22	Orbiter crew egress/ingress side hatch is opened.
5/03:50	Orbiter flight crew and ground crew are exchanged.

GLOSSARY

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

HDRS	high data rate system
HGAS	high-gain antenna system
HRM	hand-held radiation meter
HUD	head-up display
IEF	Isoelectric Focusing Experiment
IMU	inertial measurement unit
IRCFE	Infrared Communications Flight Experiment
IUS	inertial upper stage
IV	intravehicular
JEA	joint endeavor agreement
JSC	Johnson Space Center
kbps	kilobits per second
KSC	Kennedy Space Center
LDEF	long-duration exposure facility
LEASAT	leased communication satellite
LES	launch entry suit
LPS	launch processing system
LRU	line replaceable unit
MC	midcourse correction maneuver
MCC-H	Mission Control Center-Houston
MDM	multiplexer/demultiplexer
MEB	main electronics box
MECO	main engine cutoff
MEM	middeck electronics module
MET	mission elapsed time
MFR	manipulator foot restraint
MILA	Merritt Island
MLE	Mesoscale Lightning Experiment
MLR	monodisperse latex reactor
MM	major mode
MMU	manned maneuvering unit
MPESS	mission-peculiar equipment support structure
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
PCM	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
PRM	pocket radiation meter
PS	payload specialist
PTI	preprogrammed test input
PVTOS	Physical Vapor Transport Organic Solids Experiment
RAHF-VT	research animal holding facility-verification test
RCC	reinforced carbon-carbon
RCS	reaction control system
RGA	rate gyro assembly
RME	radiation monitoring equipment
RMS	remote manipulator system
RTGS	radioisotope thermoelectric generators
RTLS	return to launch site
S&A	safe and arm
SAS	space adaption syndrome
SCOP	scopolamine
SESA	special equipment stowage assembly
SHARE	Space Station Heat Pipe Radiator Element Experiment
SL	Spacelab
sm	statute mile
SMS	space motion sickness
SRB	solid rocket booster
SRSS	shuttle range safety system
SSBUV	Shutter Solar Backscatter Ultraviolet
SSIP	shuttle student involvement project
SSME	space shuttle main engine
ST	star tracker
STEX	Sensor Technology Experiment
STS	space transportation system
SYNCOM	synchronous communication satellite

TACAN	tactical air navigation
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite system
TI	thermal phase initiation
TIG	time of ignition
TLD	thermoluminescent dosimeter
TPAD	trunnion pin acquisition device
TPF	terminal phase final maneuver
TPI	terminal phase initiation maneuver
TPS	thermal protection system
TV	television
VCGS	vapor crystal growth system
VRCS	vernier reaction control system
VTR	video tape recorder
VWFC	very wide field camera
WCS	waste collection system