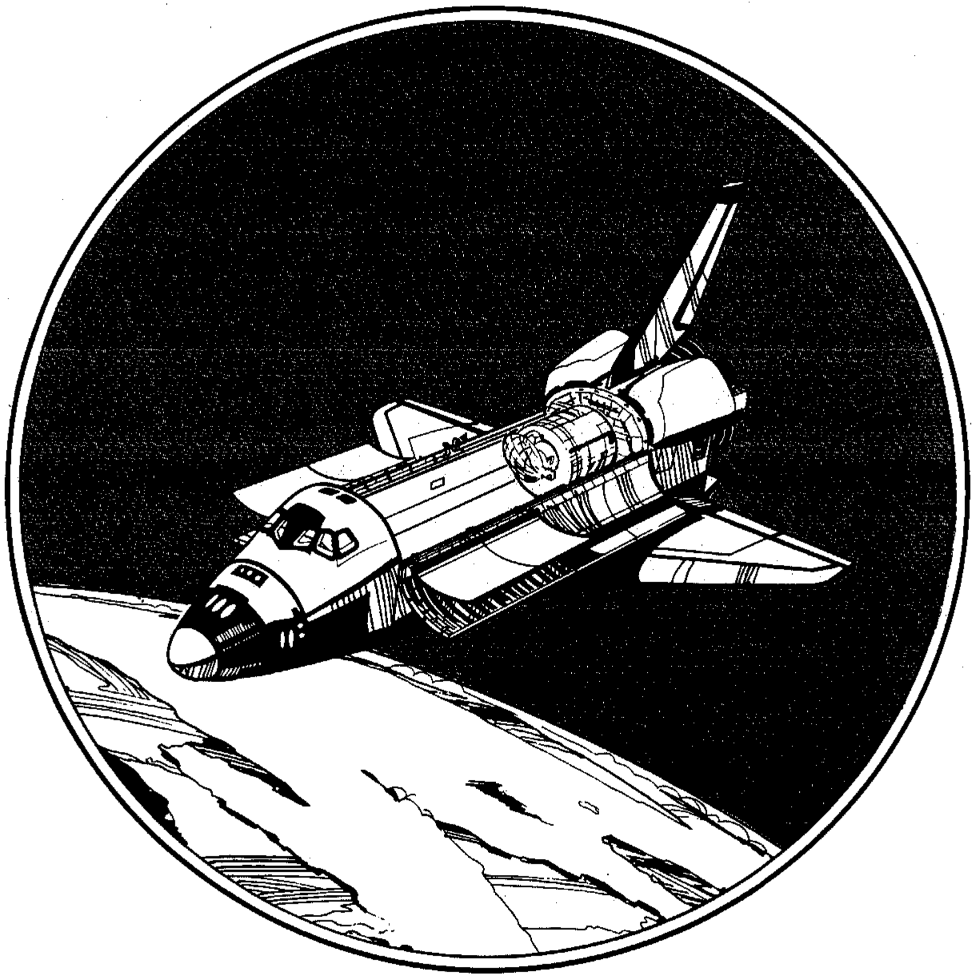

# STS-32
# PRESS INFORMATION

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## CONTENTS

## MISSION OVERVIEW

This is the ninth flight of Columbia and the 33rd in the space transportation system. It is also the first flight launched from Launch Complex 39-A since January 1986.

The flight crew for the STS-32 mission consists of commander Daniel C. Brandenstein; pilot James D. Wetherbee; and mission specialists Bonnie J. Dunbar, Marsha S. Ivins and G. David Low.

The primary objectives of this nine-day mission are to deploy the Syncom (synchronous communication) IV-5 (or F5) satellite, rendezvous with the Long-Duration Exposure Facility and retrieve and berth it in Columbia's payload bay for return to Earth, and acquire data on the flight crew's exposure to long periods of zero gravity and its effects on landing Columbia. The exposure data will be used as part of the efforts to develop a kit that will allow an orbiter to remain in orbit for up to 16 days initially and eventually 28 days.

The LDEF was deployed from Challenger into Earth orbit during the STS 41-C mission on April 7, 1984, and is approaching the end of its orbital lifetime. It has been in orbit in a gravity-gradient, stabilized attitude for five years.

Syncom IV-5 is the last in a series of five communications satellites for the U.S. Navy. Syncom IV-5 will be deployed from Columbia's payload bay, nominally at a mission elapsed time of day one, zero hours and 44 minutes on orbit 17. Backup deployment opportunities are available on orbits 32, 33, 34, 38 and 48.

Syncom F2 was deployed by Discovery on Aug. 31, 1984, during the STS 41-D mission and is operational. Syncom F1 was deployed by Discovery during the STS 51-A mission on Nov. 8, 1984, and is also operational. Syncom F3 was deployed by Discovery during the STS 51-D mission on April 13, 1985, but its perigee kick motor failed to fire. The mission was extended to allow the crew to use a "flyswatter" technique to fix the PKM, but the effort was unsuccessful. Syncom F4 was deployed by Discovery on the STS 51-I mission on Aug. 29, 1985, but it failed to operate. During the mission, Syncom F3 was repaired and is operational.

The exact launch time of Columbia for this mission will be determined by the LDEF's location in Earth orbit 12 hours before the launch.

The rendezvous with the LDEF includes maneuvers to ensure that the external tank misses islands near Hawaii after it separates from the orbiter and an orbital maneuvering system separation maneuver following the deployment of Syncom IV-5.

Columbia nominally will approach the LDEF from the rear (catching up with it). It will then move in front of the LDEF, above the LDEF, and then down to grapple the LDEF with Columbia's remote manipulator system and berth it in Columbia's payload bay.

Nominally, the LDEF capture is scheduled to occur on orbit 49, followed by berthing in Columbia's payload bay on orbit 51 after photographic and television documentation of the LDEF. If a decision is made at launch to delay the nominal retrieval of the LDEF, retrieval could occur on orbits 64 or 80. The documentation of LDEF's condition before it is berthed is required due to the possible effects of atmospheric pressure on the LDEF during entry and its five-year exposure to the space environment.

Eight secondary payloads will also be carried aboard Columbia on this mission.

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

LDEF and for Earth viewing. Opportunities for filming will be provided to the flight crew before the flight and in real time. The camera and supporting equipment are stowed in the middeck.

The Fluids Experiment Apparatus experiment is one of the first designed specifically to investigate the effects of disturbances on crystal growth processes. The main sources of disturbance to be investigated are Columbia's engine firings and flight crew exercise on the treadmill, but several other disturbances typical of orbiter operations will be included. This research is expected to provide information useful in establishing the microgravity-level requirements for processing materials aboard space station Freedom and a greater understanding of the role of residual gravity in materials processing. This experiment will also investigate the effects of disturbances on the stability of a freely suspended molten zone and provide information on the impurity-refining capability of float zone processing in space. The FEA and its computer are located in the middeck of Columbia's crew compartment.

In collaboration with the University of Alabama in Birmingham, NASA's Marshall Space Flight Center, Huntsville, Ala., is continuing a series of experiments in protein crystal growth that may be a major benefit to medical technology. These experiments could improve food production and lead to innovative drugs to combat cancer, AIDS, high blood pressure, organ transplant rejection, rheumatoid arthritis, and many other diseases.

Protein crystal growth experiments were first carried out during the Spacelab 2 mission in April 1985 and have been flown on the space shuttle six times. The first four flights were designed primarily to develop hardware and techniques for growing crystals in space. The STS-26 and 29 experiments were the first scientific attempts to grow useful crystals by vapor diffusion in microgravity. The STS-26 and 29 payloads, unlike those on previous flights, featured temperature control and the automation of some of the processes to improve accuracy and reduce the flight crew's time required.

During this mission, 120 different PCG experiments will be conducted simultaneously on as many as 24 proteins. Though there are three processes used to grow crystals on Earth—vapor diffusion, liquid diffusion and dialysis—only vapor diffusion will be used in this mission's set of experiments. The PCG experiments are installed and operated in Columbia's middeck.

The Air Force Maui Optical Site Calibration Test allows ground-based electro-optical sensors located on Mt. Haleakala on Maui, Hawaii, to collect imagery and signature data for Columbia during cooperative overflights while Columbia performs reaction control system thruster firings and water dumps or activates payload bay lights. The data are used to support the calibration of AMOS sensors and the validation of spacecraft contamination models. This experiment is a continuation of tests made on the STS-29, 30 and 34 missions.

The Characterization of Neurospora Circadian Rhythms in Space experiment is to determine if the circadian rhythm (diurnal cycle) of neurospora (pink bread mold) persists in the microgravity of space. The fundamental question to be addressed by this experiment is whether the conditions of space, especially the absence of Earth's strong gravitational field, affect neurospora's circadian rhythms. This is a middeck experiment.

The American Flight Echocardiograph experiment is designed to provide in-flight measurements of the size and functioning of the heart and record heart volume and cardiovascular responses to space flight. Results from the AFE will be used in the development of optimal countermeasures for crew members' cardiovascular changes. The AFE hardware is located in a middeck locker.

The Mesoscale Lightning experiment is designed to obtain nighttime images of lightning in order to better understand the global distribution of lightning events in storms that are close together and the relationships of lightning, convective storms and precipitation. Cameras in Columbia's payload bay will record lightning directly below Columbia, and if time permits, the flight crew will also use handheld 35mm cameras to photograph lightning in storm systems not directly below Columbia's ground track. The MLE has gathered data on STS-26, 30 and 34.

The Latitude/Longitude Locater experiment uses a modified 70mm Hasselblad camera with a fixed and moving reticle to make sightings on targets and take angle marks (as well as photographs). A camera-computer interface unit connects the camera to a GRID compass computer. The collection of marks is reduced to the longitude and latitude of each of the targets on which the marks are taken. The objective of the experiment is to evaluate the accuracy and usability of the instrument by viewing and marking on known sites on Earth during the flight.

## MISSION STATISTICS

Launch: The exact time of launch on a given day is determined by the LDEF's exact location in Earth orbit, which will not be known until 12 hours prior to launch. The launch window varies from day to day due to a variety of technical requirements.

| | | | |
|---|---|---|---|
| 12/18/89 | 7:29 p.m. EST | Nominal | |
| | 6:29 p.m. CST | estimated | |
| | 4:29 p.m. PST | launch time | |

Mission Duration: 216 hours (nine days), 21 hours, 35 minutes

Landing: Nominal end of mission is on orbit 159.

| | | |
|---|---|---|
| 12/28/89 | 5:04 p.m. EST | Based on |
| | 4:04 p.m. CST | nominal estimated |
| | 2:04 p.m. PST | launch time |

Inclination: 28.5 degrees

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

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

Altitude: 161 by 190 nautical miles (185 by 218 statute miles), then 156 by 190 nautical miles (179 by 218 statute miles), then 166 by 191 nautical miles (191 by 219 statute miles), then 166 by 167 nautical miles (191 by 192 statute miles), then 161 by 166 nautical miles (185 by 191 statute miles), then 149 by 166 nautical miles (171 by 191 statute miles), then 145 by 149 nautical miles (166 by 171 statute miles), then 147 by 149 nautical miles (169 by 171 statute miles), then 148 by 150 nautical miles (170 by 172 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,540,161 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 229,848 pounds

Payload Weight Up: Approximately 26,625 pounds

Payload Weight Down: Approximately 37,732 pounds

Orbiter Weight at Landing: Approximately 229,285 pounds

Payloads: Syncom IV-5 deployment, Long-Duration Exposure Facility retrieval, Fluids Experiment Apparatus 3, Protein Crystal Growth III-02, Latitude/Longitude Locater, American Flight Echocardiograph 02, Characterization of Neurospora Circadian Rhythms in Space 01, Air Force Maui Optical Site 04, Mesoscale Lightning, and IMAX. The FEA, PCG, LLL, AFE, CNCR, and IMAX payloads are located in Columbia's crew compartment.

Flight Crew Members:
- Commander: Daniel C. Brandenstein, third space shuttle flight
- Pilot: James D. Wetherbee, first space shuttle flight
- Mission Specialist 1: Bonnie J. Dunbar, second space shuttle flight
- Mission Specialist 2: Marsha S. Ivins, first space shuttle flight
- Mission Specialist 3: G. David Low, first space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Daniel Brandenstein
Flight deck front right seat, pilot James Wetherbee
Flight deck aft center seat, MS 2 Marsha Ivins
Flight deck aft right seat, MS 1 Bonnie Dunbar
Middeck, MS 3 David Low

Entry Seating:
Flight deck aft right seat, MS 3 David Low
Middeck, MS 1 Bonnie Dunbar

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut 1 would be David Low and EV 2 would be Bonnie Dunbar.

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 lake bed Runway 17 at Edwards Air Force Base, Calif.

Notes:

- The remote manipulator is installed in Columbia's payload bay for the retrieval of the LDEF on this mission. The galley is installed in the middeck of Columbia.

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

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

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

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

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

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

- Five power reactant storage and distribution cryogenic oxygen and hydrogen tank sets were installed in Columbia to support this nine-day mission.

## MISSION OBJECTIVES

- Deployment of Syncom IV-5 satellite
- Rendezvous with and retrieval of the LDEF
- Acquisition of data on flight crew's exposure to long periods of zero gravity (nine days) and its effects on landing Columbia. A kit is being developed to allow an orbiter to operate in Earth orbit for up to 16 days and eventually 28 days.
- Secondary payloads
  - — IMAX
  - — FEA-3
  - — PCG-III-02
  - — LLL
  - — CNCR-01
  - — AMOS-04
  - — MLE

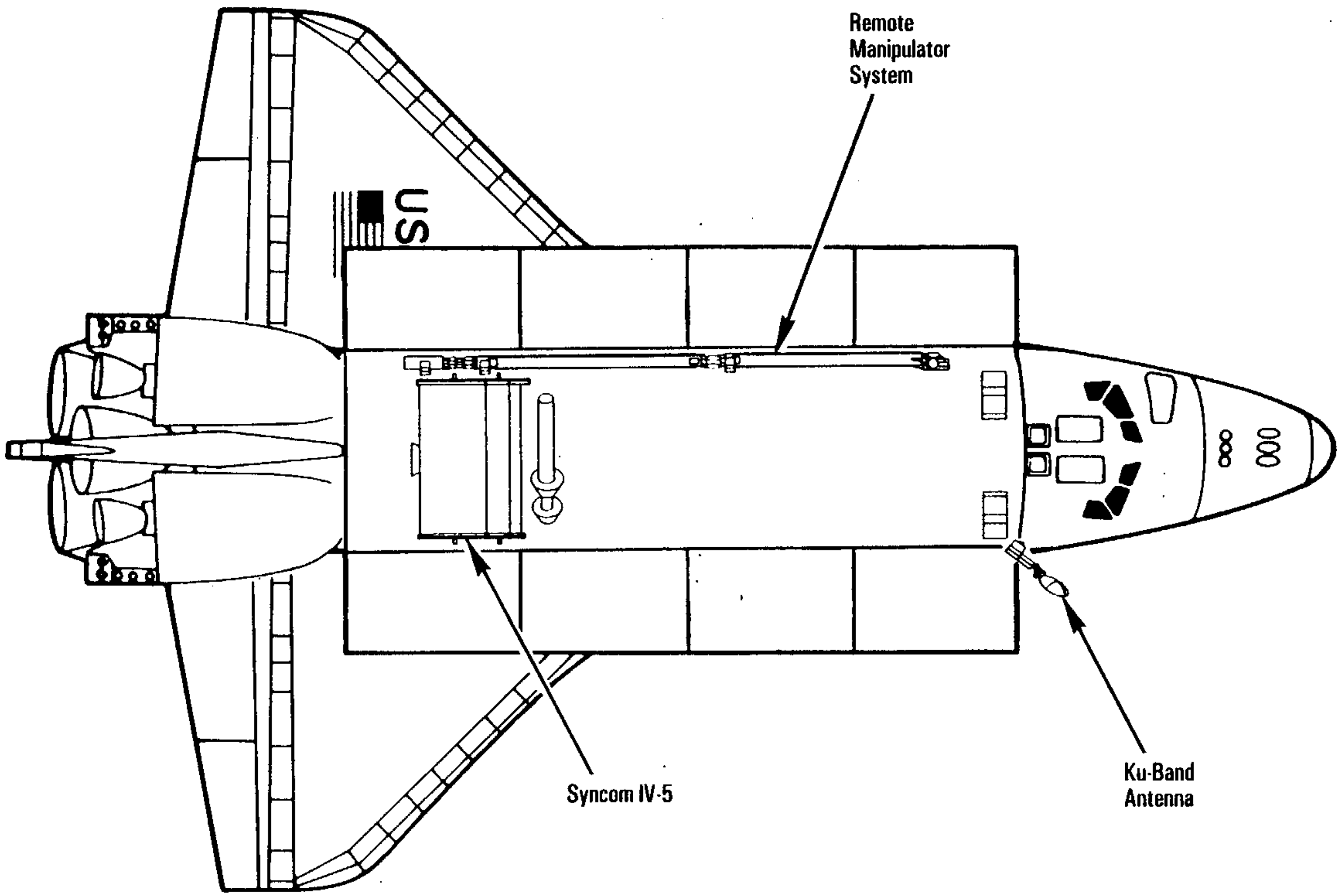
## DEVELOPMENT TEST OBJECTIVES

- Cold soak of Columbia's observation windows
- Ascent wing aerodynamic distributed loads verification on Columbia
- Entry aerodynamic control surfaces test
- Ascent structural capability evaluation
- Reinforced carbon-carbon life evaluation
- Entry structural capability
- Pogo stability performance
- Thermal protection system performance of external tank
- Shuttle/payload frequency environment
- Cabin air monitoring
- Remote manipulator system operating loads and data during LDEF retrieval
- Camcorder demonstration
- RMS direct drive exercise
- TDRS-to-TDRS demonstrations
- Gravity-gradient attitude control
- Additional stowage for extended-duration orbiter
- Orbiter experiments
  - — Shuttle infrared leeside temperature sensing
  - — Shuttle entry air data system
  - — Aerothermal instrumentation package

## DETAILED SUPPLEMENTARY OBJECTIVES

- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Characterization of airborne particulate matter in shuttle atmospheres
- Intraocular pressure
- Delayed-type hypersensitivity
- In-flight aerobic exercise
- In-flight lower body negative pressure
- Muscle biopsy
- Muscle performance
- Influence of weightlessness on baroreflex function
- Variations in supine and standing heart rate, blood pressure and cardiac size as a function of space flight duration and time, postflight
- Documentary television
- Documentary motion picture photography

## PAYLOAD CONFIGURATION




*STS-32 Payload*

## SYNCOM IV-5

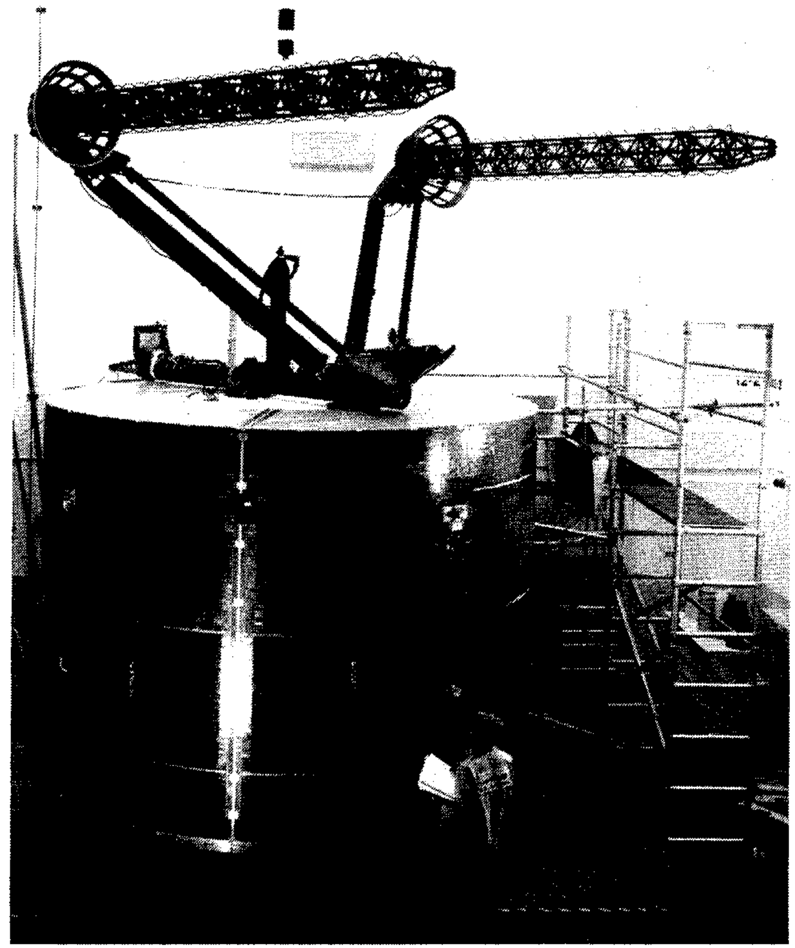
Syncom IV-5 is the last of five communications satellites designed and built by Hughes Communications Services Inc., a wholly owned subsidiary of Hughes Aircraft Co., Los Angeles, Calif. Although NASA's space shuttle manifest refers to the satellite as Syncom, Hughes calls it Leasat because the satellite will be leased to the U.S. Navy, which awarded Hughes the satellite contract.

Hughes owns and operates the Leasat network and offers leasing services for worldwide voice and data communications to the Department of Defense for five years per satellite orbital position. The contract allows the Navy, which acts as executive agent on behalf of the Department of Defense, the option to extend the lease for up to two years and to purchase the satellites after five years. Users include mobile air, surface, subsurface and fixed Earth stations of the Navy, Marine Corps, Air Force and Army.

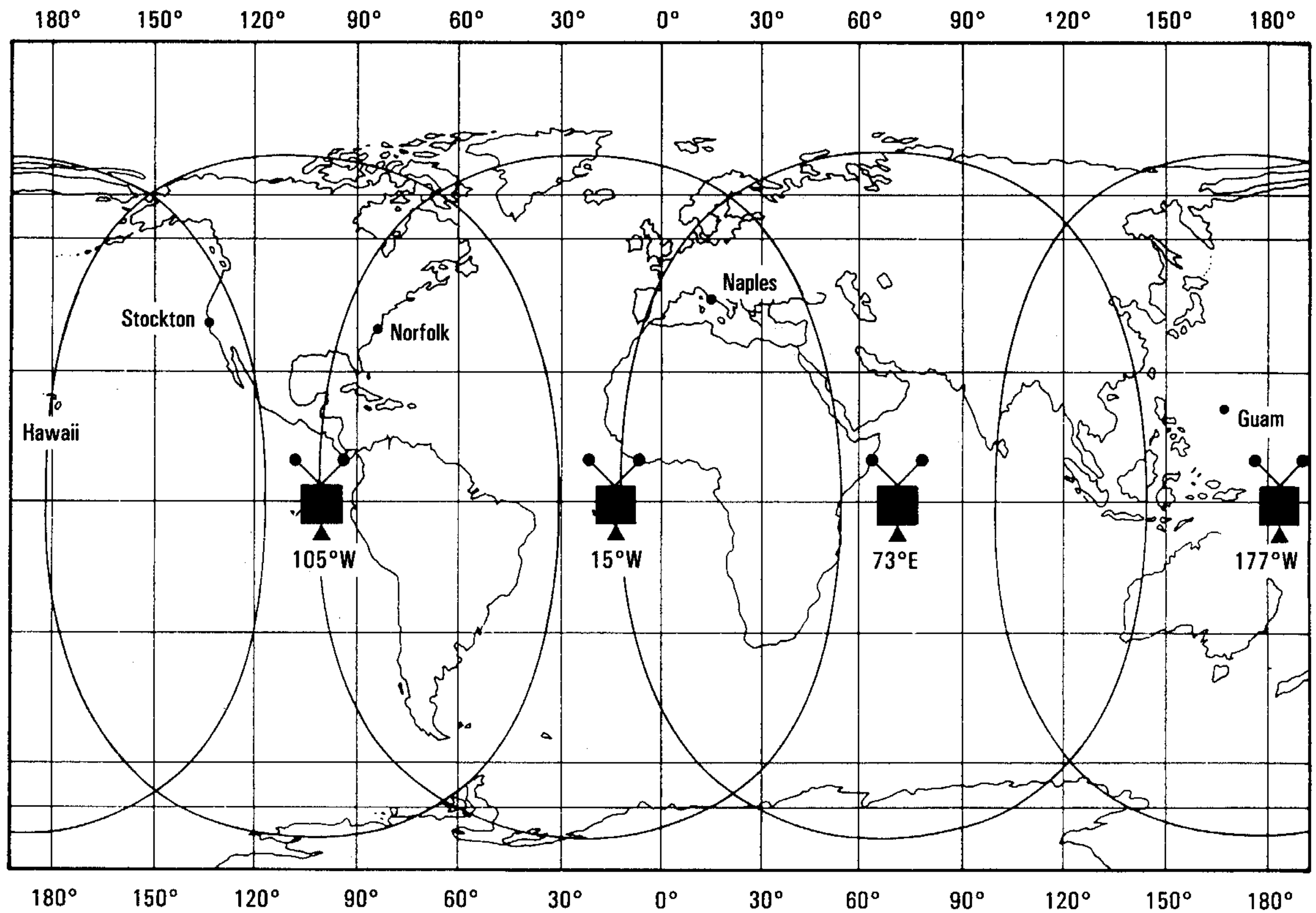
The ground segment of Leasat includes Hughes' Operation Control Center in Los Angeles, Calif.; two movable ground stations in Guam and Norfolk, Va.; and five satellite control sites located in Guam, Hawaii, Italy, Stockton, Calif., and Norfolk, Va. Leasat operations are coordinated via dedicated leased terrestrial lines to the Naval Space Command Operations Center in Dahlgren, Va.

Syncom IV-2 was deployed from Discovery during the STS 41-D mission on Aug. 31, 1984. It was originally positioned in geosynchronous orbit above the equator at 100 degrees for U.S. coverage but was subsequently repositioned above the equator over the Atlantic Ocean at 15 degrees west longitude. Syncom IV-1, which was deployed from Discovery in the STS 51-A mission on Nov. 8, 1984, was originally positioned in geosynchronous orbit above the equator over the Atlantic Ocean but was repositioned above the equator over the Indian Ocean at 73 degrees east longitude.

When Syncom IV-3 was deployed from Discovery on the STS 51-D mission on April 13, 1985, its perigee kick motor failed to fire despite efforts to fix it. Syncom IV-4, deployed from Discovery on the STS 51-I mission on Aug. 29, 1985, failed to operate shortly after it reached geosynchronous orbit. During the mission, however, Syncom IV-3 was repaired during astronaut extravehicular activity and was positioned in geosynchronous orbit above the equator for U.S. coverage at 105 degrees west longitude.



*Syncom IV-5, or F5*




*Leasat Orbital Locations*

Syncom IV-5, to be deployed from Columbia on this mission, is targeted for geosynchronous orbit above the equator over the Pacific Ocean at 177 degrees west longitude. When it reaches its destination, Syncom IV-5 will complete the system Hughes was contracted to provide. Originally designed as a ground spare, Syncom IV-5 has been modified to allow a normal postejection sequence mode, a subtransfer Earth orbit mode, or a low Earth orbit mode.

The normal PES mode consists of omnidirectional antenna deployment 80 seconds after satellite deployment from Columbia, perigee kick motor firing 45 minutes after deployment from Columbia, liquid apogee motor firing by ground command 14 hours after PKM firing and UHF antenna deployment upon ground command.

The SEO mode activity sequence is omni antenna deployment 80 seconds after satellite deployment from Columbia, PKM firing 45 minutes after deployment from Columbia, LAM firing by ground command one to 20 days after PKM firing and UHF antenna deployment upon ground command.

The LEO mode activity sequence is omni antenna deployment 80 seconds after deployment from Columbia, PKM firing upon ground command one to 48 days after deployment from Columbia, LAM firing by ground command 14 hours after PKM firing and UHF antenna deployment upon ground command.

These modes can be changed at the prelaunch countdown time of T minus 11 hours.

*Syncom Nominal Postejection Sequence*

| Activity | PES Option | SEO Option | LEO Option |
|---|---|---|---|
| Omni antenna deployment | PES 80 seconds after spacecraft deployment | | |
| PKM firing | PES 45 minutes after spacecraft deployment | | |
| LAM firing | Ground command 14 hours after PKM | | |
| UHF antenna deployment | Ground command | | |

*Syncom Subtransfer Earth Orbit Sequence*

| Activity | PES Option | SEO Option | LEO Option |
|---|---|---|---|
| Omni antenna deployment | PES 80 seconds after spacecraft deployment | → | |
| PKM firing | PES 45 minutes after spacecraft deployment | → | |
| LAM firing | Ground command 14 hours after PKM | Ground command 1-20 days after PKM | |
| UHF antenna deployment | Ground command | Ground command | |

*Syncom Low Earth Orbit Sequence*

| Activity | PES Option | SEO Option | LEO Option |
|---|---|---|---|
| Omni antenna deployment | PES 80 seconds after spacecraft deployment | → | → |
| PKM firing | PES 45 minutes after spacecraft deployment | → | Ground command 1-48 days after spacecraft deployment |
| LAM firing | Ground command 14 hours after PKM | Ground command 1-20 days after PKM | Ground command 14 hours after PKM |
| UHF antenna deployment | Ground command | Ground command | Ground command |

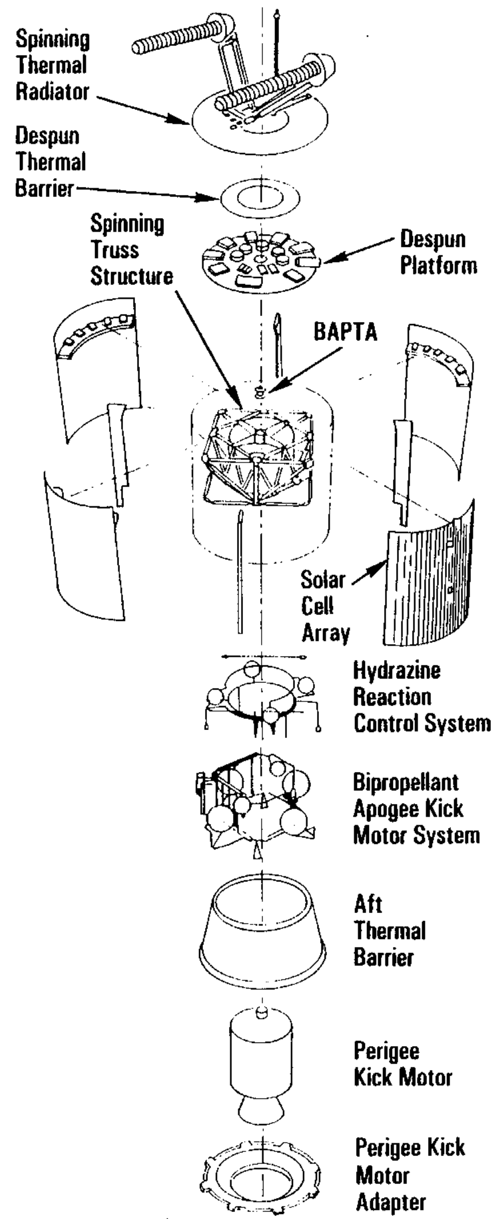
The Syncom satellites are the first designed for launch exclusively by the space shuttle because their 14-foot diameter is too large for any other launch vehicle. Syncom is a cylindrical satellite deployed from the payload bay in a horizontal position.

Each satellite is 20 feet, 3 inches long with the UHF and omnidirectional antennas deployed. With its antennas stowed in the launch configuration, the satellite is 14 feet, 1 inch long. In orbit with its twin helical antennas extended, Syncom is 25 feet long. Each satellite and its cradle in the payload bay of the space shuttle orbiter weigh approximately 17,000 pounds. Weight after deployment from the payload bay is approximately 15,200 pounds, and the weight of each satellite on station at the beginning of life is approximately 3,060 pounds.

Syncom's wide body allows its perigee and apogee kick motors to be designed into the satellite structure. The PKM is a third-stage Minuteman solid rocket motor. Syncom's two kick motors are fueled by a bipropellant system that wraps around the cavity containing the PKM. This concept eliminates the extra length of a separate-stage solid-rocket-fuel PKM and reduces launch cost.

The deployment of Syncom IV-5 with its unique propulsive stage from Columbia's payload bay is nominally scheduled at the mission elapsed time of day one, zero hours and 44 minutes on orbit 17. Backup deployment opportunities are available on orbits 32, 33, 34, 38 and 48.

The Syncom satellite is attached at five contact points (four longeron and one keel) to a cradle in Columbia's payload bay. In preparation for Syncom deployment, Columbia is oriented so that Syncom's spin axis is pointed in the direction that its PKM must thrust. Columbia's attitude is negative Z, local vertical (tail forward and payload bay toward Earth). Locking pins at four of the contact points are mechanically retracted by electrical motors, which takes about five minutes per pin. A pyrotechnic device at the fifth contact point is initiated to release a spring that pushes one side of the satellite up while the other side pivots. This provides Syncom with a separation velocity of 1.5 feet per second and



*Syncom Satellite*

a stabilizing spin of approximately two revolutions per minute. This simultaneous rotation and translation maneuver (Frisbee concept) also settles the liquid propellants.

Syncom is a spin-stabilized satellite with a spun portion that contains the solar array, sun and Earth sensors for attitude determination and Earth-pointing reference, batteries for eclipse operation, and all propulsion and attitude control hardware. The despun platform contains the Earth-pointing twin helical antennas, communication repeaters, and the majority of the telemetry, tracking and command equipment.

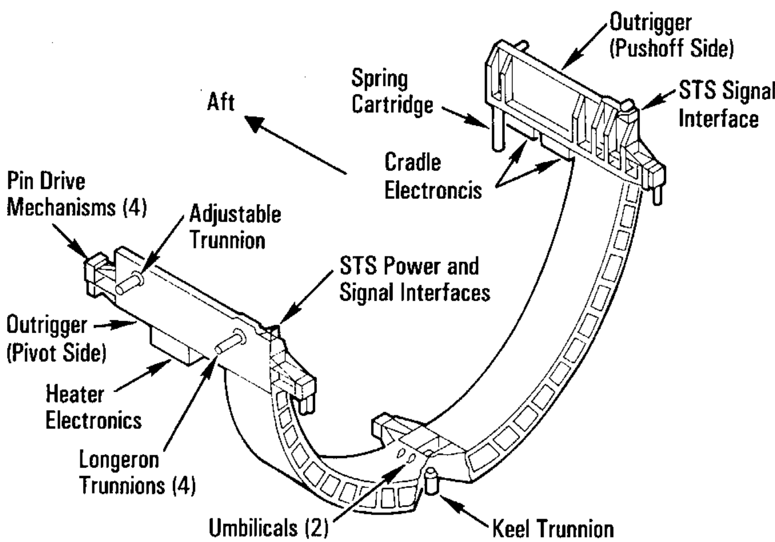
The satellite's solar drum generates about 1,200 watts at the end of seven years. Three 25-ampere-hour nickel-cadmium batteries provide electrical power for eclipse operations. Twelve UHF channels operating in the range of 240 to 400 MHz provide Syncom's main communication capability.

Upon nominal deployment, Syncom's power is turned on, and 80 seconds after deployment the omnidirectional antenna is deployed. Forty-five minutes after deployment, the solid-fuel PKM is ignited and its spent case is jettisoned. Shortly after perigee motor firing, the satellite is acquired by one of the Leasat ground stations. Orbital determination is made, and Syncom is configured by ground command for the transfer orbit augmentation maneuvers, which are made with the two liquid apogee motors. The first of three such maneuvers raises the apogee to 10,800 nautical miles, the second raises the apogee to 14,300 nautical miles, and the third achieves synchronous orbital altitude. At this point, Syncom is in a transfer orbit with a 160-nautical-mile perigee and a 19,300-nautical-mile apogee. The final maneuver by the LAMs circularizes the orbit with a planned 3-degree inclination to the equator at geosynchronous altitude.

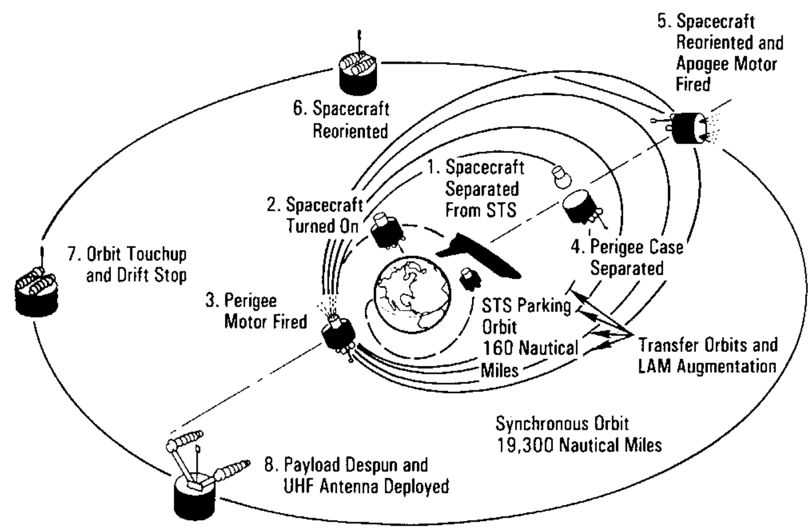
The LAMs are 100-pound-thrust, hydrazine-fueled apogee kick motors. A hydrazine reaction control system and small thrusters provide Syncom's orbit and attitude control.

Fifteen minutes after the satellite's deployment, Columbia performs an orbital maneuvering system separation maneuver at 18 feet per second, resulting in a nominal 166- by 191-nautical-






*Syncom Cradle in Columbia's Payload Bay*




*Syncom Launch Sequence*

mile orbit. Twenty-nine minutes after Syncom's deployment, Columbia is maneuvered to protect its windows from the firing of the satellite's solid rocket perigee kick motor, and Columbia's remote manipulator system is positioned so that its wrist television camera can film the motor's thrusting.

## LONG-DURATION EXPOSURE FACILITY

The Long-Duration Exposure Facility is essentially a free-flying cylindrical structure for experiments that required long-term exposure to the space environment.

The LDEF is carrying 57 science and technology experiments involving approximately 200 investigators from the United States and eight other countries. It could have accommodated 86 experiment trays, 72 around its circumference and 14 on the two ends.

The LDEF was built by NASA's Langley Research Center in Hampton, Va. It is a 12-sided, open-grid structure made of aluminum rings and longerons (fore and aft framing members). The LDEF is 30 feet long and 14 feet in diameter and weighs approximately 8,000 pounds. The combined weight of the structure and the 57 experiments on board is approximately 21,400 pounds.

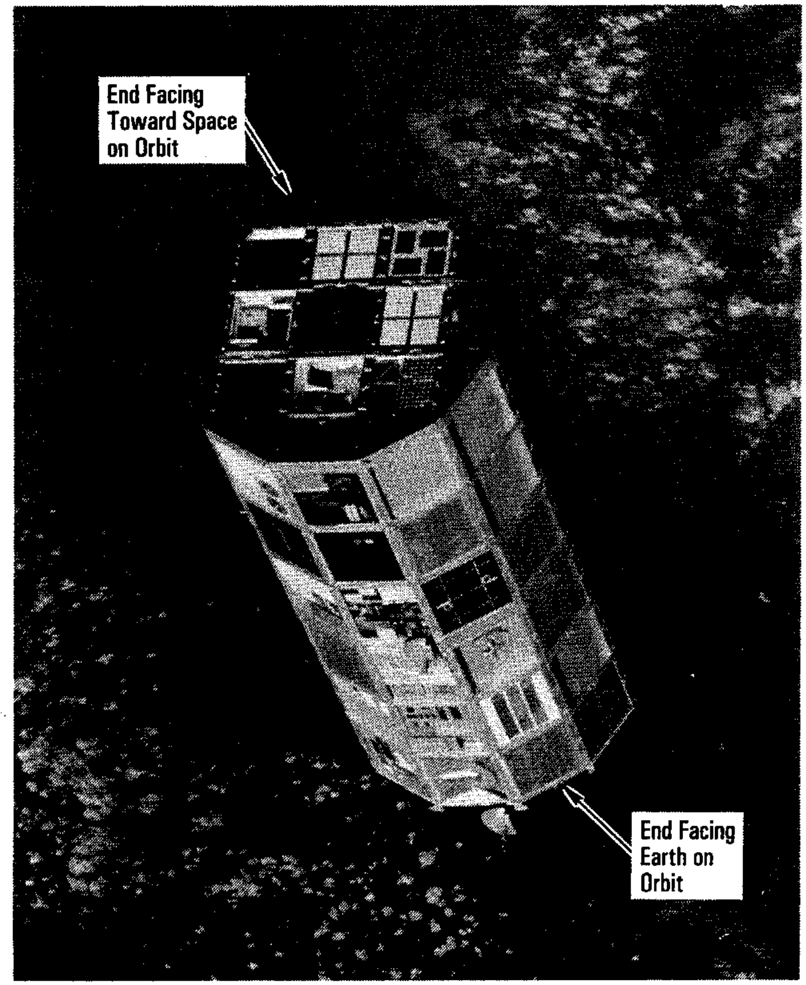
The LDEF was deployed into Earth orbit from Challenger on the STS 41-C mission on April 7, 1984. Originally, the LDEF was to be retrieved in February 1986, but the loss of Challenger in January 1986 and return-to-flight activities delayed the retrieval until this mission.

The LDEF has remained on orbit in a gravity-gradient, stabilized mode. Everything is in the same position on the LDEF as it was when the facility was deployed.

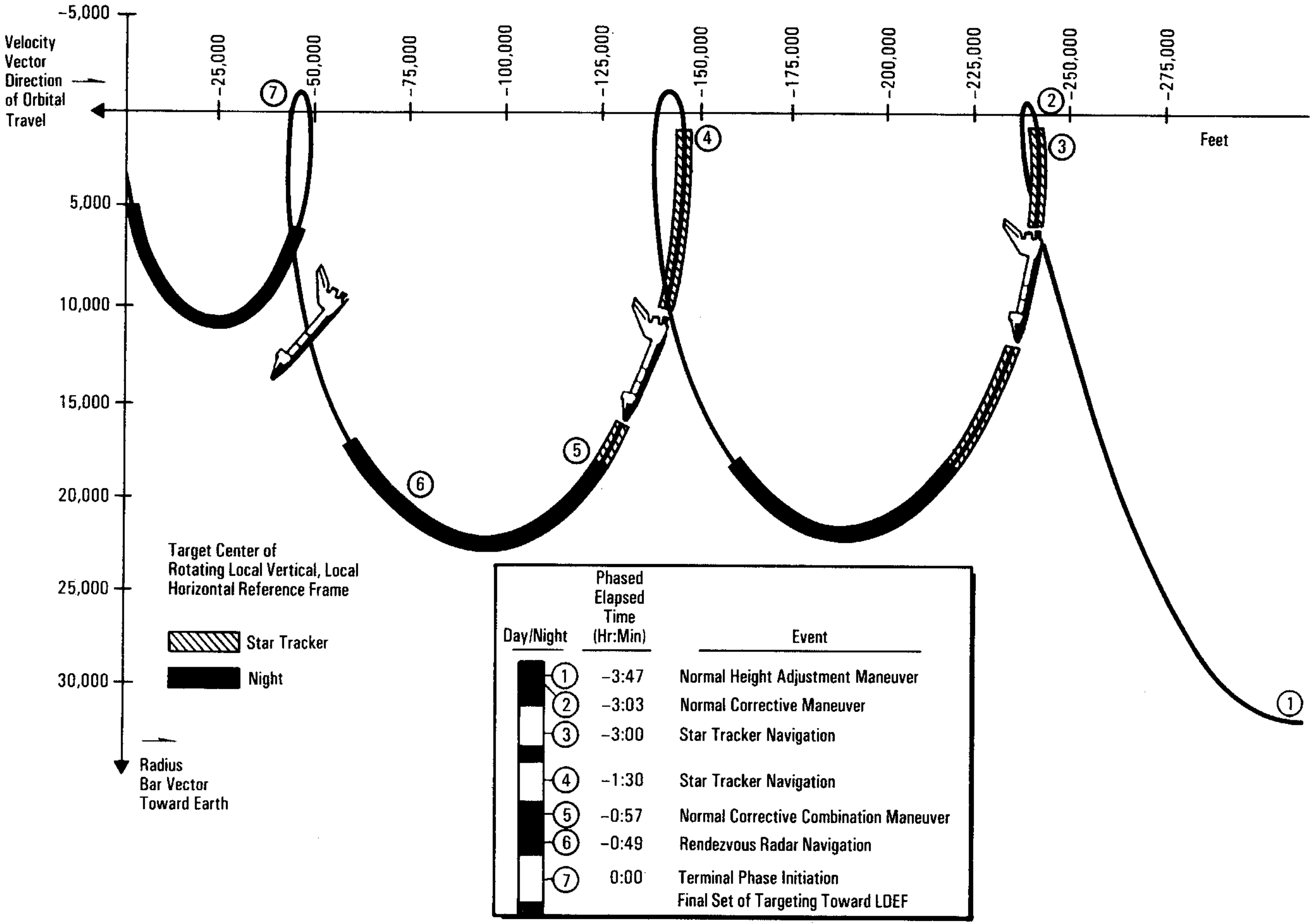
The experiments on the LDEF are organized in four categories: materials, coatings and thermal systems; power and propulsion; science; and electronics and optics.

Trays for mounting experiment hardware to the periphery of the LDEF structure are 34 inches wide and 50 inches long. Trays for mounting hardware on the end frames are smaller—34 inches square. The trays are 3, 6 or 12 inches deep depending on the requirements of the experiments. Experiments in the periphery trays weigh 180 pounds, while the end tray experiments weigh 200 pounds.

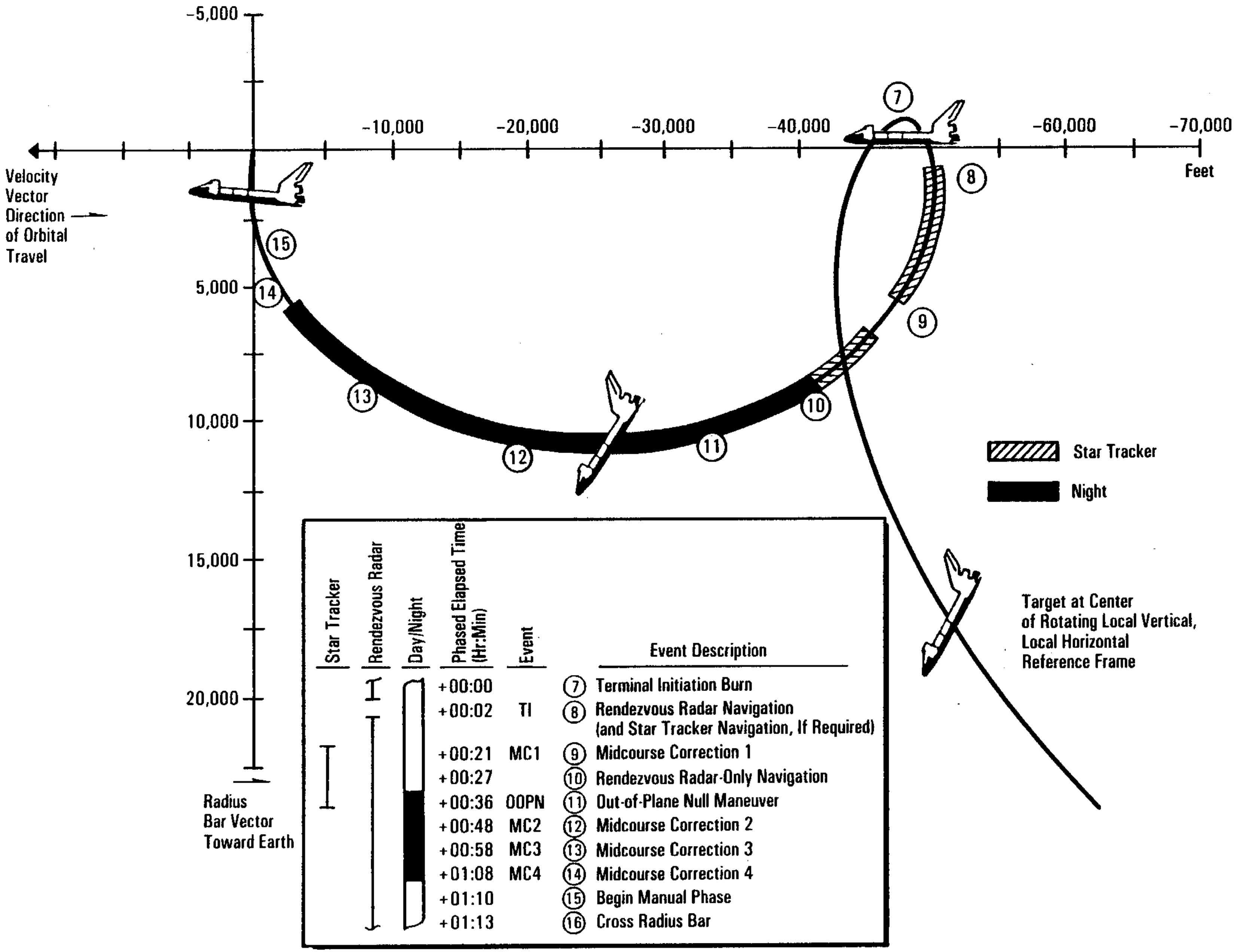
The launch of Columbia will be determined by LDEF's exact location in orbit, which will not be determined until 12 hours before the launch.




*Long-Duration Exposure Facility in Earth Orbit*




*LDEF Rendezvous Profile*




*LDEF Rendezvous Profile*

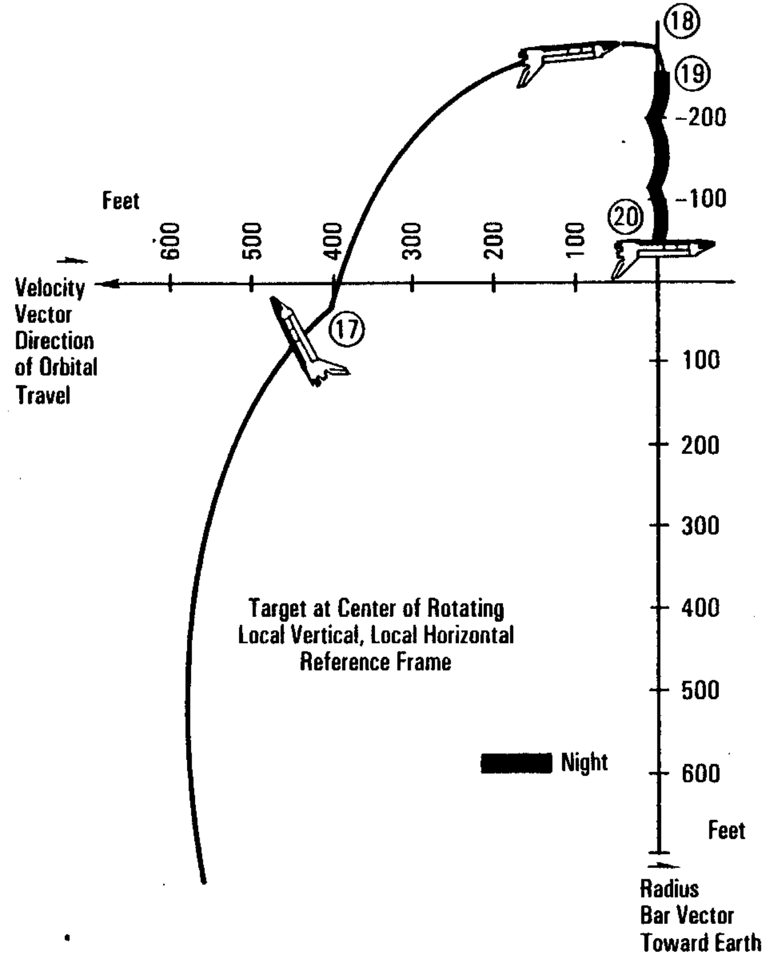
The rendezvous with the LDEF requires maneuvering to ensure the external tank misses islands near Hawaii and performing the orbital maneuvering system separation maneuver after Syncom IV-5 is deployed.

In a nominal rendezvous, Columbia will approach the LDEF from the rear (catching up with the LDEF). The orbiter will then move in front of the LDEF, above it and down to grapple the LDEF with the remote manipulator system and berth it in the payload bay.

Nominal LDEF capture with the RMS is scheduled to occur on orbit 49, followed by berthing in Columbia's payload bay on orbit 51 after photographic and television documentation of the LDEF. If it is decided at launch to delay the nominal retrieval of the LDEF, it could be retrieved on orbits 64 or 80. The LDEF's condition must be documented before it is berthed due to the possible effects of atmospheric pressure on it during entry and its five-year exposure to the space environment. During the documentation period, Columbia's upward-firing reaction control system thrusters will be inhibited. It will take approximately three orbits to complete the documentation.

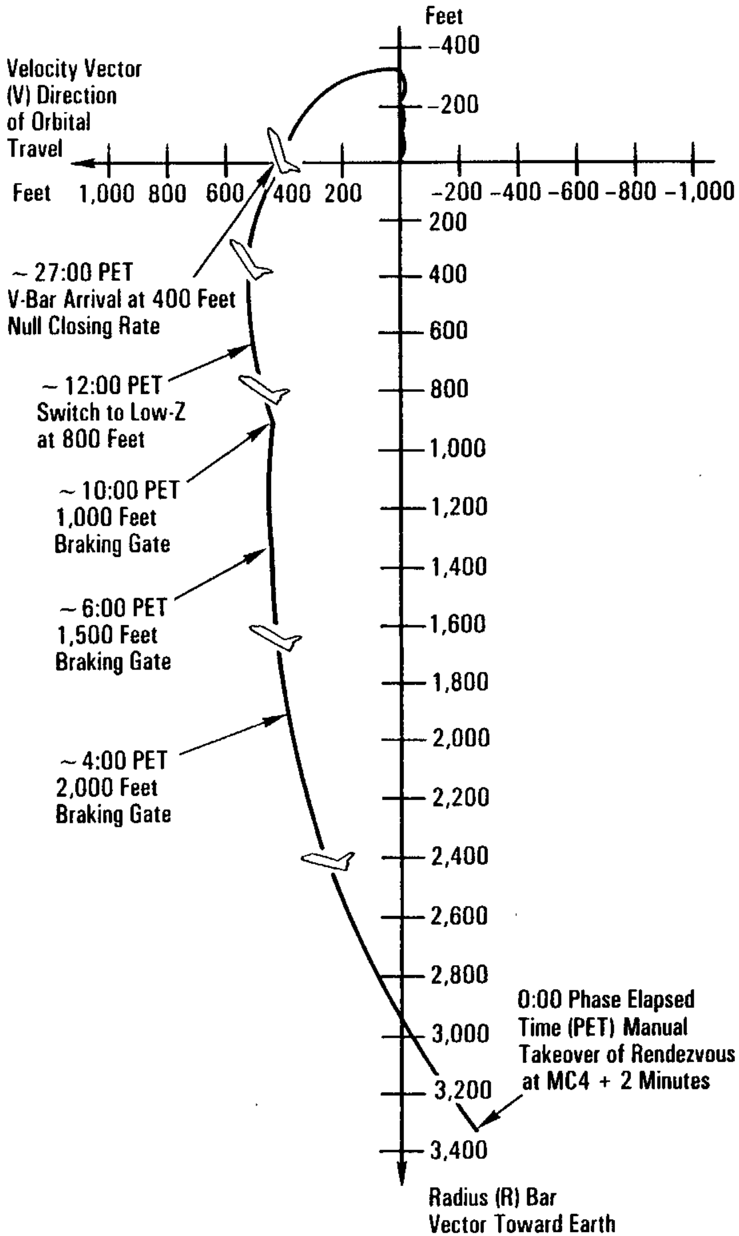
Columbia's rendezvous sequence is automated until the orbiter is within approximately 10 miles of the LDEF. Then the flight crew switches to manual control. Columbia's rendezvous radar, which is part of the Ku-band system, is used to skin-track the LDEF. The Ku-band antenna is gimbaled, which permits it to radar search for the LDEF. Before the radar search begins, Columbia gives the Ku-band system the general location of the LDEF. The radar makes a spiral scan of up to 60 degrees to search for the LDEF and pinpoint its location. The radar detects the LDEF by bouncing a radar beam off the LDEF's surface in a passive mode. When the rendezvous radar mode is no longer required, the Ku-band system is switched to the communication mode.

There are two grapple fixtures on the LDEF. The grapple fixture on the starboard side and an adjacent chevron are part of the LDEF experiment initiation system, which was used when the




| Rendezvous Radar | Day/Night | Time (Hr:Min) | Event Description |
|---|---|---|---|
| | | +1:35 | 17 Cross Velocity Bar |
| | | +1:58 | 18 Establish Radius Bar |
| | | +2:02 | 19 Radius Bar Approach |
| | | +2:31 | 20 Target Capture |

*Proximity Operations*

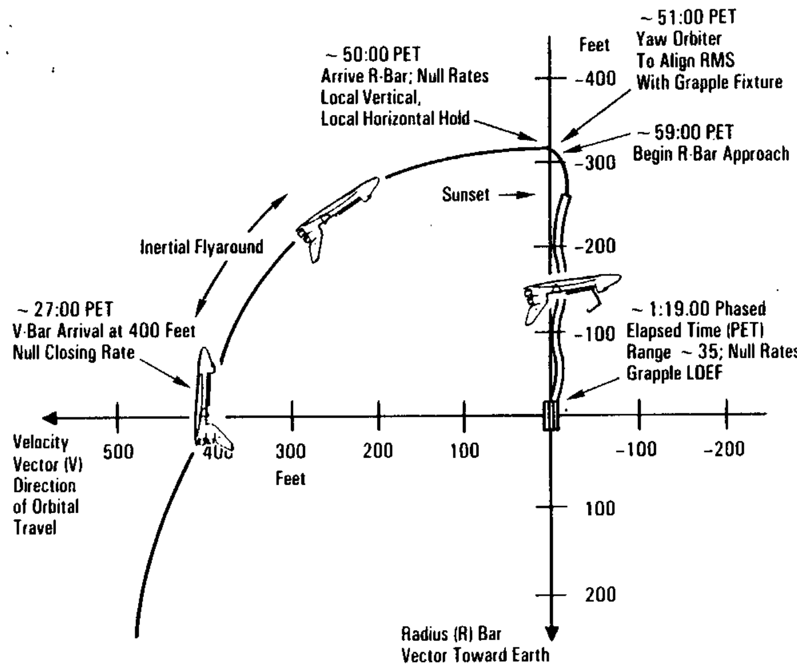



*Proximity Operations*

LDEF was deployed. The grapple fixture on the port side, without a chevron, is a standard grapple fixture. For the nominal retrieval of the LDEF, the port grapple fixture will be used; however, either one could be used.

The LDEF has two side support trunnions on its port and starboard sides and a keel trunnion for berthing it in Columbia's payload bay. The side support trunnions will mate with the payload retention latch assemblies on Columbia, and the LDEF's keel trunnion will mate with a keel payload retention latch assembly on the orbiter.

The five active payload retention latch assemblies (four longeron and one keel) are controlled by dual-redundant alternating current electric motors, which release or latch the assemblies. The active retention latch assemblies are controlled from Columbia's



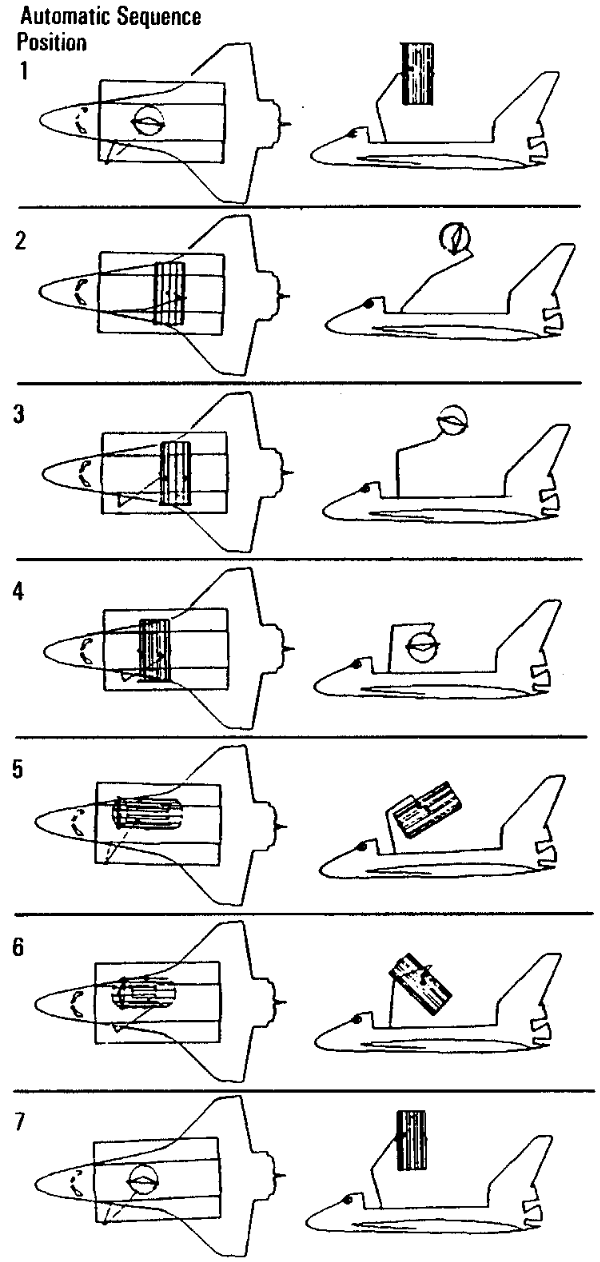

*Proximity Operations*

aft flight deck control panel A6U. On this mission, the five retention latch assemblies are opened after Columbia is on orbit on the first day of the mission.

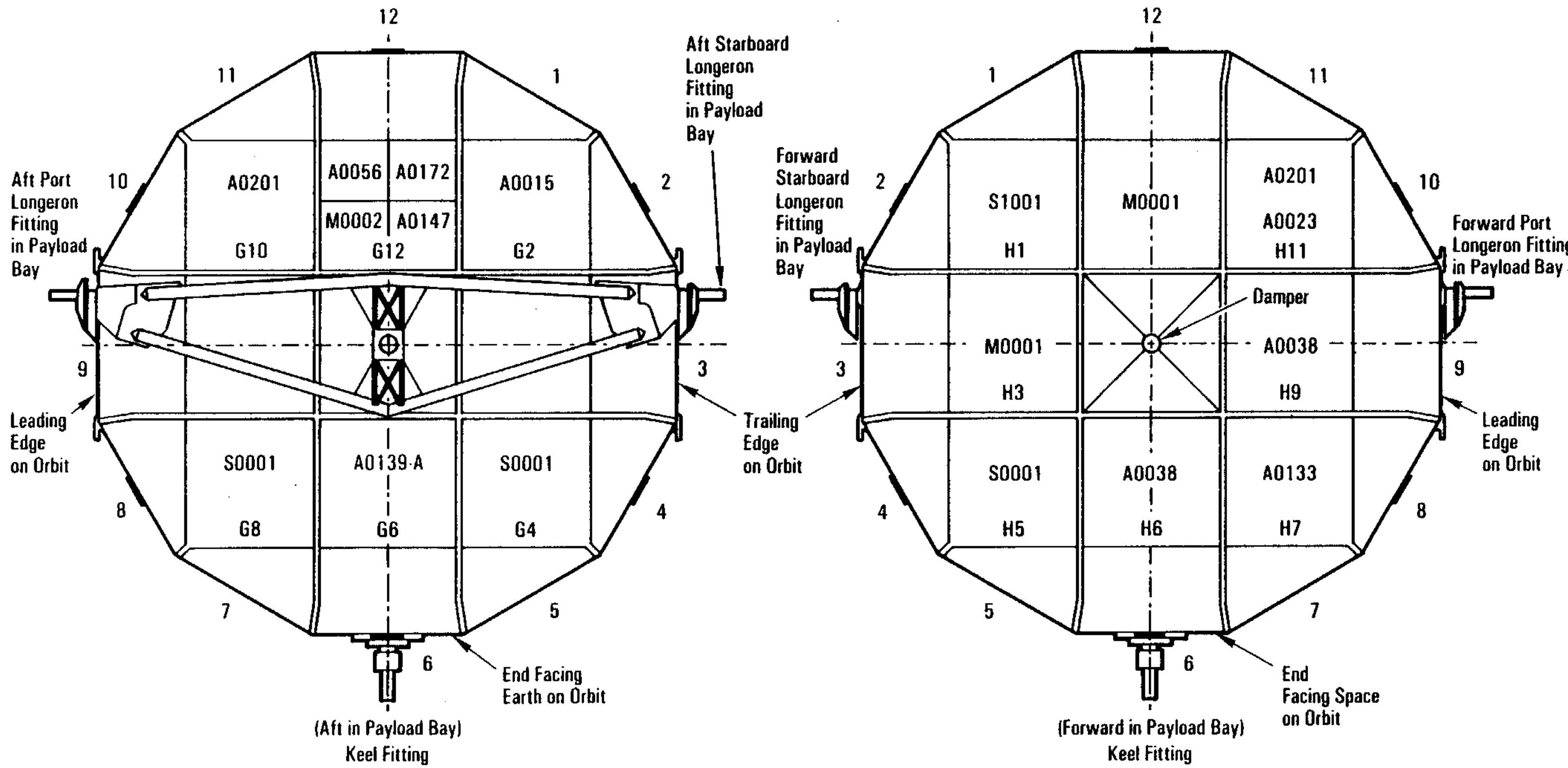
Positioning a *payload retention latches* switch to *release* provides ac power to the dual electric motors associated with the retention latch of the selected payload, driving the retention latch open. The operating time of the latch with both motors operating is 30 seconds; with only one motor operating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

Upon completion of the documentary photography and television, the RMS berths the LDEF in Columbia's payload bay. The keel active retention latch centers the LDEF in the yaw direction. It can float plus or minus 2.75 inches in the X direction and must be latched closed before the longeron latches are closed. The four longeron latches and the keel latch must be latched closed to return the LDEF to Earth.

Positioning a *payload retention latches* switch to *latch* provides ac power to the dual electric motor associated with the latch of the payload selected, driving the retention latch closed. The operating time of one or both motors is the same as for releasing a payload. A barberpole talkback indicator immediately above each *retention latches* switch indicates that latch is ready to latch. The indicator shows *lat* when the latch is closed. There are two microswitches for the *lat* indication; however, one is required to control the talkback indicator. The *payload retention latches ready for latch* talkback indicator for a *retention latches* switch is gray when the payload latch is ready to latch.




*LDEF Photo Survey Positions*




*LDEF Experiments Panel Configuration Located on Ends of LDEF*

Earth End on Orbit (Aft in Payload Bay)

Trailing Edge On Orbit (Row 3)

Leading Edge On Orbit (Row 9)

| Row \ Bay | A | B | C | | D | E | F |
|---|---|---|---|---|---|---|---|
| 1 | A0175 | S0001 | Grapple | | A0178 | S0001 | S0001 |
| 2 | A0178 | S0001 | A0015 / A0187 / M0006 | Port Trunnion | A0189 / A0172 / S0001 | A0178 | P0004 / P0006 |
| 3 | A0187 | A0138 | A0023 / A0034 / A0114 / A0201 | | M0003 / M0002 | S1002 / A0187 | S0001 |
| 4 | A0178 | A0054 | S0001 | | M0003 | S0001 | A0178 |
| 5 | S0001 | A0178 | A0178 | P0005 | A0178 | S0050 / A0044 / A0135 | S0001 |
| 6 | S0001 | S0001 | A0178 | P0003 / Keel Trunnion | S0001 / A0201 | A0023 / S1006 / S1003 / M0002 | A0038 |
| 7 | A0175 | A0178 | S0001 | | A0178 | S0001 | S0001 |
| 8 | A0171 | S0001 / A0056 / A0147 | A0178 | | M0003 | A0187 | M0004 |
| 9 | S0069 | S0010 / A0134 | A0023 / A0034 / A0114 / A0201 | Starboard Trunnion | M0003 / M0002 | S0014 | A0076 |
| 10 | A0178 | S1005 | Grapple | | A0054 | A0178 | S0001 |
| 11 | A0187 | S0001 | A0178 | | A0178 | S0001 | S0001 |
| 12 | S0001 | A0201 | S0109 | | A0023 / A0019 / A0180 | A0038 | S1001 |

Space End On Orbit (Forward in Payload Bay)

*LDEF Experiments Panel Configuration*

| Panel No. | Experiment No. | Required Observation |
|---|---|---|
| 1A | A0175 | Note fading or color changes of black matte finish. Is yellow printing evident? |
| 1B | S0001 | Note discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 1C | Grapple | Note any degradation in block chevron painted on tray. |
| 1D | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 1E | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 1F | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 2A | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 2B | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 2C | A0015 | Note any discoloration or variation in color on white canisters or aluminum base plate. Note condition of thermal cover in canister. |
| | A0187 | Note any degradation in mirrorlike surface. |
| | M0006 | Note whether canister is closed as expected. |
| 2D | A0189 | Note any degradation in white-painted diagonal thermal control stripes. |
| | A0172 | Note any discoloration in white-painted thermal cover. |
| | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 2E | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 2F | P0006 | TBS |
| | P0004 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variation in reflectivity. |
| 3A | A0187 | Is each canister closed as expected? |
| 3B | A0138 | Are three canisters closed as expected? Note whether thermal cover is intact. Note any splits or tears. |
| 3C | A0023 | Note if foil surfaces are intact. |
| | A0034 | Note any deviation from uniform color of aluminum cover plate. |
| | A0114 | Note any deviation in color of white-painted cover plate and in color of black insert in one quadrant. |
| | A0201 | Note any deviation from uniform color of anodized aluminum cover plate. Note any mirrorlike surface sensors that differ from others. |
| 3D | M0003 | Note whether larger thin foils are intact. Note general condition of other test specimens. |
| | M0002 | Note any degradation/discoloration of white-painted surfaces. |
| 3E | S1002 | Note whether canister is closed as expected. Note condition of anodized aluminum cover. |
| | A0187 | Note any apparent degradation in mirrorlike surface. |
| 3F | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 4A | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 4B | A0054 | Note any degradation to aluminized Kapton. |
| 4C | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 4D | M0003 | Note whether canister is closed as expected. Note the condition of aluminum cover. Note any discoloration of white paint. |
| 4E | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 4F | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |

*LDEF Documentation via Photography/Television Prior to Berthing (Cont)*

| Panel No. | Experiment No. | Required Observation |
|---|---|---|
| 5A | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 5B | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 5C | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| | P0005 | TBS |
| 5D | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 5E | A0044<br>S0050<br>A0135 | Note any variation in color of anodized aluminum sunscreens. |
| 5F | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 6A | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 6B | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 6C | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| | P0003 | TBS |
| 6D | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| | A0201 | Note any deviation from uniform color of anodized aluminum cover plate. Note any mirrorlike surface sensors that differ from others. |
| 6E | A0023 | Note if foil surfaces are intact. |
| | S1006 | Note any degradation in test specimens. |
| | S1003 | Note any deviations in uniform color of cover plate. |
| | M0002 | Note whether aluminized Kapton thermal cover is intact. |
| 6F | A0038 | Note any discoloration in white-painted base plate and tray walls. |
| 7A | A0175 | Note any fading or color change of black matte finish. Is yellow printing still evident? |
| 7B | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 7C | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 7D | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 7E | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 7F | S0001 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 8A | A0171 | Note any thin films or foils that may not be intact. |
| 8B | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| | A0056 | Note any discoloration in anodized aluminum cover plates. |
| | A0147 | Note any discoloration in white-painted cover plate. |
| 8C | A0178 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 8D | M0003 | Note whether canister is closed as expected. Note condition of aluminum cover. Note any discoloration of white paint. |
| 8E | A0187 | Note any degradation in mirrorlike surface. Red substrate may be visible. |
| 8F | M0004 | Note any discoloration in aluminum and white base and cover plates. Note any change in color or other degradation in fiber-optic samples. |

| Panel No. | Experiment No. | Required Observation |
|---|---|---|
| 9A | S0069 | Note position of carousel. Note which, if any, test specimens are visible. |
| 9B | S0010 | Note whether canister is closed as expected. Note condition of anodized aluminum cover plate. |
| | AD134 | Note any foils or specimens that may not be intact. |
| 9C | A0023 | Note if foil surfaces are intact. |
| | A0134 | Note any deviation from uniform color of aluminum cover plate. |
| | A0114 | Note any deviation in color of white-painted cover plate and black insert in one quadrant. |
| | A0201 | Note any deviation from uniform color of anodized aluminum cover plate and any mirrorlike surface sensors that differ from others. |
| 9D | M0003 | Note whether large foils are intact. Note general condition of other test specimens. |
| | M0002-1 | Note any degradation or discoloration in white-painted surfaces. |
| 9E | S0014 | Note any variations in black-painted face plate. |
| 9F | A0076 | Note any loose foil surfaces or strips, particularly around squares located in lower left and lower right of tray. Note whether cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 10A | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 10B | S1005 | Note any discolorations or variations in reflectivity of surfaces. |
| 10C | Grapple | Note condition/state on intro indicators. Note any variation in color of anodized aluminum base plate, particularly around target. |
| 10D | A0054 | Note any degradation of aluminized Kapton. |
| 10E | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 10F | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 11A | A0187 | Note any discoloration or marks on pure aluminum panels. |
| 11B | S0001 | Note any discolorations or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 11C | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 11D | A0178 | Note whether thermal cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |
| 11E | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 11F | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 12A | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 12B | A0201 | Note any deviation from uniform color of anodized aluminum cover plate. Note any mirrorlike surface sensors that differ from others. |
| 12C | S0109 | Note any discoloration in aluminum and white base and cover plates. Note any change in color or other degradation in fiber-optic samples. |
| 12D | A0023 | Note if foil surfaces are intact. |
| | A0180 | Note any test specimens that are not intact. Note any variations in color. |
| | A0019 | Note general condition of test specimens and whether temperature tabs are intact. |
| 12E | A0038 | Note any discoloration in white-painted base plate and tray walls. |
| 12F | S0001 | Note any loose foil surfaces or strips, particularly squares located in lower left and lower right of tray. Note whether cover is intact. Note any splits, tears or unusual edge conditions. Note any variations in reflectivity. |

*LDEF Documentation via Photography/Television Prior to Berthing (Cont)*

| Panel No. | Experiment No. | Required Observation |
|---|---|---|
| 10G | A0201 | Note any deviation from uniform color of anodized aluminum cover plate and any mirrorlike surface sensors that differ from others. |
| 12G | A0056 | Note any discoloration in anodized aluminum and white-painted cover plates. |
| | A0172 | Note any discoloration in white-painted thermal cover. |
| | M0002-1 | Note any degradation or discoloration in white-painted surfaces. |
| | A0147 | Note any discoloration in white-painted cover plate. |
| 2G | A0015 | Note any discoloration or variation in color in aluminum canisters or base plate. |
| 8G | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 6G | A0139-A | Note any discoloration in white thermal cover. |
| 4G | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |

| Panel No. | Experiment No. | Required Observation |
|---|---|---|
| 1H | S1001 | Note any abnormal appearance of 4 solar panels. |
| 12H | M0001 | Note whether thermal covers are intact. Document by sketch any deviation in thermal cover's condition. |
| 11H | A0201 | Note any deviation from uniform color of anodized aluminum cover plate. Note any mirrorlike surface sensors that differ from others. |
| | A0023 | Note if foil surfaces are intact. |
| 3H | M0001 | Note whether thermal covers are intact. Document by sketch any deviation in thermal cover's condition. |
| 9H | A0038 | Note any discoloration in white-painted base plate and tray walls. |
| 5H | S0001 | Note any discoloration or dissimilarity in color with other debris trays. Note any evidence of impacts. |
| 6H | A0038 | Note any discoloration in white-painted base plate and tray walls. |
| 7H | A0133 | Note any foils or test specimens that are not intact. Note any variations in color of black face plate. |

**Radar Rendezvous Range**

Passive Skin Track

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

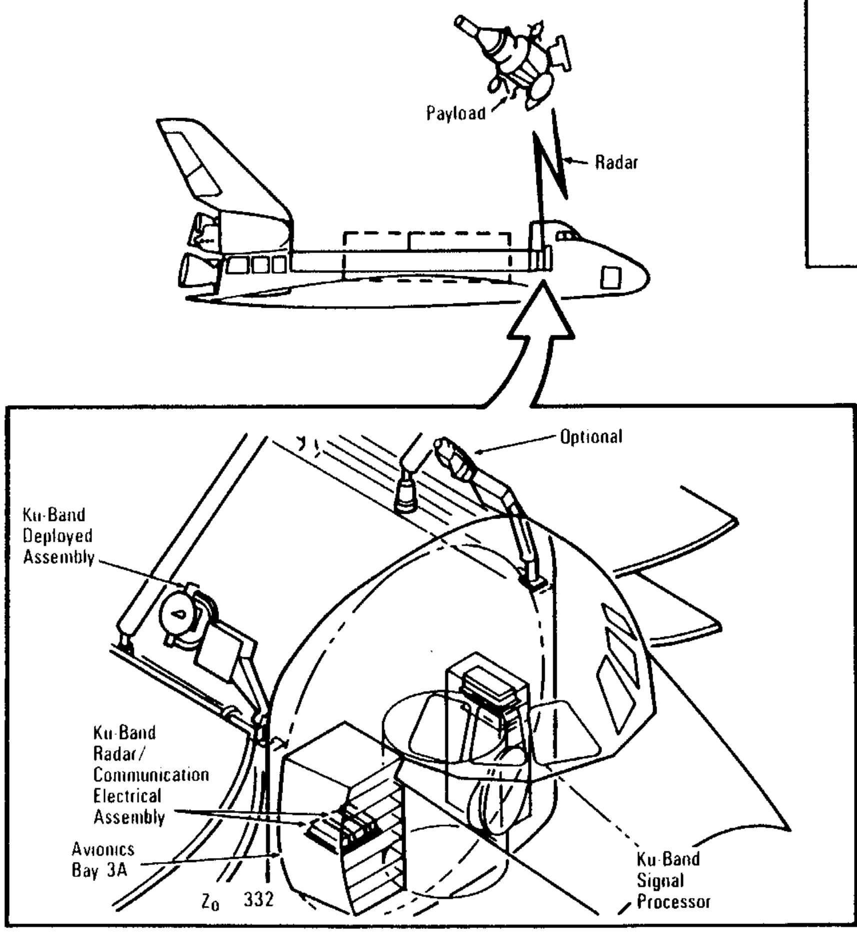
Range Rate 148 Feet per Second Opening Maximum
to 75 Feet per Second Closing Maximum

Active (Transponder on the Vehicle Being Tracked)

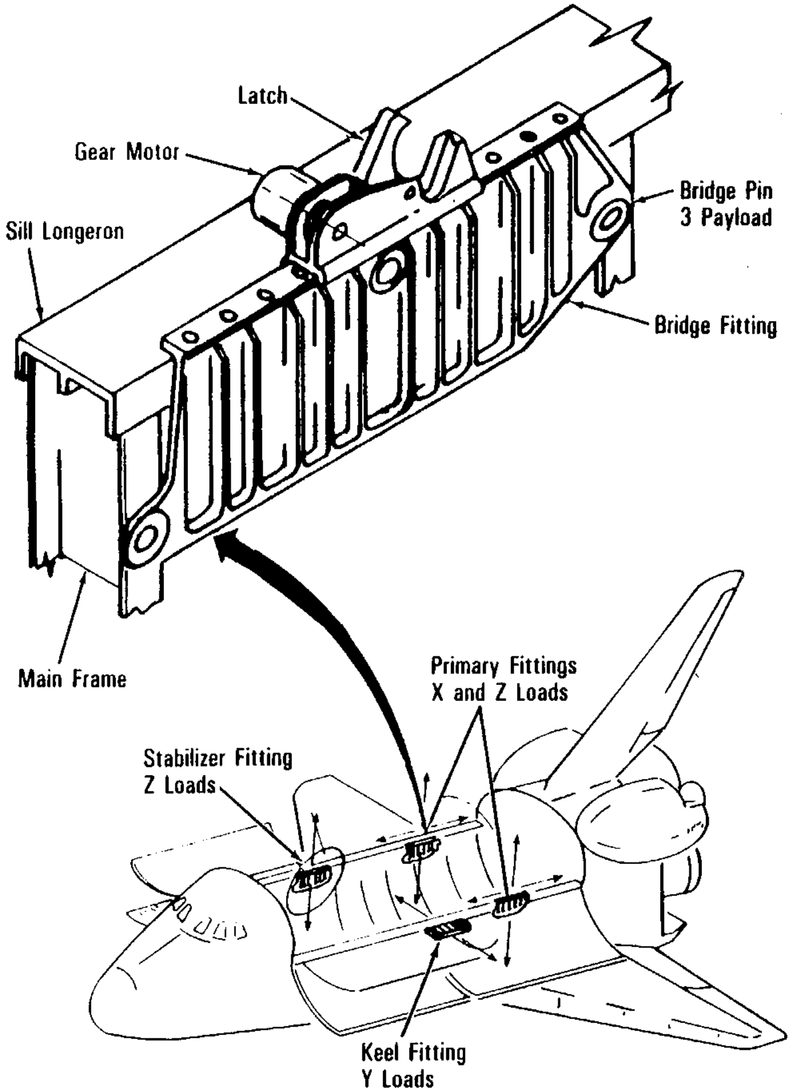
Range 100 Feet to 300 Nautical Miles (345 Statute Miles)

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

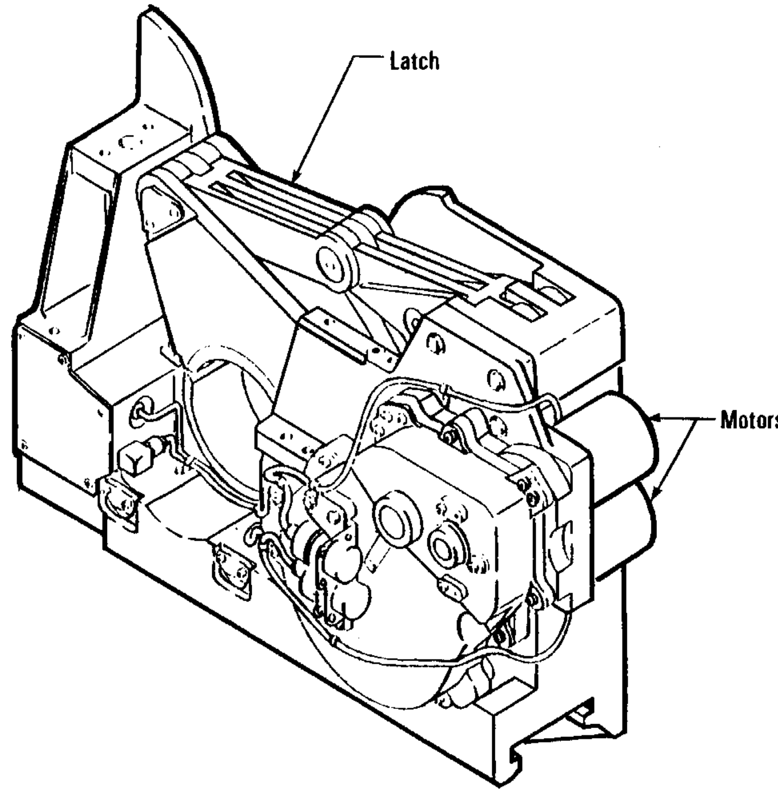
The shuttle program has not baselined a transponder;
however, TRW has a transponder that can be placed on a payload.




*Ku-Band Radar System*




*Active Payload Retention System*



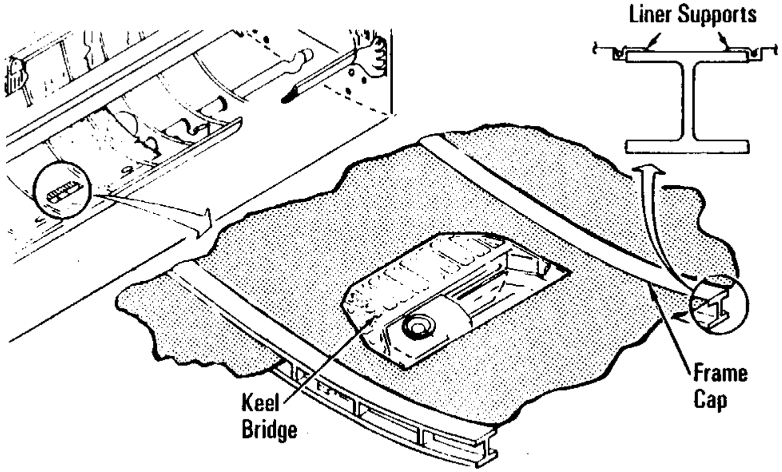

*Active Payload Retention Latch*



If the keel latch is not working properly, Columbia could reboost the LDEF approximately 45 nautical miles above the altitude it was retrieved at.

The LDEF was designed to be reusable, and repeat missions with new complements of experiments were planned for the structure.

LDEF's center ring frame and end frames are welded and bolted aluminum (6061-T6). The longerons are bolted to both frames, and intercostals (cross pieces positioned between the main




*Active Keel Fitting*

rings) are bolted to the longerons to form intermediate rings. The main load of the LDEF is transmitted to Columbia through two side support trunnions on the center ring. The keel fitting on the center ring provides lateral support. The end support beam attached by a pin joint to one end frame will take vertical loads and ensure that loads through the attachment fittings are static. The end support beam also reduces the effects of thermal distortion and other misalignments when the LDEF is berthed in Columbia's payload bay.

## IMAX CAMERA

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

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

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

The IMAX camera, last carried on STS-34, will be used on this mission to cover the retrieval of the LDEF and to gather material on the use of observations of the Earth from space for IMAX films to succeed "The Dream Is Alive."

## FLUIDS EXPERIMENT APPARATUS

Materials are processed in space because crystals superior to those grown on the ground have been produced in the low gravity levels achievable in low Earth orbit. The focus of the Fluids Experiment Apparatus 3 experiment, called the Microgravity Disturbances experiment, is to investigate the effects of both orbiter- and crew-induced disturbances in the microgravity environment of the resulting microstructure of indium crystals grown using the float zone technique.

The FEA-3 experiment is one of the first experiments designed specifically to grow crystals during known disturbances in order to investigate their effects on crystal growth processes. The main sources of the disturbances to be investigated in this experiment are orbiter engine firings and crew exercise on the treadmill, but several other disturbances typical of orbiter operations will be included. This research is expected to provide information useful in establishing the microgravity-level requirements for processing materials aboard space station Freedom and will also provide a greater understanding of the role of residual gravity in materials processing.

In addition, this experiment will investigate the effects of disturbances on the stability of a freely suspended molten zone and will provide information on the impurity-refining capability of float zone processing in space.

Rockwell International Corp.'s Space Transportation Systems Division, Downey, Calif., is engaged in a Joint Endeavor Agreement with NASA's Office of Commercial Programs to conduct floating zone crystal growth and purification research. The agreement, signed on March 17, 1987, provides for microgravity experiments to be performed on two space shuttle missions in the company's microgravity laboratory, the FEA.

Under the sponsorship of NASA's Office of Commercial Programs, the FEA will be flown on Columbia on STS-32. STSD is responsible for developing the FEA hardware and integrating the experiment payload. NASA's Lyndon B. Johnson Space Center, Houston, Texas, developed the materials science experiments and will analyze their results.

The Indium Corporation of America, Utica, N.Y., is collaborating with NASA in developing and analyzing the experiments and is providing the seven indium samples to be processed on the FEA-3 mission. NASA will provide standard space shuttle flight services under the JEA.

## PROTEIN CRYSTAL GROWTH

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

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

During this mission, 120 different PCG experiments will be conducted simultaneously, using as many as 24 different proteins. Though there are three processes used to grow crystals on Earth—vapor diffusion, liquid diffusion and dialysis—only vapor diffusion will be used in this set of experiments. The PCG is installed and operated in Columbia's middeck.

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

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

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

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

Shortly after the shuttle reaches orbit, either mission specialists Marsha Ivins or David Low will combine each of the protein solutions with other solutions containing a precipitation agent to form small droplets on the ends of double-barreled syringes positioned in small chambers. Water vapor will diffuse from each droplet to a solution absorbed in a porous reservoir that lines each chamber. The loss of water in this vapor diffusion process will produce conditions in the droplets that cause protein crystals to grow.

In three of the 20-chambered, 15- by 10- by 1.5-inch trays, crystals will be grown at room temperature (22 C); the other three trays will be refrigerated (at 4 C) during crystal growth. STS-32 will be the first mission during which PCG experiments will be run at 4 C, making it possible to crystalize a wider selection of proteins. The STS-32 mission also provides more time for crystals to grow.

A seventh tray will not have temperature control. The crew will videotape droplets in the tray to study the effects of orbiter maneuvers and crew activity on droplet stability and crystal formation.

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

To further develop the scientific and technological foundation for protein crystal growth in space, NASA's Office of Commercial Programs and the Microgravity Science and Applications Division are co-sponsoring the STS-32 experiments, with management provided through MSFC. Blair Herren is the Marshall experiment manager and Richard E. Valentine is the mission manager for the PCG experiment at MSFC.

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

The STS-32 industry, university and government PCG research investigators include CNRS, Marseille, France; Eli Lilly & Co.; the U.S. Naval Research Laboratory; Du Pont de Nemours & Co.; Merck Sharp & Dohme Laboratories; Texas A&M University; the University of Alabama in Birmingham/Schering Corp.; Yale University; the University of Pennsylvania; the University of California, Riverside; the Weizmann Institute of Science; Marshall Space Flight Center; Australian National University/BioCryst Ltd.; the University of Alabama in Birmingham/BioCryst; Smith Kline & French Laboratories; the Upjohn Co.; Eastman Kodak Co.; Wellcome Research Laboratories; and the Georgia Institute of Technology.

*Protein Description/Affiliation for STS-32*

| Principal Investigator | Affiliation | Protein | Description | Temp |
|---|---|---|---|---|
| Juan Fontecilla | CNRS, Marseille, France | Lectin, lathyrus ochrus | These proteins are essential for cell-cell recognition, which is important in tissue growth. This protein structure will provide a unique understanding of protein-sugar interactions, which are fundamental in cellular metabolic processes. | 22°C |
| Noel Jones | Eli Lilly & Co. | Human growth hormone | Human somatotropin (growth hormone) is one of several proteins with variant forms that are synthesized in the anterior lobe of the pituitary gland. The biosynthetic human somatotropin being flown on STS-32 is identical in all respects to the natural hormone. Biosynthetic human somatotropin is marketed by Eli Lilly & Co. for the treatment of children who are unusually small because their pituitary glands produce too little growth homone. | 22°C |
| Keith Ward | Naval Research Laboratory | Porcine pancreatic phospholipase $A_2$ | Phospholipase is an enzyme that is associated with many human disease states, including rheumatoid arthritis and septic shock. Successful structure analyses of phospholipase crystals will lead to the development of drugs to treat these conditions. | 22°C |
| Patricia Weber | Du Pont de Nemours & Co. | Isocitrate lyase | This is a target enzyme for fungicides. Better understanding of this enzyme should lead to more potent fungicides to treat serious crop diseases such as rice blast. | 22°C |
| Manuel Navia<br><br>Edgar Meyer | Merck Sharp & Dohme Laboratories<br><br>Texas A&M University | Porcine elastase | This enzyme is associated with the degradation of lung tissue in people suffering from emphysema. A more detailed knowledge of this enzyme's structure will be useful in studying the causes of this debilitating disease. | 22°C |
| Vijay Senadhi | University of Alabama in Birmingham/ Schering Corp. | $\gamma$-interferon | This enzyme stimulates the body's immune system and is used clinically in the treatment of cancer. | 22°C |
| Paul Sigler | Yale University | TRP repressor/ operator complex or TRP operator DNA | This protein is used to study the structural bases for the specific affinity of a genetic regulatory protein and its DNA target. The mechanisms derived during these studies have important implications in the regulation of cell growth and development. | 22°C |
| Ponzy Lu | University of Pennsylvania | Lac repressor/ operator | All of our ideas of how genes are turned on and off come from lac repressor and how it works. The crystals being flown are the first ever obtained for the complex. | 22°C |
| Alexander McPherson | University of California at Riverside | Satellite tobacco mosaic virus | Satellite tobacco mosaic virus is the spherical T = 1 icosahedral satellite virus of the classical rod virus TMV and is a plant pathogen. It is the largest biological particle to be crystallized in space. | 22°C |

*Protein Description/Affiliation for STS-32*

| Principal Investigator | Affiliation | Protein | Description | Temp |
|---|---|---|---|---|
| Ada Yonath | The Weizmann Institute of Science | Ribosome | Ribosomes play a major role in protein processing in cells. | 22°C |
| Dan Carter | Marshall Space Flight Center | Human serum albumin | This protein contributes to many transport and regulatory processes and has multifunctional binding properties ranging from various metals, fatty acids, hormones and a wide spectrum of therapeutic drugs. | 22°C |
| Patricia Weber | Du Pont de Nemours & Co. | Cyanobacterium photosystem I complex | This is an integral membrane protein complex involved in the second, more reducing step of photosynthetic electron transfer required for the reduction of NADP to NADPH. The 28,000 MW complex incorporates 8 to 9 polypeptide chains, approximately 80 chlorophyll molecules and 3 non-heme iron centers. Knowledge of its structure will provide a clearer understanding of photosynthetic mechanisms. | 22°C |
| Graeme Laver | Australian National University/ BioCryst Ltd. | Neuraminidase (B/Hong Kong/ 73) | Neuraminidase is an enzyme of the surface of the influenza virus that enables the virus to spread in the body and cause disease. When the precise crystal structure of the neuraminidase is known, specific, effective and safe neuraminidase inhibitors that will stop the virus from spreading in the body and provide a cure for influenza can be designed. | 22°C |
| Larry DeLucas | University of Alabama in Birmingham/ BioCryst Ltd. | Aldose reductase | Aldose reductase belongs to a group of aldo-keto reductases that have broad substrate specificity. This enzyme has been implicated in the development of diabetic complications because of its ability to catalyze the reduction of glucose to sorbitol. | 4°C |
| Drake Eggleston | Smith Kline & French Laboratories | Aridicin aglycone or SKF 104662 | SKF 104662 is a molecure representative of a whole class of antibiotics in which there is much current industrial interest. | 4°C |
| Howard Einspahr | The Upjohn Co. | Phospholipase A-2 | This enzyme performs functions associated with cell membranes, and a better understanding of it could lead to improved medications for pain and inflammation. | 4°C |
| Patricia Weber | Du Pont de Nemours & Co. | Cyclosporin A, cyclophilin complex | Cyclosporin A is a cyclic polypeptide analog that is the principal drug in current use to suppress immune rejection during organ transplants in humans. The drug binds to a highly conserved protein, cyclophilin, which has also been shown to possess activity as a cis-trans prolyl isomerase. | 4°C |

*Protein Description/Affiliation for STS-32*

| Principal Investigator | Affiliation | Protein | Description | Temp |
|---|---|---|---|---|
| Byron Rubin | Eastman Kodak Co. | Diacetinase | Diacetinase is an enzyme isolated from a common bacteria by researchers at Kodak in 1982. The enzyme catalyzes the breakdown of glycerol esters and is specific for short-chain alkyl esters where the alkyl group has from 1 to 4 carbon atoms. It is particularly useful in breaking down diacetyl glycerol ester and is used in a Kodak clinical product. The determination of the atomic structure of this enzyme should provide a basis for understanding the way fat-metabolizing enzymes work and could suggest new uses for the enzyme. | 4°C |
| Dave Stammers | Wellcome Research Laboratories | Reverse transcriptase | This enzyme is a chemical key to the replication of the AIDS virus. More detailed knowledge of its 3-dimensional structure could lead to new drug treatments for AIDS. | 4°C |
| Bud Suddath | Georgia Institute of Technology | Human serum transferrin | Human serum transferrin is responsible for iron transport to hemoglobin synthesizing red blood cells. Transferrin also participates directly in the regulation and control of iron absorption and protects against iron intoxication. Furthermore, almost all cultured cells require transferrin for growth. | 4°C |
| Donald Voet | University of Pennsylvania | 12 base pair DNA | This nucleic acid is a segment of DNA that participates in the control of the synthesis of various proteins. | 4°C |
| Alexander McPherson | University of California at Riverside | Catalase | Catalase, from beef liver, is a major mammalian detoxifying enzyme responsible for clearing free peroxide radicals from tissue carrying out a high rate of catabolism. | 4°C |
| Manuel Navia | Merck Sharp & Dohme Laboratories | HIV protease | HIV protease is a critical enzyme in the life cycle of HIV-I, the AIDS virus. | 4°C |
| Alexander McPherson | University of California at Riverside | Canavalin | Canavalin represents the major reserve protein of leguminous seeds, such as beans and peas, and therefore constitutes one of the major sources of dietary protein for man and domestic animals. | 4°C |

## LATITUDE/LONGITUDE LOCATER

The Latitude/Longitude Locater is a modified 70mm Hasselblad camera with a fixed and moving reticle for sighting on targets and taking angle marks (as well as photographs). A camera-computer interface unit connects the camera to a GRID compass computer. The collection of marks is reduced to the longitude and latitude for each of the targets on which the marks are taken. The objective of the LLL mission is to evaluate the accuracy and usability of the instrument by viewing and marking on known sites on the Earth during the flight.

## 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 Columbia during cooperative overflights. This experiment is a continuation of tests made on the STS-29, 30 and 34 missions. The scientific observations made of Columbia while it performs reaction control system thruster firings and water dumps or activates payload bay lights are used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models. The AMOS tests involve no payload-unique flight hardware and only require that Columbia 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.

## MESOSCALE LIGHTNING EXPERIMENT

The Mesoscale Lightning experiment will be conducted on the STS-32 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, 30, and 34 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.

Columbia's payload bay cameras will be pointed directly below Columbia to observe nighttime lightning in large, or mesoscale, storm systems to gather global estimates of lightning as observed from Columbia's 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 Columbia's 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.

## AMERICAN FLIGHT ECHOCARDIOGRAPH

The American Flight Echocardiograph is an off-the-shelf medical ultrasonic imaging system that has been modified for space shuttle compatibility. The AFE non-invasively generates a two-dimensional, cross-sectional image of the heart or other soft tissues that is displayed on a cathode-ray tube at 30 frames per second.

The AFE is designed to provide in-flight measurements of the size and functioning of the heart and record heart volume and cardiovascular responses to space flight. AFE results will be used in the development of optimal countermeasures to cardiovascular changes of crew members.

Operated by STS-32 mission specialist Marsha Ivins, the AFE hardware will be stored in one of Columbia's middeck lockers. All five crew members will participate as experiment subjects as time allows. Crew members also will use the AFE to support a detailed supplementary objective, the first flight of a collapsible lower body negative pressure unit. The AFE was previously flown on STS 51-D.

In echocardiography, a probe next to the skin sends high-frequency sound (ultrasound) waves through the skin and into the body and detects reflections, or echos, from the surfaces of the organs, producing pictures.

The Life Sciences Division of NASA's Office of Space Science and Applications is sponsoring the AFE, which was developed at the Johnson Space Center. Dr. Michael Bungo, the director of JSC's Space Biomedical Research Institute, is the principal investigator.

# CHARACTERIZATION OF NEUROSPORA CIRCADIAN RHYTHMS

Characterization of Neurospora Circadian Rhythms in Space is a middeck payload sponsored by the Office of Space Science and Applications' Life Sciences Division. The objective of the CNCR experiment is to determine if the circadian rhythm (diurnal cycle) of neurospora (pink bread mold) persists in the mircogravity environment of space.

This experiment is intended to provide information about endogenously driven biological clocks that might then be applied to other organisms. An endogenous activity is one that occurs within a single cell's outer membrane.

Neurospora grows in two forms: a smooth confluence of silky threads called mycelia and cottony tufts of upright stalks tipped with tiny ball-shaped spores called conidia. When it grows in a constant, completely uniform external environment, neurospora mold cycles rhythmically from one growth form to the other. This cycle causes the mold to produce the ball-shaped spores in approximately 21-hour intervals. This interval is believed to be controlled by an internal cell clock.

However, under typical circumstances, alterations in the external environment, particularly day-night cycles with a period of 24 hours, are capable of readjusting neurospora's internal clock. The fundamental question addressed by this experiment is: Do the conditions of space, especially the absence of Earth's strong gravitational field, affect neurospora's circadian rhythms? Because these rhythmic phenomena are also found in all plants and animals, including humans, this experiment addresses a broad and important biological question.

The principal investigator is Dr. James S. Ferraro of Southern Illinois University, Carbondale, Ill. The project manager is Dr. Randall Berthold of NASA's Ames Research Center, Mountain View, Calif. Dr. Charles Winget, also from Ames Research Center, is the project scientist, and Dr. Thora Halstead of NASA Headquarters' Life Sciences Division, is the program scientist-manager. The mission manager is Willie Beckham of NASA's Johnson Space Center.

## ON-ORBIT DEVELOPMENT TEST OBJECTIVES

### COLD SOAK OF COLUMBIA'S OBSERVATION WINDOWS

The purpose of this development test objective is to collect thermal data during extended cold attitudes.

### ASCENT WING AERODYNAMIC DISTRIBUTED LOADS VERIFICATION

This DTO will collect ascent aerodynamic loads data on Columbia.

### ENTRY AERODYNAMIC CONTROL SURFACES TEST

The purpose of this DTO is to collect entry aerodynamics data to be used in evaluating the effectiveness of various control surfaces. These are referred to as programmed test inputs.

### REINFORCED CARBON-CARBON LIFE EVALUATION

The purpose of this DTO is to collect entry data on the nose cap and wing leading edge.

### ENTRY STRUCTURAL CAPABILITY

This DTO will collect loads data during Columbia's entry.

### ASCENT STRUCTURAL CAPABILITY EVALUATION

This DTO will collect ascent structural loads.

### POGO STABILITY PERFORMANCE

The purpose of this DTO is to record data during space shuttle main engine powered flight.

### THERMAL PROTECTION SYSTEM PERFORMANCE

This DTO will perform umbilical well camera photography of the external tank after separation.

### SHUTTLE/PAYLOAD LOW-FREQUENCY ENVIRONMENT

The purpose of this DTO is to collect heavy payload data (low-frequency response) during ascent.

### CABIN AIR MONITORING

This DTO will utilize the solid sorbent sampler to continuously sample Columbia's atmosphere throughout the flight.

### REMOTE MANIPULATOR SYSTEM OPERATING LOADS AND DATA DIVING LDEF RETRIEVAL

The purpose of this DTO is to take advantage of the LDEF's weight and size to collect unique and extreme combinations of forces on the RMS. Data will be collected during loaded RMS operations with the LDEF payload.

### CAMCORDER DEMONSTRATION

The purpose of this DTO is to document cabin and exterior scenes with an 8mm camcorder. The equipment will be evaluated as a possible future enhancement of orbiter cabin television equipment.

### TRACKING AND DATA RELAY SATELLITE HANDOVER DEMONSTRATION

S-band and Ku-band TDRS-to-TDRS handover capability will be demonstrated during this DTO. Ku-band handovers will involve the return link only.

### DIRECT-DRIVE RMS EXERCISE

The purpose of this DTO is to collect data on the integrity of RMS joints and brakes.

## GRAVITY-GRADIENT ATTITUDE CONTROL

Data collection will help refine the computer models used to predict gravity-gradient attitudes. The long-duration tests (eight to 12 hours) will help determine the amplitude of steady-state attitude oscillations and the sensitivity of these oscillations to attitude and rate errors at attitude initiation.

## EXTENDED-DURATION ORBITER ADDITIONAL STOWAGE EVALUATION

Several provisions for additional stowage will be tested for use on EDO missions.

## ORBITER EXPERIMENT ORBITAL ACCELERATION RESEARCH EXPERIMENT

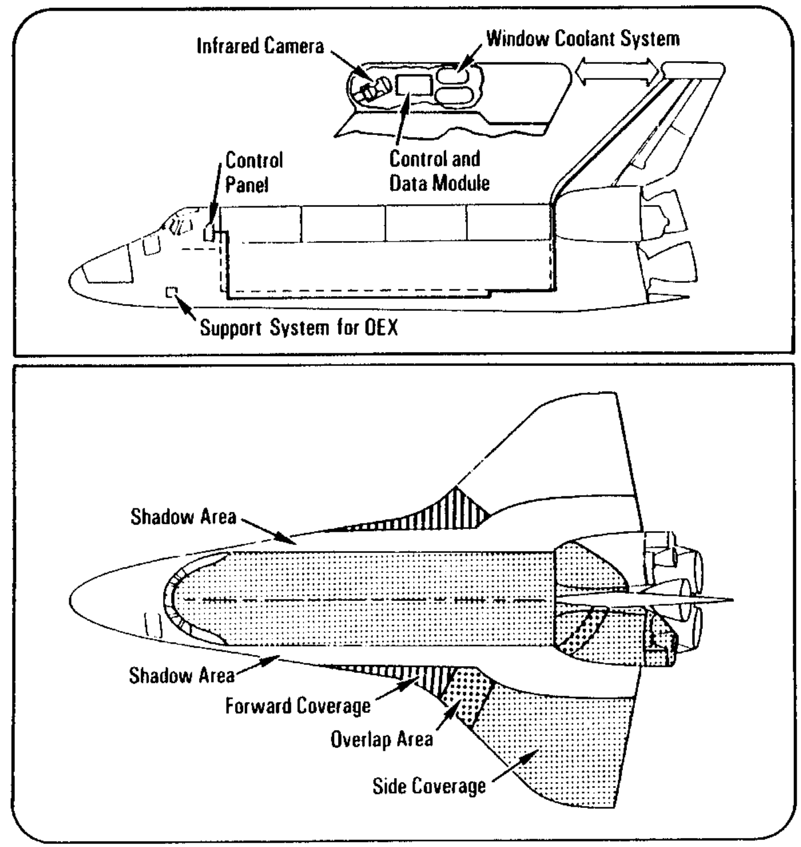
Measurements of orbiter aerodynamic acceleration will be recorded in the nano-g range along the principal axes in the free-molecular flow regime at orbital altitudes through the transition regime during reentry. Orbiter maneuvers about the principal axes as well as center of gravity-measuring free-drift will be performed to record aerodynamic accelerations at very sensitive levels.

## OEX SHUTTLE INFRARED LEESIDE TEMPERATURE SENSING

One visible difference between Columbia and Discovery and Atlantis is the shuttle infrared leeside temperature sensing pod on Columbia's vertical tail. SILTS consists of a cylindrical housing approximately 20 inches in diameter that is capped at the leading edge by a hemispherical dome. Mounted inside the dome is an infrared camera that obtains high-resolution infrared imagery of the upper (leeside) surfaces of Columbia's port (left) wing and fuselage during entry. The images provide detailed temperature maps at the surface of the leeside thermal protection materials and indicate the degree of aerodynamic heating of the surface in flight. SILTS is activated by Columbia's computer at about 400,000 feet and is terminated after the orbiter passes through the period of significant aerodynamic heating.

This information will increase understanding of leeside aeroheating phenomena and will be used to design a less conservative thermal protection system. SILTS provides the opportunity to obtain data under flight conditions for comparison with data obtained in ground-based facilities.

Six primary components make up the SILTS experiment system: (1) an infrared camera, (2) infrared-transparent windows, (3) a temperature-reference surface, (4) a data and control electronics module, (5) a pressurized nitrogen module and (6) window protection plugs. These components are installed in a pod that is mounted atop the vertical stabilizer and capped at the leading edge




*Shuttle Infrared Leeside Temperature Sensing System* by a hemispherical dome. (The SILTS pod replaces the top 24 inches of the vertical stabilizer.) Inside the dome, the infrared camera system is mounted so that it can rotate to view the orbiter leeside surfaces through either of two windows—one offering a view of the orbiter fuselage and the other, a view of the left wing. The camera is sensitive to heat sources from 200 to 1,000 F.

The camera's indium-antimonide detector is cooled to cryogenic temperatures by a Joule-Thompson cryostat. The camera's field of view is 40 by 40 degrees. Its rotating prism system scans four 100-line fields each second, with a 4-1 interlace, resulting in a 400-line image.

Each of the two infrared-transparent window assemblies consists of dual silicone windows constrained within a carbon-phenolic window mount. The windows and window mount assemblies are designed to withstand the entry thermal environment to which they would be subjected without active cooling. They are, however, transpiration-cooled with gaseous nitrogen during experiment operations so that they do not reach temperatures at which they would become significant radiators in the infrared. A small thermostatically controlled surface between the two window assemblies provides an in-flight temperature reference source for the infrared camera.

The pressurized nitrogen system comprises two 3,000-psi gaseous nitrogen bottles and all associated valves and plumbing. The pressure system supplies gaseous nitrogen to the cryostat for camera detector cooling, to the external window cavities for window transpiration cooling, and to pin pullers that initiate the ejection of the advanced flexible reusable surface insulation window protection plugs upon SILTS activation to expose the viewing ports and camera.

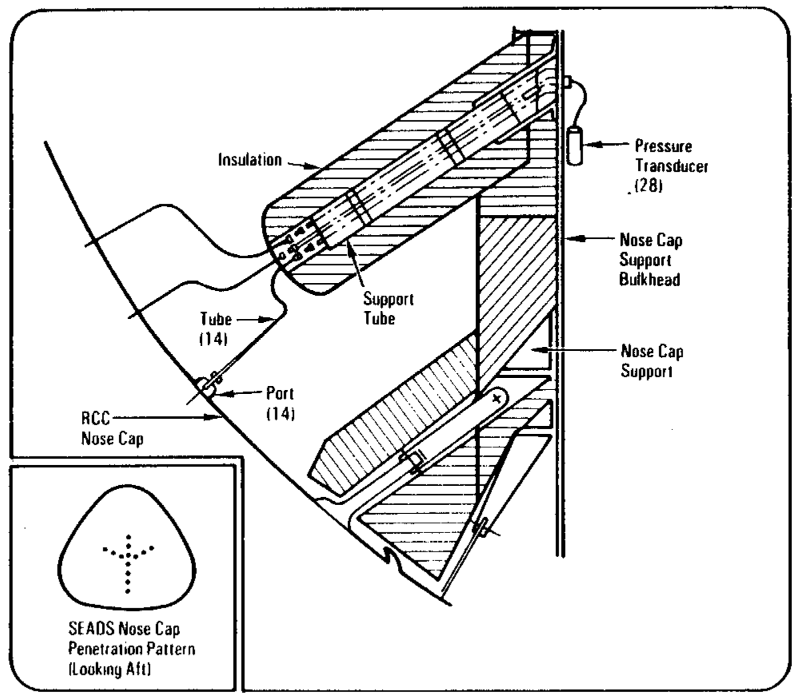
The information obtained by the camera is recorded on the OEX tape recorder. The data, when reduced and analyzed, will produce a thermal map of the viewed areas.

The SILTS experiment is initiated by the onboard computers approximately five minutes before entry interface, which occurs at an altitude of approximately 400,000 feet. The camera operates for approximately 18 minutes through the forward-facing window and left-facing window, alternating evenly between the two about every five seconds.

After the six planned SILTS missions, an analysis of structural loads will determine whether the SILTS pod should be removed and replaced with the original structure or remain in position for other uses. The pod's thermal protection system is high-temperatures reusable surface insulation black tiles, whose density is 22 pounds per cubic foot.

## OEX SHUTTLE ENTRY AIR DATA SYSTEM

Accurate aerodynamic research requires precise knowledge of vehicle attitude and state. This information, commonly referred




*Shuttle Entry Air Data System*

to as air data, includes vehicle angle of attack, angle of sideslip, free-stream dynamic pressure, Mach number and total pressure. An evaluation of the orbiter baseline air data system indicated that flight air data would not be available above approximately Mach 3.5 and that the accuracy of the air data would not satisfy aerodynamic research requirements. Therefore, the shuttle entry air data system was developed under the OEX program to take the measurements required for the precise determination of air data across the orbiter's atmospheric flight-speed range (i.e., hypersonic, supersonic, transonic and subconic Mach numbers) or from lift-off to 280,000 feet during ascent and from 280,000 feet to touchdown during entry.

The key to incorporating SEADS in the shuttle orbiter was the development of a technique for penetrating the orbiter's reinforced carbon-carbon nose cap to obtain the required pressure measurements. The SEADS nose cap penetration assembly evolved as a result of extensive design, fabrication and test programs that evaluated high-temperature (greater than 2,600 F) materials and configuration concepts. The coated columbium penetration assembly selected was fabricated for installation in a specially modified baseline geometry nose cap. The SEADS nose cap contains an array of 14 penetration assemblies, associated coated columbium pressure tubing, support structure, pressure transducers and systems-monitoring instrumentation. Data from the SEADS pressure transducers are transmitted to the OEX support system and stored on the OEX tape recorder for postflight data analysis.

## DELAYED-TYPE HYPERSENSITIVITY

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

## IN-FLIGHT AEROBIC EXERCISE

Daily in-flight aerobic exercise will (1) inhibit the decrease in cardiac dimensions observed during space flight and thus improve postflight orthostatic tolerance and (2) minimize the loss of aerobic capacity after flight. The STS-32 crew is divided into two groups (exercisers and nonexercisers), and both groups will participate in daily measurements of resting heart rate. While the exercisers conduct detailed test protocols of aerobic exercise, measurements of ECG and heart rate will be recorded. Researchers hope to develop countermeasures that will prevent postspace flight orthostatic intolerance.

## IN-FLIGHT LOWER BODY NEGATIVE PRESSURE

Fluid loading via ingestion of salt tablets and water in association with lower body negative pressure treatment will protect tolerance to orthostasis (simulated in flight by LBNP). The objective of this study is to evaluate the effectiveness of fluid loading during LBNP in improving tolerance of an LBNP stress protocol.

## VARIATIONS IN SUPINE AND STANDING HEART RATE, BLOOD PRESSURE AND CARDIAC SIZE AS A FUNCTION OF SPACE FLIGHT DURATION AND TIME POSTFLIGHT

The purpose of this DSO is to perform preflight and postflight echocardiograph evaluations of physical cardiothoracic diminishment that occurs in space flight.

## 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 space flight 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.

## CHARACTERIZATION OF AIRBORNE PARTICULATE MATTER IN SHUTTLE ATMOSPHERES

Airborne particles and floating debris have been reported as the cause of eye and respiratory tract irritation by crew members. Some instrument failures have also been attributed to airborne particulates. The airborne particulate sampler will be used to characterize the type and amount of debris in the cabin atmosphere. Samples will be analyzed to determine the health and safety consequences of airborne matter and to identify sources of contamination.

## INTRAOCULAR PRESSURE

Pressure measurements 20 to 25 percent above normal and preflight levels were observed in bed rest studies, during zero-gravity conditions experienced on the KC-135, and on the D-1 shuttle mission. The possible deleterious effects of sustained deviations in intraocular pressure are difficult to predict since no statistically valid flight data exist. Even though a few days or weeks of elevated intraocular pressure would be harmless, months or years of sustained high pressure, due to microgravity, could cause ocular disturbances. Significant baseline data are needed to define normal intraocular pressure ranges in microgravity and to determine the magnitude of pressure rises to be expected in crew members. A tono-pen will be used to measure STS-32 crew members' intraocular pressure.

## INFLUENCE OF WEIGHTLESSNESS ON BAROREFLEX FUNCTION

This DSO will consist of preflight and postflight tests only.

## MUSCLE BIOPSY

The purpose of this DSO is to collect data on the morphologic and biochemical effects of space flight on skeletal muscle fibers.

## MUSCLE PERFORMANCE

The purpose of this DSO is to collect more specific information concerning muscle atrophy in weightlessness.

## DOCUMENTARY TELEVISION

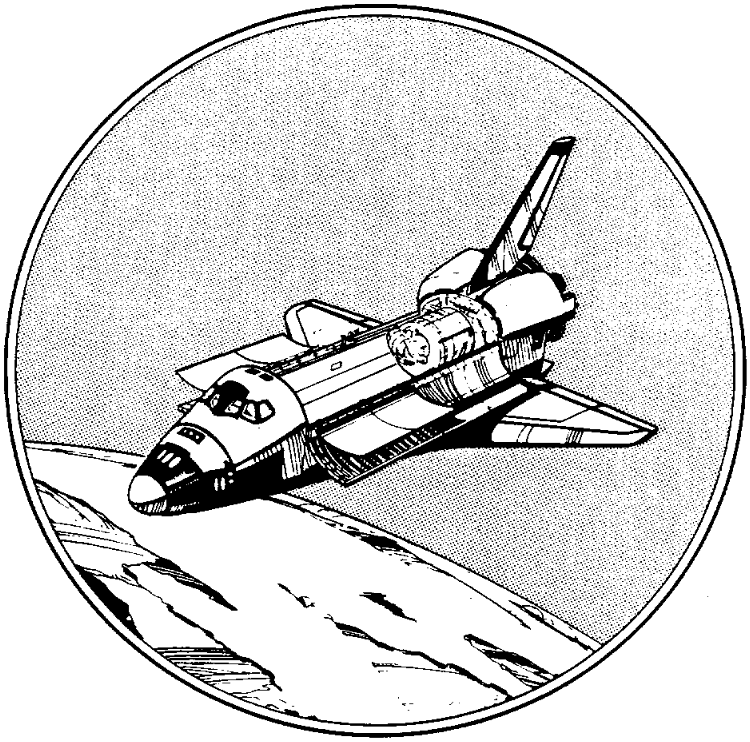
This DSO requires live television transmission or videotape recorder dumps of crew activities and spacecraft functions, such as payload bay views; Syncom predeployment, deployment, and separation activities; views of the Syncom perigee kick motor firing; views of the LDEF during capture through berthing; the inflight crew conference; views of American Flight Echocardiograph sessions; and unscheduled activities.

## DOCUMENTARY MOTION PICTURE PHOTOGRAPHY

This DSO requires documentary and public-affairs motion picture photography of significant activities that best depict the basic capabilities of the space shuttle and its key objectives. This DSO includes filming Syncom predeployment and deployment activities, flight deck activities, middeck activities, and unscheduled events as well.

## DOCUMENTARY STILL PHOTOGRAPHY

This DSO requires still photography of crew activities in the orbiter, spacecraft accommodations and mission-related scenes of general public and historical interest. Exterior shots will be taken with a 70mm camera, while a 35mm camera will be used for interior shots.



# STS-32

## MISSION STATISTICS

## PRELAUNCH COUNTDOWN TIMELINE

## MISSION TIMELINE

December 1989


Rockwell International

**Space Transportation Systems Division**

Office of Media Relations

## CONTENTS

# MISSION OVERVIEW

This is the ninth flight of Columbia and the 33rd in the space transportation system. It is also the first flight launched from Launch Complex 39-A since January 1986.

The flight crew for the STS-32 mission consists of commander Daniel C. Brandenstein; pilot James D. Wetherbee; and mission specialists Bonnie J. Dunbar, Marsha S. Ivins and G. David Low.

The primary objectives of this nine-day mission are to deploy the Syncom (synchronous communication) IV-5 (or F5) satellite, rendezvous with the Long-Duration Exposure Facility and retrieve and berth it in Columbia's payload bay for return to Earth, and acquire data on the flight crew's exposure to long periods of zero gravity and its effects on landing Columbia. The exposure data will be used as part of the efforts to develop a kit that will allow an orbiter to remain in orbit for up to 16 days initially and eventually 28 days.

The LDEF was deployed from Challenger into Earth orbit during the STS 41-C mission on April 7, 1984, and is approaching the end of its orbital lifetime. It has been in orbit in a gravity-gradient, stabilized attitude for five years.

Syncom IV-5 is the last in a series of five communications satellites for the U.S. Navy. Syncom IV-5 will be deployed from Columbia's payload bay, nominally at a mission elapsed time of day one, zero hours and 44 minutes on orbit 17. Backup deployment opportunities are available on orbits 32, 33, 34, 38 and 48.

Syncom F2 was deployed by Discovery on Aug. 31, 1984, during the STS 41-D mission and is operational. Syncom F1 was deployed by Discovery during the STS 51-A mission on Nov. 8, 1984, and is also operational. Syncom F3 was deployed by Discovery during the STS 51-D mission on April 13, 1985, but its perigee kick motor failed to fire. The mission was extended to allow the crew to use a "flyswatter" technique to fix the PKM, but the effort was unsuccessful. Syncom F4 was deployed by Discovery on the STS 51-I mission on Aug. 29, 1985, but it failed to operate. During the mission, Syncom F3 was repaired and is operational.

The exact launch time of Columbia for this mission will be determined by the LDEF's location in Earth orbit 12 hours before the launch.

The rendezvous with the LDEF includes maneuvers to ensure that the external tank misses islands near Hawaii after it separates from the orbiter and an orbital maneuvering system separation maneuver following the deployment of Syncom IV-5.

Columbia nominally will approach the LDEF from the rear (catching up with it). It will then move in front of the LDEF, above the LDEF, and then down to grapple the LDEF with Columbia's remote manipulator system and berth it in Columbia's payload bay.

Nominally, the LDEF capture is scheduled to occur on orbit 49, followed by berthing in Columbia's payload bay on orbit 51 after photographic and television documentation of the LDEF. If a decision is made at launch to delay the nominal retrieval of the LDEF, retrieval could occur on orbits 64 or 80. The documentation of LDEF's condition before it is berthed is required due to the possible effects of atmospheric pressure on the LDEF during entry and its five-year exposure to the space environment.

Eight secondary payloads will also be carried aboard Columbia on this mission.

The IMAX camera project is a collaboration between the National Aeronautics and Space Administration and the Smithsonian Institution's National Air and Space Museum to document significant space activities using the IMAX film medium. This system developed by the IMAX Systems Corp. of Toronto, Canada, uses specially designed 70mm cameras and projectors to record and display very high definition, large-screen motion pictures. IMAX will be used on this mission to cover the retrieval of the LDEF and for Earth viewing. Opportunities for filming will be provided to the flight crew before the flight and in real time. The camera and supporting equipment are stowed in the middeck.

The Fluids Experiment Apparatus experiment is one of the first designed specifically to investigate the effects of disturbances on crystal growth processes. The main sources of disturbance to be investigated are Columbia's engine firings and flight crew exercise on the treadmill, but several other disturbances typical of orbiter operations will be included. This research is expected to provide information useful in establishing the microgravity-level requirements for processing materials aboard space station Freedom and a greater understanding of the role of residual gravity in materials processing. This experiment will also investigate the effects of disturbances on the stability of a freely suspended molten zone and provide information on the impurity-refining capability of float zone processing in space. The FEA and its computer are located in the middeck of Columbia's crew compartment.

In collaboration with the University of Alabama in Birmingham, NASA's Marshall Space Flight Center, Huntsville, Ala., is continuing a series of experiments in protein crystal growth that may be a major benefit to medical technology. These experiments could improve food production and lead to innovative drugs to combat cancer, AIDS, high blood pressure, organ transplant rejection, rheumatoid arthritis, and many other diseases.

Protein crystal growth experiments were first carried out during the Spacelab 2 mission in April 1985 and have been flown on the space shuttle six times. The first four flights were designed primarily to develop hardware and techniques for growing crystals in space. The STS-26 and 29 experiments were the first scientific attempts to grow useful crystals by vapor diffusion in microgravity. The STS-26 and 29 payloads, unlike those on previous flights, featured temperature control and the automation of some of the processes to improve accuracy and reduce the flight crew's time required.

During this mission, 120 different PCG experiments will be conducted simultaneously on as many as 24 proteins. Though there are three processes used to grow crystals on Earth—vapor diffusion, liquid diffusion and dialysis—only vapor diffusion will be used in this mission's set of experiments. The PCG experiments are installed and operated in Columbia's middeck.

The Air Force Maui Optical Site Calibration Test allows ground-based electro-optical sensors located on Mt. Haleakala on Maui, Hawaii, to collect imagery and signature data for Columbia during cooperative overflights while Columbia performs reaction control system thruster firings and water dumps or activates payload bay lights. The data are used to support the calibration of AMOS sensors and the validation of spacecraft contamination models. This experiment is a continuation of tests made on the STS-29, 30 and 34 missions.

The Characterization of Neurospora Circadian Rhythms in Space experiment is to determine if the circadian rhythm (diurnal cycle) of neurospora (pink bread mold) persists in the microgravity of space. The fundamental question to be addressed by this experiment is whether the conditions of space, especially the absence of Earth's strong gravitational field, affect neurospora's circadian rhythms. This is a middeck experiment.

The American Flight Echocardiograph experiment is designed to provide in-flight measurements of the size and functioning of the heart and record heart volume and cardiovascular responses to space flight. Results from the AFE will be used in the development of optimal countermeasures for crew members' cardiovascular changes. The AFE hardware is located in a middeck locker.

The Mesoscale Lightning experiment is designed to obtain nighttime images of lightning in order to better understand the global distribution of lightning events in storms that are close together and the relationships of lightning, convective storms and precipitation. Cameras in Columbia's payload bay will record lightning directly below Columbia, and if time permits, the flight crew will also use handheld 35mm cameras to photograph lightning in storm systems not directly below Columbia's ground track. The MLE has gathered data on STS-26, 30 and 34.

The Latitude/Longitude Locater experiment uses a modified 70mm Hasselblad camera with a fixed and moving reticle to make sightings on targets and take angle marks (as well as photographs). A camera-computer interface unit connects the camera to a GRID compass computer. The collection of marks is reduced to the longitude and latitude of each of the targets on which the marks are taken. The objective of the experiment is to evaluate the accuracy and usability of the instrument by viewing and marking on known sites on Earth during the flight.

## MISSION STATISTICS

Launch: The exact time of launch on a given day is determined by the LDEF's exact location in Earth orbit, which will not be known until 12 hours prior to launch. The launch window varies from day to day due to a variety of technical requirements.

| | | |
|---|---|---|
| 12/18/89 | 7:29 p.m. EST | Nominal |
| | 6:29 p.m. CST | estimated |
| | 4:29 p.m. PST | launch time |

Mission Duration: 216 hours (nine days), 21 hours, 35 minutes

Landing: Nominal end of mission is on orbit 159.

| | | |
|---|---|---|
| 12/28/89 | 5:04 p.m. EST | Based on |
| | 4:04 p.m. CST | nominal estimated |
| | 2:04 p.m. PST | launch time |

Inclination: 28.5 degrees

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

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

Altitude: 161 by 190 nautical miles (185 by 218 statute miles), then 156 by 190 nautical miles (179 by 218 statute miles), then 166 by 191 nautical miles (191 by 219 statute miles), then 166 by 167 nautical miles (191 by 192 statute miles), then 161 by 166 nautical miles (185 by 191 statute miles), then 149 by 166 nautical miles (171 by 191 statute miles), then 145 by 149 nautical miles (166 by 171 statute miles), then 147 by 149 nautical miles (169 by 171 statute miles), then 148 by 150 nautical miles (170 by 172 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,540,161 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 229,848 pounds

Payload Weight Up: Approximately 26,625 pounds

Payload Weight Down: Approximately 37,732 pounds

Orbiter Weight at Landing: Approximately 229,285 pounds

Payloads: Syncom IV-5 deployment, Long-Duration Exposure Facility retrieval, Fluids Experiment Apparatus 3, Protein Crystal Growth III-02, Latitude/Longitude Locater, American Flight Echocardiograph 02, Characterization of Neurospora Circadian Rhythms in Space 01, Air Force Maui Optical Site 04, Mesoscale Lightning, and IMAX. The FEA, PCG, LLL, AFE, CNCR, and IMAX payloads are located in Columbia's crew compartment.

Flight Crew Members:
Commander: Daniel C. Brandenstein, third space shuttle flight
Pilot: James D. Wetherbee, first space shuttle flight
Mission Specialist 1: Bonnie J. Dunbar, second space shuttle flight
Mission Specialist 2: Marsha S. Ivins, first space shuttle flight
Mission Specialist 3: G. David Low, first space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Daniel Brandenstein
Flight deck front right seat, pilot James Wetherbee
Flight deck aft center seat, MS 2 Marsha Ivins
Flight deck aft right seat, MS 1 Bonnie Dunbar
Middeck, MS 3 David Low

Entry Seating:
Flight deck aft right seat, MS 3 David Low
Middeck, MS 1 Bonnie Dunbar

Extravehicular Activity Crew Members, If Required:
Extravehicular activity astronaut 1 would be David Low and EV 2 would be Bonnie Dunbar.

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 lake bed Runway 17 at Edwards Air Force Base, Calif.

Notes:

- The remote manipulator is installed in Columbia's payload bay for the retrieval of the LDEF on this mission. The galley is installed in the middeck of Columbia.

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

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

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

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

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

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

- Five power reactant storage and distribution cryogenic oxygen and hydrogen tank sets were installed in Columbia to support this nine-day mission.

## MISSION OBJECTIVES

- Deployment of Syncom IV-5 satellite
- Rendezvous with and retrieval of the LDEF
- Acquisition of data on flight crew's exposure to long periods of zero gravity (nine days) and its effects on landing Columbia. A kit is being developed to allow an orbiter to operate in Earth orbit for up to 16 days and eventually 28 days.
- Secondary payloads
  - — IMAX
  - — FEA-3
  - — PCG-III-02
  - — LLL
  - — CNCR-01
  - — AMOS-04
  - — MLE

## DEVELOPMENT TEST OBJECTIVES

- Cold soak of Columbia's observation windows
- Ascent wing aerodynamic distributed loads verification on Columbia
- Entry aerodynamic control surfaces test
- Ascent structural capability evaluation
- Reinforced carbon-carbon life evaluation
- Entry structural capability
- Pogo stability performance
- Thermal protection system performance of external tank
- Shuttle/payload frequency environment
- Cabin air monitoring
- Remote manipulator system operating loads and data during LDEF retrieval
- Camcorder demonstration
- RMS direct drive exercise
- TDRS-to-TDRS demonstrations
- Gravity-gradient attitude control
- Additional stowage for extended-duration orbiter
- Orbiter experiments
  - — Shuttle infrared leeside temperature sensing
  - — Shuttle entry air data system
  - — Aerothermal instrumentation package

## DETAILED SUPPLEMENTARY OBJECTIVES

- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Characterization of airborne particulate matter in shuttle atmospheres
- Intraocular pressure
- Delayed-type hypersensitivity
- In-flight aerobic exercise
- In-flight lower body negative pressure
- Muscle biopsy
- Muscle performance
- Influence of weightlessness on baroreflex function
- Variations in supine and standing heart rate, blood pressure and cardiac size as a function of space flight duration and time, postflight
- Documentary television
- Documentary motion picture photography

## PRELAUNCH COUNTDOWN

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

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

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

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

| T – (MINUS) HR:MIN:SEC | TERMINAL COUNTDOWN EVENT |
|---|---|
| 00:09:00 Hold 10 Minutes | A planned 10-minute hold starts.<br><br>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.<br><br>All test support team members verify that they are "go for launch."<br><br>Final GLS configuration is complete. |
| 00:09:00 Counting | The GLS auto sequence starts and the terminal count-down begins.<br><br>The chase aircraft are launched.<br><br>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.<br><br>The ground power is disconnected and the vehicle goes on internal power at this time. It will remain on internal power through the rest of the mission. |
| 00:03:30 | The SSMEs' nozzles are moved (gimbaled) through a preprogrammed pattern to ensure that they will be ready for ascent flight control. At completion of the gimbal profile, the SSMEs' nozzles are in the start position. |
| 00:02:55 | ET liquid oxygen prepressurization is started. At this point, the liquid oxygen tank vent valve is closed and the ET liquid oxygen tank is pressurized to its flight pressure of 21 psi. |
| 00:02:50 | The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted. |
| 00:02:35 | Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the onboard tanks so that a full load at lift-off is assured. This filling operation is terminated at this time. |
| 00:01:57 | Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time. |

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

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

| T – (MINUS) HR:MIN:SEC | TERMINAL COUNTDOWN EVENT |
|---|---|
| 00:00:06.6 | The main fuel and oxidizer valves in each engine are commanded open by the onboard computers, permitting fuel and oxidizer flow into each SSME for SSME start.<br><br>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.<br><br>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

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| **DAY ZERO** | |
| 0/00:00:06.8 | Tower is cleared (SRBs above lightning rod tower). |
| 0/00:00:08 | 90-degree roll maneuver positive roll (right-clockwise) is started. Pitch profile is heads down (astronauts) wings level. |
| 0/00:00:18 | Roll maneuver ends. |
| 0/00:00:28 | All three SSMEs throttle from 104 to 65 percent for maximum aerodynamic load (max q). |
| 0/00:00:52 | 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. |
| 0/00:04:06 | Negative return. The vehicle is no longer capable of return-to-launch-site (RTLS) abort to Kennedy Space Center runway. |
| 0/00:05:58 | Single engine to main engine cutoff (MECO). |
| 0/00:07:32 | All three SSMEs throttle from 104 percent for vehicle no greater than 3-g acceleration capability. |
| 0/00:08:25 | All three SSMEs throttle down to 65 percent for MECO. |
| 0/00:08:33 | MECO, approximate velocity 25,841 feet per second (fps), 184 by 33 nautical miles (nmi) (211 by 37 statute miles [sm]). |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/00:08:57 | ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry). |

The orbiter forward and aft RCSs, which provide 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. |
| 0/00:40:26 | OMS-2 thrusting maneuver is performed, 2 minutes 54 seconds in duration, 227.2 fps, 190 by 19 nmi (185 by 218 sm), normal corrective maneuver (NC)-1. |
| 0/00:53 | Mission specialists (MSs) egress seats. |
| 0/00:54 | Commander and pilot configure general-purpose computers (GPCs) for OPS-2. |
| 0/00:57 | MS performs preliminary middeck configuration. |
| 0/00:59 | MS performs aft flight station configuration. |
| 0/01:08 | Pilot activates payload bus. |
| 0/01:10 | Commander and pilot don and configure communications. |
| 0/01:12 | Pilot maneuvers vehicle to payload bay door opening attitude, negative Z local vertical, positive Y velocity vector attitude. |
| 0/01:16 | Orbit 2 begins. |
| 0/01:17 | Commander activates Syncom IV-5 spacecraft heater. |
| 0/01:19 | MS configures for payload bay door operations. |
| 0/01:28 | Pilot opens payload bay doors. |
| 0/01:35 | Commander, turns two star tracker (ST) power switches to ON. |
| 0/01:36 | MCC-H gives "go for orbit operations." |
| 0/01:37 | Commander and pilot egress seats. |
| 0/01:38 | Commander and pilot configure clothing. |
| 0/01:39 | MSs configure clothing. |
| 0/01:50 | Pilot performs fuel cell auto purge. |
| 0/01:51 | MS activates teleprinter. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/01:52 | Commander performs post payload bay door radiator operations configuration. |
| 0/01:55 | MSs remove and stow seats. |
| 0/01:56 | Commander performs ST self test and opens doors. |
| 0/01:57 | Pilot closes MNB supply $H_2O$ dump isolation circuit breaker, ML86B:A, and opens supply $H_2O$ dump isolation valve, R12L. |
| 0/01:58 | MS configures middeck. |
| 0/01:59 | MS performs Syncom IV-5 status check. |
| 0/02:00 | APU steam vent heater is activated, three boiler controller/heater switches are turned to A-POWER, three to ON. |
| 0/02:10 | Commander configures for vernier RCS control. |
| 0/02:12 | Commander and pilot configure controls for on-orbit operations. |
| 0/02:19 | MS configures remote manipulator system (RMS). |
| 0/02:21 | Pilot enables hydraulic thermal conditioning. |
| 0/02:24 | MS resets caution/warning (C/W) system. |
| 0/02:26 | MS unstows and installs treadmill. |
| 0/02:27 | Pilot turns APU coolant system, R2, APU fuel pump/valve cool A to OFF, B to AUTO. |
| 0/02:29 | Pilot plots fuel cell performance. |

EZ ACTIVITIES

— Launch entry suit (LES) cleaning and drying.

— Pressure control system (PCS) environmental control life support system (ECLSS), configure system 1, 5 minutes, 2 crewmen.

— Lamp and fire suppression test, 10 minutes.

— Protein crystal growth (PCG) fan inlet cleaning and temperature checks.

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| | — Food preparation, 30 minutes. |
| 0/02:30 | All crew members unstow cabin equipment. |
| 0/02:35 | Systems management (SM) cockpit initiation is performed. |
| 0/02:35 | Cryo $O_2$ tank heater sensor is checked. |
| 0/02:45 | Ku-band antenna is deployed. |
| 0/02:45 | Cabin air monitoring. |
| 0/02:47 | Orbit 3 begins. |
| 0/02:50 | Characterization of airborne particulate matter in shuttle atmospheres is performed. |
| 0/02:55 | Ku-band is activated in communication mode. |
| 0/03:05 | RMS is powered up. |
| 0/03:05 | Two crewmen assemble photo and TV camera. |
| 0/03:20 | RMS checkout is performed. |
| 0/03:25 | Vehicle is maneuvered to inertial measurement unit (IMU) alignment attitude. |
| 0/03:35 | Photo/TV are set up for PCG. |
| 0/03:35 | PCG is activated. |
| 0/03:40 | IMU is aligned using ST. |
| 0/03:45 | Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude. |
| 0/04:05 | APU cool is turned to OFF; APU fuel pump/valve cool B is turned to OFF; APU steam vent heater is deactivated, boiler power (3) is turned to OFF. |
| 0/04:05 | RMS is powered down. |
| 0/04:05 | Photo/TV are activated for PCG. |
| 0/04:18 | Orbit 4 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/04:20 | Crew members' mealtime. |
| 0/05:25 | Aft controller is checked out. |
| 0/05:25 | Fluids experiment apparatus (FEA) are unstowed. |
| 0/05:25 | PCG 1 is activated. |
| 0/05:35 | Two crewmen perform intraocular pressure (IOP) detailed supplementary objective (DSO). |
| 0/05:49 | Orbit 5 begins. |
| 0/06:05 | A12, APU heater gas generator/fuel pump (3) is turned to A-AUTO. |
| 0/06:05 | Vehicle is in free drift. |
| 0/06:40 | American Flight Echocardiograph (AFE) operations are performed. |
| 0/06:57 | Normal plane change (NPC) maneuver is achieved by single OMS engine thrusting period, 4.9 fps, 161 by 181 nmi (185 by 219 sm). |
| 0/07:05 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 0/07:05 | Characterization of Neurospora Circadian Rhythms (CNCR) operations are performed. |
| 0/07:20 | Orbit 6 begins. |
| 0/07:45 | Crewmen optical alignment site (COAS) power is turned to OFF, COAS is mounted aft. |
| 0/07:50 | Vehicle is maneuvered to IMU alignment attitude. |
| 0/08:15 | IMU is aligned using ST. |
| 0/08:15 | Crew begins presleep activity. |
| 0/08:20 | COAS is calibrated. |
| 0/08:20 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 0/08:40 | 019, COAS power is turned to OFF, COAS is stowed. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/08:50 | Orbit 7 begins. |
| 0/09:30 | Crew members begin 8-hour sleep period. |
| 0/10:21 | Orbit 8 begins. |
| 0/11:52 | Orbit 9 begins. |
| 0/13:23 | Orbit 10 begins. |
| 0/14:54 | Orbit 11 begins. |
| 0/16:25 | Orbit 12 begins. |
| 0/17:30 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 0/17:56 | Orbit 13 begins. |
| 0/18:05 | Scopolamine (SCOP) and dextroamphetamine (DEX) medical DSO dosages are taken by crew members. |
| 0/18:10 | Two crewmen perform IOP medical DSO. |
| 0/18:35 | SCOP-DEX medical DSO sample is taken. |
| 0/18:35 | Vehicle is maneuvered to IMU alignment attitude. |
| 0/18:50 | IMU is aligned using ST. |
| 0/18:55 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 0/19:00 | Photo/TV are set up for FEA. |
| 0/19:05 | SCOP-DEX medical DSO sample is taken. |
| 0/19:27 | Orbit 14 begins. |
| 0/19:30 | Photo/TV are activated FEA. |
| 0/19:35 | Air sampler DSO is performed. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/19:50 | FEA sample 1 is activated. |
| 0/20:05 | SCOP-DEX medical DSO sample is taken. |
| 0/20:26 | NC-2 maneuver is performed single OMS engine thrusting period, 8 fps, 156 by 190 nm (179 by 218 sm). |
| 0/20:35 | AFE operations are performed. |
| 0/20:45 | Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude. |
| 0/20:58 | Orbit 15 begins. |
| 0/21:20 | FEA sample 1 status is checked. |
| 0/21:35 | Scheduled, inflight maintenance and filter cleaning are performed. |
| 0/21:50 | FEA sample 1 status is checked. |
| 0/22:05 | SCOP-DEX medical DSO sample is taken. |
| 0/22:05 | Photo/TV are set up for Syncom IV-5 deployment. |
| 0/22:20 | FEA sample 1 status is checked. |
| 0/22:28 | Orbit 16 begins. |
| 0/22:40 | Photo/TV are activated for Syncom IV-5 deployment. |
| 0/22:55 | Vehicle is in free drift. |
| 0/23:00 | Syncom IV-5 deployment is reviewed. |
| 0/23:10 | FEA sample 1 status is checked. |
| 0/23:20 | Four crewmen perform Syncom IV-5 checkout and deployment. |
| 0/23:20 | Photo/TV are activated for Syncom IV-5 deployment. |
| 0/23:30 | Syncom IV-5 pivot/keel pin retraction is performed. |
| 0/23:50 | Syncom IV-5 deployment operations. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 0/23:59 | Orbit 17 begins. |

**DAY ONE**

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 1/00:05 | SCOP-DEX medical DSO sample is taken. |
| 1/00:10 | Vehicle is maneuvered to deployment attitude. |
| 1/00:20 | Syncom IV-5 pushoff pin retraction is performed. |
| 1/00:25 | Syncom IV-5 status is checked. |
| 1/00:44 | Syncom IV-5 deployment occurs. |
| 1/00:50 | FEA sample 1 status is checked. |
| 1/00:59 | OMS-3 separation thrusting maneuver is performed, 18 fps, 166 by 191 nmi (191 by 219 smi). |
| 1/01:00 | Vehicle is maneuvered to window protection attitude. |
| 1/01:05 | FEA sample 1 status is checked. |
| 1/01:15 | Syncom IV-5 perigee kick motor (PKM) is viewed using RMS. |
| 1/01:25 | RMS is powered down. |
| 1/01:25 | Digital autopilot (DAP) A, B are changed to A1, B1. |
| 1/01:25 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 1/01:30 | Orbit 18 begins. |
| 1/01:40 | SCOP-DEX medical DSO sample is taken. |
| 1/01:40 | Crew members' mealtime |
| 1/01:50 | Video tape recorder (VTR) is set up for Syncom IV-5 satellite deployment. |
| 1/03:00 | VTR playback of Syncom IV-5 occurs from 1/03:00 to 1/03:15 through TDRS West. |
| 1/03:01 | Orbit 19 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 1/03:55 | SCOP-DEX medical DSO sample is taken. |
| 1/04:05 | MS-3 performs aerobics medical DSO. |
| 1/04:10 | FEA sample 1 status is checked. |
| 1/04:32 | Orbit 20 begins. |
| 1/04:50 | FEA sample 1 status is checked. |
| 1/05:05 | Aerobics medical DSO is performed. |
| 1/05:15 | Vehicle is maneuvered to IMU alignment attitude. |
| 1/05:30 | Crew begin presleep activity. |
| 1/05:35 | IMU is aligned using ST. |
| 1/05:40 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 1/05:55 | FEA sample 1 is terminated. |
| 1/06:05 | SCOP-DEX medical DSO sample is taken. |
| 1/06:05 | Pilot performs aerobics medical DSO. |
| 1/06:03 | Orbit 21 begins. |
| 1/07:34 | Orbit 22 begins. |
| 1/08:30 | Crew begins 8-hour sleep period. |
| 1/09:05 | Orbit 23 begins. |
| 1/10:36 | Orbit 24 begins. |
| 1/12:07 | Orbit 25 begins. |
| 1/13:38 | Orbit 26 begins. |
| 1/15:09 | Orbit 27 begins. |
| 1/16:30 | Crew ends 8-hour sleep period and begins postsleep activity. |
| 1/16:40 | All crew members perform aerobics and pulse rate medical DSO. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature checks. |
| 1/16:40 | Orbit 28 begins. |
| 1/18:00 | SCOP-DEX medical DSO sample is taken. |
| 1/18:11 | Orbit 29 begins. |
| 1/18:45 | 01, COAS is turned to OFF, COAS is mounted forward. |
| 1/18:45 | Photo/TV are set up for FEA. |
| 1/18:50 | FEA is reset. |
| 1/18:50 | Vehicle is maneuvered to IMU alignment attitude. |
| 1/19:10 | IMU is aligned using ST. |
| 1/19:15 | Vehicle is maneuvered to COAS calibration attitude. |
| 1/19:15 | Photo/TV are activated for FEA. |
| 1/19:30 | COAS is calibrated. |
| 1/19:35 | 01, COAS is turned to OFF, COAS is stowed. |
| 1/19:35 | FEA is activated for sample 2. |
| 1/19:42 | Orbit 30 begins. |
| 1/20:55 | FEA sample 2 status is checked. |
| 1/21:13 | Orbit 31 begins. |
| 1/21:35 | FEA sample 2 status is checked. |
| 1/21:55 | AFE operations are performed. |
| 1/22:05 | FEA sample 2 status is checked. |
| 1/22:44 | Orbit 32 begins. |
| 1/23:40 | MS-3 performs aerobics medical DSO. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 1/23:55 | FEA sample 2 status is checked. |

**DAY TWO**

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 2/00:15 | Orbit 33 begins. |
| 2/00:35 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 2/01:00 | Crew members' mealtime. |
| 2/01:46 | Orbit 34 begins. |
| 2/02:03 | Normal slow rate (NSR) maneuver occurs with an OMS single engine thrusting period, 41.8 fps, 166 by 167 nmi (191 by 192 smi). |
| 2/02:20 | Photo/TV are set up for middeck activities. |
| 2/02:50 | FEA sample 2 status is checked. |
| 2/02:50 | Photo/TV are activated for middeck activities through TDRS West from 2/03:15 to 2/03:30. |
| 2/03:05 | AFE operations. |
| 2/03:16 | Orbit 35 begins. |
| 2/03:52 | NC-3 occurs with a single OMS engine thrusting period, 8 fps, 161 by 166 nmi (185 by 191 smi). |
| 2/04:10 | FEA sample 2 status is checked. |
| 2/04:20 | Pilot performs aerobics medical DSO. |
| 2/04:35 | FEA sample 2 status is checked. |
| 2/04:35 | Photo/TV are set up for FEA. |
| 2/04:47 | Orbit 36 begins. |
| 2/05:00 | Crew begins presleep activity. |
| 2/05:20 | Commander performs aerobics medical DSO. |
| 2/05:30 | Vehicle is maneuvered to IMU alignment attitude. |
| 2/05:40 | FEA sample 2 is terminated. |
| 2/05:45 | IMU is aligned using ST. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 2/05:45 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 2/06:05 | SCOP-DEX medical DSO sample is taken. |
| 2/06:17 | Orbit 37 begins. |
| 2/06:20 | Crew resets FEA. |
| 2/07:48 | Orbit 38 begins. |
| 2/08:00 | Crew begins 8-hour sleep period. |
| 2/09:18 | Orbit 39 begins. |
| 2/10:48 | Orbit 40 begins. |
| 2/12:19 | Orbit 41 begins. |
| 2/13:49 | Orbit 42 begins. |
| 2/15:20 | Orbit 43 begins. |
| 2/16:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature checks. |
| 2/16:10 | All crew members perform aerobics and pulse rate medical DSO. |
| 2/16:50 | Orbit 44 begins. |
| 2/17:10 | Photo/TV are activated for FEA. |
| 2/17:10 | FEA sample 3 is activated. |
| 2/17:35 | Vehicle is maneuvered to IMU alignment attitude. |
| 2/17:55 | IMU is aligned using ST. |
| 2/17:55 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 2/18:17 | Commander configures aft flight station for rendezvous. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 2/18:21 | Orbit 45 begins. |
| 2/18:24 | Commander enables rendezvous navigation. |
| 2/18:29 | Commander configures DAP A, B to A9, B6. |
| 2/18:35 | AFE operations are performed. |
| 2/18:35 | FEA sample 3 status is checked. |
| 2/18:58 | Normal height adjustment (NH) maneuver is performed with a single OMS thrusting period, 21.2 fps, 149 by 166 nmi (171 by 191 sm), range to LDEF is approximately 400,000 feet. |
| 2/19:05 | FEA sample 3 status is checked. |
| 2/19:25 | FEA sample 3 status is checked. |
| 2/19:43 | NC-4 maneuver is performed with a single OMS engine thrusting period 35.8 fps, 145 by 149 nmi (166 by 171 sm). |
| 2/19:44 | Commander performs initial target track; range to LDEF is approximately 243,000 feet. |
| 2/19:48 | Commander performs ST target acquisition. |
| 2/19:51 | Orbit 46 begins. |
| 2/20:10 | Photo/TV are set up for LDEF retrieval. |
| 2/20:10 | FEA sample 3 status is checked. |
| 2/20:13 | MS ends ST navigation. |
| 2/20:49 | When range to LDEF is less than approximately 150,000 feet, pilot configures for rendezvous radar target acquisition. |
| 2/21:10 | Photo/TV are activated for LDEF retrieval. |
| 2/21:17 | MS performs ST target acquisition. |
| 2/21:21 | Orbit 47 begins. |
| 2/21:42 | MS ends ST navigation. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 2/21:43 | MS-1 turns port RMS heater (2) to AUTO, panel A8L. |
| 2/21:49 | Commander performs normal corrective combination (NCC) maneuver with an RCS thrusting period. |
| 2/21:57 | When rendezvous radar lock-on occurs, commander activates rendezvous radar navigation at a range of approximately 114,000 feet from LDEF. |
| 2/22:30 | FEA sample 3 is terminated. |
| 2/22:43 | Terminal phase initiation (TPI) occurs, commander performs RCS thrusting period, 3.2 fps, 147 by 149 nmi (169 by 171 smi); range to LDEF is approximately 49,000 feet. |
| 2/22:48 | MS performs RMS power up. |
| 2/22:51 | Orbit 48 begins. |
| 2/22:57 | MS performs RMS maneuver to poise position for LDEF capture. |
| 2/23:08 | Commander performs midcourse correction (MC)-1 maneuver using RCS, range to LDEF is approximately 50,000 feet. |
| 2/23:34 | Commander performs MC-2 using RCS, approximately 31,000 feet from LDEF. |
| 2/23:44 | Commander performs MC-3 using RCS, approximately 23,000 feet from LDEF. |
| 2/23:46 | Commander configures CCTV. |
| 2/23:55 | Commander performs MC-4 using RCS, approximately 4,500 feet from LDEF. |
| 2/23:56 | Manual trajectory control occurs. |
| 2/23:58 | MS notes LDEF orientation when approximately 3,500 feet from LDEF. |

**DAY THREE**

| | |
|---|---|
| 3/00:00 | Vehicle crosses radius (R)-bar; commander configures for velocity (V)-bar. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 3/00:16 | Proximity operations are performed. |
| 3/00:17 | Commander turns Ku-radar output to LO, panel A1U. |
| 3/00:19 | Commander notes LDEF orientation. |
| 3/00:20 | Orbit 49 begins. |
| 3/00:21 | Vehicle crosses V-bar. |
| 3/00:26 | Commander configures for R-bar approach. |
| 3/00:44 | Commander establishes R-bar. |
| 3/00:46 | MS-1 notes LDEF orientation. |
| 3/00:47 | Commander performs vehicle alignment. |
| 3/00:48 | Commander initiates closing rate using RCS. |
| 3/00:49 | MS-1 turns payload bay flood docking to bright; panel A7U. |
| 3/01:12 | Commander configures Ku-band for communication mode. |
| 3/01:17 | MS-1 performs LDEF capture. |
| 3/01:21 | MS-1 sets RMS brakes to ON. |
| 3/01:24 | Commander disables rendezvous navigation. |
| 3/01:45 | Vehicle is maneuvered to survey attitude, positive Y local vertical, positive Z velocity vector attitude. |
| 3/01:50 | Orbit 50 begins. |
| 3/02:05 | When vehicle is maneuvered to survey attitude, LDEF photo survey is performed. |
| 3/03:05 | Photo/TV are activated for LDEF retrieval. |
| 3/03:20 | Orbit 51 begins. |
| 3/04:25 | The LDEF is berthed in Columbia's payload bay. |
| 3/04:50 | Orbit 52 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 3/05:00 | The LDEF experiment initiation system (EIS) is deactivated. |
| 3/05:10 | Vehicle is maneuvered to bias plus Y local vertical, plus Z velocity vector attitude |
| 3/05:15 | RMS is powered down. |
| 3/05:15 | Star table is cleared. |
| 3/05:25 | Crew begins presleep activity. |
| 3/05:41 | IMU is aligned using ST. |
| 3/05:45 | Vehicle is maneuvered to negative X solar inertial attitude. |
| 3/06:00 | Vehicle is maneuvered to negative X solar inertial orbit rotation rate. |
| 3/06:20 | Orbit 53 begins. |
| 3/07:45 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 3/07:50 | Orbit 54 begins. |
| 3/08:00 | Crew begins 8-hour sleep period. |
| 3/09:20 | Orbit 55 begins. |
| 3/10:50 | Orbit 56 begins. |
| 3/12:19 | Orbit 57 begins. |
| 3/13:49 | Orbit 58 begins. |
| 3/15:19 | Orbit 59 begins. |
| 3/16:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 3/16:10 | All crew members perform aerobics and pulse rate medical DSO. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 3/16:35 | SCOP-DEX medical DSO dosage is taken. |
| 3/16:49 | Orbit 60 begins. |
| 3/17:05 | ECLSS supply water dump from the flash evaporator system (FES) occurs. |
| 3/17:05 | SCOP-DEX medical DSO sample is taken. |
| 3/17:35 | SCOP-DEX medical DSO sample is taken. |
| 3/17:55 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 3/17:55 | Star table is cleared. |
| 3/18:19 | Orbit 61 begins. |
| 3/18:23 | IMU is aligned using ST. |
| 3/18:30 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 3/18:35 | AFE operations are performed. |
| 3/18:35 | SCOP-DEX medical DSO sample is taken. |
| 3/19:05 | Latitude/longitude locator (L3) is set up. |
| 3/19:40 | VTR is set up for LDEF retrieval. |
| 3/19:45 | L3 state vector (SV) update occurs. |
| 3/19:49 | Orbit 62 begins. |
| 3/19:55 | Photo/TV are set up for crew conference. |
| 3/20:00 | VTR playback of LDEF retrieval occurs through TDRS West from 3/20:00 to 3/20:20. |
| 3/20:25 | L3 observation of Isla Guv occurs. |
| 3/20:25 | Photo/TV are activated for crew conference through TDRS East, 3/20:48 to 3/21:05. |
| 3/20:35 | SCOP-DEX medical DSO sample is taken. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 3/20:48 | Crew conference with all crew members occurs. |
| 3/21:19 | Orbit 63 begins. |
| 3/21:50 | MS-3 performs aerobics medical DSO. |
| 3/21:50 | Crew resets FEA. |
| 3/22:00 | L3 observation of Monterre and KSC occurs. |
| 3/22:30 | SCOP-DEX medical DSO sample is taken. |
| 3/22:30 | Photo/TV is set up for FEA. |
| 3/22:49 | Orbit 64 begins. |
| 3/23:00 | Crew members' mealtime. |

**DAY FOUR**

| | |
|---|---|
| 4/00:15 | L3 SV update occurs. |
| 4/00:15 | Photo/TV are activated for FEA. |
| 4/00:18 | Orbit 65 begins. |
| 4/00:35 | SCOP-DEX medical DSO sample is taken. |
| 4/00:35 | FEA sample 4 is activated. |
| 4/00:55 | L3 observation of Lanai Island occurs. |
| 4/01:05 | L3 observation of Cedros Island occurs. |
| 4/01:20 | L3 observation of San Juan occurs. |
| 4/01:35 | AFE operations are performed. |
| 4/01:48 | Orbit 66 begins. |
| 4/02:05 | ECLSS supply dump from the FES occurs. |
| 4/02:05 | FEA sample 5 status is checked. |
| 4/02:30 | SCOP-DEX medical DSO sample is taken. |
| 4/02:35 | Commander performs aerobics medical DSO. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 4/02:35 | FEA sample 5 status is checked. |
| 4/02:50 | L3 observation of La Guna occurs. |
| 4/03:05 | FEA sample 5 status is checked. |
| 4/03:18 | Orbit 67 begins. |
| 4/03:40 | FEA sample 5 is terminated. |
| 4/03:50 | Pilot performs aerobics medical DSO. |
| 4/04:00 | Crew begins presleep activity. |
| 4/04:35 | Star table is cleared. |
| 4/04:45 | SCOP-DEX medical DSO sample is taken. |
| 4/04:48 | Orbit 68 begins. |
| 4/05:02 | IMU is aligned using ST. |
| 4/06:18 | Orbit 69 begins. |
| 4/07:00 | Crew begins 8-hour sleep period. |
| 4/07:48 | Orbit 70 begins. |
| 4/09:18 | Orbit 71 begins. |
| 4/10:47 | Orbit 72 begins. |
| 4/12:17 | Orbit 73 begins. |
| 4/13:47 | Orbit 74 begins. |
| 4/15:00 | Crew ends 8-hour sleep period, and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 4/15:10 | All crew members perform aerobics and pulse rate medical DSO. |
| 4/15:17 | Orbit 75 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 4/16:30 | SCOP-DEX medical DSO sample is taken. |
| 4/16:45 | Star table is cleared. |
| 4/16:47 | Orbit 76 begins. |
| 4/17:00 | RCS regulator is reconfigured, 07/08, helium pressure A (3) to CLOSED; B(3) to GPC, OPEN. |
| 4/17:12 | IMU is aligned using ST. |
| 4/17:25 | Cabin temperature controller is reconfigured, MD44F, pin cabin temperature controller actuator linkage to actuator 2, L1, cabin temperature controller 2 |
| 4/17:50 | Humidity separator is reconfigured, L1, humidity SEP B to OFF, A to ON. |
| 4/17:55 | Manual fuel cell purge is performed. |
| 4/18:00 | AFE operations are performed. |
| 4/18:05 | Crew resets FEA. |
| 4/18:05 | Heater is reconfigured to B. |
| 4/18:15 | Pressure control system is configured to 1. |
| 4/18:17 | Orbit 77 begins. |
| 4/18:25 | ECLSS redundant component checkout is performed. |
| 4/18:55 | L3 SV update occurs. |
| 4/19:05 | AFE operations are performed. |
| 4/19:05 | Photo/TV are set up for FEA. |
| 4/19:05 | FEA sample 4 is activated. |
| 4/19:10 | L3 observation of Isla Juv occurs. |
| 4/19:25 | L3 observation of Tenerife occurs. |
| 4/19:35 | Photo/TV are activated for FEA. |
| 4/19:47 | Orbit 78 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 4/20:50 | L3 observation of Lake Oke occurs. |
| 4/21:05 | L3 observation of Presqui occurs. |
| 4/21:15 | Filter cleaning and scheduled inflight maintenace occur. |
| 4/21:16 | Orbit 79 begins. |
| 4/22:00 | Crew members' mealtime. |
| 4/22:46 | Orbit 80 begins. |
| 4/23:05 | L3 SV update occurs. |
| 4/23:45 | L3 observation of Mauna Lo occurs. |
| 4/23:55 | L3 observation of Cedros Island occurs. |

**DAY FIVE**

| | |
|---|---|
| 5/00:10 | FEA sample 4 is terminated. |
| 5/00:16 | Orbit 81 begins. |
| 5/00:35 | AFE operations are performed. |
| 5/01:20 | L3 observation of Niihau occurs. |
| 5/01:20 | Commander performs aerobics medical DSO. |
| 5/01:40 | L3 observation of Kingston occurs. |
| 5/01:45 | Photo/TV are set up for middeck activities. |
| 5/01:46 | Orbit 82 begins. |
| 5/02:15 | Photo/TV are activated for middeck activities through TDRS West from 5/03:40 to 5/03:22. |
| 5/02:20 | Crew resets FEA. |
| 5/02:35 | Pilot performs aerobics medical DSO. |
| 5/02:50 | L3 observation of Midway occurs. |
| 5/03:00 | Crew begins presleep activity. |
| 5/03:15 | Vehicle is maneuvered to bias negative Z local vertical negative Y velocity vector attitude. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 5/03:16 | Orbit 83 begins. |
| 5/03:25 | Star table is cleared. |
| 5/03:51 | IMU is aligned using ST. |
| 5/04:00 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 5/04:35 | SCOP-DEX medical DSO sample is taken. |
| 5/04:46 | Orbit 84 begins. |
| 5/06:00 | Crew begins 8-hour sleep period. |
| 5/06:16 | Orbit 85 begins. |
| 5/07:45 | Orbit 86 begins. |
| 5/09:15 | Orbit 87 begins. |
| 5/10:45 | Orbit 88 begins. |
| 5/12:15 | Orbit 89 begins. |
| 5/13:45 | Orbit 90 begins. |
| 5/14:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 5/14:10 | All crew members perform aerobics and pulse rate medical DSO. |
| 5/15:15 | Orbit 91 begins. |
| 5/15:37 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 5/15:37 | Star table is cleared. |
| 5/15:45 | Photo/TV are set up for middeck activities. |
| 5/16:09 | IMU is aligned using ST. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 5/16:15 | Photo/TV are activated for middeck activities through TDRS West from 5/17:30 to 5/18:00. |
| 5/16:15 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 5/16:35 | MS-1 performs lower body negative pressure (LBNP) medical DSO. |
| 5/16:45 | Orbit 92 begins. |
| 5/17:15 | L3 SV update occurs. |
| 5/17:55 | MS-3 performs LBNP medical DSO. |
| 5/17:55 | L3 observation of Cosiguin occurs. |
| 5/18:10 | L3 observation of Tenerife occurs. |
| 5/18:14 | Orbit 93 begins. |
| 5/18:25 | L3 observation of L Tana occurs. |
| 5/18:45 | Crew resets FEA. |
| 5/18:50 | Photo/TV are set up for CNCR. |
| 5/19:20 | Photo/TV are activated for CNCR. |
| 5/19:30 | L3 observation of Mexico City occurs. |
| 5/19:40 | CNCR remarks are made. |
| 5/19:44 | Orbit 94 begins. |
| 5/19:55 | L3 observation of Chari Ri occurs. |
| 5/20:10 | Crew members' mealtime. |
| 5/21:45 | MS-1 performs LBNP medical DSO. |
| 5/22:00 | L3 SV update occurs. |
| 5/22:35 | MS-3 performs LBNP medical DSO. |
| 5/22:45 | Orbit 96 begins. |
| 5/22:45 | L3 observation of Galveston Bay. |
| 5/23:35 | AFE operations are performed. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| **DAY SIX** | |
| 6/00:05 | L3 observation of Niihau occurs. |
| 6/00:14 | Orbit 97 begins. |
| 6/00:20 | Commander performs aerobics medical DSO. |
| 6/00:25 | L3 observation of Lago Eng occurs. |
| 6/00:45 | Photo/TV are set up for FEA. |
| 6/01:05 | Commander performs aerobics medical DSO. |
| 6/01:20 | Photo/TV are activated for FEA. |
| 6/01:35 | Pilot performs aerobics medical DSO. |
| 6/01:35 | FEA sample 6 is activated. |
| 6/01:44 | Orbit 98 begins. |
| 6/01:50 | L3 observation of Laguna occurs. |
| 6/02:17 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 6/02:17 | Star table is cleared. |
| 6/02:30 | Crew begins presleep activity. |
| 6/02:48 | IMU is aligned using ST. |
| 6/02:50 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 6/03:13 | Orbit 99 begins. |
| 6/03:35 | FEA sampie 6 is terminated. |
| 6/04:43 | Orbit 100 begins. |
| 6/05:30 | Crew begins 8-hour sleep period. |
| 6/06:13 | Orbit 101 begins. |
| 6/07:43 | Orbit 102 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 6/09:13 | Orbit 103 begins. |
| 6/10:43 | Orbit 104 begins. |
| 6/12:12 | Orbit 105 begins. |
| 6/13:30 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 6/13:35 | All crew members perform aerobics medical DSO. |
| 6/13:42 | Orbit 106 begins. |
| 6/13:45 | Vehicle is maneuvered to waste water dump attitude. |
| 6/14:10 | Waste water dump occurs. |
| 6/14:35 | ECLSS supply dump from the FES occurs. |
| 6/15:12 | Orbit 107 begins. |
| 6/15:59 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 6/15:59 | Star table is cleared. |
| 6/16:15 | Photo/TV are set up for middeck activities. |
| 6/16:20 | Air sample medical DSO is performed. |
| 6/16:29 | IMU is aligned using ST. |
| 6/16:35 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 6/16:42 | Orbit 108 begins. |
| 6/16:50 | Photo/TV are set up for Mesoscale Lightning Experiment (MLE.) |
| 6/17:00 | Photo/TV are activated for middeck activities through TDRS East from 6/17:00 to 6/17:20. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 6/17:05 | MS-1 performs LBNP medical DSO. |
| 6/17:10 | L3 SV update occurs. |
| 6/17:20 | Photo/TV are activated for MLE. |
| 6/18:12 | Orbit 109 begins. |
| 6/18:15 | L3 observation of Laguna occurs. |
| 6/18:35 | L3 observation of Canary Island occurs. |
| 6/18:55 | Crew resets FEA. |
| 6/19:05 | ECLSS supply dump from the FES occurs. |
| 6/19:10 | Photo/TV are activated for MLE. |
| 6/19:42 | Orbit 110 begins. |
| 6/19:55 | L3 observation of KSC occurs. |
| 6/20:15 | L3 observation of L. Faguib occurs. |
| 6/20:35 | Photo/TV are set up for FEA. |
| 6/20:40 | Photo/TV are activated for MLE. |
| 6/21:00 | Crew members' mealtime. |
| 6/21:11 | Orbit 111 begins. |
| 6/22:05 | FEA sample 7 is activated. |
| 6/22:05 | Photo/TV are activated for FEA. |
| 6/22:10 | L3 SV update occurs. |
| 6/22:10 | Photo/TV are activated for MLE. |
| 6/22:41 | Orbit 112 begins. |
| 6/22:50 | L3 observation of Lanai occurs. |
| 6/23:10 | L3 observation of Lake Oke occurs. |
| 6/23:35 | AFE operations are performed. |
| 6/23:35 | FEA sample 7 status is checked. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| **DAY SEVEN** | |
| 7/00:05 | FEA sample 7 status is checked. |
| 7/00:11 | Orbit 113 begins. |
| 7/00:20 | Commander performs aerobics medical DSO. |
| 7/00:35 | FEA sample 7 status is checked. |
| 7/00:50 | L3 observation of Essequib occurs. |
| 7/01:35 | Pilot performs aerobics medical DSO. |
| 7/01:41 | Orbit 114 begins. |
| 7/01:55 | L3 observation of Midway occurs. |
| 7/02:00 | Crew begins presleep activity. |
| 7/02:05 | Pilot performs aerobics medical DSO. |
| 7/02:05 | FEA sample 7 status is checked. |
| 7/02:39 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 7/02:40 | Star table is cleared. |
| 7/03:08 | IMU is aligned using ST. |
| 7/03:11 | Orbit 115 begins. |
| 7/03:15 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 7/03:35 | FEA sample 7 is terminated. |
| 7/04:41 | Orbit 116 begins. |
| 7/05:00 | Crew begins 8-hour sleep period. |
| 7/06:10 | Orbit 117 begins. |
| 7/07:40 | Orbit 118 begins. |
| 7/09:10 | Orbit 119 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 7/10:40 | Orbit 120 begins. |
| 7/12:10 | Orbit 121 begins. |
| 7/13:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 7/13:10 | All crew members perform aerobics medical DSO. |
| 7/13:40 | Orbit 122 begins. |
| 7/14:45 | L3 SV update occurs. |
| 7/14:50 | Star table is cleared. |
| 7/15:09 | Orbit 123 begins. |
| 7/15:18 | IMU is aligned using ST. |
| 7/16:00 | L3 observation of Socotra occurs. |
| 7/16:10 | Crew resets FEA. |
| 7/16:15 | MS-1 performs LBNP medical DSO. |
| 7/16:39 | Orbit 124 begins. |
| 7/16:50 | Crew stows FEA. |
| 7/17:05 | MS-3 performs LBNP medical DSO. |
| 7/17:30 | L3 observation of Emi Kous occurs. |
| 7/17:30 | Photo/TV are set up for middeck activity. |
| 7/18:00 | Photo/TV are activated for middeck activities through TDRS West from 7/18:15 to 7/18:45. |
| 7/18:09 | Orbit 125 begins. |
| 7/19:00 | L3 observation of Richat occurs. |
| 7/19:10 | L3 observation of Kilimanj occurs. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 7/19:39 | Orbit 126 begi |
| 7/20:15 | L3 observatior /i River occurs. |
| 7/20:35 | L3 observation akar and Lao Tome occurs. |
| 7/21:00 | Crew members' mealtime. |
| 7/21:09 | Orbit 127 begins. |
| 7/22:25 | L3 SV update occurs. |
| 7/22:39 | Orbit 128 begins. |
| 7/22:50 | All crew members perform skin test medical DSO. |
| 7/23:50 | AFE operations are performed. |

**DAY EIGHT**

| | |
|---|---|
| 8/00:08 | Orbit 129 begins. |
| 8/00:40 | Commander performs aerobics medical DSO. |
| 8/01:05 | L3 observation of Lake Nic occurs. |
| 8/01:30 | Star table is cleared. |
| 8/01:38 | Orbit 130 begins. |
| 8/01:50 | Pilot performs aerobics medical DSO. |
| 8/01:57 | IMU is aligned using ST. |
| 8/02:00 | Crew begins presleep activity. |
| 8/03:08 | Orbit 131 begins. |
| 8/04:38 | Orbit 132 begins. |
| 8/05:00 | Crew begins 8-hour sleep period. |
| 8/06:08 | Orbit 133 begins. |
| 8/07:37 | Orbit 134 begins. |
| 8/09:07 | Orbit 135 begins. |
| 8/10:37 | Orbit 136 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 8/12:07 | Orbit 137 begins. |
| 8/13:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| | EZ ACTIVITIES |
| | — Food preparation, 30 minutes. |
| | — PCG fan inlet cleaning and temperature check. |
| 8/13:10 | All crew members perform aerobics medical DSO. |
| 8/13:37 | Orbit 138 begins. |
| 8/15:07 | Orbit 139 begins. |
| 8/15:12 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 8/15:12 | Star table is cleared. |
| 8/15:20 | APU steam vent heater is activated; boiler controller/heater (3) is turned to B; power (3) to ON. |
| 8/15:38 | IMU is aligned using ST. |
| 8/15:45 | Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude. |
| 8/16;15 | Flight control system checkout is performed. |
| 8/16;36 | Orbit 140 begins. |
| 8/17:05 | MS-3 performs LBNP medical DSO. |
| 8/17:35 | RCS hot fire test occurs. |
| 8/17:50 | Crew configures DAP to AI/AUTO/VERNIER. |
| 8/17:50 | AFE operations are performed. |
| 8/18:00 | Orbit 141 begins. |
| 8/18:15 | APU fuel pump/valve cool A is turned to OFF. |
| 8/18:30 | APU heater is reconfigured. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 8/18:50 | L3 SV update occurs. |
| 8/19:05 | Commander performs aerobics medical DSO. |
| 8/19:20 | L3 observation of Presqui and Cameroon occurs. |
| 8/19:36 | Orbit 142 begins. |
| 8/20:10 | Crew members' mealtime. |
| 8/21:06 | Orbit 143 begins. |
| 8/21:15 | Photo/TV are set up for PCG. |
| 8/21:15 | Crew stows LBNP medical DSO. |
| 8/21:20 | L3 SV update occurs. |
| 8/21:45 | Photo/TV are activated for PCG through TDRS West from 8/22:03 to 8/22:27. |
| 8/21:47 | Orbit 142 begins. |
| 8/22:05 | L3 observation of San Juan occurs. |
| 8/22:05 | Pilot performs aerobics medical DSO. |
| 8/22:05 | PCG is deactivated. |
| 8/22:36 | Orbit 144 begins. |
| 8/23:00 | All crew members perform cabin configuration and stowage. |

**DAY NINE**

| | |
|---|---|
| 9/00:05 | Orbit 145 begins. |
| 9/01:51 | Vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 9/01:35 | Orbit 146 begins. |
| 9/01:51 | Star table is cleared. |
| 9/02:00 | Crew begins presleep activity. |
| 9/02:17 | IMU is aligned using ST. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 9/02:25 | Vehicle is maneuvered to negative Z local vertical, negative Y velocity vector attitude. |
| 9/03:05 | Orbit 147 begins. |
| 9/04:35 | Orbit 148 begins. |
| 9/05:00 | Crew begins 8-hour sleep period. |
| 9/06:05 | Orbit 149 begins. |
| 9/07:34 | Orbit 150 begins. |
| 9/09:04 | Orbit 151 begins. |
| 9/10:34 | Orbit 152 begins. |
| 9/12:04 | Orbit 153 begins. |
| 9/13:00 | Crew ends 8-hour sleep period and begins postsleep activity. |
| 9/13:10 | All crew members perform aerobics medical DSO. |
| 9/13:34 | Orbit 154 begins. |
| 9/14:01 | Maneuver vehicle is maneuvered to bias negative Z local vertical, negative Y velocity vector attitude. |
| 9/14:01 | Star table is cleared. |
| 9/14:30 | IMU is aligned using ST. |
| 9/14:35 | Vehicle is maneuvered to negative X solar inertial attitude. |
| 9/14:50 | PCG is deactivated. |
| 9/14:50 | Vehicle rotation is maneuvered. |
| 9/15:03 | Orbit 155 begins. |
| 9/15:20 | Cabin air monitoring DTO is performed. |
| 9/15:20 | Two crewmen perform IOP medical DSO. |
| 9/15:35 | Characterization of airborne particulate matter in shuttle atmosphere is performed. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| | EZ ACTIVITIES |
| | — Air sample. |
| | — Fluid loading preparation, fill 4 drink containers with 8 ounces of H2O each (per person). |
| 9/16:01 | Cathode-ray tube (CRT) timer is set up. |
| 9/16:06 | Coldsoak attitude is initiated. |
| 9/16:16 | Crew stows radiators, if required. |
| 9/16:33 | Orbit 156 begins. |
| 9/16:33 | Crew configures data processing system (DPS) for deorbit preparation. |
| 9/16:36 | MCC updates IMU pad, if required. |
| 9/16:46 | Crew configures for payload bay door closure. |
| 9/16:56 | Crew stows Ku-band antenna, if required. |
| 9/17:02 | Vehicle is maneuvered to IMU alignment attitude. |
| 9/17:09 | DAP is set to B/AUTO/NORMAL. |
| 9/17:10 | Radiator is set to BYPASS and FES is checked out. |
| 9/17:12 | MCC issues "go for payload bay door closure" command. |
| 9/17:16 | IMU is aligned with ST. |
| 9/17:21 | Payload bay doors are closed. |
| 9/17:31 | Preliminary deorbit udpate/uplink occurs. |
| 9/17:40 | Crew configures dedicated displays. |
| 9/17:44 | MCC issues "go for OPS 3" command. |
| 9/17:47 | Vehicle is maneuvered to deorbit burn attitude. |
| 9/17:56 | Crew configures DPS for entry. |
| 9/18:03 | Orbit 157 begins. |

| T + (PLUS) DAY/ HR:MIN:SEC | EVENT |
|---|---|
| 9/18:06 | All crew members verify entry switch list. |
| 9/18:21 | All crew members perform entry review. |
| 9/18:36 | Commander and pilot don LES clothing. |
| 9/18:51 | MSs don LES clothing. |
| 9/19:01 | Commander and pilot ingress seats. |
| 9/19:33 | Orbit 158 begins. |
| 9/19:47 | Deorbit update is performed. |
| 9/19:49 | Flight crew performs OMS gimbal check. |
| 9/20:12 | MCC issues "go for deorbit thrusting maneuver" command. |
| 9/20:19 | Crew maneuvers vehicle to deorbit ignition attitude. |
| 9/20:21 | Crew terminates vehicle to deorbit ignition attitude. |
| 9/20:21 | MSs ingress seats. |
| 9/20:29 | First APU is activated. |
| 9/20:34:52 | Deorbit thrusting maneuver is performed, 4 minutes, 34 seconds in duration, 259 fps. |
| 9/20:40 | Crew proceeds to major mode (MM) 303. |
| 9/20:41 | Crew maneuvers vehicle to post deorbit thrusting attitude. |
| 9/20:43 | Forward RCS dump is performed if required. |
| 9/20:45 | Crew terminates vehicle post deorbit thrusting attitude. |
| 9/20:51 | Crew starts two remaining APUs. |
| 9/20:53 | SSME hydraulic systems are repressurized. |
| 9/20:59 | MM 304 is selected. |
| 9/21:03 | Orbit 159 begins. |
| 9/21:04:50 | Vehicle achieves entry interface (EI), 400,000 feet altitude. |

## 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 |