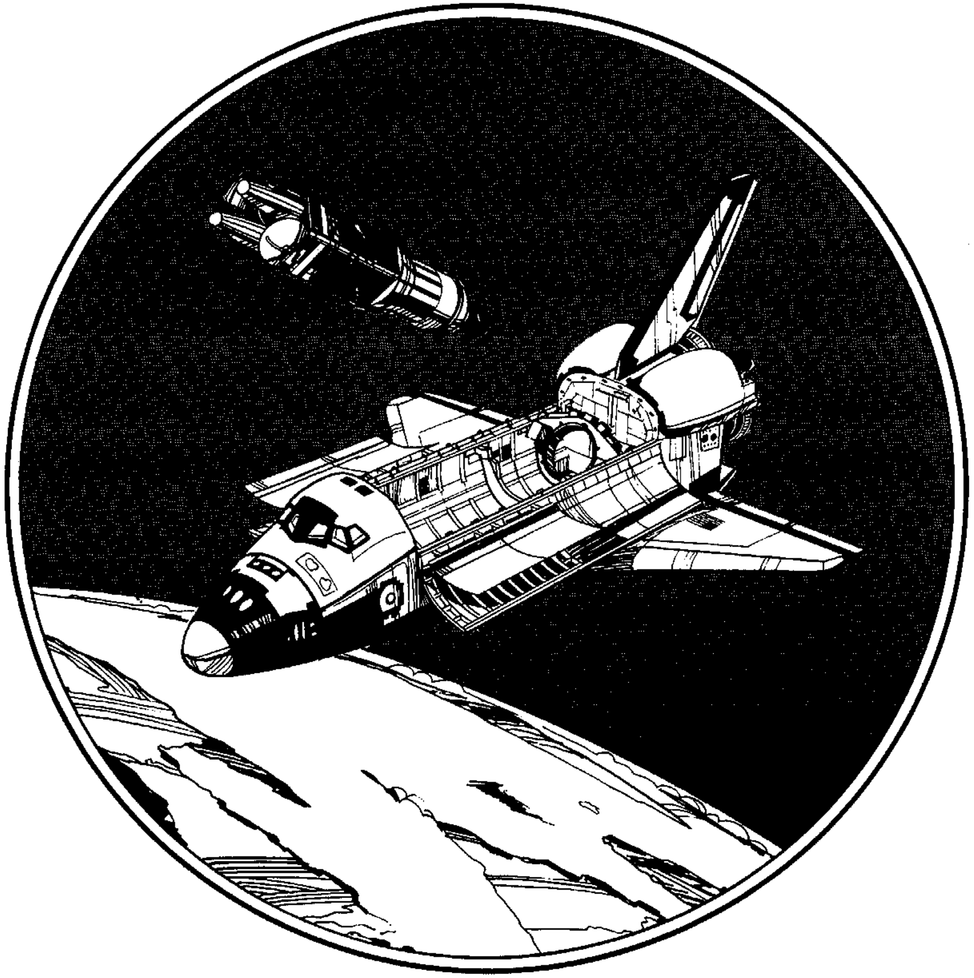

STS-29
PRESS INFORMATION

March 1989

Rockwell International

Space Transportation
Systems Division

Office of Media Relations

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CONTENTS

MISSION OVERVIEW

This is the eighth flight of Discovery and the 28th in the space transportation system program.

The flight crew for the STS-29 mission consists of commander Michael L. Coats; pilot John E. Blaha; and mission specialists James F. Buchli, Robert C. Springer and James P. Bagian.

The primary objective of this five-day mission is to deploy the third Tracking and Data Relay Satellite mated with an inertial upper stage. After the deployment of TDRS-D and its IUS from Discovery's payload bay, the IUS will provide the necessary velocity to place the satellite in a geosynchronous orbit, where it will join TDRS-A and TDRS-C. TDRS-A was launched from Challenger on the STS-6 mission in April 1983, and TDRS-C was launched from Discovery on the STS-26 mission in September 1988. TDRS-D will take the place of TDRS-A at 41 degrees west longitude above the equator and will be referred to as TDRS-East. TDRS-A will then be relocated to 79 degrees west longitude above the equator over central South America and will be maintained as an on-orbit spare. TDRS-B was lost on the STS 51-L mission.

TDRS-D and its IUS are scheduled to be deployed from Discovery's payload bay on the fifth orbit at a mission elapsed time of six hours and 13 minutes. Backup deployment opportunities are available on orbits 6, 7 and 15, with a contingency capability on orbit 17.

The IUS will ignite its first-stage solid rocket motor on orbit 6A (ascending node) for transfer orbit insertion approximately 60 minutes after deployment. (Each orbit starts when the orbiter begins its ascent across the equator on its ascending node.) The IUS will ignite its second-stage SRM approximately seven hours after deployment. Backup transfer orbit insertions could occur 60 minutes after deployment on orbits 7A, 8D (descending node), 16A or 18A.

Seven other payloads will be carried aboard Discovery on this mission. Five are located in Discovery's crew compartment and two are located in the payload bay.

Five experiments will be carried in Discovery's crew compartment. They are the Protein Crystal Growth, Space Life Science Training Program Chromosome and Plant Cell Division in Space (CHROMEX), and IMAX 70mm Camera experiments and two Shuttle Student Involvement Project experiments: SSIP 82-8, Effects of Weightlessness in Space Flight on the Healing of Bone Fractures, and SSIP 83-9, Chicken Embryo Development in Space.

The two experiments located in Discovery's payload bay are the Space Station Heat Pipe Advanced Radiator Element and Orbiter Experiment Autonomous Supporting Instrumentation System I.

The Air Force Maui Optical Site Calibration Test experiment allows ground-based electro-optical sensors on Maui, Hawaii, to collect imagery and signature data of Discovery's reaction control system plumes during overflights.

This mission is the first reflight of the main landing gear brakes without refurbishment. These are the same brakes flown on Discovery on the STS-26 mission.

MISSION STATISTICS

Launch: Launch window duration is limited to 2.5 hours because flight crew members are lying on their backs in Discovery on the launch pad. Launch period duration is four hours due to lighting at the transatlantic landing abort site. Discovery is to be launched from Launch Complex 39-B.

3/11/89 8:10 a.m. EST
7:10 a.m. CST
5:10 a.m. PST

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

Landing: Nominal end of mission is on orbit 81.

3/16/89 9:17 a.m. EST
8:17 a.m. CST
6:17 a.m. PST

Inclination: 28.45 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 an elliptical orbit. This direct-insertion profile lofts the ascent 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.

Because of the direct-insertion ascent profile, the external tank's impact area will be in the Pacific Ocean south of Hawaii.

Altitude: 160 nautical miles (184 statute miles), then 160 by 177 nautical miles (184 by 203 statute miles)

Space Shuttle Main Engine Thrust Level in Ascent: 104 percent

Total Lift-off Weight: Approximately 4,536,861 pounds

Orbiter Weight, Including Cargo at Lift-off: Approximately 208,285 pounds

Payload Weight Up: Approximately 47,384 pounds

Payload Weight Down: Approximately 9,861 pounds

Orbiter Weight at Landing: Approximately 194,460 pounds

Payloads: TDRS-D/IUS-2; SHARE, IMAX, PCG, CHROMEX, AMOS, and OASIS-I experiments; and two SSIP experiments—SSIP 82-8, bone healing, and SSIP 83-9, chicken eggs

Flight Crew Members:
- Commander: Michael L. Coats, second space shuttle flight
- Pilot: John E. Blaha, first space shuttle flight
- Mission Specialist 1: James F. Buchli, third space shuttle flight
- Mission Specialist 2: Robert C. Springer, first space shuttle flight
- Mission Specialist 3: James P. Bagian, first space shuttle flight

Ascent Seating:
- Flight deck front left seat, commander Michael Coats
- Flight deck front right seat, pilot John Blaha
- Flight deck aft center seat, mission specialist James Buchli
- Flight deck aft right seat, mission specialist Robert Springer
- Middeck, mission specialist James Bagian

Entry Seating:
Mission specialist Robert Springer will be in the middeck and James Bagian will be in the aft right center seat on the flight deck.

Extravehicular Activity Crew Members, If Required:
Extravehicular 1 would be Robert Springer and EV-2 would be James Bagian.

Entry Angle of Attack: 40 degrees.

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

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

Notes: The remote manipulator system is not installed in Discovery's payload bay for this flight. The galley is installed in the middeck of Discovery.

A spare general-purpose computer is stowed in a modular locker in Discovery's middeck.

The uplink to Discovery on this mission will be encrypted.

Location of payloads in Discovery's payload bay, looking forward from the aft end of Discovery, is OASIS-I and IUS-2 with TDRS-D and, on the starboard side, SHARE.

MISSION OBJECTIVES

- Deployment of TDRS-D/IUS-2
- SHARE
- IMAX
- PCG
- CHROMEX
- OASIS-I
- SSIP 83-9, chicken eggs
- SSIP 82-8, bone healing

DEVELOPMENT TEST OBJECTIVES

- Direct-insertion external tank tracking
- Water dump cloud formation
- Nose wheel steering runway evaluation (test number 2)
- Revised braking system test (third flight test)
- Text and graphics system
- Attitude match update
- Payload and general-support computer evaluation
- Inertial measurement and recovery techniques
- Crosswind landing performance
- Ascent structural capability evaluation (data only)
- Ascent compartment venting evaluation (data only)
- Descent compartment venting evaluation (data only)
- Entry structural capability (data only)
- Vibration and acoustic evaluation (data only)
- Pogo stability performance (data only)
- Shuttle/payload low-frequency environment (data only)

- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Salivary acetaminophen pharmacokinetics
- Central venous pressure estimation
- Pre- and postflight cardiovascular assessment
- Influence of weightlessness on baroreflex function
- Preflight adaptation training
- Relationship of space adaptation syndrome to cerebral blood flow
- Documentary television
- Documentary motion picture photography
- Documentary still photography

Notes:

- The text and graphics system is considered operational with TDRS-C operational at 171 degrees west longitude and TAGS as the primary mode of text uplink. TAGS 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 TDRS 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 is operated 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 by 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.

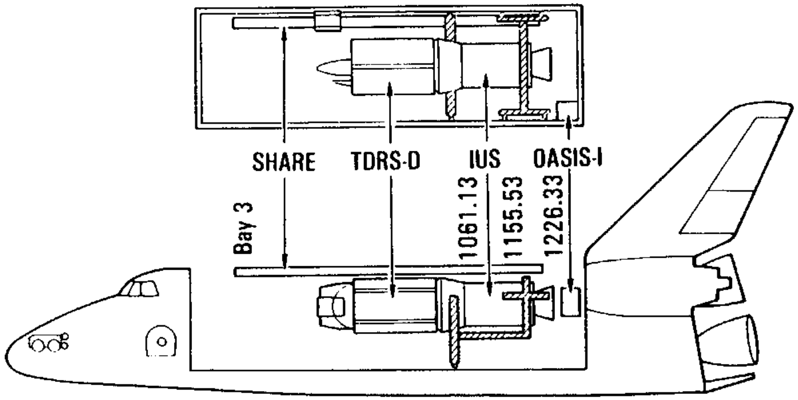
  The hard copier can be powered from the ground or by the crew.

  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, aboard the orbiter from the Mission Control Center in Houston. It uses the S-band and is not dependent on the TDRS Ku-band. It is a modified teletype machine located in a locker in the crew compartment middeck.

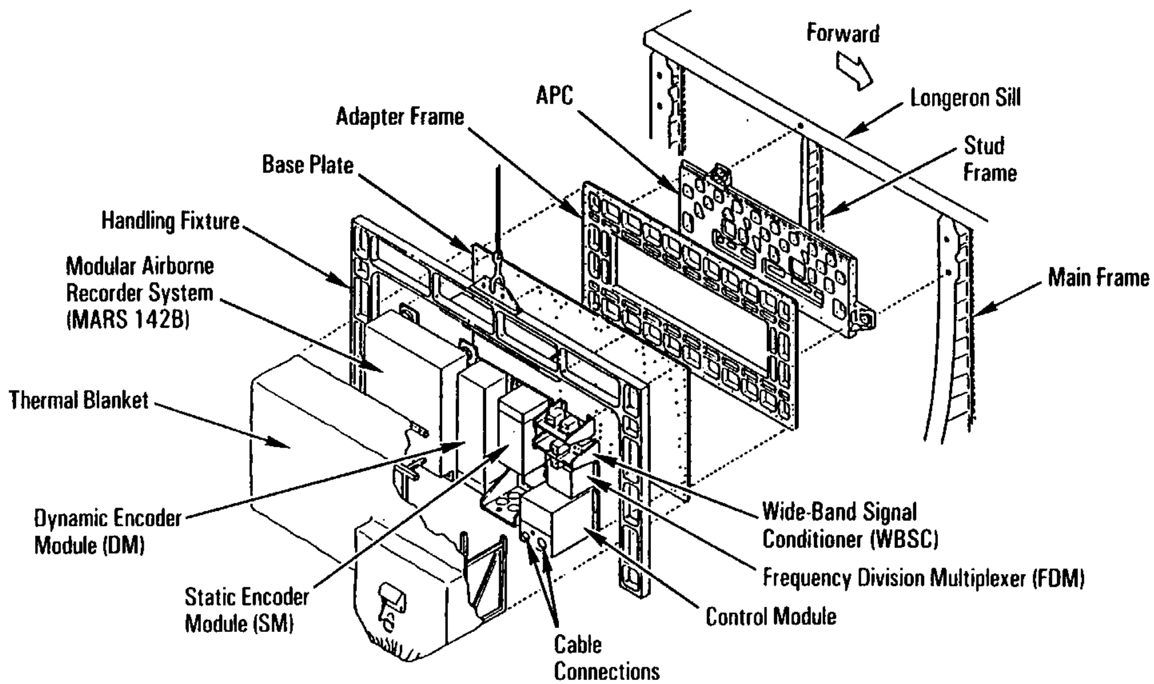
  The teleprinter uplink requires one to 2.5 minutes per message, depending on the number of lines (up to 66). When the ground has sent a message, a *msg rcv* yellow light on the teleprinter is illuminated to indicate a message is waiting to be removed.

PAYLOAD CONFIGURATION



IUS – Inertial Upper Stage
SHARE – Space Station Heat Pipe Advanced Radiator Element
TDRS – Tracking and Data Relay Satellite
OASIS – Orbiter Experiment Autonomous Supporting Instrumentation System

Orbiter Payload Locations



Orbiter Experiment (OEX) Autonomous Supporting Instrumentation System (OASIS) I Payload Configuration

INERTIAL UPPER STAGE

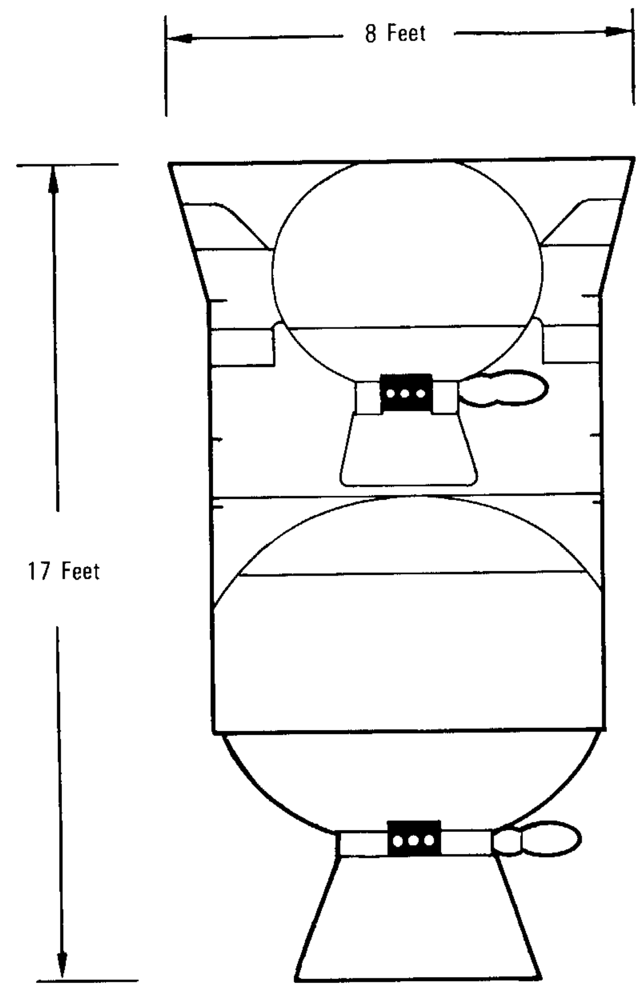
The inertial upper stage is used with the space shuttle to transport NASA's Tracking and Data Relay satellites to geosynchronous orbit, 22,300 statute miles from Earth. The IUS was also selected by NASA for the Magellan, Galileo and Ulysses planetary missions.

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

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

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

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



Inertial Upper Stage

FLIGHT SEQUENCE

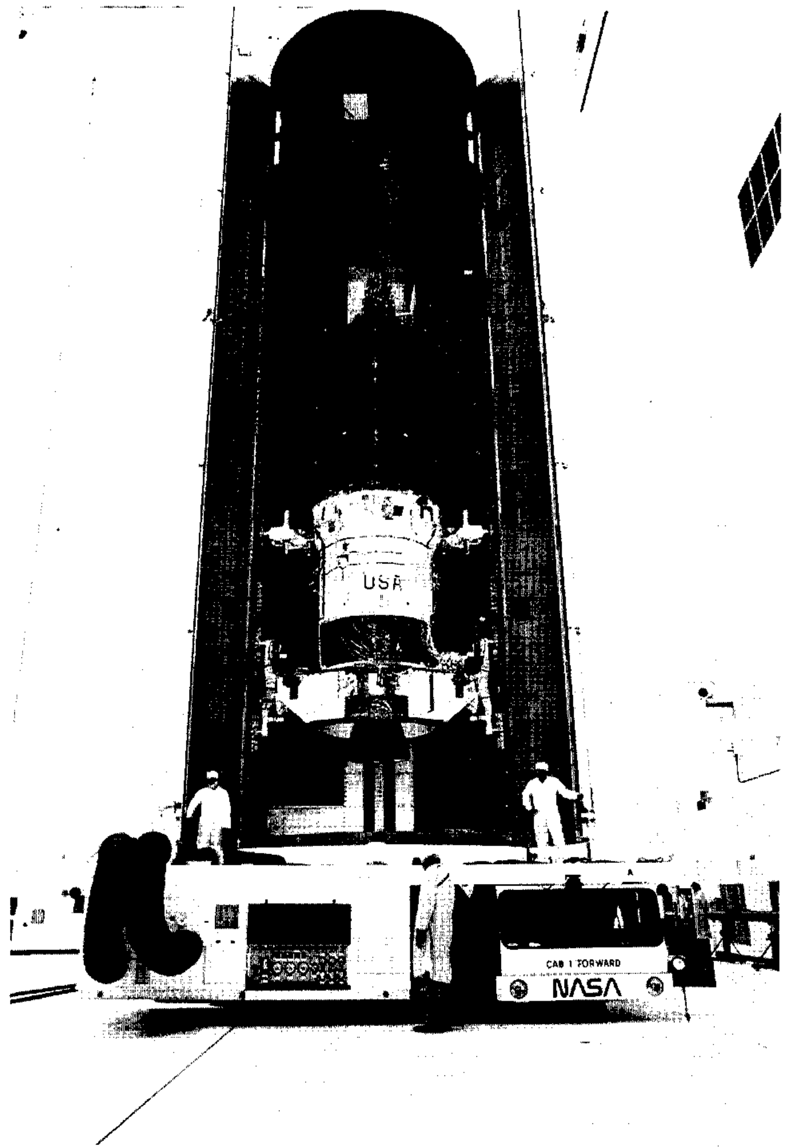
After the orbiter's payload bay doors are opened in Earth orbit, the orbiter maintains a preselected attitude to fulfill payload thermal requirements and constraints except during those operations that require special attitudes (e.g., orbiter inertial measurement unit alignments, RF communications and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

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

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

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

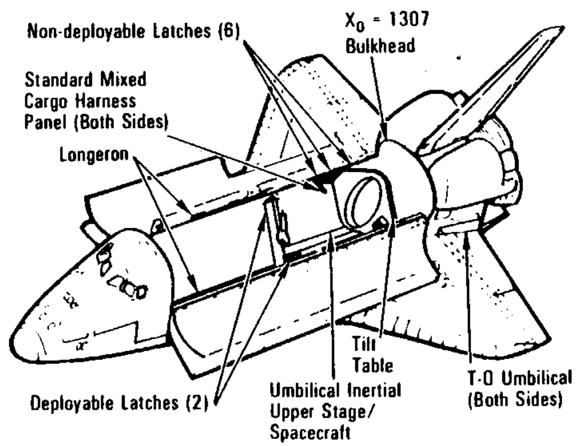
When the orbiter flight crew is given a go decision, the orbiter flight crew activates the ordnance that separates the IUS and spacecraft's umbilical cables. The flight crew then commands the electromechanical tilt actuator to raise the tilt table to a 50-degree deployment position. The orbiter's reaction control system



IUS/TDRS With Airborne Support Equipment in Payload Canister Transporter thrusters are inhibited, and the Super*zip ordnance separation device physically separates the IUS and spacecraft combination from the tilt table. Compressed springs provide the force to jettison the IUS and spacecraft from the orbiter payload bay at approximately 0.4 foot per second. The IUS and spacecraft are deployed in the shadow of the orbiter or in Earth eclipse. The tilt table is lowered to minus 6 degrees after deployment. Approximately 19 minutes after deployment, the orbiter's orbital maneuvering system engines are ignited to separate the orbiter from the IUS and spacecraft.

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

Approximately 45 minutes after IUS and spacecraft ejection from the orbiter, the SRM-1 ordnance inhibits are removed. At

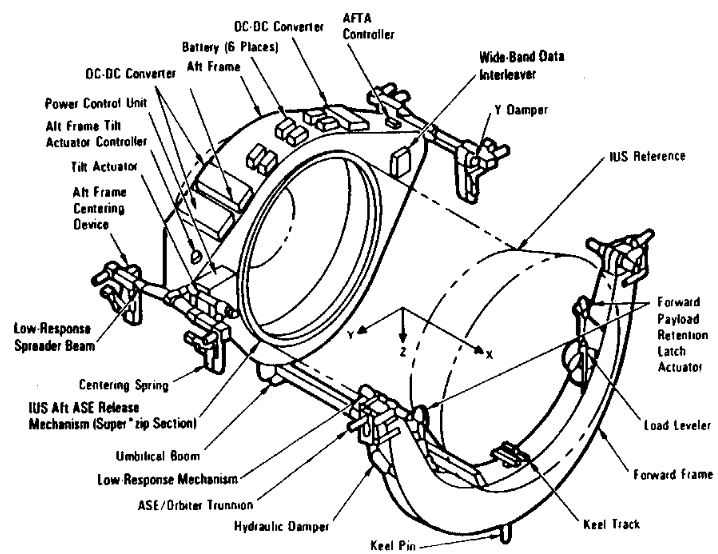


Inertial Upper Stage Airborne Support Equipment

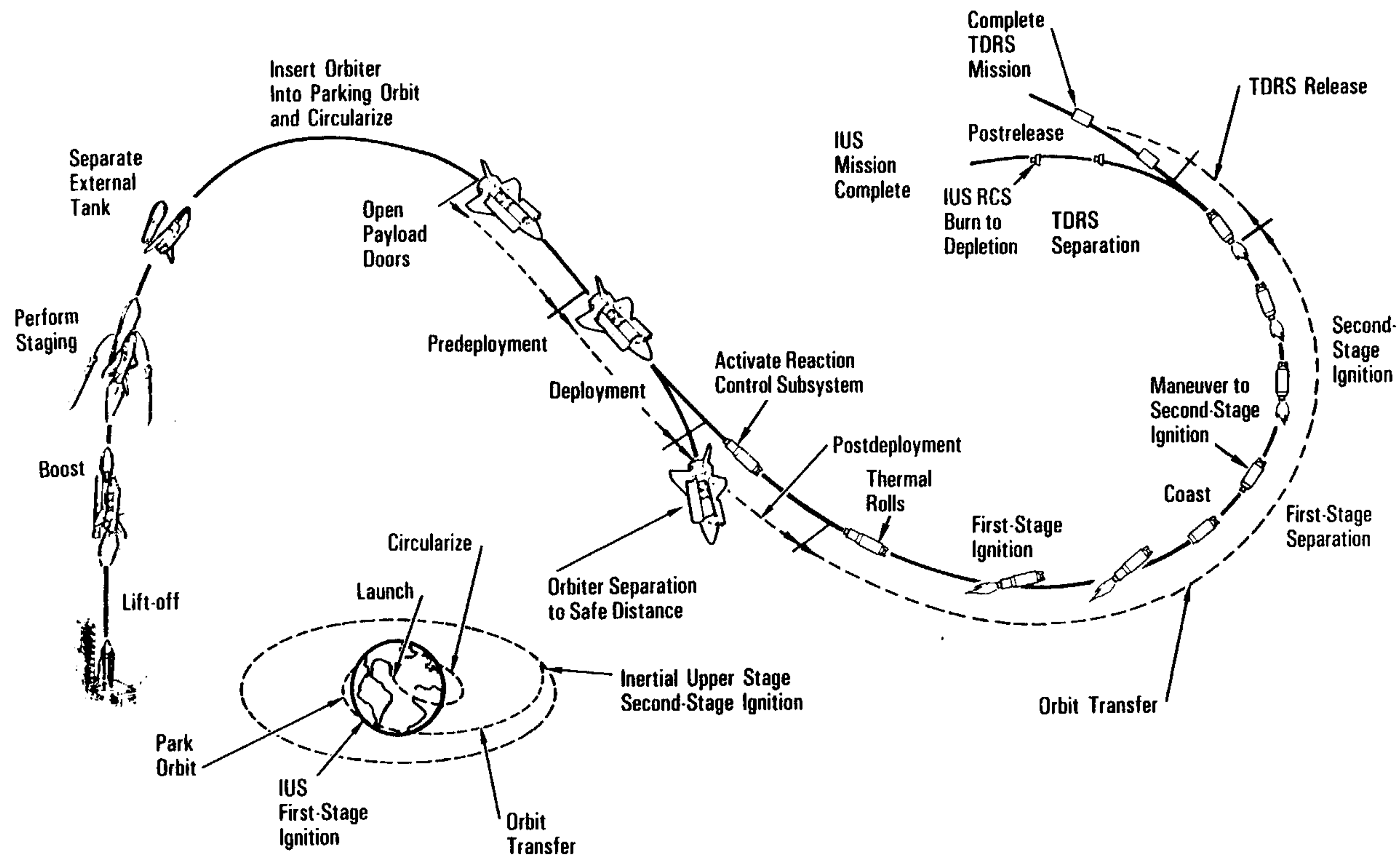
this time, the bottom of the orbiter is oriented toward the IUS and spacecraft to protect the orbiter windows from the IUS SRM-1 plume. The IUS then recomputes SRM-1 ignition time and maneuvers to the proper attitude for the SRM-1 thrusting period. When the transfer orbit or planetary trajectory injection opportunity is reached, the IUS computer enables and applies ordnance power, arms the safe and arm devices and ignites the first-stage SRM. The SRM-1 thrusting period lasts approximately 145 seconds to provide sufficient thrust for the orbit transfer phase of a geosynchronous mission or to provide the predetermined contribution of thrust for planetary trajectory for planetary missions. The IUS first stage and interstage are separated from the second stage before the IUS reaches the apogee point of its trajectory for geosynchronous missions.

If sufficient coast time is available during the coast phase, the IUS can perform the maneuvers required by the spacecraft for thermal protection or communication reasons.

For geosynchronous missions, the second-stage motor is ignited at apogee and its thrusting period lasts approximately 103



Inertial Upper Stage Airborne Support Equipment

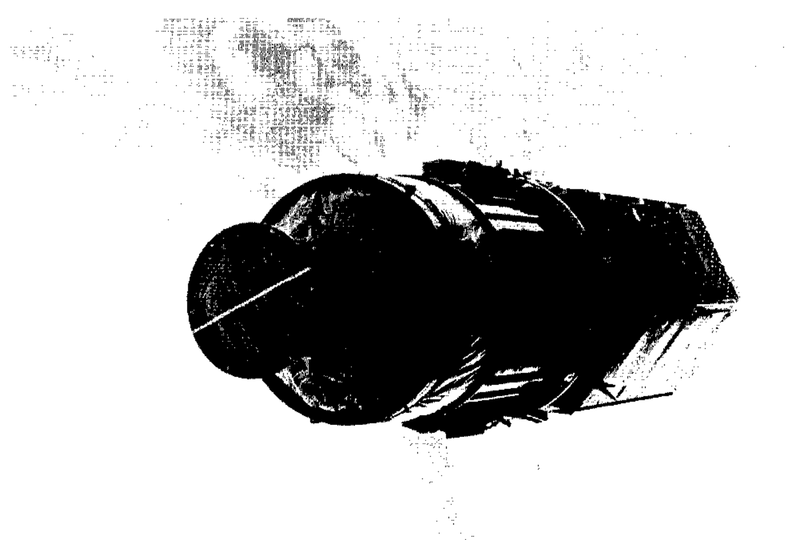


Sequence of Events For Typical Geosynchronous Mission seconds, which provides the final injection to geosynchronous orbit. The IUS then supports spacecraft separation and performs a final collision and contamination avoidance maneuver before deactivating its subsystems.

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

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

Boeing also integrates the IUS with various satellites and joins the satellite with the IUS, checks out the configuration and



Inertial Upper Stage Tracking and Data Relay Satellite Deployment

supports launch and mission control operations for both the Air Force and NASA. Boeing also develops airborne support equipment to support the IUS in the space shuttle and monitors it while it is in the orbiter payload bay.

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

AIRBORNE SUPPORT EQUIPMENT

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

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

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

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

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

IUS STRUCTURE

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

EQUIPMENT SUPPORT SECTION

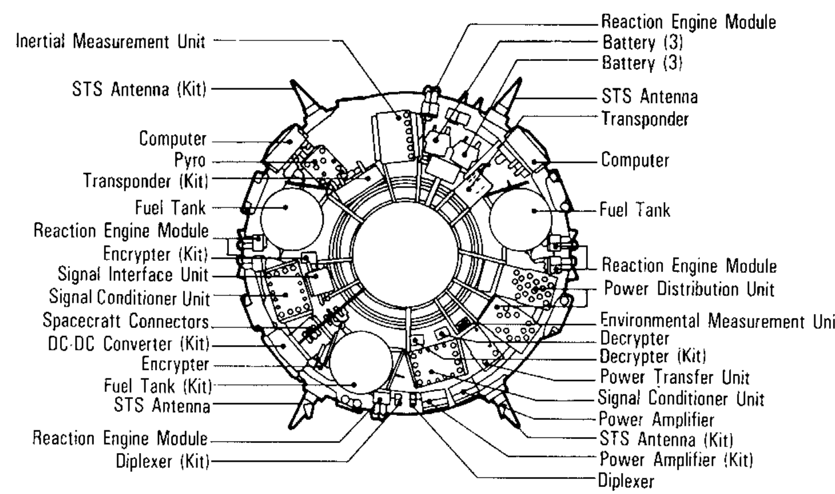
The ESS houses the majority of the IUS avionics and control subsystems. The top of the ESS contains the 10-foot-diameter interface mounting ring and electrical interface connector segment for mating and integrating the spacecraft with the IUS. Thermal isolation is provided by a multilayer insulation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

IUS AVIONICS SUBSYSTEM

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

Data management performs the computation, data processing and signal conditioning associated with guidance, navigation and control; safing and arming and ignition of the IUS two-stage solid rocket motors and electroexplosive devices; command decoding and telemetry formatting; and redundancy management and issues spacecraft discretes. The data management subsystem consists of two computers, two signal conditioner units and a signal interface unit.

Modular general-purpose computers use operational flight software to perform in-flight calculations and to initiate the vehicle thrust and attitude control functions necessary to guide the IUS and spacecraft through a flight path determined on board to a final orbit or planned trajectory. A stored program, including data known as the onboard digital data load, is loaded into the IUS



Inertial Upper Stage Equipment Support Section known as the onboard digital data load, is loaded into the IUS flight computer memory from magnetic tape through the memory load unit during prelaunch operations. Memory capacity is 65,536 (64K) 16-bit words.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

IUS SOLID ROCKET MOTORS

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

IUS REACTION CONTROL SYSTEM

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

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

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

IUS-TO-SPACECRAFT INTERFACES

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

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

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

TRACKING AND DATA RELAY SATELLITE SYSTEM

When fully operational, the TDRSS will provide continuous global coverage of Earth-orbiting satellites at altitudes from 750 miles to about 3,100 miles. At lower altitudes, there will be brief periods when satellites or spacecraft over the Indian Ocean near the equator are out of view. The TDRSS will be able to handle up to 300 million bits of information per second. Because eight bits of information make one word, this capability is equivalent to processing 300 14-volume sets of encyclopedias every minute.

The fully operational TDRSS network will consist of three satellites in geosynchronous orbits. The first, positioned at 41 degrees west longitude, is TDRS-East (TDRS-A). TDRS-C was carried into Earth orbit aboard Discovery on the STS-26 mission in September 1988. It was deployed and positioned in geosynchronous orbit at 171 degrees west longitude and will be referred to as TDRS-West. TDRS-D, carried aboard Discovery on the STS-29 mission, will take the place of TDRS-A at 41 degrees west longitude and will be referred to as TDRS-East. TDRS-A will be relocated to 79 degrees west longitude over central South America and will be maintained as an on-orbit spare.

The satellites are positioned in geosynchronous orbits above the equator at an altitude of 22,300 statute miles. At this altitude, because the speed of the satellite is the same as the rotational speed of Earth, it remains fixed in orbit over one location. The eventual positioning of two TDRSs will be 130 degrees apart instead of the usual 180-degree spacing. This 130-degree spacing will reduce the ground station requirements to one station instead of the two stations required for 180-degree spacing.

The TDRS system serves as a radio data relay, carrying voice, television, and analog and digital data signals. It offers three frequency band services: S-band, C-band and high-capacity Ku-band. The C-band transponders operate at 4 to 6 GHz and the Ku-band transponders operate at 12 to 14 GHz.

The highly automated TDRSS network ground station, located at the White Sands Ground Terminal, is owned and managed by Contel.

TDRSS also provides communication and tracking services for low Earth-orbiting satellites. It measures two-way range and Doppler for up to nine user satellites and one-way and Doppler for up to 10 user satellites simultaneously. These measurements are relayed to the Flight Dynamics Facility at the Goddard Space Flight Center in Greenbelt, Md., from the WSGT.

Seven TDRSs will be built by TRW's Defense and Space Systems Group, Redondo Beach, Calif. Contel owns and operates the satellites and the WSGT, which was built jointly by the team of TRW, Harris Corporation and Spacecom. Electronic hardware was jointly supplied by TRW and Harris's Government Communications Division, Melbourne, Fla. TRW integrated and tested the ground station, developed software for the TDRS system and integrated the hardware with the ground station and satellites.

The ground station is located at a longitude with a clear line of sight to the TDRSs and very little rain, because rain can interfere with the Ku-band uplink and downlink channels. It is one of the largest and most complex communication terminals ever built.

The most prominent features of the ground station are three 60-foot Ku-band dish antennas used to transmit and receive user traffic. Several other antennas are used for S-band and Ku-band communications. NASA developed sophisticated operational control facilities at GSFC and next to the WSGT to schedule TDRSS support of each user and to distribute the user's data from White Sands to the user.

Automatic data processing equipment at the WSGT aids in satellite tracking measurements, control and communications. Equipment in the TDRS and the ground station collects system status data for transmission, along with user spacecraft data, to NASA. The ground station software and computer component, with more than 900,000 machine language instructions, will eventually control three geosynchronous TDRSs and the 300 racks of ground station electronic equipment.

Many command and control functions ordinarily found in the space segment of a system are performed by the ground station, such as the formation and control of the receive beam of the TDRS multiple-access phased-array antenna and the control and tracking functions of the TDRS single-access antennas.

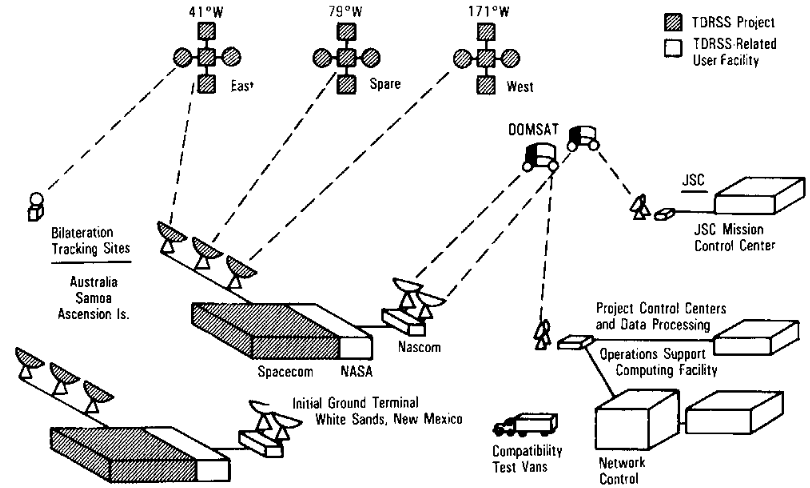
Data acquired by the satellites are relayed to the ground terminal facilities at White Sands. White Sands sends the raw data directly by domestic communications satellite to NASA control centers at the Johnson Space Center in Texas (for space shuttle operations) and GSFC, which schedules TDRSS operations and controls a large number of satellites. To increase system reliability and availability, no signal processing is done aboard the TDRSs; instead, they act as repeaters, relaying signals to and from the ground station or to and from satellites or spacecraft. No user signal processing is done aboard the TDRSs.

A second TDRS ground terminal is being built at White Sands approximately 3 miles north of the initial ground station. The $18.5-million facility will back up the existing facility and meet growing communication needs in late 1992.

When the TDRSS is fully operational, ground stations of the worldwide space flight tracking and data network will be closed or consolidated, resulting in savings in personnel and operating and maintenance costs. However, the Merritt Island, Fla.; Ponce de Leon, Fla.; and Bermuda ground stations will remain open to support the launch of the space transportation system and the landing of the space shuttle at the Kennedy Space Center in Florida.

Deep-space probes and Earth-orbiting satellites above approximately 3,100 miles will use the three ground stations of the deep-space network, operated for NASA by the Jet Propulsion Laboratory, Pasadena, Calif. The deep-space network stations are in Goldstone, Calif.; Madrid, Spain; and Canberra, Australia.

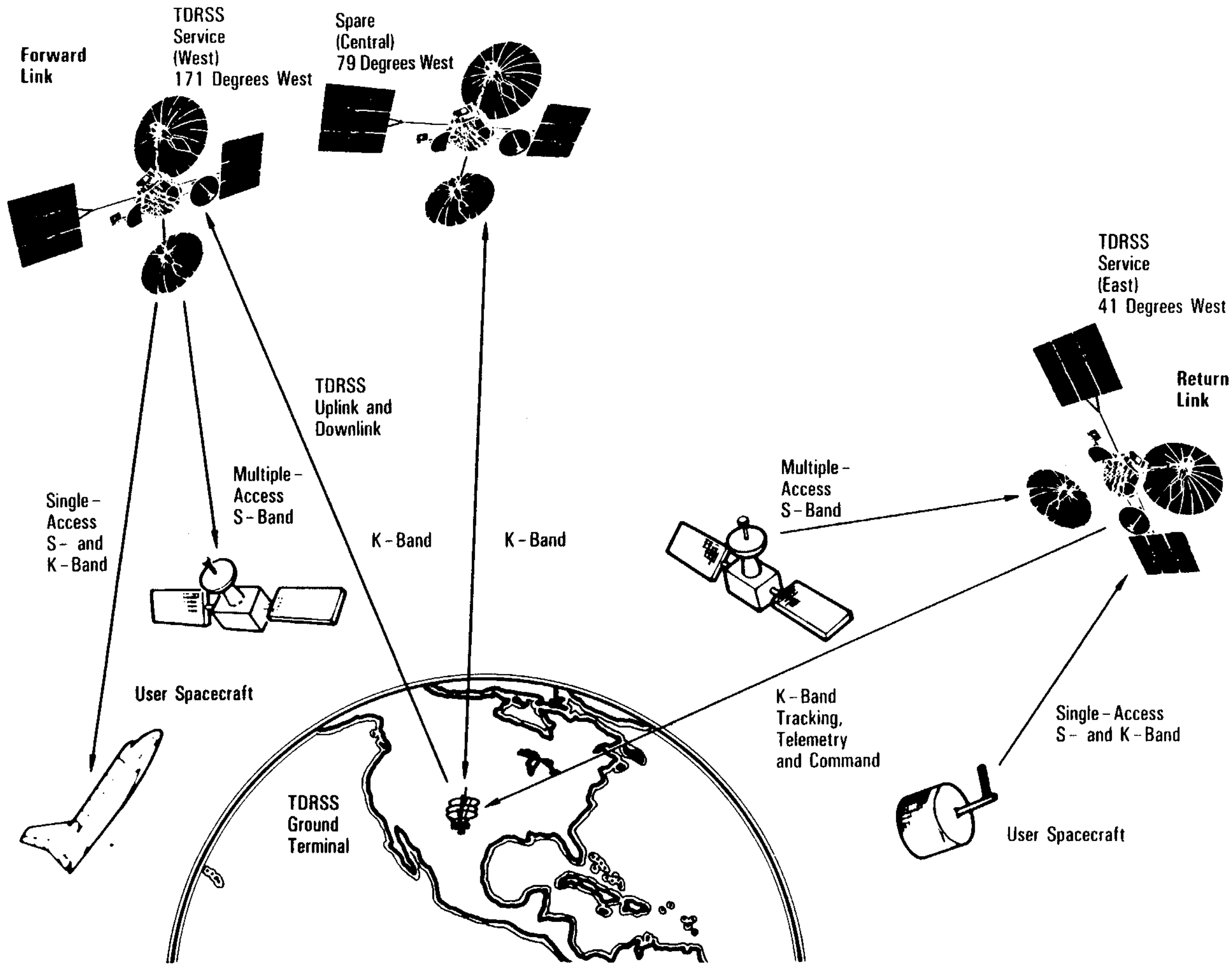
During the lift-off and ascent phase of a space shuttle mission launched from the Kennedy Space Center, the space shuttle S-band system is used in a high-data-rate mode to transmit and receive through the Merritt Island, Ponce de Leon and Bermuda STDN tracking stations. When the shuttle leaves the line-of-sight



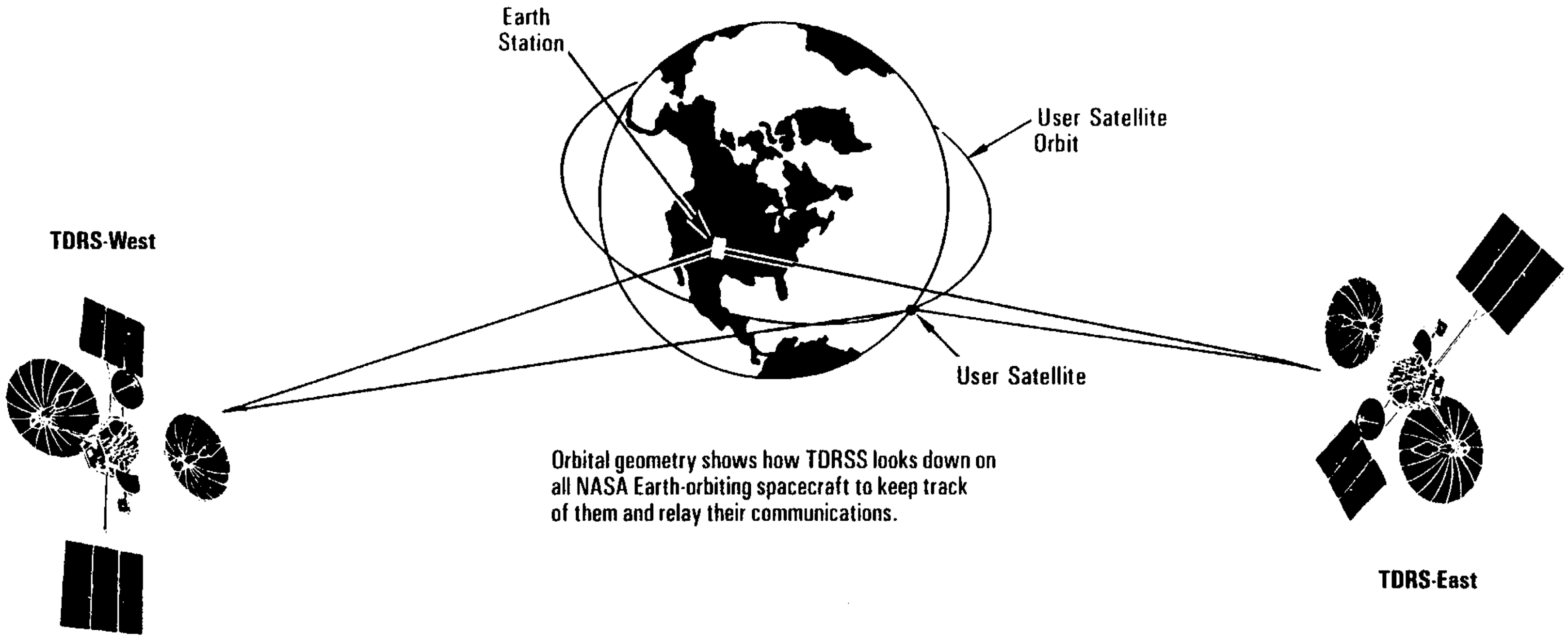
(Second ground station, under construction 3 miles north of existing station, is expected to be fully operational by 1993.)

TDRSS Elements

Tracking and Data Relay Satellite on Station at Geosynchronous Orbit



Linking Three Identical and Interchangeable Satellites With Earth Station



Tracking and Data Relay Satellite System

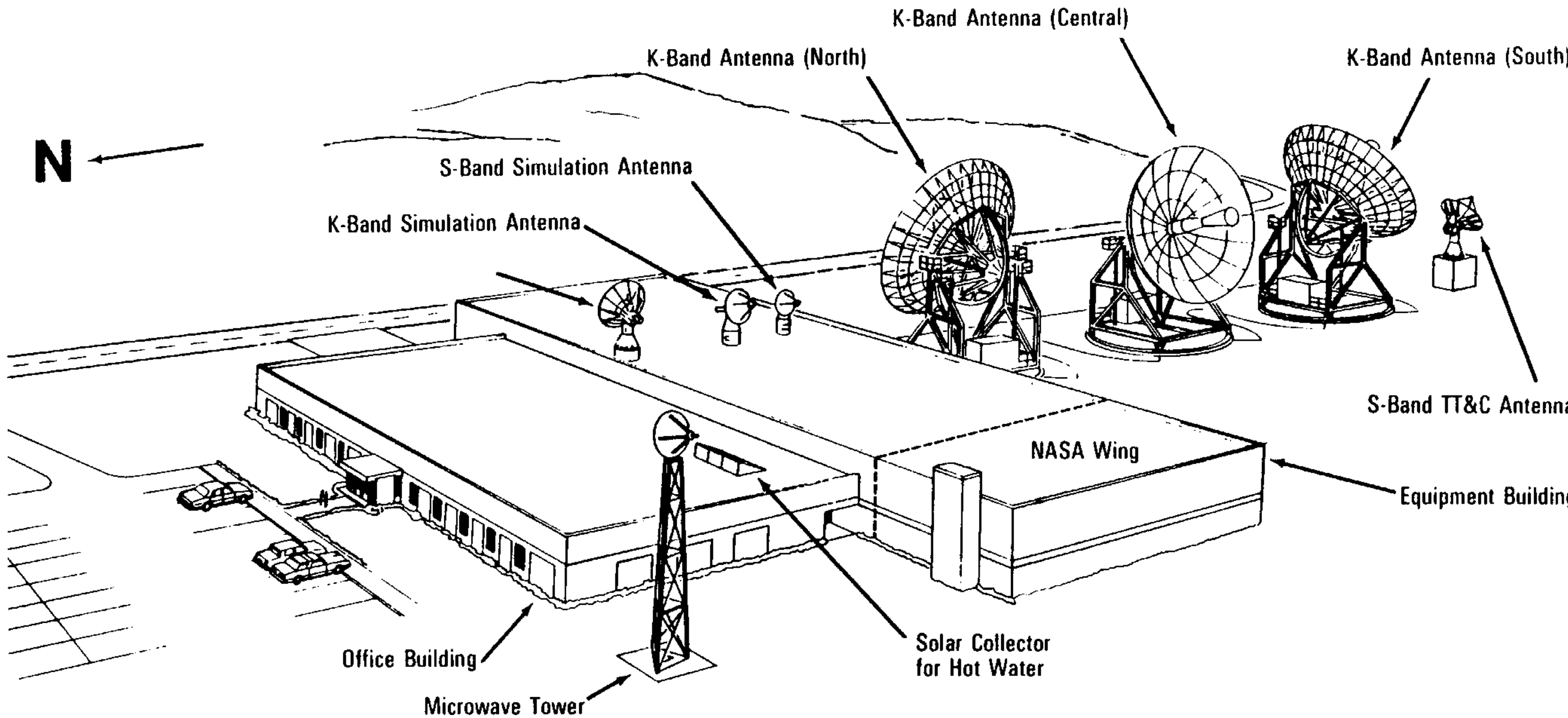
tracking station at Bermuda, its S-band system transmits and receives through the TDRSS. (There are two communication systems used in communicating between the space shuttle and the ground. One is referred to as the S-band system; the other, the Ku-band, or K-band, system.)

To date, the TDRSs are the largest privately owned telecommunication satellites ever built. Each satellite weighs nearly 5,000 pounds in orbit. The TDRSs will be deployed from the space shuttle at an altitude of approximately 160 nautical miles, and inertial upper stage boosters will propel them to geosynchronous orbit.

The TDRS single-access parabolic antennas deploy after the satellite separates from its inertial upper stage. After the TDRS acquires the sun and Earth, its sensors provide attitude and velocity control to achieve the final geostationary position.

Three-axis stabilization aboard the TDRS maintains attitude control. Body-fixed momentum wheels in a vee configuration combine with body-fixed antennas pointing constantly at Earth, while the satellite's solar arrays track the sun. Monopropellant hydrazine thrusters are used for TDRS positioning and north-south, east-west stationkeeping.

The antenna module houses four antennas. For single-access services, each TDRS has two dual-feed S-band/Ku-band deployable parabolic antennas. They are 16 feet in diameter, unfurl like a giant umbrella when deployed, and are attached on two axes that can move horizontally or vertically (gimbal) to focus the beam on satellites or spacecraft below. Their primary function is to relay communications to and from user satellites or spacecraft. The high-bit-rate service made possible by these antennas is available to users on a time-shared basis. Each antenna simultaneously supports two user satellites or spacecraft (one on S-band and one on Ku-band) if both users are within the antenna's bandwidth.

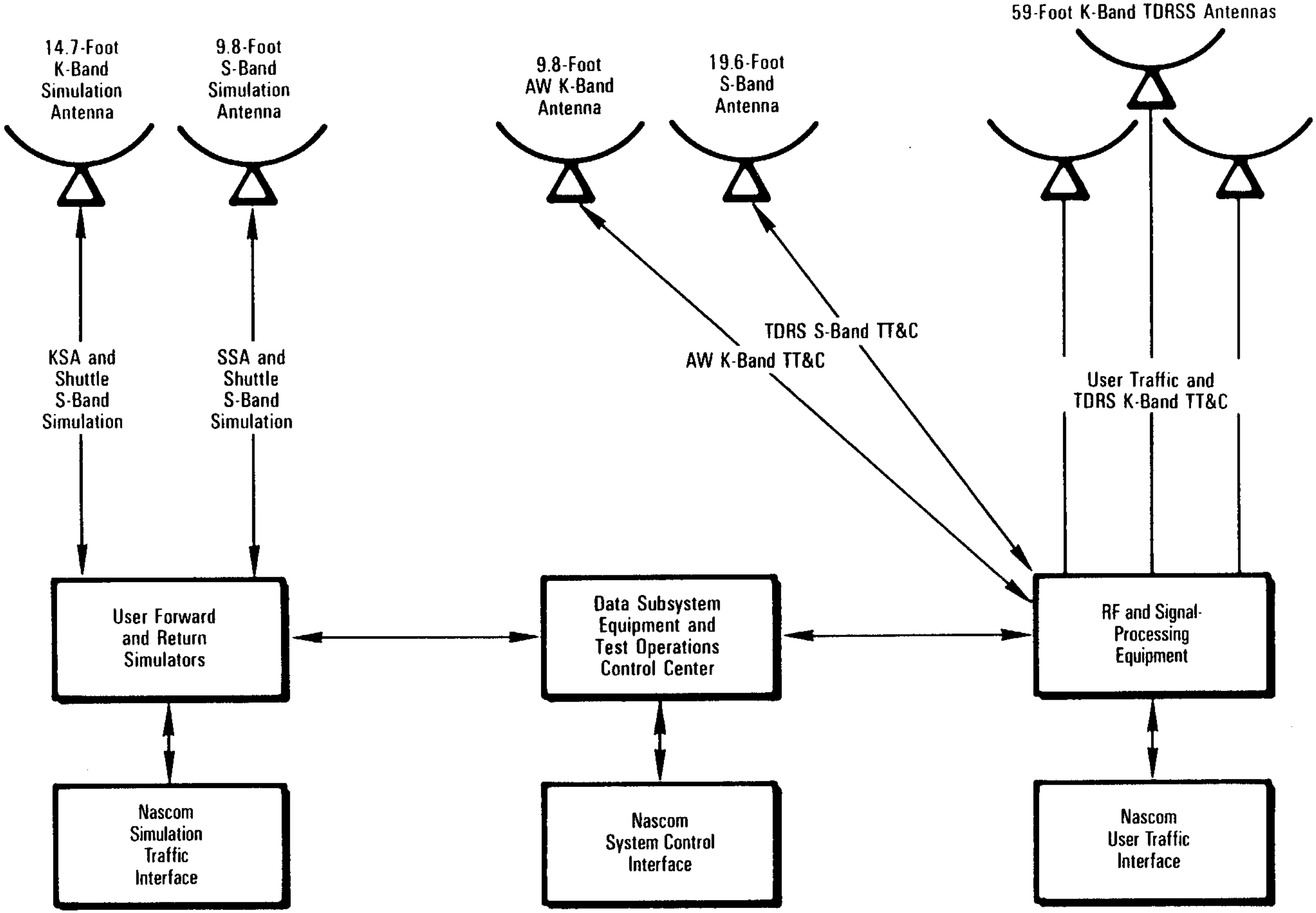


Tracking and Data Relay Satellite System Ground Station, White Sands, N.M.

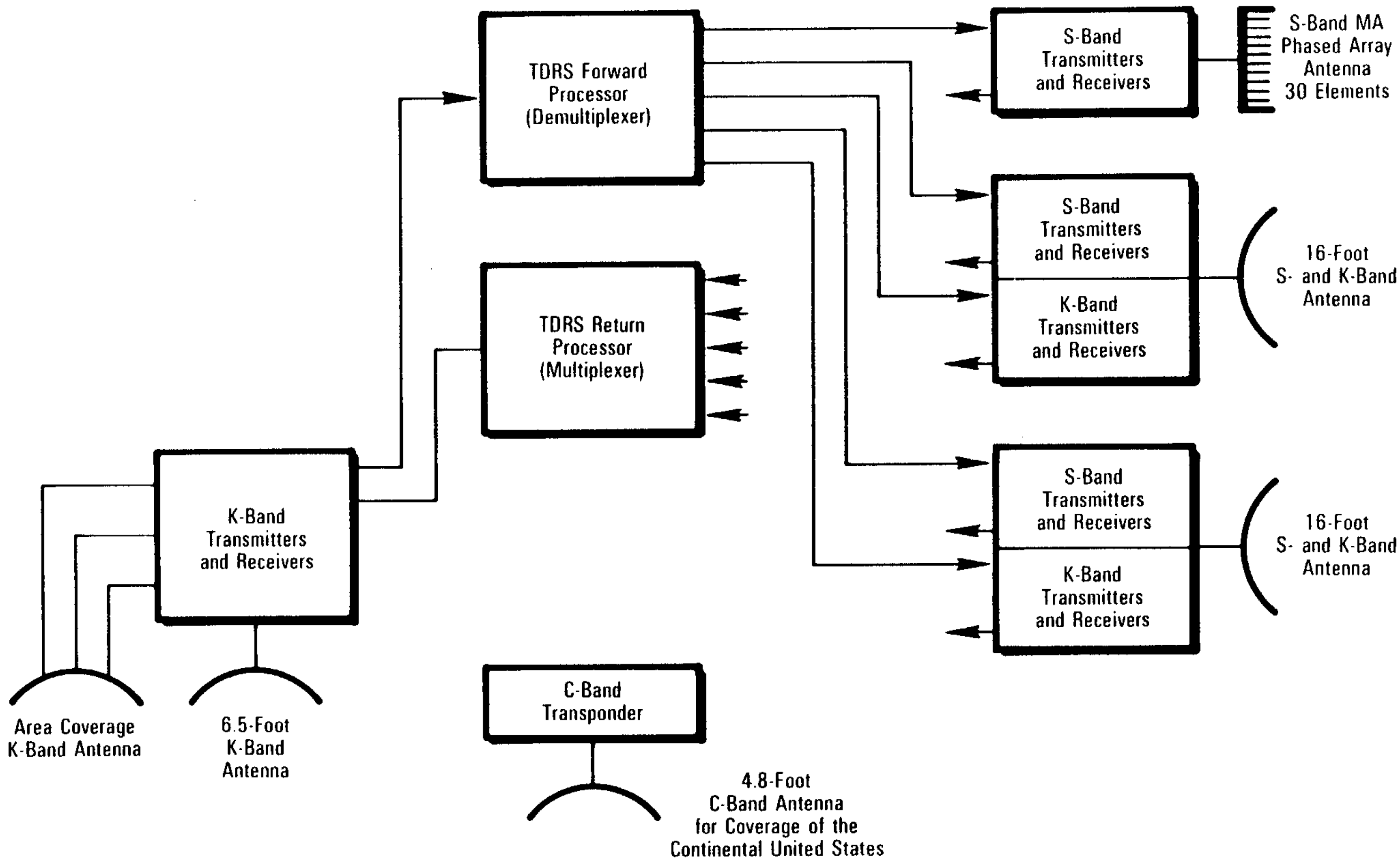
The antenna's primary reflector surface is a gold-clad molybdenum wire mesh, woven like cloth on the same type of machine used to make material for women's hosiery. When deployed, the antenna's 203 square feet of mesh are stretched tautly on 16 supporting tubular ribs by fine threadlike quartz cords. The antenna looks like a glittering metallic spiderweb. The entire antenna structure, including the ribs, reflector surface, a dual-frequency antenna feed and the deployment mechanisms needed to fold and unfold the structure like a parasol, weighs approximately 50 pounds.

For multiple-access service, the multielement S-band phased array of 30 helix antennas on each satellite is mounted on the satellite's body. The multiple-access forward link (between the TDRS and the user satellite or spacecraft) transmits command data to the user satellite or spacecraft, and the return link sends the signal outputs separately from the array elements to the WSGT's parallel processors. Signals from each helix antenna are received at the same frequency, frequency-division-multiplexed into a single composite signal and transmitted to the ground. In the ground equipment, the signal is demultiplexed and distributed to 20 sets of beam-forming equipment that discriminates among the 30 signals to select the signals of individual users. The multiple-access system uses 12 of the 30 helix antennas on each TDRS to form a transmit beam.

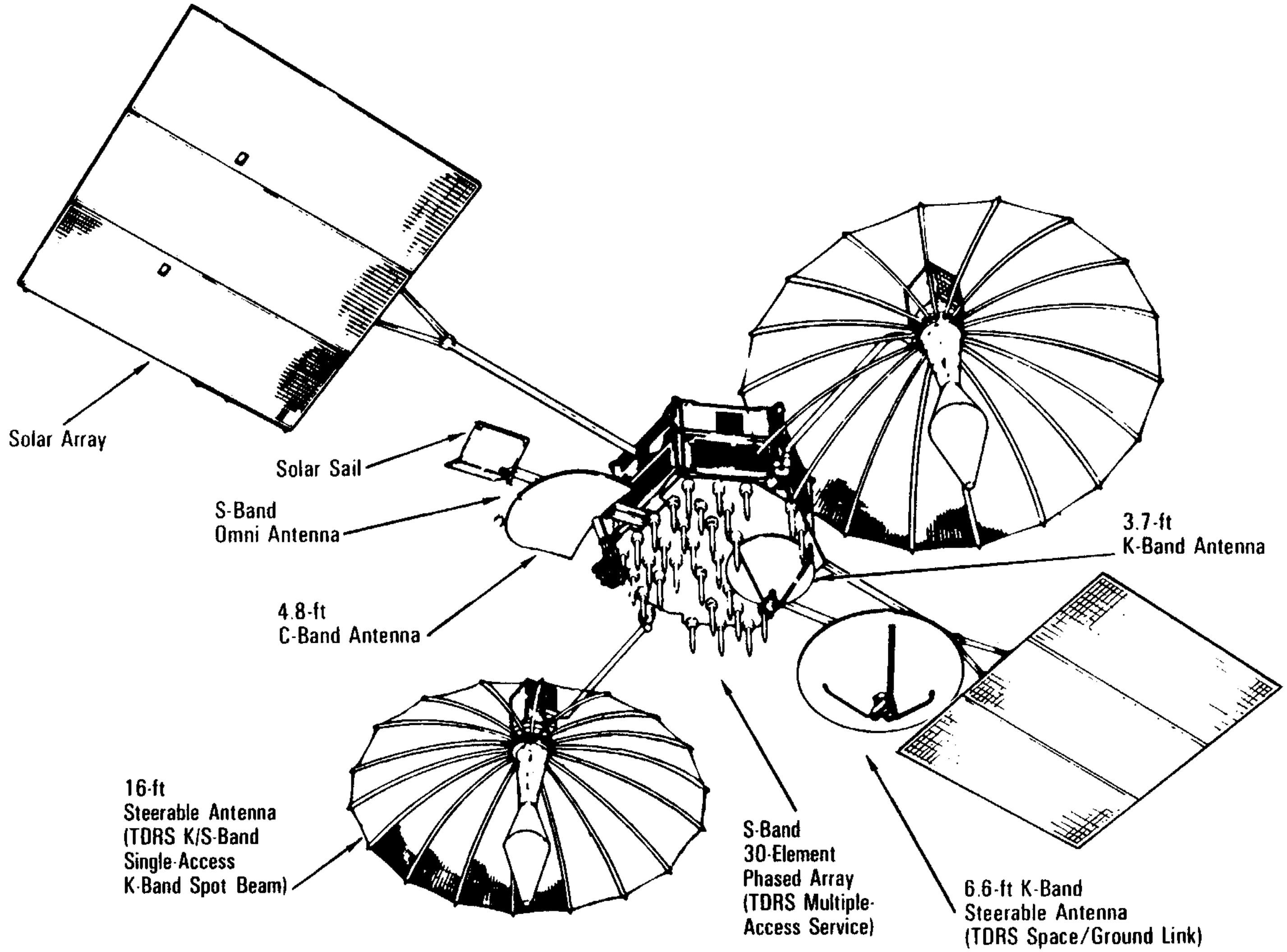
A 6.6-foot parabolic reflector is the space-to-ground-link antenna that communicates all data and tracking information to



Tracking and Data Relay Satellite System Antenna



Tracking and Data Relay Satellite System Transmission and Receive System



Tracking and Data Relay Satellite

and from the ground terminal on Ku-band. The omni telemetry, tracking and communication antenna is used to control TDRS while it is in transfer orbit to geosynchronous altitude.

The solar arrays on each satellite, when deployed, span more than 57 feet from tip to tip. The two single-access, high-gain parabolic antennas, when deployed, measure 16 feet in diameter and span 42 feet from tip to tip.

Each TDRS is composed of three distinct modules: the equipment module, the communication payload module and the antenna module. The modular structure reduces the cost of individual design and construction.

The equipment module housing the subsystems that operate the satellite and the communication service is located in the lower hexagon of the satellite. The attitude control subsystem stabilizes the satellite so that the antennas are properly oriented toward the Earth and the solar panels are facing toward the sun. The electrical power subsystem consists of two solar panels that provide approximately 1,850 watts of power for 10 years. Nickel-cadmium rechargeable batteries supply full power when the satellite is in the shadow of the Earth. The thermal control subsystem consists of surface coatings and controlled electric heaters. The solar sail compensates for the effects of solar winds against the asymmetrical body of the TDRS.

The communication payload module on each satellite contains electronic equipment and associated antennas required for linking the user spacecraft or satellite with the ground terminal. The receivers and transmitters are mounted in compartments on the back of the single-access antennas to reduce complexity and possible circuit losses.

TDRS-A and its IUS were carried aboard the space shuttle Challenger on the April 1983 STS-6 mission. After it was deployed on April 4, 1983, and first-stage boost of the IUS solid rocket motor was completed, the second-stage IUS motor malfunctioned and TDRS-A was left in an egg-shaped orbit of 13,579 by 21,980 statute miles—far short of the planned 22,300-mile geosynchronous altitude. Also, TDRS-A was spinning out of control at a rate of 30 revolutions per minute until the Contel/TRW flight control team recovered control and stabilized it.

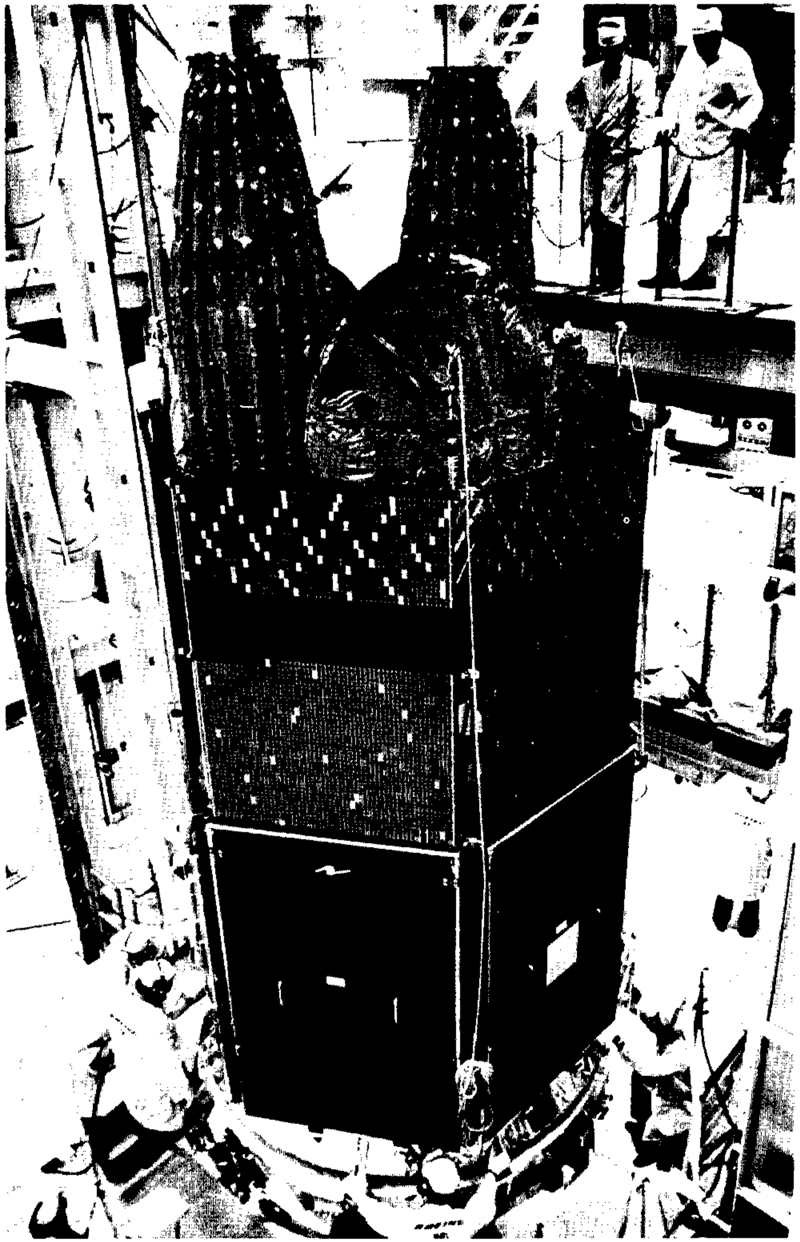
Later Contel, TRW and NASA TDRS program officials devised a procedure for using the small (1-pound) hydrazine-fueled reaction control system thrusters on TDRS-A to raise its orbit. The thrusting, which began on June 6, 1983, required 39 maneuvers to raise TDRS-A to geosynchronous orbit. The maneuvers consumed approximately 900 pounds of the satellite's propellant, leaving approximately 500 pounds of hydrazine for the 10-year on-orbit operations.

During the maneuvers, overheating caused the loss of one of the redundant banks of 12 thrusters and one thruster in the other bank. The flight control team developed procedures to control TDRS-A properly in spite of the thruster failures.

TDRS-A was turned on for testing on July 6, 1983. Tests proceeded without incident until October 1983, when one of the Ku-band single-access-link diplexers failed. Shortly afterward, one of the Ku-band traveling-wave-tube amplifiers on the same single-access antenna failed, and the forward link service was lost. On Nov. 19, 1983, one of the Ku-band TWT amplifiers serving the other single-access antenna failed. TDRS-A testing was completed in December 1984. Although the satellite can provide only one Ku-band single-access forward link, it is still functioning.

TDRS-B, C and D are identical to TDRS-A except for modifications to correct the malfunctions that occurred in TDRS-A and a modification of the C-band antenna feeds. The C-band minor modification was made to improve coverage for providing government point-to-point communications. TDRS-B was lost on the 51-L mission.

The mission plan for TDRS-D is similar to that originally planned for TDRS-A and will be the same as the mission plan for TDRS-C. Backup project operations control centers have been added at TRW and at the TDRS Launch/Deployment Control Center in White Sands. These facilities will improve the reliability



Tracking and Data Relay Satellite Mating With Inertial Upper Stage

of control operations and the simultaneous control of TDRS-A, and TDRS-C in mission support and of TDRS-D during launch and deployment operations.

TDRS-D and its IUS are to be deployed from the space shuttle orbiter. Approximately 60 minutes later, the IUS first-stage solid rocket motor is scheduled to ignite. This will be followed by five maneuvers to allow monitoring of TDRS-D telemetry.

After the IUS second-stage thrusting is completed, the TDRSS mission team at White Sands will command deployment of the TDRS-D solar arrays, the space-to-ground-link antenna and the C-band antenna while the TDRS is still attached to the IUS. Upon separation of the IUS from TDRS-D, the 16-foot-diameter single-access antennas will be deployed, unfurled and oriented toward Earth. Nominal deployment will place TDRS-D at 41 degrees west longitude.

Testing of TDRS-D will be initiated; and after initial check-out, TDRS-D will drift westward to its operational location at 41 degrees west longitude over the northeast corner of Brazil, where it will be referred to as TDRS-East. Operational testing will continue to verify the full-system capability with two operating satellites. On completion of this testing, about three to five months after the launch of TDRS-D, the TDRSS, for the first time, will provide its full-coverage capability in support of NASA space missions.

TDRS-D, identical to TDRS-C, will take the place of TDRS-A, which will then be relocated to 79 degrees west longitude above the equator over central South America and will be maintained as an on-orbit spare.

These three satellites will make up the space segment of the TDRS system. The on-orbit spare, available for use if one of the operational satellites malfunctions, will augment system capabilities during peak periods. The two remaining satellites will be available as flight-ready spares.

The failure of TDRS-A's Ku-band forward link prohibits the operation of the text and graphics system that it is desired be placed on board all space shuttle orbiters. TAGS is a high-resolution facsimile system that scans text or graphic material and converts the analog scan data into serial digital data. It provides on-orbit capability to transmit text material, maps, schematics and photographs to the spacecraft through a two-way Ku-band link through the TDRSS. This is basically a hard-copy machine that operates by telemetry.

Until there is a dual TDRS capability, a teleprinter must be used on orbit to receive and reproduce text only (such as procedures, weather data and crew activity plan updates or changes) from the Mission Control Center. The teleprinter uses S-band and is not dependent on the TDRSS Ku-band.

When the space shuttle orbiter is on orbit and its payload bay doors are opened, the space shuttle orbiter Ku-band antenna, stowed on the right side of the forward portion of the payload bay, is deployed. One drawback of the Ku-band system is its narrow pencil beam, which makes it difficult for the TDRS antennas to lock on to the signal. Because the S-band system has a larger beamwidth, the orbiter uses it first to lock the Ku-band antenna into position. Once this has occurred, the Ku-band signal is turned on.

The Ku-band system provides a much higher gain signal with a smaller antenna than the S-band system. The orbiter's Ku-band antenna is gimbaled so that it can acquire the TDRS. Upon communication acquisition, if the TDRS is not detected within the first 8 degrees of spiral conical scan, the search is automatically expanded to 20 degrees. The entire TDRS search requires approximately three minutes. The scanning stops when an increase in the received signal is sensed. The orbiter Ku-band system and antenna then transmits and receives through the TDRS in view.

At times, the orbiter may block its Ku-band antenna's view to the TDRS because of attitude requirements or certain payloads that cannot withstand Ku-band radiation from the main beam of the orbiter's antenna. The main beam of the Ku-band antenna produces 340 volts per meter, which decreases in distance from the antenna—e.g., 200 volts per meter 65 feet away from the antenna. A program can be instituted in the orbiter's Ku-band antenna control system to limit the azimuth and elevation angle, which inhibits direction of the beam toward areas of certain onboard payloads. This area is referred to as an obscuration zone. In other cases, such as deployment of a satellite from the orbiter payload bay, the Ku-band system is turned off temporarily.

When the orbital mission is completed, the orbiter's payload bay doors must be closed for entry; therefore, its Ku-band antenna must be stowed. If the antenna cannot be stowed, provisions are incorporated to jettison the assembly from the spacecraft so that the payload bay doors can be closed for entry. The orbiter can then transmit and receive through the S-band system, the TDRS in view and the TDRS system. After the communications blackout during entry, the space shuttle again operates in S-band through the TDRS system in the low- or high-data-rate mode as long as it can view the TDRS until it reaches the S-band landing site ground station.

Environmental testing of TDRS-E is complete and the satellite is in storage. Final build will be scheduled to meet a July 1990 launch. TDRS-F has undergone initial integration testing and partial buildup and went to storage at the end of 1988. Environmental testing and buildup to call-up level will be completed by late 1989, and the satellite will be placed in storage until needed. TDRS-G is the replacement for TDRS-B. It is in design and the early stages of manufacturing and will be available for launch in May 1992.

SPACE STATION HEAT PIPE ADVANCED RADIATOR ELEMENT

The SHARE flight experiment is mounted on the starboard sill of Discovery's payload bay, and a small instrumentation package is mounted in the forward portion of the payload bay. The goal of the experiment is to test a first-of-its-kind method for cooling the space station Freedom.

The heat pipe radiator is 12 inches wide, 1.25 inches high and 51.1 inches long. It was developed for NASA's Johnson Space Center by the Grumman Aerospace Corporation. JSC designed and fabricated the structural support. This is the first payload to occupy the starboard remote manipulator system envelope.

The heat pipe instrumentation control system mounts to Discovery's sidewall by means of an adaptive payload carrier designed and developed by JSC. The long-duration exposure facility's data components are used for data acquisition and control.

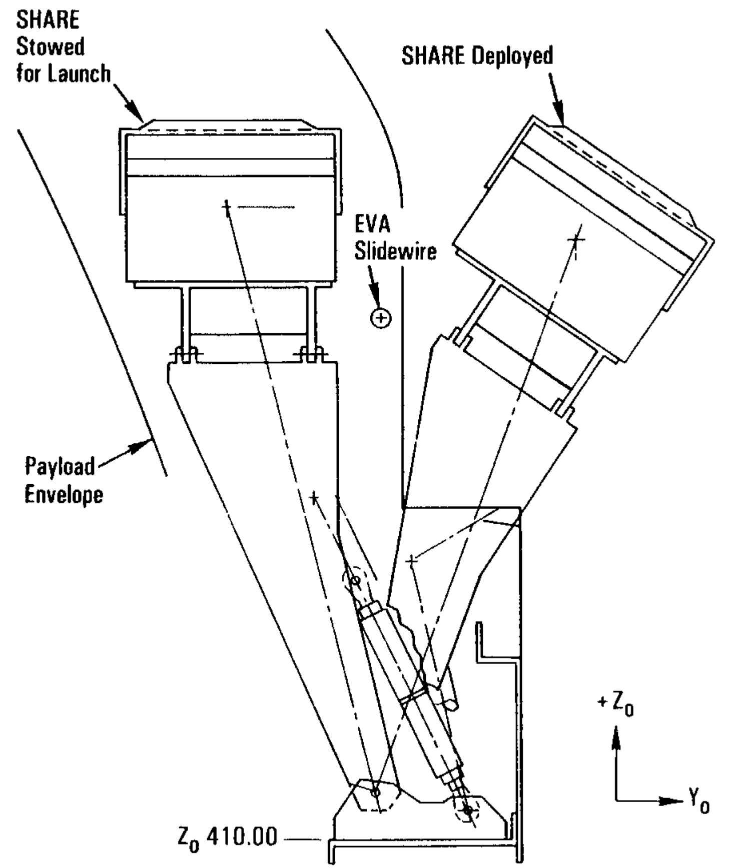
This experiment is sponsored by the Office of Aeronautics and Space Technology and is partially funded through the Office of Space Station.

The heat pipe method uses no moving parts and works through the convection currents of ammonia. Three electric heaters will warm one end of the 51-foot long SHARE. The heaters turn liquid ammonia into vapor, which transports the heat through the length of the pipe. A foot-wide aluminum fin radiates the heat into space. The fin is cooled by the space environment and the ammonia is condensed and recirculated.

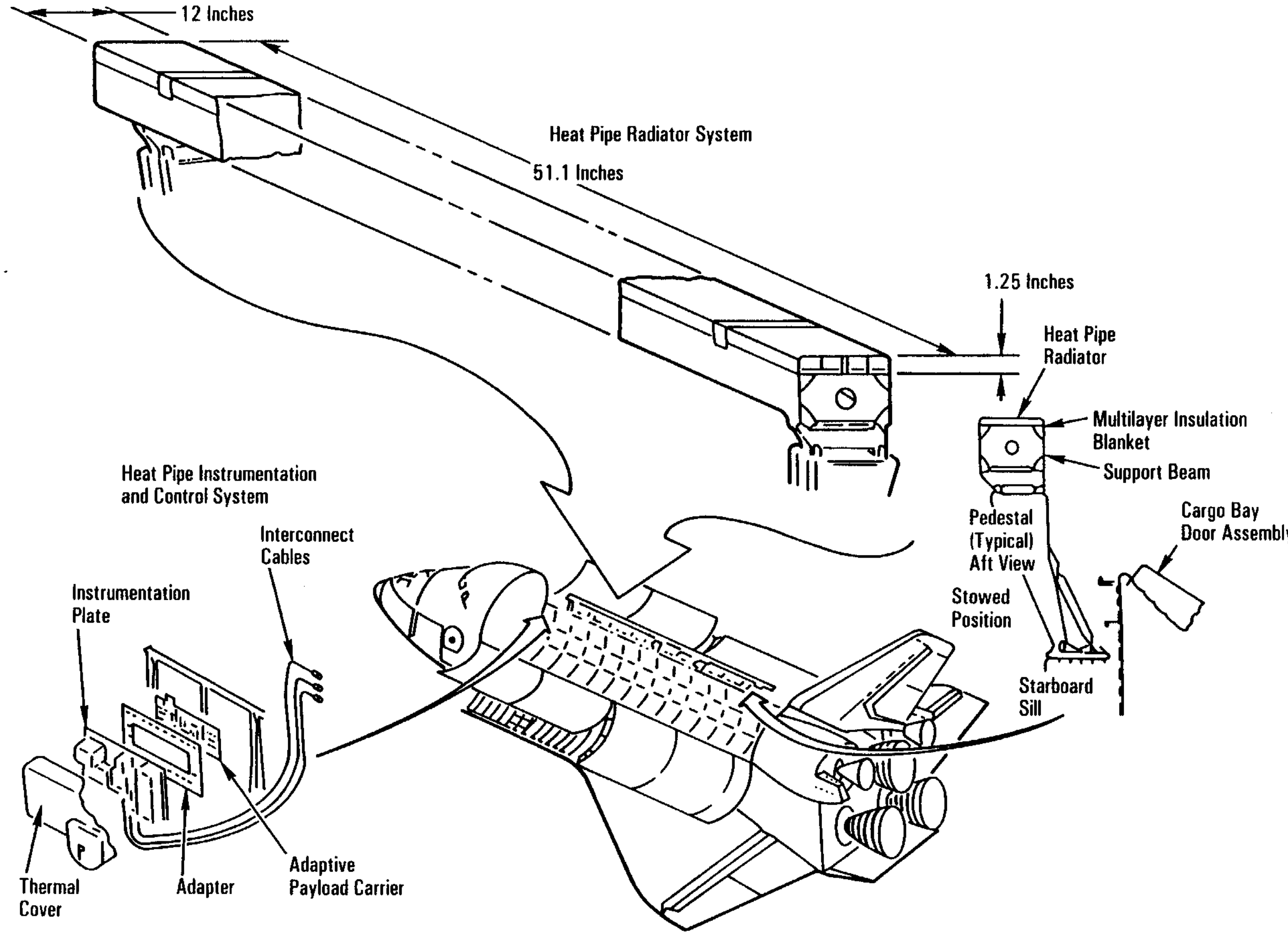
Two small pipes run through the center of the radiator down its length, branching out like the tines of a fork at the end that receives heat, called the evaporator. The top pipe holds the vaporized ammonia; the bottom holds liquid ammonia. In the evaporator portion, a fine wire-mesh wick, which works on the same principle as the wick of an oil lamp, pulls the liquid ammonia from one pipe to the other, where it vaporizes. Small grooves allow the condensed ammonia to return to the bottom pipe.

The radiator weighs about 135 pounds; but with its support pedestals, support beam, heaters and instrumentation package, the total experiment weighs about 750 pounds.

Crew members will switch the heaters on using controls located on the aft flight deck. The experiment's two 500-watt heaters and its 1,000-watt heater are controlled individually and



SHARE Experiment Stowed and Deployed



SHARE Flight Experiment

will be switched on in turn, applying heat that will increase steadily in 500-watt increments up to a maximum of 2,000 watts.

The experiment will be activated for two complete orbits in each of two different attitudes, the first with the payload bay toward Earth and the second with the orbiter's tail toward the sun. The heaters will go through a complete 500-watt to 2,000-watt cycle during activation. This will simulate the heat that needs to be dissipated from the space station, and the two attitudes will provide data on the heat pipe's operation in different thermal environments.

Other information also may be obtained during STS-29 if time permits, including a test of the heat pipe's minimum operating temperature, thought to be about minus 20°F, and a test of its ability to recover from acceleration. The crew may fire the orbiter's aft reaction control system thrusters for about six seconds to push the fluid in SHARE to one end of the pipe. The heaters may then be turned on again to see if the heat pipe will automatically reprime itself and begin operating.

IMAX CAMERA

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

In this mission, the IMAX camera will be used to gather material on the use of observations of the Earth from space for a new film to succeed "The Dream Is Alive." The camera will be operated by members of the flight crew, primarily from the windows in the aft flight deck.

IMAX cameras have been flown on Shuttle missions 41-C, 41-D and 41-G to document crew operations in the payload bay and the orbiter's middeck and flight deck and to film spectacular views of space and Earth. Film from those missions formed 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 of crew members demonstrating space construction techniques.

PROTEIN CRYSTAL GROWTH EXPERIMENT

The PCG experiments conducted on this mission are expected to help advance a technology attracting intense interest from major pharmaceutical houses, the biotech industry and agrichemical companies.

A team of industry, university and government research investigators will explore the potential advantages of using protein crystals grown in space to determine the complex, three-dimensional structures of specific protein molecules. Knowing the precise structure of these complex molecules is the key to understanding their biological function and could lead to methods of altering or controlling the function in ways that may result in new drugs.

It is through sophisticated analysis of a protein in crystalized form that scientists are able to construct a model of its molecular structure. Protein crystals grown on Earth are often small and flawed. PCG experiments flown on four previous space shuttle missions have already provided evidence that superior crystals can be obtained in the microgravity environment of space.

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 cosponsoring the experiments on this mission. The experiments are being managed through the Marshall Space Flight Center in Huntsville, Ala.

Sixty different crystal growth experiments will be conducted simultaneously using 19 different proteins. The experiment apparatus, first flown aboard Discovery on STS-26, fits into a middeck locker. The experiment apparatus differs from previous protein crystal payloads in that it incorporates temperature control and automates some processes.

On orbit, one of the mission specialists will initiate the crystal-growing process.

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

Sponsors of crystal growth experiments flown on this mission through their affiliation with the university's center are Dupont; Eli Lilly and Company; Kodak; Merck Institute for Therapeutic Research; Schering-Plough Corporation; Smith Kline and French; Upjohn; and BioCryst, Limited. The following table lists 15 of the proteins that will be studied.

Principal Investigator	Affiliation	Protein	Description
Vijay Senadhi	University of Alabama, Birmingham	Interferon	This enzyme stimulates the body's immune system and is used clinically in the treatment of cancer.
Alex McPherson	University of California, Riverside	Tobacco mosaic virus	This virus is known to have a harmful effect on tobacco plants.
Keith Ward	Naval Research Lab	Green fluorescent protein	This protein is an acidic, globular, energy transfer protein with a molecular weight of 29,000 found in the photocytes of the hydromedusae *Aeqourea aequorea.*
Ada Yonath	Weizmann Institute	Ribosome	Ribosomes play a major role in protein processing in cells.
Juan Fontecilla	CNRS, Marseille, France	Lectin, lathyrus ochrus	This protein binds glycames of glycoproteins localized at the surface cell. It is inhibited by specific binding of glycose and mannose.
Drake Eggleston	Smith Kline and French	SKF 104662	The molecule is representative of a whole class of antibiotics that are the object of much industrial interest.
Byron Rubin	Eastman Kodak	Diacetinase	Diacetinase is a glycerol ester hydrolase from *Bacillus subtilis.*
Noel Jones	Eli Lilly and Company	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-29 is identical in all respects to this natural hormone. Biosynthetic human somatotropin is marketed by Eli Lilly and Company for treating children who are unusually small because their pituitary glands produce too little growth hormone.
Pat Weber	DuPont de Nemour	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.
Ed Meehan	University of Alabama, Huntsville	Urease	There is great commercial interest in the development of urease inhibitors. Private companies and government agencies, such as the National Fertilizer Development Center, have devoted significant efforts to synthesizing new and more effective urease inhibitors. This work is motivated by the fact that urea is a major source of solid nitrogen in the world for agriculture. The development of an effective inhibitor could have a large impact on the pattern of world agriculture.
Ponzy Lu	Univeristy of Pennsylvania Smith Kline and French	Lac repressor	This protein regulates the expression of lactose operon in *E. coli.* This system has been highly studied and much is known about it.
Howard Einspahr	The Upjohn Company	Renin	This enzyme is produced by the kidneys and plays a major role in the chemical reaction that controls blood pressure.
Dan Carter	Marshall Space Flight Center	Alcohol oxidase	This enzyme is involved in cellular metabolism.
Bill Cook	University of Alabama, Birmingham BioCryst, Limited	Purine necleoside phosphorylase	This protein is a target for the design of immunosuppressive and anticancer drugs.
Manuel Navia	Merck Institute	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.

CHROMOSOME AND PLANT CELL DIVISION IN SPACE EXPERIMENT

This experiment will determine whether the roots of a plant will develop in microgravity as they do on Earth. It will determine whether the normal rate, frequency and patterning of cell division in the root tops can be sustained in space; whether chromosomes and genetic makeup are maintained during and after exposure to space flight conditions; and whether aseptically grown tissue cultures will grow and differentiate normally in space.

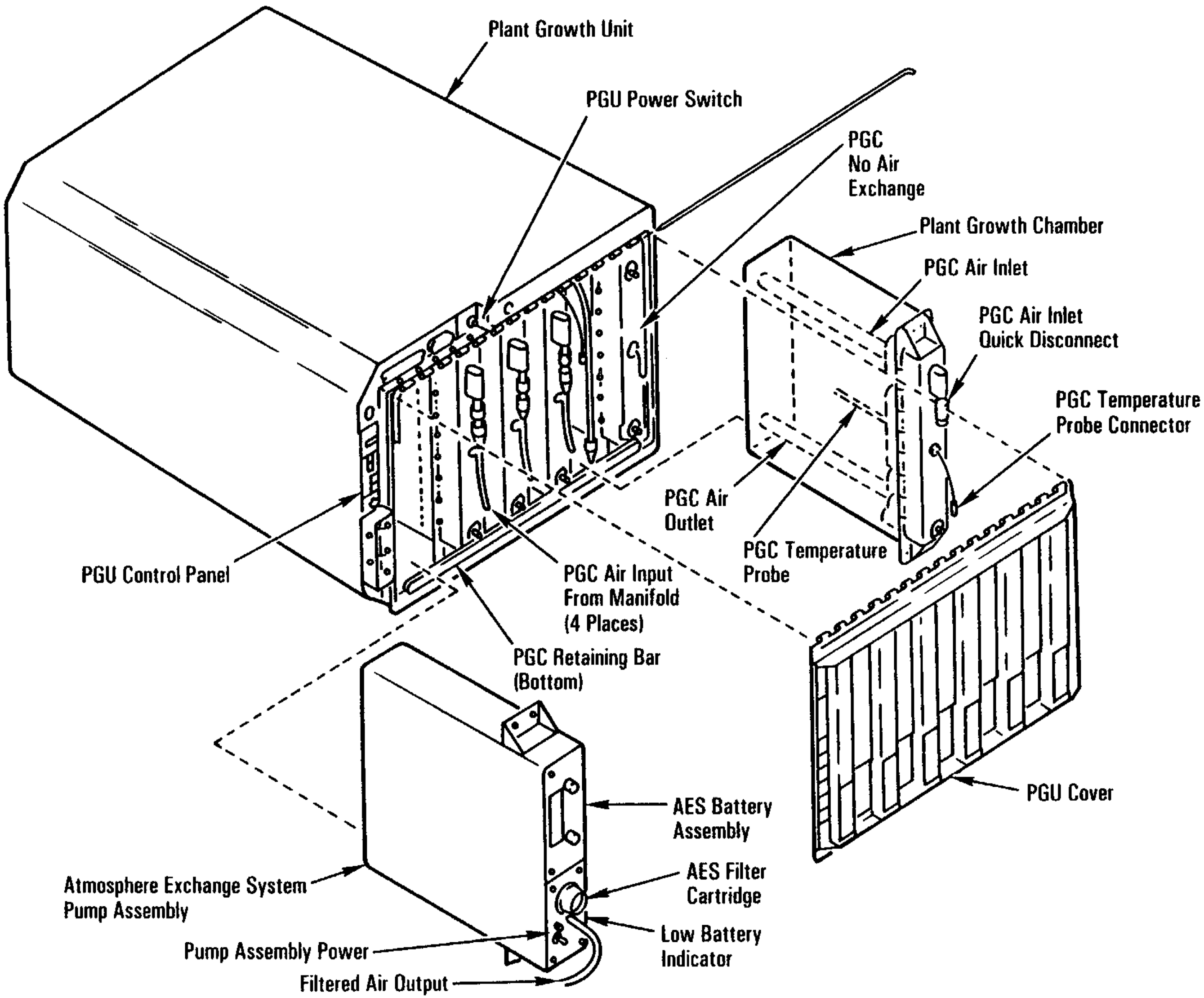
Root-free shoots of the day lily and haplopappus plants will be used.

The criteria for comparison include the number of roots formed and their length, weight and quality based on a subjective appraisal as well as quantitative morphological and histological examination.

Cells from root tips will be analyzed after the flight for their karyotype and the configuration of their chromosomes. Haplopappus is a unique flowering plant that has four chromosomes in its diploid cells ($2n = 4$). Day lily monocotyledon is also of interest because of the specific features of its karyotype ($2n = 22$).

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

Previous observations of some plants grown in space have indicated a substantially lowered level of cell division in primary root tips and a range of chromosomal abnormalities, such as breakage and fusion.



Plant Growth Unit With Atmosphere Exchange System

ORBITER EXPERIMENT AUTONOMOUS SUPPORTING INSTRUMENTATION SYSTEM

OASIS-I is designed to collect and record a variety of environmental measurements in Discovery's payload bay during the various flight phases of the mission.

NASA is flying OASIS aboard Discovery in support of the inertial upper stage program office of the Air Force Space Division. The system was developed by Lockheed Engineering and Management Services Company under a NASA contract. Development was sponsored by the Air Force Space Division.

The primary device of OASIS is a large tape recorder mounted on the aft port side of Discovery's payload bay. The portion of OASIS installed in the aft portion of the payload bay is approximately 4 feet long, 1 foot wide and 3 feet deep and weighs 230 pounds.

OASIS is configured on this mission to monitor the TDRS-D and IUS. Transducers and sensors are mounted on the forward and aft IUS airborne support equipment to measure thermal, acoustic, vibration, stress and acceleration data. These sensors are attached to accelerometers, strain gauges, microphones, pressure sensors and various thermal devices on the IUS ASE.

The information obtained will be used to study the effects of temperature, pressure, vibration, sound, acceleration, stress and strain on the IUS ASE. It will also be used in designing future payloads and upper stages.

The OASIS recorder can be commanded from the ground to store information at low, medium, or high data rates.

OASIS will be turned on nine minutes before the lift-off of Discovery to begin recording at high speed for recovering high-speed data. Following the orbital maneuvering system thrusting period, it will be switched to a low data rate and commanded to high speed for any subsequent OMS thrusting periods.

OASIS was flown on Discovery on the STS-26 mission to gather data in Discovery's payload bay.

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

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

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

SSIP 83-9, CHICKEN EMBRYO DEVELOPMENT IN SPACE

This experiment, devised by John C. Vellinger, formerly of Jefferson High School, Lafayette, Ind., will determine the effects of space flight on the development of fertilized chicken embryos. Vellinger is now a senior at Purdue University majoring in mechanical engineering and is scheduled to graduate in December 1989. He has been working on this experiment for nine years. It was manifested on the 51-L mission.

The experiment is to fly 32 chicken eggs—16 fertilized two days before launch and the other 16 fertilized nine days before launch—to see if any changes in the developing embryos can be attributed to weightlessness.

All 32 eggs will be placed in an incubator designed by Vellinger. The incubator will be placed in the middeck of Discovery. An identical group of 32 eggs will remain on Earth as a control group. Throughout the mission, Vellinger will attend to the control eggs much as a mother hen would, turning them five times a day to counter the effects of Earth's gravity on the yolks.

After the mission, the eggs flown on Discovery will be returned to Vellinger, who will open and examine 16 of them. He will also open and examine half of the control eggs. The examinations are intended to identify any statistically significant differences in cartilage, bone and digit structures; muscle and nervous systems; facial structure; and internal organs. The other eggs will be hatched at 21 days; and the chicks' weight, growth rates and reproductive rates will be studied.

Vellinger's goal is to determine whether a chicken embryo can develop normally in a weightless environment.

The experiment is mostly self-sustaining and only requires periodic temperature and humidity checks by a crew member.

The scientific team supporting Vellinger includes Dr. Cesar Fermin, Tulane University; Dr. Patricia Hester, Purdue University; Dr. Michale Holick, Boston University; Dr. Ronald Hullinger, Purdue University; and Dr. Russell Kerschmann, University of Massachusetts.

Stanley W. Poelstra of Jefferson High School is Vellinger's student advisor. Dr. Lisbeth Kraft, of NASA Ames Research Center, Mountain View, Calif., served as NASA's technical advisor. Kentucky Fried Chicken, Louisville, is sponsoring the experiment.

SSIP 82-8, THE EFFECTS OF WEIGHTLESSNESS IN SPACE FLIGHT ON THE HEALING OF BONE FRACTURES

This experiment was proposed by Andrew I. Fras, formerly of Binghamton High School, Binghamton, N.Y., to establish whether the environmental effects of space flight inhibit the healing of bones. Fras is now attending Brown University's Medical School.

Observations of rats on previous space flights, as well as studies of nonweight-bearing bone of rats in gravity, have shown that minerals, particularly calcium, are lost from the body, resulting in a condition similar to osteoporosis. Calcium is the main mineral needed for bone formation. A veterinarian will remove a minute piece of bone from a nonweight-bearing bone in four Long Evans rats which will be carried on board Discovery. The effects of zero gravity on the origin, development and differentiation of the osteoblasts (bone cells) and their production of callus will be studied. A matched control group will be Earth-based.

The four rats will be flown in an animal enclosure module in the middeck of Discovery. In addition to housing the rats, the module also will contain a microgravity rodent bottle (water supply) and food bars. The experiment is completely autonomous. The experimenter only requests visual observations and video taping when possible.

Fras, working with scientists and researchers at Orthopaedic Hospital and the University of Southern California, will attempt to determine whether bone healing in the rats is impeded by the loss of calcium and the absence of weight bearing during space flight.

Andrew Fras is the only student to be selected for NASA/NSTA's SSIP twice. His first project, The Effect of Weightlessness on the Aging of Brain Cells, flew on STS 51-D in 1985.

Fras's student advisor is Howard I. Fisher of Binghamton High School. Orthopaedic Hospital/University of Southern California, Los Angeles, Calif., is sponsoring the experiment and providing advice, direction and scientific monitoring. The advisors are Dr. June Marshall and Dr. Augusto Sarmiento. Dr. Emily Holton, of NASA Ames Research Center, Mountain View, Calif., is serving as the NASA technical advisor.

AIR FORCE MAUI OPTICAL SITE CALIBRATION TEST

The AMOS tests allow ground-based electro-optical sensors located on Mt. Haleakala, Maui, Hawaii, to collect imagery and signature data of Discovery during cooperative overflights. The scientific observations made of Discovery while it performs reaction control system thruster firings or 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 require no unique flight hardware and only require that Discovery perform predefined attitude operations 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. It is administered and operated by the AVCO Everett Research Laboratory in Maui. The principal investigators for the AMOS tests on the space shuttle are from AFSC's Air Force Geophysics Laboratory, 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 Division at NASA's Johnson Space Center in Houston. Flight operations are conducted at NASA's Mission Control Center in coordination with the AMOS facility in Hawaii.

WATER DUMP CLOUD FORMATION

The purpose of this DTO is to define the formation of the water dump plume and its angular extent with respect to the orbiter's coordinate system and trajectory. Provided there are opportunities that satisfy the viewing constraints over a ground site, up to three observations will be made. When possible, the orbiter will be in specific attitudes, and the water dumps will be initiated and terminated at specific times relative to the site acquisition of signal.

TEXT AND GRAPHICS SYSTEM

This DTO is designed to provide a significant confidence test and evaluation of TAGS under zero g and to generate data for comparison with data from 1-g test conditions. Approximately 400 images will be sent, mostly while the crew is asleep. A second test is intended to validate paper-loading techniques.

ATTITUDE MATCH UPDATE VALIDATION UPDATE

The purpose of this DTO is to test a procedure needed to update the IUS attitude base to provide the required accuracy for planetary missions (Magellan, Galileo and Ulysses). The implementation of this DTO on STS-29 will nominally reflect data collection before and after two rotations of at least 90 degrees about axes approximately 90 degrees apart.

PAYLOAD AND GENERAL-SUPPORT COMPUTER EVALUATION

The PGSC is a portable computer that provides a common crew interface for a variety of space transportation system payloads. The PGSC will also be used to functionally replace the 1530 portable laptop computer. The purpose of this DTO is to evaluate the unique hardware aspects of the GRID Case 1530 as well as crew use of and interaction with the PGSC.

INERTIAL MEASUREMENT UNIT REFERENCE RECOVERY TECHNIQUES

The crew performs activities on orbit that consist of various techniques in support of IMU reference recovery after an unforeseen loss. The crewman optical alignment sight and universal pointing software are used with celestial targets that are easily identified. The objective is to verify the operational feasibility of each technique.

IN-FLIGHT SALIVARY PHARMACOKINETICS OF SCOPOLAMINE AND DEXTROAMPHETAMINE

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

SALIVARY ACETAMINOPHEN PHARMACOKINETICS

This DSO investigates the pharmacokinetics of acetaminophen (Tylenol). This drug is used for evaluation because it distributes into the saliva with a ratio similar to that of blood plasma. The crew will take Tylenol after an eight-hour fast and will take salivary samples at specified intervals during the flight day.

NON-INVASIVE ESTIMATION OF CENTRAL VENOUS PRESSURE DURING SPACE FLIGHT

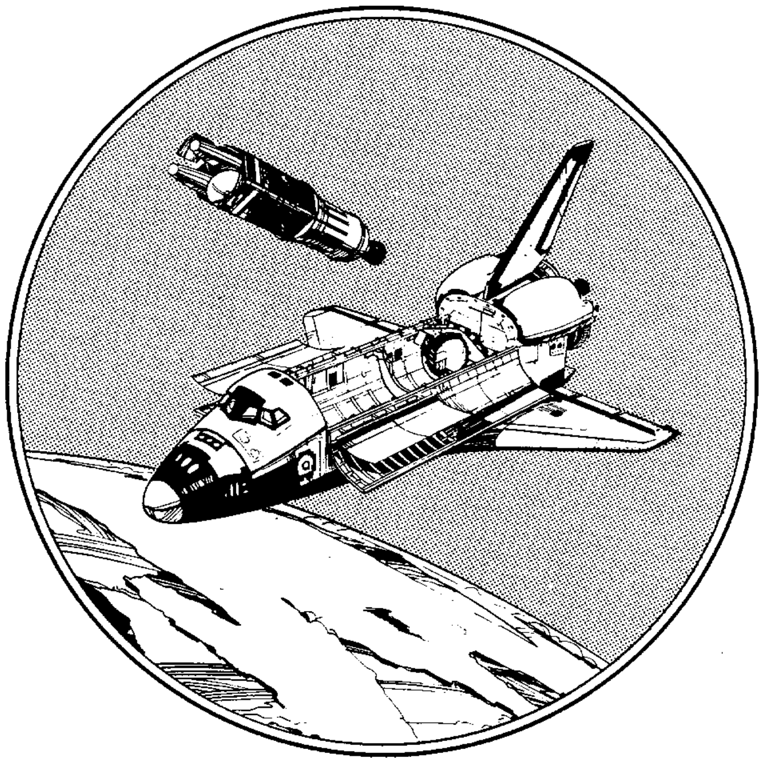
The objective of this investigation is to measure physiological adaptations to the headward fluid shift seen in microgravity. The non-invasive technique of determining central venous pressure uses a mouthpiece instrument utilizing Doppler flowmetry. The specified crew member will take measurements as early as possible on flight day 1 and before and after sleeping as time permits during the remainder of the flight.

PREFLIGHT ADAPTATION TRAINING

The purpose of this DSO is to obtain reactions to the stimulus rearrangement produced by a prototype trainer before and immediately following orbital flight. The bulk of this DSO will be done on the ground. In flight, the crew members will be asked to document (via cassette tape recorder) perceived self-motion and surround motion accompanying slow head motions during reentry and descent.

RELATIONSHIP OF SPACE ADAPTATION SYNDROME TO MIDDLE CEREBRAL ARTERY BLOOD VELOCITY MEASURED IN FLIGHT BY DOPPLER

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



STS-29

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

March 1989

Rockwell International

Space Transportation
Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the eighth flight of Discovery and the 28th in the space transportation system program.

The flight crew for the STS-29 mission consists of commander Michael L. Coats; pilot John E. Blaha; and mission specialists James F. Buchli, Robert C. Springer and James P. Bagian.

The primary objective of this five-day mission is to deploy the third Tracking and Data Relay Satellite mated with an inertial upper stage. After the deployment of TDRS-D and its IUS from Discovery's payload bay, the IUS will provide the necessary velocity to place the satellite in a geosynchronous orbit. TDRS-A, which is in a geosynchronous orbit, was launched from Challenger on the STS-6 mission in April 1983; and TDRS-C was launched from Discovery on the STS-26 mission in September 1988. TDRS-D will take the place of TDRS-A at 41 degrees west longitude above the equator. and will be referred to as TDRS-East. TDRS-A will then be relocated to 79 degrees west longitude above the equator over central South America and will be maintained as an on-orbit spare. TDRS-B was lost on the STS 51-L mission.

TDRS-D and its IUS are scheduled to be deployed from Discovery's payload bay on the fifth orbit at a mission elapsed time of six hours and 13 minutes. Backup deployment opportunities are available on orbits 6, 7 and 15, with a contingency capability on orbit 17.

The IUS will ignite its first-stage solid rocket motor on orbit 6A (ascending node) for transfer orbit insertion approximately 60 minutes after the satellite and IUS are deployed. (Each orbit starts when the orbiter begins its ascent across the equator on its ascending node.) The IUS will ignite its second-stage SRM approximately seven hours after deployment. Backup transfer orbit insertions could occur 60 minutes after deployment on orbits 7A, 8D (descending node), 16A or 18A.

Seven other payloads will be carried aboard Discovery on this mission. Five are located in the crew compartment and two in the payload bay.

Five experiments will be carried in Discovery's crew compartment. They are the Protein Crystal Growth, Space Life Science Training Program Chromosome and Plant Cell Division in Space, and IMAX 70mm Camera experiments and two Shuttle Student Involvement Project experiments: SSIP 82-8, Effects of Weightlessness in Space Flight on the Healing of Bone Fractures, and SSIP 83-9, Chicken Embryo Development in Space.

The two experiments located in Discovery's payload bay are the Space Station Heat Pipe Advanced Radiator Element and Orbiter Experiment Autonomous Supporting Instrumentation System I.

The Air Force Maui Optical Site Calibration Test experiment allows ground-based electro-optical sensors on Maui, Hawaii, to collect imagery and signature data of Discovery's reaction control system plumes during overflights.

This mission is the first time that the orbiter's main landing gear brakes are being reused without undergoing refurbishment. These are the same brakes flown on Discovery on the STS-26 mission.

MISSION STATISTICS

Launch: Launch window duration is limited to 2.5 hours because flight crew members are lying on their backs in Discovery on the launch pad. Launch period duration is four hours due to lighting at the transatlantic landing abort site. Discovery is to be launched from Launch Complex 39-B.

3/11/89 8:10 a.m. EST
7:10 a.m. CST
5:10 a.m. PST

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

Landing: Nominal end of mission is on orbit 81.

3/16/89 9:17 a.m. EST
8:17 a.m. CST
6:17 a.m. PST

Inclination: 28.45 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 an elliptical orbit. This direct-insertion profile lofts the ascent 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.

Because of the direct-insertion ascent profile, the external tank's impact area will be in the Pacific Ocean south of Hawaii.

Altitude: 160 nautical miles (184 statute miles), then 160 by 177 nautical miles (184 by 203 statute miles)

Space Shuttle Main Engine Thrust Level in Ascent: 104 percent

Total Lift-off Weight: Approximately 4,536,861 pounds

Orbiter Weight, Including Cargo at Lift-off: Approximately 208,285 pounds

Payload Weight Up: Approximately 47,384 pounds

Payload Weight Down: Approximately 9,861 pounds

Orbiter Weight at Landing: Approximately 194,460 pounds

Payloads: TDRS-D/IUS-2; SHARE, IMAX, PCG, CHROMEX, AMOS, and OASIS-I experiments; and two SSIP experiments—SSIP 82-8, bone healing, and SSIP 83-9, chicken eggs

Flight Crew Members:
Commander: Michael L. Coats, second space shuttle flight
Pilot: John E. Blaha, first space shuttle flight
Mission Specialist 1: James F. Buchli, third space shuttle flight
Mission Specialist 2: Robert C. Springer, first space shuttle flight
Mission Specialist 3: James P. Bagian, first space shuttle flight

Ascent Seating:
Flight deck front left seat, commander Michael Coats
Flight deck front right seat, pilot John Blaha
Flight deck aft center seat, mission specialist James Buchli
Flight deck aft right seat, mission specialist Robert Springer
Middeck, mission specialist James Bagian

Entry Seating:
Mission specialist Robert Springer will be in the middeck and James Bagian will be in the aft right center seat on the flight deck.

Extravehicular Activity Crew Members, If Required:
Extravehicular 1 would be Robert Springer and EV-2 would be James Bagian.

Entry Angle of Attack: 40 degrees.

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

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

Notes: The remote manipulator system is not installed in Discovery's payload bay for this flight. The galley is installed in the middeck of Discovery.

A spare general-purpose computer is stowed in a modular locker in Discovery's middeck.

The uplink to Discovery on this mission will be encrypted.

Location of payloads in Discovery's payload bay, looking forward from the aft end of Discovery, is OASIS-I and IUS-2 and TDRS-D with SHARE on the starboard side.

MISSION OBJECTIVES

- Deployment of TDRS-D/IUS-2
- SHARE
- IMAX
- PCG
- CHROMEX
- OASIS-I
- SSIP 83-9, chicken eggs
- SSIP 82-8, bone healing

DEVELOPMENT TEST OBJECTIVES

- Direct-insertion external tank tracking
- Water dump cloud formation
- Nose wheel steering runway evaluation (test number 2)
- Revised braking system test (third flight test)
- Text and graphics system
- Attitude match update
- Payload and general-support computer evaluation
- Inertial measurement unit recovery techniques
- Crosswind landing performance
- Ascent structural capability evaluation (data only)
- Ascent compartment venting evaluation (data only)
- Descent compartment venting evaluation (data only)
- Entry structural capability (data only)
- Vibration and acoustic evaluation (data only)
- Pogo stability performance (data only)
- Shuttle/payload low-frequency environment (data only)

DETAILED SUPPLEMENTARY OBJECTIVES

- In-flight salivary pharmacokinetics of scopolamine and dextroamphetamine
- Salivary acetaminophen pharmacokinetics
- Central venous pressure estimation
- Pre- and postflight cardiovascular assessment
- Influence of weightlessness on baroreflex function
- Preflight adaptation training
- Relationship of space adaptation syndrome to cerebral blood flow
- Documentary television
- Documentary motion picture photography
- Documentary still photography

Notes:

- The text and graphics system is considered operational with TDRS-C operational at 171 degrees west longitude and TAGS as the primary mode of text uplink. TAGS 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 TDRS 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 is operated 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 by 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, aboard the orbiter from the Mission Control Center in Houston. It 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.

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.
01:20:00	Orbiter side hatch is closed.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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.
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.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
	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.
00:09:00	A planned 10-minute hold starts.

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
Hold 10 Minutes	NASA and contractor project managers will be formally polled by the deputy director of NASA, National Space Transportation System (NSTS) Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records. All test support team members verify that they are "go for launch." Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins. The chase aircraft are launched. From this point the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the onboard orbiter PASS redundant-set computers.
00:09:00	Operations recorders are on. MCC-H, Johnson Space Center, sends a command to turn these recorders on. They record shuttle system performance during ascent and are dumped to the ground once orbit is achieved.
00:08:00	Payload and stored prelaunch commands proceed.
00:07:30	The orbiter access arm (OAA) connecting the access tower and the orbiter side hatch is retracted. If an emergency arises requiring flight crew activation, the arm can be extended either manually or by GLS computer control in approximately 30 seconds or less.
00:05:00	Orbiter APUs start. The orbiter APUs provide pressure to the three orbiter hydraulic systems. These systems are used to move the SSME engine nozzles and aerosurfaces.
00:05:00	ET/SRB range safety system (RSS) is armed. At this point, the firing circuit for SRB ignition and destruct devices is mechanically enabled by a motor-driven switch called a safe and arm device (S&A).
00:04:30	As a preparation for engine start, the SSME main fuel valve heaters are turned off.

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

T – (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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.
	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.

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

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

MISSION TIMELINE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY ZERO	
0/00:00:06.8	Tower is cleared (SRBs above lightning rod tower).
0/00:00:07	120-degree roll maneuver positive roll (right-clockwise) is started. Pitch profile is heads down (astronauts) wings level.
0/00:00:14	Roll maneuver ends.
0/00:00:32.6	All three SSMEs throttle from 104 to 65 percent for maximum aerodynamic load (max q).
0/00:01:01	All three SSMEs throttle to 104 percent.
0/00:01:03	Max q occurs.
0/00:01:26.4	SRBs separate.
	When chamber pressure (P_C) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where they are recovered for reuse in another mission. Flight control system switchover from SRB to orbiter RGAs occurs.
0/00:04:01	Negative return. The vehicle is no longer capable of return-to-launch-site (RTLS) abort to Kennedy Space Center runway.
0/00:07:20	Single engine to main engine cutoff (MECO).
0/00:07:30	All three SSMEs throttle from 104 percent for vehicle no greater than 3-g acceleration capability.
0/00:08:24	All three SSMEs throttle down to 65 percent for MECO.
0/00:08:31	MECO, approximate velocity 25,871 feet per second (fps), 156 by 35 nautical miles (nmi) (179 by 40 statute miles [sm]).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:08:49	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft reaction control systems (RCSs), which provide attitude 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.
0/00:39.54	OMS-2 thrusting maneuver is performed, 2 minutes 21 seconds in duration, 221.5 fps, 160 by 160 nmi (184 by 184 sm).
0/00:53	Mission specialist (MS) seat egress occurs.
0/00:54	Commander and pilot configure general-purpose computers (GPCs) for OPS-2.
0/00:57	MS preliminary middeck configuration.
0/00:59	MS configures aft station.
0/01:00	Pilot activates payload bus.
0/01:03	Commander and pilot don and configure communications.
0/01:05	Commander activates radiator.
0/01:07	Pilot maneuvers to payload bay door opening attitude, negative Z local vertical biased negative Y velocity vector.
0/01:13	Commander and pilot seat egress occurs.
0/01:13	Orbit 2 begins.
0/01:14	MS configures for payload bay door operations.
0/01:22	Pilot opens payload bay doors.
0/01:23	Commander loads payload data interleaver (PDI).
0/01:28	Pilot checks out cryo heaters.
0/01:34	Commander configures postpayload bay door operations radiator.
0/01:40	Commander powers the star trackers (STs) on.
0/01:44	MCC-H and flight crew are given command "go for orbit operations."
0/01:47	MS configures middeck.
0/01:48	Pilot activates auxiliary power unit (APU) steam vent heater, boiler control power heater (3) to A, controller (3) power ON.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:50	MS engages inertial upper stage (IUS) actuator.
0/01:53	Pilot closes MNB supply H_2O dump isolation circuit breaker, ML86, and activates supply H_2O dump isolation valve open (OP) on R12L.
0/01:57	Pilot activates auto fuel cell purge.
0/01:59	Commander star tracker self-test/door open.
0/02:00	Commander and pilot configure clothing.
0/02:02	MS configures clothing.
0/02:07	MS activates teleprinter.
0/02:08	Pilot plots fuel cell performance.
0/02:09	Commander and pilot configure controls for on orbit and unstow and install head-up display (HUD) covers.
0/02:12	MS removes and stows seat.
0/02:14	Commander configures RCS vernier control.
0/02:17	Commander configures cabin temperature controller to 1.
0/02:17	MS unstows and installs treadmill.
0/02:20	Vehicle maneuvered to inertial measurement unit (IMU) align/attitude match update (AMU) attitude.
0/02:22	Pilot enables hydraulic thermal conditioning.
0/02:25	Pilot switches APU fuel pump/valve cool from A-OFF to B-AUTO.
0/02:27	Pilot resets caution and warning (C/W).
0/02:30	Status of CHROMEX experiment.
	EZ CAP (CREW ACTIVITY PLANS) FOR TODAY
	— Launch entry suit cleaning and drying.
	— Cryo oxygen tank heater sensor check.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— Pressure control system (PCS) configuration to system 1.
	— Lamp and fire suppression test.
	— Meal preparation.
	— Perform central venous pressure detailed secondary objective (DSO) as soon as possible on orbit.
	— Perform cerebral blood flow velocity DSO as soon as possible on orbit.
	— IMAX status.
0/02:31	Activation of SHARE experiment.
0/02:31	Photo/TV are activated for satellite deployment.
0/02:34	AMU data take.
0/02:35	Maneuver to AMU attitude.
0/02:43	Orbit 3 begins.
0/02:43	AMU data take.
0/02:44	Crew performs IMU align with ST.
0/02:46	Maneuver to negative Z local vertical, negative Y velocity vector attitude.
0/02:50	AMU data take.
0/02:54	IUS predeploy checkout early checks.
0/02:55	Unstow cabin equipment.
0/03:01	Photo/TV cameras are assembled.
0/03:02	IUS direct check and early checks are performed.
0/03:16	Early checks are performed on the Tracking and Data Relay Satellite (TDRS).
0/03:26	APU steam vent heater is deactivated; boiler power switches (3) are turned to OFF.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:36	Aft controller checkout is performed.
0/03:36	Unstow IMAX.
0/03:56	APU fuel pump/valve cool B is turned to OFF.
0/04:01	Photo/TV are set up for satellite deploy.
0/04:13	Orbit 4 begins.
0/04:13	Vehicle transfers state vector (SV) to TDRS-West for IUS deploy; late checks are performed.
0/04:16	Vehicle maneuvers to TDRS check attitude for IUS deploy; late checks are performed.
0/04:20	Crew members' mealtime.
0/04:28	Tilt table elevated to 29 degrees for IUS deploy; late checks are performed.
0/04:31	Photo/TV are activated for satellite deploy scene.
0/04:36	Step 1 of TDRS direct check for IUS deployment and late checks are performed.
0/04:40	Step 2 of TDRS direct check with Goldstone for IUS deployment and late checks are performed.
0/04:51	IUS payload interrogator (PI) lock for IUS deployment; late checks are performed.
0/05:16	CHROMEX experiment status.
0/05:33	Vehicle is maneuvered to deploy attitude.
0/05:36	Photo/TV are activated for satellite deploy scenes.
0/05:44	Orbit 5 begins.
0/05:44	Deploy countdown occurs for the IUS deployment.
0/05:47	APU heater gas generators/fuel pumps (3) A are switched to AUTO.
0/05:54	IUS transfers to internal power.
0/05:57	IUS umbilicals are released.
0/05:59	IUS tilt table is raised to 52 degrees.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/05:59	Flight crew is informed to "go for deploy".
0/06:01	IUS deploy countdown begins.
0/06:13	Deploy IUS/TDRS.
0/06:14	Postdeploy separation maneuver occurs; RCS, 0.08 second in duration, 2.2 fps, 160 by 161 nmi (184 by 185 sm).
0/06:18	IUS tilt table is lowered to minus 6 degrees.
0/06:28	OMS-3 separation thrusting maneuver 0.16 second in duration, 31 fps, 177 by 161 nmi (196 by 185 sm).
0/06:29	Vehicle is maneuvered to IUS viewing attitude.
0/06:35	Crew ends photo/TV activation for the satellite deployment.
0/06:36	Crew activates Protein Crystal Growth (PCG) experiment.
0/06:45	PI is turned to OFF.
0/06:52	Vehicle maneuvers to orbiter window protection attitude (IUS solid rocket motor [SRM] ignition).
0/07:13	IUS SRM-1 ignition.
0/07:14	Orbit 6 begins.
0/07:16	Close out IUS deploy and perform postdeployment operations.
0/07:19	Digital autopilot A is changed to A1.
0/07:30	Crew begins presleep activity.
0/07:31	Vehicle is maneuvered to TDRS downlink attitude.
0/07:46	Crew deploys Ku-band antenna for communications and instrumentation.
0/07:51	Video tape recorder (VTR) is set up for satellite deploy scenes via TDRS-West.
0/07:55	Crew activates Ku-band system in communications mode.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/08:16	VTR playback of satellite deploy via TDRS-West.
0/08:22	Vehicle is maneuvered to IMU align attitude.
0/08:30	Crew empties TAGS paper tray.
0/08:31	Crew checks chicken eggs experiment.
0/08:37	Crew performs IMU align with ST.
0/08:42	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector.
0/08:45	Orbit 7 begins.
0/09:30	Crew empties TAGS paper tray.
0/10:00	Crew begins 8-hour sleep period.
0/10:15	Orbit 8 begins.
0/11:46	Orbit 9 begins.
0/13:17	Orbit 10 begins.
0/14:47	Orbit 11 begins.
0/16:18	Orbit 12 begins.
0/17:49	Orbit 13 begins.
0/18:00	Crew ends 8-hour sleep period and begins postsleep activities. EZ CAP ACTIVITIES — Exercise, one hour (all). — Food preparation, 30 minutes. — Salivary scopolamine/dextroamphetamine pharmacokinetics, 5 minutes (MS-2). — Central venous pressure, 5 minutes (MS-3). — Cerebral blood flow velocity, 5 minutes (all). — Test, unload and reload TAGS paper roll, 30 minutes.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— IMAX status
	— PCG fan inlet cleaning.
	— Payload and general-support computer (PGSC) evaluation.
0/19:00	Crew uses last TAGS message to sort crew messages from TAGS development test objectives (DTOs).
0/19:20	Orbit 14 begins.
0/20:00	Crewman optical alignment sight (COAS) power to OFF. Mount COAS at aft flight station.
0/20:25	Vehicle is maneuvered to IMU align attitude.
0/20:45	Crew performs IMU align with ST.
0/20:45	Photo/TV are set up for IMAX.
0/20:50	Orbit 15 begins.
0/20:50	Crew calibrates COAS.
0/21:00	COAS power to OFF. Stow COAS.
0/21:00	Set up PGSC.
0/21:15	Maneuver vehicle to Rift Valley track.
0/21:15	Photo/TV are activated for IMAX.
0/21:35	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
0/21:40	VTR is set up for satellite deploy.
0/21:55	VTR playback, satellite deploy at TDRS-West.
0/22:20	Orbit 16 begins.
0/22:25	Photo/TV are set up for IMAX.
0/22:55	Photo/TV are activated for IMAX.
0/22:58	Vehicle is maneuvered to Betsiloka track.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/23:15	Vehicle maneuvered to negative Z local vertical, positive X velocity vector attitude.
0/23:51	Orbit.17 begins.

DAY ONE

1/00:25	Crew members' mealtime.
1/01:22	Orbit 18 begins.
1/01:25	Air Force Maui Optical Site (AMOS) Calibration Test performed.
1/01:35	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
1/01:40	Scheduled in-flight maintenance, filter cleaning.
1/02:52	Orbit 19 begins.
1/02:55	SHARE experiment is powered up.
1/03:45	Photo/TV are set up for CHROMEX experiment.
1/04:10	PGSC temperature test.
1/04:15	Photo/TV are activated for CHROMEX experiment.
1/04:23	Orbit 20 begins.
1/04:35	CHROMEX experiment status.
1/05:05	CHROMEX experiment is activated.
1/05:20	SHARE experiment is powered down.
1/05:54	Orbit 21 begins.
1/05:55	Photo/TV are set up for IMAX.
1/06:25	Vehicle is maneuvered to Earth scene initiate track.
1/06:25	Photo/TV are activated for IMAX.
1/06:45	Vehicle is maneuvered to Earth scene track.
1/07:00	Vehicle is maneuvered to IMU align attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/07:10	Crew checks chicken eggs experiment.
1/07:20	Crew performs IMU align with ST.
1/07:24	Orbit 22 begins.
1/07:25	Crew begins presleep activity.
1/07:35	Crew empties TAGS paper tray.
1/08:55	Orbit 23 begins.
1/09:00	Crew begins 8-hour sleep period.
1/10:25	Orbit 24 begins.
1/11:56	Orbit 25 begins.
1/13:27	Orbit 26 begins.
1/14:57	Orbit 27 begins.
1/16:28	Orbit 28 begins.
1/17:00	Crew ends 8-hour sleep period and begins postsleep activity.
	EZ CAP ACTIVITIES
	— Central venous pressure, 5 minutes (MS-3).
	— Salivary Tylenol kinetics, 5 minutes (pilot, MS-1 and MS-3).
	— IMAX status.
	— Exercise, 1 hour (all).
	— Food preparation.
	— RCS regulator reconfigure He press A (3) to CL, B (3) to GPC-OP.
	— Electrical power system (EPS) heater reconfigure to B.
	— Environmental control and life support system (ECLSS) redundant component checkout.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— PCS configure from system 1 to 2, 5 minutes (2 crewmen).
	— Cabin temperature controller reconfigure, pin cabin temperature controller actuator linkage to activator 2 (CAB TEMP CONTLR to 2).
	— PGSC dc power test and screen evaluation.
	— PCG experiment fan inlet cleaning.
1/17:59	Orbit 29 begins.
1/18:30	Last TAGS message is used to sort crew messages from TAGS DTO pages.
1/18:45	COAS to OFF. Mount COAS forward.
1/19:05	Vehicle is maneuvered to IMU align attitude.
1/19:15	Crew performs IMU align using ST.
1/19:20	Vehicle is maneuvered to COAS calibration.
1/19:29	Orbit 30 begins.
1/19:35	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector.
1/20:00	COAS to OFF. Stow COAS.
1/20:05	CHROMEX experiment is deactivated.
1/21:00	Orbit 31 begins.
1/21:15	Crew begins supply water dump.
1/22:10	Vehicle is maneuvered to negative X solar inertial attitude.
1/22:30	Orbit 32 begins.
1/22:35	SHARE experiment is powered up.
1/23:45	Crew members' mealtime.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY TWO	
2/00:01	Orbit 33 begins.
2/00:50	SHARE experiment is powered down.
2/01:30	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
2/01:32	Orbit 34 begins.
2/01:45	AMOS RCS test is performed.
2/01:45	Photo/TV are set up for IMAX.
2/02:15	Vehicle is maneuvered to Earth scene initiate track.
2/02:15	Photo/TV are activated for IMAX.
2/02:55	Photo/TV are set up for IMAX.
2/03:02	Orbit 35 begins.
2/03:25	Photo/TV are activated for IMAX.
2/03:39	Vehicle is maneuvered to Panama Canal track.
2/03:44	Vehicle is maneuvered to TDRS downlink.
2/03:45	Photo/TV are set up for crew activity.
2/04:00	Chicken eggs experiment is checked.
2/04:15	CHROMEX experiment status.
2/04:20	Photo/TV are activated for crew activity.
2/04:33	Orbit 36 begins.
2/04:40	Photo/TV are set up for IMAX.
2/05:05	Photo/TV are activated for IMAX.
2/05:08	Vehicle is maneuvered to Rondonia track.
2/05:25	Vehicle is maneuvered to IMU align attitude.
2/05:50	Crew performs IMU align with ST.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/05:50	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
2/05:55	Crew performs presleep activity.
2/06:00	Orbit 37 begins.
2/06:10	Crew empties TAGS paper tray.
2/07:34	Orbit 38 begins.
2/08:00	Crew begins 8-hour sleep period.
2/09:05	Orbit 39 begins.
2/10:35	Orbit 40 begins.
2/12:06	Orbit 41 begins.
2/13:37	Orbit 42 begins.
2/15:07	Orbit 43 begins.
2/16:00	Crew ends 8-hour sleep period and begins postsleep activity.
	EZ CAP ACTIVITIES
	— Exercise, 1 hour (all).
	— Food preparation.
	— Central venous pressure, 5 minutes (MS-3).
	— Photo/TV setup, SSIP experiment for rats.
	— Photo/TV activation, SSIP experiment for rats.
	— IMAX status.
	— PCG fan inlet cleaning.
2/16:20	Crew uses last TAGS message to sort crew messages from TAGS DTO pages.
2/16:38	Orbit 44 begins.
2/16:45	Crew purges fuel cells manually.
2/17:50	Vehicle is maneuvered to IMU align attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/18:05	Crew performs IMU align with ST.
2/18:05	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
2/18:09	Orbit 45 begins.
2/18:30	Photo/TV are set up for chicken eggs experiment.
2/19:00	Photo/TV setup is activated for chicken eggs experiment.
2/19:20	Crew checks chicken eggs experiment.
2/19:39	Orbit 46 begins.
2/21:10	Orbit 47 begins.
2/22:40	Orbit 48 begins.
2/23:15	Crew members' mealtime.

DAY THREE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/00:11	Orbit 49 begins.
3/00:15	AMOS RCS test is performed.
3/00:25	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/01:10	COAS to OFF. Mount COAS forward.
3/01:20	Maneuver vehicle for target 1 attitude test 1 for IMU reference recovery techniques.
3/01:35	Maneuver vehicle for target 2 attitude test 1 for IMU reference recovery techniques.
3/01:42	Orbit 50 begins.
3/01:45	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/02:45	Vehicle is maneuvered to target 1 attitude test 2 for IMU reference recovery techniques.
3/03:00	Vehicle is maneuvered to target 2 attitude test 2 for IMU reference recovery techniques.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/03:10	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/03:12	Orbit 51 begins.
3/04:10	Vehicle is maneuvered to target 1 attitude test 3 for IMU reference recovery techniques.
3/04:30	Vehicle is maneuvered to target 2 attitude test 3 for IMU reference recovery techniques.
3/04:35	CHROMEX experiment status.
3/04:40	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/04:43	Orbit 52 begins.
3/05:00	Crew begins presleep activity.
3/05:10	COAS power OFF. Stow COAS.
3/05:50	Vehicle is maneuvered to IMU align attitude.
3/06:00	Crew checks chicken eggs experiment.
3/06:14	Orbit 53 begins.
3/06:15	Crew performs IMU align with ST.
3/06:15	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/06:35	Crew empties TAGS paper tray.
3/07:44	Orbit 54 begins.
3/08:00	Crew begins 8-hour sleep period.
3/09:15	Orbit 55 begins.
3/10:45	Orbit 56 begins.
3/12:16	Orbit 57 begins.
3/13:46	Orbit 58 begins.
3/15:17	Orbit 59 begins.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/16:00	Crew ends 8-hour sleep period and begins postsleep activities. EZ CAP ACTIVITIES — Exercise, 1 hour (all). — Food preparation. — Central venous pressure, 5 minutes (MS-3). — IMAX status. — Protein crystal growth fan inlet cleaning.
3/16:48	Orbit 60 begins.
3/17:00	Crew uses last TAGS message to sort crew messages from TAGS DTO pages.
3/18:00	Vehicle is maneuvered to IMU align attitude.
3/18:19	Orbit 61 begins.
3/18:20	Crew performs IMU align with ST.
3/18:20	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
3/18:50	APU steam vent heater activation, boiler controller/heater (3) B, power (3) ON.
3/19:10	Flight control system checkout.
3/19:49	Orbit 62 begins.
3/20:25	Load pulse code modulation master unit format.
3/20:35	RCS hot-fire test.
3/21:00	Vehicle is maneuvered to TDRS attitude.
3/21:00	Photo/TV are set up for crew conference.
3/21:20	Orbit 63 begins.
3/21:20	APU cool OFF, APU fuel pump/valve cool A OFF.
3/21:30	Photo/TV are activated for crew conference.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/21:45	All crew members participate in conference.
3/22:15	Vehicle is maneuvered to negative Z local vertical, positive Y velocity vector attitude.
3/22:20	Primary RCS thrusting; SHARE deprime.
3/22:40	SHARE experiment deprime test; translation hand control +X for 6 seconds at 3/22:45.
3/22:50	Orbit 64 begins.
3/23:00	Crew members' mealtime.

DAY FOUR

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/00:21	Orbit 65 begins.
4/01:05	SHARE experiment is powered up.
4/01:52	Orbit 66 begins.
4/02:00	Crew performs cabin configuration stow.
4/02:05	SHARE experiment is powered down.
4/03:05	COAS OFF. Mount COAS forward.
4/03:15	Vehicle is maneuvered to target 1 attitude test 4 for IMU reference recovery techniques.
4/03:22	Orbit 67 begins.
4/03:32	Vehicle is maneuvered to target 2 attitude test 4 for IMU reference recovery techniques.
4/03:50	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
4/04:00	Protein Crystal Growth experiment is deactivated.
4/04:25	CHROMEX experiment status.
4/04:25	Vehicle is maneuvered to target 1 attitude test 5 for IMU reference recovery techniques.
4/04:40	Vehicle is maneuvered to target 2 attitude test 5 for IMU reference recovery techniques.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/04:50	CHROMEX experiment is activated.
4/04:53	Orbit 68 begins.
4/04:55	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
4/05:00	Crew performs presleep activity.
4/05:00	IMAX stow.
4/05:20	COAS OFF. Stow COAS.
4/06:05	Crew checks chicken eggs experiment.
4/06:05	Vehicle is maneuvered to IMU align attitude.
4/06:24	Orbit 69 begins.
4/06:25	Crew performs IMU align with ST.
4/06:25	Vehicle is maneuvered to negative Z local vertical, positive X velocity vector attitude.
4/06:35	Crew empties TAGS paper tray.
4/07:54	Orbit 70 begins.
4/08:00	Crew begins 8-hour sleep period.
4/09:25	Orbit 71 begins.
4/10:55	Orbit 72 begins.
4/12:26	Orbit 73 begins.
4/13:57	Orbit 74 begins.
4/15:27	Orbit 75 begins.
4/16:00	Crew ends 8-hour sleep period and begins postsleep activity.
	EZ CAP ACTIVITIES
	— Air sample.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	— Fluid loading preparation: four drink containers per person are filled with 8 ounces of water each.
	— Central venous pressure, 5 minutes (MS-3).
4/16:58	Orbit 76 begins.
4/17:25	Crew uses last TAGS message to sort crew messages from TAGS DTO pages.
4/18:10	Vehicle is maneuvered to IMU align attitude.
4/18:29	Orbit 77 begins.
4/18:30	Crew performs IMU align with ST.
4/18:33	Vehicle is maneuvered to negative X solar inertial attitude, biased.
4/18:45	SHARE experiment coldsoak test is performed.
4/19:15	CHROMEX experiment status.
4/19:45	CHROMEX experiment is deactivated.
4/19:55	Crew checks chicken eggs experiment.
4/19:59	Orbit 78 begins.
4/20:05	CRT timer setup.
4/20:07	Digital autopilot B is set to B1.
4/20:10	Initiate coldsoak.
4/20:20	Radiators are stowed, if required.
4/20:37	Data processing system is configured for deorbit preparation.
4/20:40	MCC updates IMU pad, if required.
4/20:48	MCC issues "go for payload bay door closing" command. MSs configure for payload bay door closing.
4/21:00	Ku-band antenna is stowed, if required.
4/21:06	Vehicle is maneuvered to IMU align attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/21:15	Check out radiators in bypass and flash evaporator system.
4/21:20	Align IMU.
4/21:25	Close payload bay doors.
4/21:30	Orbit 79 begins.
4/21:35	Preliminary deorbit update/uplink.
4/21:45	Configure dedicated displays.
4/21:48	MCC issues "go for OPS 3" command.
4/21:51	Vehicle is maneuvered to deorbit burn attitude.
4/22:00	Data processing system is configured for entry.
4/22:10	All crew members verify entry switch list.
4/22:25	All crew members review entry.
4/22:40	Commander and pilot configure clothing.
4/22:55	MSs configure clothing.
4/23:00	Orbit 80 begins.
4/23:05	Commander and pilot ingress seats.
4/23:18	Final deorbit update/uplink.
4/23:18	Flight crew performs OMS thrust vector control checkout.
4/23:25	APU prestart sequence begins.
4/23:42	Flight crew selects MM-302.
4/23:43	MCC issues "go/no-go for deorbit burn" command.
4/23:50	MSs ingress seats.
4/23:59	Single APU start.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY FIVE	
5/00:06	Deorbit thrusting period, 2 minutes 39 seconds in duration, 317 fps, 164 by 7 nmi (188 by 8 sm).
5/00:16	Forward RCS propellants are dumped, if required.
5/00:24	Crew starts two remaining APUs.
5/00:25	SSME hydraulics are repressurized.
5/00:31	Orbit 81 begins.
5/00:37	Vehicle is at entry interface, 400,000 feet altitude.
5/00:39:19	Vehicle enters S-band blackout.
5/00:41:32	RCS roll thrusters are deactivated automatically.
5/00:48:08	RCS pitch thrusters are deactivated automatically.
5/00:53:04	Vehicle performs first roll reversal.
5/00:54:22	Vehicle exits blackout.
5/00:56:45	Vehicle performs second roll reversal.
5/00:59:42	Air data system is deployed.
5/00:59:53	Vehicle performs third roll reversal.
5/01:01:08	Entry/terminal area entry management interface.
5/01:01:14	Vent doors are opened.
5/01:03:20	RCS yaw thrusters are deactivated automatically.
5/01:03:20	Vehicle is at 50,000 feet altitude.
5/01:06:11	TAEM-approach and landing interface.
5/01:07:08	Landing gear deployment is initiated.
5/01:07:40	Vehicle has weight on main landing gear wheels.
5/01:07:49	Vehicle has weight on nose landing gear wheels.
5/01:08:22	Wheels stop.
5/01:14	Flight crew safes OMS/RCS.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/01:17	Sniff checks are performed.
5/01:19	Aft vehicles are positioned.
5/01:29	Ground purge unit (transporter) is connected to right-hand (starboard) T-O orbiter umbilical and ground cooling unit (transporter) to left-hand (port) T-O orbiter umbilical.
5/01:29	Crew compartment side hatch access vehicle is positioned at orbiter.
5/01:36	Orbiter crew egress/ingress side hatch is opened.
5/02:04	Orbiter flight crew and ground crew are exchanged.

GLOSSARY

AA	accelerometer assembly
ADSF	automatic directional solidification furnace
AES	atmosphere exchange system
A/L	approach and landing
AMOS	Air Force Maui optical site
AMU	attitude match update
AOA	abort once around
APU	auxiliary power unit
ARC	Aggregation of Red Blood Cells experiment
ARS	attitude reference system
ASE	airborne support equipment
CAP	crew activity plan
CAPS	crew altitude protection suit
CBSA	cargo bay stowage assembly
CCTV	closed-circuit television
CEC	control electronics container
CFES	continuous flow electrophoresis system
CIU	communications interface unit
CRT	cathode-ray tube
CSS	control stick steering
DMOS	diffusive mixing of organic solutions
DPS	data processing system
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
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	Meoscale 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
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
RTLS	return to launch site
S&A	safe and arm
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
SSIP	shuttle student involvement project
SSME	space shuttle main engine
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