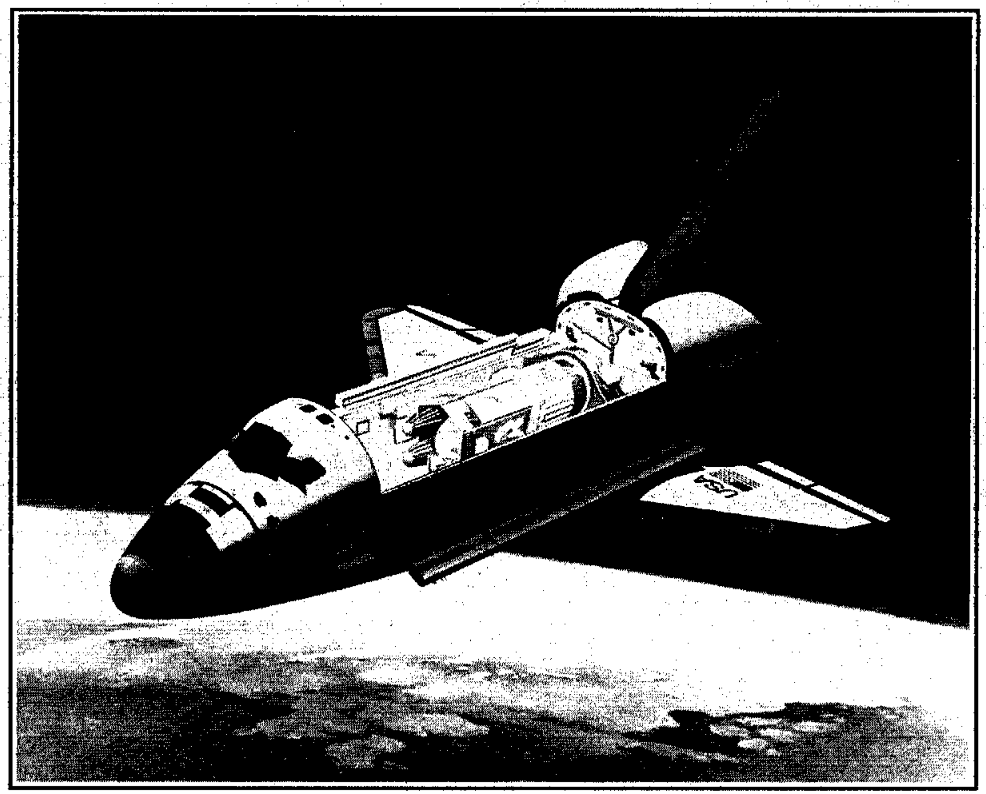

STS-43

PRESS INFORMATION

July 1991

Rockwell International
Space Systems Division

Office of Media Relations

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CONTENTS

MISSION OVERVIEW

This is the 9th flight of Atlantis and the 42nd for the space shuttle.

The flight crew for the STS-43 mission consists of commander John E. Blaha; pilot Michael (Mike) A. Baker; and mission specialists Shannon W. Lucid, G.D. (David) Low, and James (Jim) C. Adamson.

STS-43's primary mission objective is to successfully deploy NASA's Tracking and Data Relay Satellite (TDRS)-E using the Air Force's Inertial Upper Stage (IUS) booster.

TDRS-E is the fifth communications satellite launched in the process of assembling the Tracking and Data Relay Satellite System (TDRSS). TDRSS will provide a high-capacity communication and data link with the shuttle as well as other spacecraft and launch vehicles. The nominal IUS/TDRS-E deployment opportunity occurs on Orbit 5 at 0/6:13 Mission Elapsed Time (MET).

The IUS is a two-stage solid rocket, inertially stabilized upper stage that will place TDRS-E in a geosynchronous orbit. The IUS ignites its first stage (SRM-l) for transfer orbit insertion.

Twelve secondary objectives will be flown on STS-43: Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03, Space Station Heatpipe Advanced Radiator Element (SHARE)-II, Optical Communications Through the Shuttle Window (OCTW), Solid Surface Combustion Experiment (SSCE)-02, Space Acceleration Measurement System (SAMS), Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02, Tank Pressure Control Experiment (TPCE), Investigations Into Polymer Membrane Processing (IPMP)-03, Protein Crystal Growth (PCG)-III Block II, Air Force Maui Optical Site (AMOS), Auroral Photography Experiment (APE)-B. In addition, a space-based experiment, the Ultraviolet Plume Instrument (UVPI), will be conducted using the orbiter as a data source.

The SSBUV-03 instrument is designed to provide calibration of backscatter ultraviolet (UV) instruments currently being flown on free-flying satellites. The payload configuration consists of two canisters interconnected by cables mounted on a Get Away Special (GAS) adapter beam in the orbiter payload bay. One canister contains the SSBUV spectrometer; the other contains data, command, and power systems. Crew interface is through a GAS autonomous payload controller (GAPC) on the aft flight deck. After an outgassing period, the instrument will operate in three modes: Earth view, solar view, and calibration.

SHARE-II will demonstrate the on-orbit zero-gravity thermal vacuum performance of high-capacity heatpipes under various thermal conditions to determine their suitability as a dependable, durable heat rejection system for Space Station Freedom (SSF). The experiment consists of two prototypical radiator panels and an Instrumentation and Control System. Ground support equipment is located at JSC. SHARE-II is a redesigned version of the SHARE experiment that flew on STS-29.

OCTW is a JSC-sponsored experiment designed to demonstrate the optical transmission of video and audio data from the crew cabin to the payload bay and back through the shuttle aft flight deck window by means of fiber optic technology rather than conventional radio frequency technology. It consists of two modules: one inside the orbiter crew cabin and one in the payload bay. The crew cabin module will house an optoelectronic transmitter/receiver pair for video and digital subsystems, test circuitry, and interface circuitry. The payload bay module serves as a repeater station. System performance will be measured by recording video test patterns and digital signal integrity on the orbiter closed-circuit television videotape recorder system. Four tests are planned under various payload bay temperature and lighting conditions.

The primary objective of SSCE-02 is to supply information on flame spread over solid fuel surfaces in the reduced gravity environment of space. The experiment will measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds in low gravity. The data obtained will be used to validate flame spread models to improve fire safety during spaceflight.

For this flight, ashless filter paper has been selected as the "thin" fuel source, with polymethyl-methacrylate as the "thick" fuel source. The samples are mounted in a pressurized chamber.

SAMS will provide other shuttle payloads with data on the shuttle middeck and/or middeck-mounted experiments' acceleration environment. The payload consists of three triaxial accelerometers connected to a digital encoder with an optical disk data recorder. SAMS is mounted in a single middeck locker. Accelerometer heads will be mounted to the treadmill and adjacent to the PCG and SSCE experiments.

BIMDA-02 is designed to investigate the methods and commercial potential of biomedical and fluid science applications in the microgravity environment of space. Both basic and applied research will be conducted in three broad areas: bioprocessing, fluid science, and manufacturing technology. BIMDA-02 consists of three experiments housed within a refrigerator/incubator module (R/IM). The payload elements are as follows: four materials dispersion apparatus (MDA) minilabs, six bioprocessing modules (BM), six cell syringes (CS), and one automatic temperature recorder. The BIMDA occupies the space of one middeck locker, and draws 28 Vdc power for the R/IM. The MDA, BIMDA-02's primary objective, will study protein crystal growth, collagen polymerization and several other phenomena. The BM and CS experiments will study the response of live cells to various stimulating agents.

TPCE will determine the effectiveness of jet mixing as a means of controlling tank pressures and equilibrating fluid temperatures. TPCE is installed in a sealed GAS canister attached to a GAS adapter beam in the payload bay.

The research objective of the IPMP-03 payload is to flash evaporate mixed solvent systems in the absence of convection to control the porosity of the polymer membrane. With at least 24 hours remaining before entry the crew will activate the experiment and log the MET.

PCG III-Block II is designed to conduct experiments that will supply information on the scientific methods and commercial potential for growing large, high-quality protein crystals in microgravity. The PCG will be installed and operated on the orbiter middeck.

The primary objective of AMOS is to use the orbiter during cooperative overflights of Maui, Hawaii, to obtain imagery and/or signature data to support the calibration of the AMOS ground-based sensors and to observe orbiter plume phenomenology. No unique onboard hardware is associated with the AMOS test. Crew and orbiter participation may be required to establish the controlled conditions for the Maui cooperative overflight.

The objective of APE-B is to photograph and record the spectra of the following aurora phenomena: shuttle glow, thruster emissions, aurora effects on the orbiter, aurora and airglow layer. APE-B equipment consists of a 35mm SLR camera, a 55mm lens, a 135mm lens, an image intensifier, spectrometer bar, filter holder and various filters.

The primary objectives of the UVPI activity are to use the orbiter during cooperative encounters of the low-power atmospheric compensation experiment (LACE) satellite to obtain imagery and/or signature data to support the calibration of UVPI space-based sensors and to observe orbiter events. No unique onboard hardware is associated with the UVPI tests; crew and orbiter participation are required to establish the controlled conditions for the cooperative passes.

Thirteen development test objectives and 12 detailed supplementary objectives are scheduled to be flown on STS-43.

STS-43 Mission Insignia

MISSION STATISTICS

Vehicle: Atlantis (OV-104), 9th flight

Launch Date/Time:

7/23/91	10:54 a.m., EDT
	9:54 a.m., CDT
	7:54 a.m., PDT

Launch Site: Kennedy Space Center (KSC), Fla.—Launch Pad 39A

Launch Window: 4 hours, 20 minutes

Mission Duration: 8 days, 21 hours, 17 minutes

Landing: Nominal end of mission on Orbit 142

8/1/91	8:11 a.m., EDT
	7:11 a.m., CDT
	5:11 a.m., PDT

Runway: Nominal end-of-mission landing on runway 15, KSC, Fla. Weather alternates are Edwards Air Force Base (EAFB), Calif., and Northrop Strip (NOR), White Sands, New Mexico

Transatlantic Abort Landing: Banjul, Gambia; alternate is Ben Guerir, Morocco

Return to Launch Site: KSC

Abort-Once-Around: EAFB

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 orbit. This direct-insertion profile lofts the trajectory to provide the earliest opportunity for orbit in the event of a problem with a space shuttle main engine.

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 2 minutes is eliminated in this direct-insertion ascent profile. The OMS-1 thrusting maneuver is replaced by a 5-foot-per-second reaction control system maneuver to facilitate the main propulsion system propellant dump.

Altitude: 160 nautical miles (184 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,526,488 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 259,382 pounds

Payload Weight Up: Approximately 46,882 pounds

Payload Weight Down: Approximately 9,242 pounds

Orbiter Weight at Landing: Approximately 196,735 pounds

Payloads—Payload Bay (* denotes primary payload): Tracking and Data Relay Satellite (TDRS)-E/Inertial Upper Stage (IUS)*; Space Station Heatpipe Advanced Radiator Element (SHARE)-II; Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03; Optical Communications Through the Shuttle Window (OCTW)

Payloads—Middeck: Air Force Maui Optical Site (AMOS) Calibration Test; Auroral Photography Experiment (APE)-B; Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02; Investigations Into Polymer Membrane Processing (IPMP)-03; Protein Crystal Growth III Block II; Space Acceleration Measurement System (SAMS); Solid Surface Combustion Experiment (SSCE)-02; Tank Pressure Control Experiment (TPCE)

Flight Crew Members:

Commander: John E. Blaha, third space shuttle flight
Pilot: Michael (Mike) A. Baker, first space shuttle flight
Mission Specialist 1: Shannon W. Lucid, third space shuttle flight
Mission Specialist 2: G.D. (David) Low, second space shuttle flight
Mission Specialist 3: James (Jim) C. Adamson, second space shuttle flight

Ascent Seating:

Flight deck, front left seat, commander John E. Blaha
Flight deck, front right seat, pilot Michael (Mike) A. Baker
Flight deck, aft center seat, mission specialist G.D. (David) Low
Flight deck, aft right seat, mission specialist Shannon W. Lucid
Middeck, mission specialist James (Jim) C. Adamson

Entry Seating:

Flight deck, aft center seat, mission specialist G. D. (David) Low
Flight deck, aft right seat, mission specialist James (Jim) C. Adamson
Middeck, mission specialist Shannon W. Lucid

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut-l is James (Jim) C. Adamson; EV-2 is G.D. (David) Low

Intravehicular Astronaut: Michael (Mike) A. Baker

Entry: Automatic mode until subsonic, then control-stick steering

Notes:

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

MISSION OBJECTIVES

- Primary Payload
  - Deployment of Tracking and Data Relay Satellite (TDRS)-E/Inertial Upper Stage (IUS)
- Secondary Payloads
  - Payload Bay
    - Space Station Heatpipe Advanced Radiator Element (SHARE)-II
    - Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03
    - Optical Communications Through the Shuttle Window (OCTW)
  - Middeck
    - Air Force Maui Optical Site (AMOS) Calibration Test
    - Auroral Photography Experiment (APE)-B
    - Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02
    - Investigations Into Polymer Membrane Processing (IPMP)-03
    - Protein Crystal Growth (PCG)-III Block II
    - Space Acceleration Measurement System (SAMS)
    - Solid Surface Combustion Experiment (SSCE)-02
    - Tank Pressure Control Experiment (TPCE)
- Space-Based Experiment
  - Ultraviolet Plume Instrument (UVPI)
- Development Test Objectives (DTOs)/Detailed Supplementary Objectives (DSOs)

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1
- Launch
- OMS-2
- TDRS/IUS deploy, Orbit 5
- PCG activation
- TPCE activation
- SSBUV outgas

Flight Day 2
- TDRS/IUS backup deploy opportunity
- BIMDA, PCG, and SAMS operations
- SSBUV activation, calibration, solar view 1, Earth view 1
- SHARE -ZLV Tests 1 and 2
- DTOs: 645, 799, and 652
- DSOs: 476, 602, and 604

Flight Day 3
- BIMDA, SAMS, and PCG operations
- SSBUV solar view 2, calibration, Earth view 2
- DTOs: 645 and 1208
- DSOs: 476, 478, and 602

Flight Day 4
- SHARE -XSI (cold test) Tests 1 and 2
- OCTW hot test, cold test
- SSBUV solar view 3, calibration, Earth view 3
- PCG, BIMDA, SAMS operations
- DTOs: 1208, 799, and 645
- DSO: 476

Flight Day 5
- SSBUV solar view 4
- OCTW day/night test in -ZLV
- SAMS, PCG operations
- DTOs: 799, 1208, and 645
- DSOs: 602 and 476

Flight Day 6
- SHARE deprime 1
- PCG, SAMS, IPMP, BIMDA, AMOS, SSCE, and APE operations
- DTOs: 1208, 645, and 799
- DSOs: 476 and 602

Flight Day 7
- SAMS, PCG, and SSCE operations
- DTOs: 645, 798, and 1208
- DSOs: 476 and 478

Flight Day 8
- PCG, SAMS, APE, and AMOS operations
- SHARE deprime 2
- DTOs: 1208 and 645
- DSOs: 476 and 478

Flight Day 9
- LBNP ramp, STDN
- BIMDA STDN, SAMS deactivation, PCG operations
- FCS checkout, RCS hot fire, cabin STDN
- Crew conference
- DTO: 1208
- DSOs: 476, 602, and 604

Flight Day 10
- DTO: 645
- DSO: 476
- Deorbit preparation
- Deorbit burn
- Landing

Notes:

- An approved exemption authorizes a Flight Day 2 backup TDRS deployment unscheduled EVA, if necessary.
- An approved exemption provides details for the crew exercise protocol to support Extended Duration Orbiter (EDO) buildup.
- Each flight day includes a number of scheduled housekeeping activities. These include inertial measurement unit alignment, supply water dumps (as required), waste water dumps (as required), fuel cell purge, Ku-band antenna cable repositioning, and a daily private medical conference.

STS-43 CREW ASSIGNMENTS

Commander (John E. Blaha):

Overall mission decisions

Orbiter: DPS, MPS, OMS/RCS, APU/hydraulics, EPS, IV

Payload: IPMP-03, APE-B

DTOs/DSOs: DTO 798; DSOs 476 and 602

Pilot (Michael [Mike] A. Baker):

Orbiter: MPS, OMS/RCS, APU/hydraulics, EPS, IV, SPOC, IFM, FDF, flight rules, TAGS

Payload: SSBUV-03, SHARE-II, AMOS

DTOs/DSOs: DSOs 478 and 602

Other: Earth observations, geography, oceanography

Mission Specialist 1 (Shannon W. Lucid):

Orbiter: ECLSS, communications/instrumentation, payload bay door open/close, medic, crew equipment, flight rules

Payload: IUS/TDRS-E, OCTW, PCG-III Block II, BIMDA-02, SSCE-02, APE-B

DTOs/DSOs: DTOs 1208 and 799; DSOs 603 and 604

Mission Specialist 2 (G.D. [David] Low):

Orbiter: DPS, photo/TV, camcorder, EVA/EMU, SPOC, FDF

Payload: SAMS

DTOs/DSOs: DTOs 1208 and 799; DSOs 476, 478, and 602

Other: oceanography, meterology

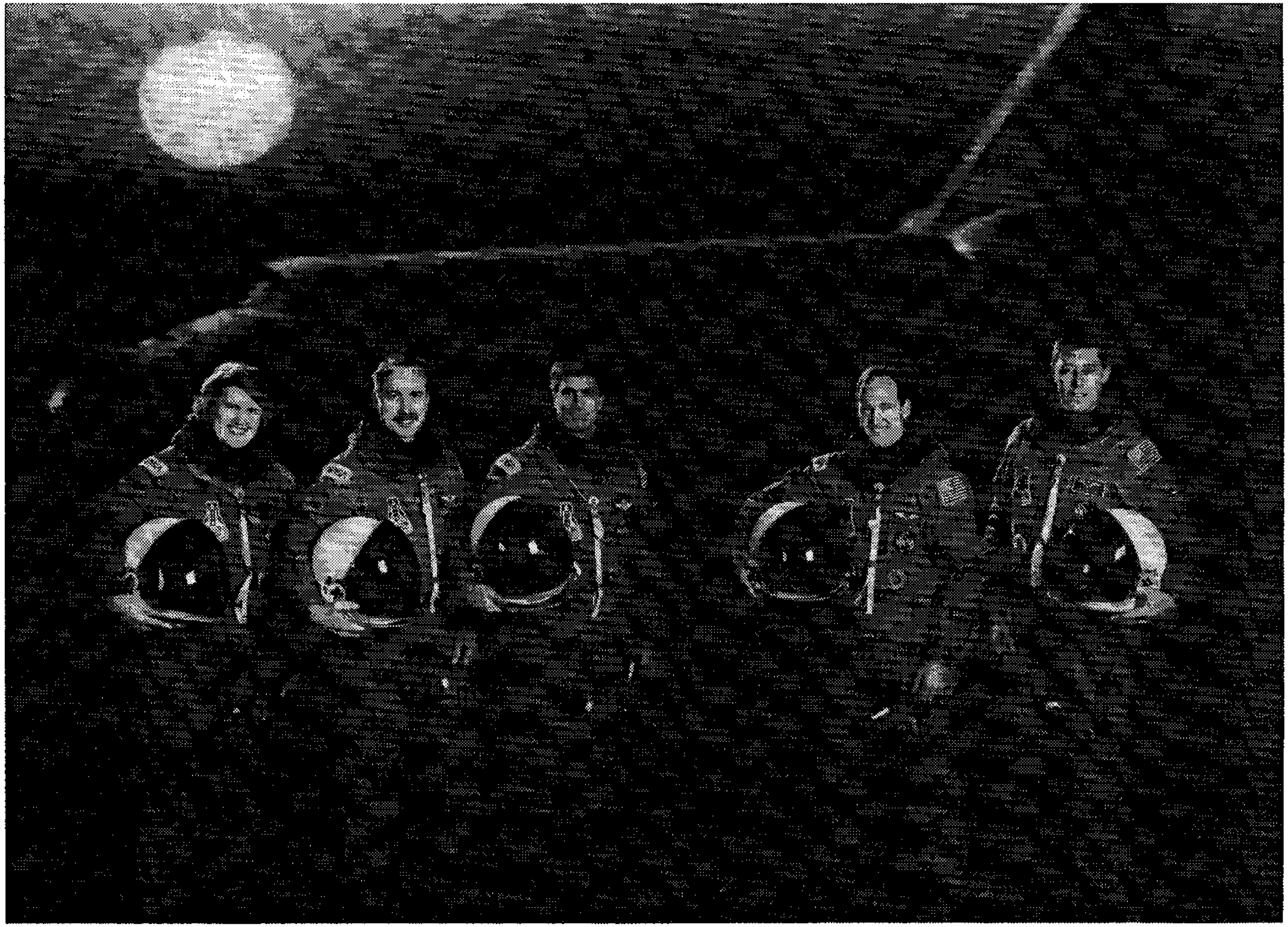
Mission Specialist 3 (James [Jim] C. Adamson):

Orbiter: ECLSS, communications/instrumentation, payload bay door open/close, photo/TV, camcorder, EVA/EMU, medic, crew equipment, IFM, TAGS

Payload: IUS/TDRS-E, SSBUV-03, SHARE-II, TPCE, OCTW, SAMS, SSCE-02, IPMP-03

DTOs/DSOs: DTOs 1208 and 798

Other: Earth observations, geography, meteorology



STS-43 Crew Members (left to right): mission specialist Shannon W. Lucid and James C. Adamson, commander John E. Blaha, mission specialist G. David Low, and pilot Michael A. Baker.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- FRCS flight test—eight-second pulse (if propellant available) (DTO 248)
- Ascent structural capability evaluation (DTO 301D)
- Ascent flutter boundary evaluation (DTO 309)
- ET TPS performance—method 2 (DTO 312)
- Hot nosewheel steering runway evaluation (DTO 517)
- Edwards lakebed runway bearing strength assessment for orbiter landings (if applicable) (DTO 520)
- Combustion products analyzer (DTO 645)
- Vibration recordings on the shuttle treadmill using an accelerometer (DTO 652)
- TDRS S-band forward link RF power level evaluation—postflight calibration instead of preflight (DTO 700-1)
- Alternate DAP mode performance evaluation (DTO 798)
- PGSC/PADM air/ground communications demonstration (DTO 799)
- Crosswind landing performance (DTO 805)
- Space station cursor control device evaluation II and advanced applications, ac power (DTO 1208)

DSOs

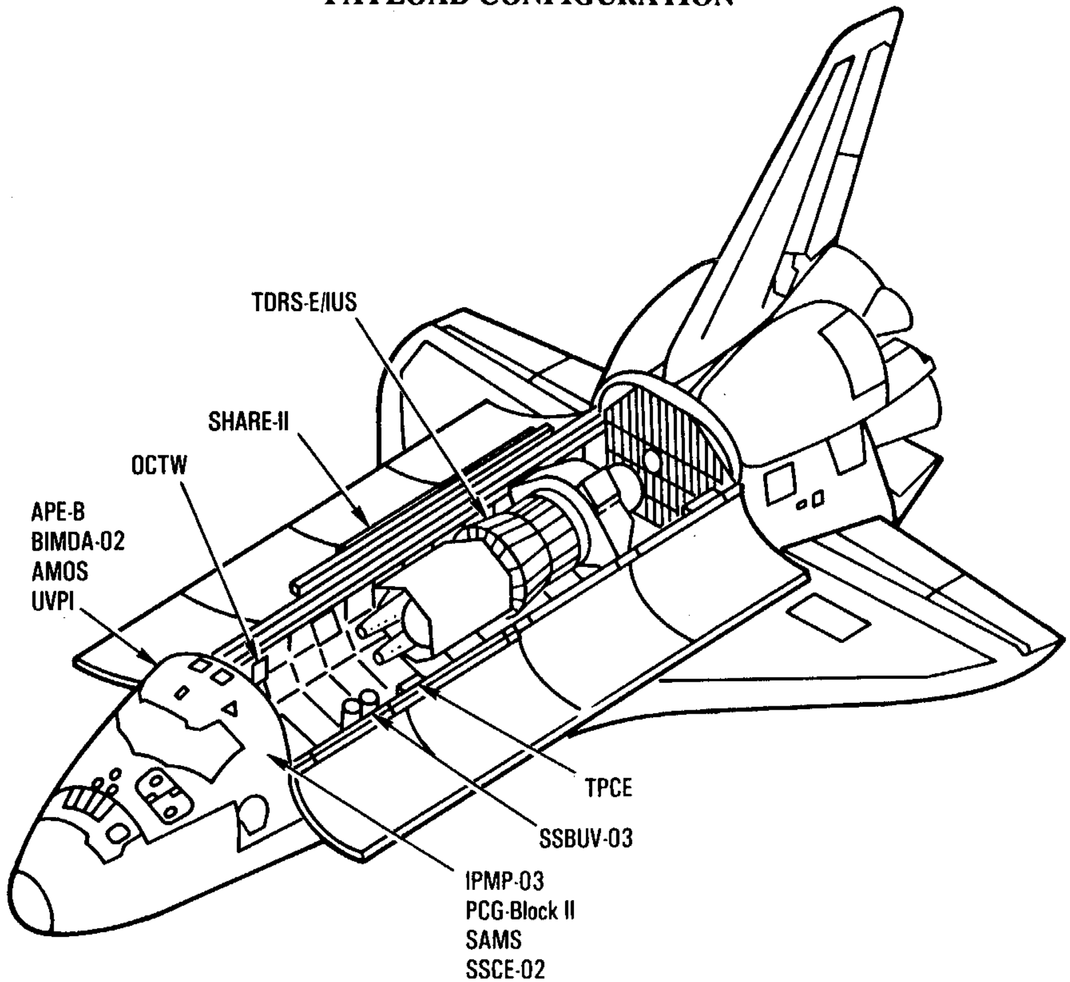
In flight:

- In-flight aerobic exercise (DSO 476)
- In-flight lower-body negative pressure (DSO 478)
- Heart rate and blood pressure variability (DSO 602)
- Orthostatic function during entry, landing, and egress (DSO 603)
- Visual vestibular integration as a function of adaption, OI-1, OI-3 (DSO 604)
- Head and gaze stability during locomotion (DSO 614)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)

Pre- and Postflight Only:

- Baroreceptor reflex function (DSO 601)
- Postural equilibrium control during landing/egress (DSO 605)
- Endocrine regulation of orthostatic tolerance following space flight (DSO 613)

PAYLOAD CONFIGURATION



INERTIAL UPPER STAGE

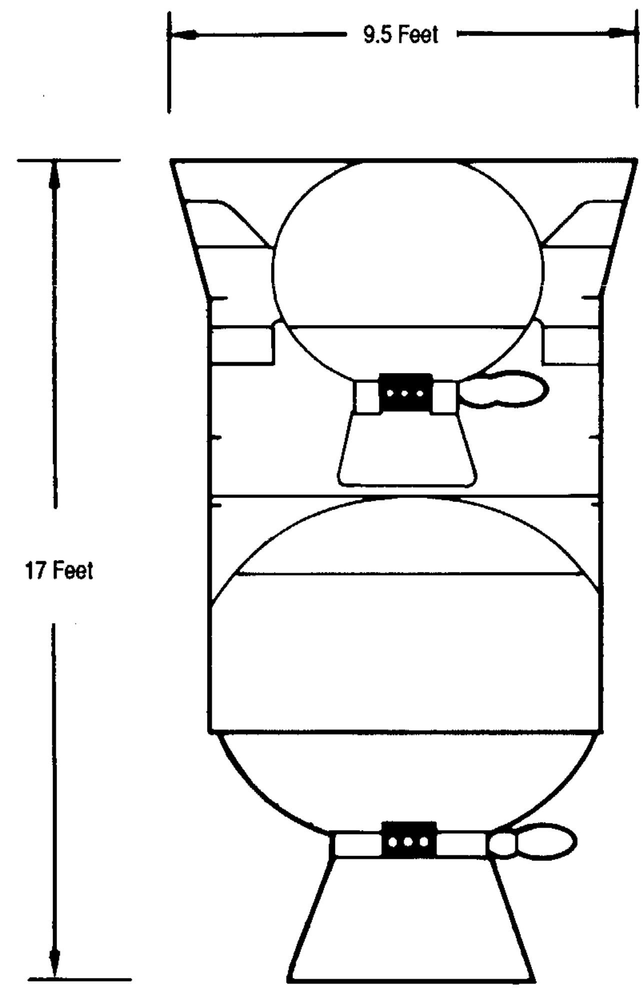
The inertial upper stage is used with the space shuttle to transport NASA's Tracking and Data Relay satellites to geosynchronous orbit, 22,300 statute miles from Earth. The IUS was also selected by NASA for the Magellan, Galileo and Ulysses planetary missions.

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 41,500 pounds of thrust, an interstage, a forward stage SRM with 6,000 pounds of propellant generating 18,100 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 Booster

FLIGHT SEQUENCE

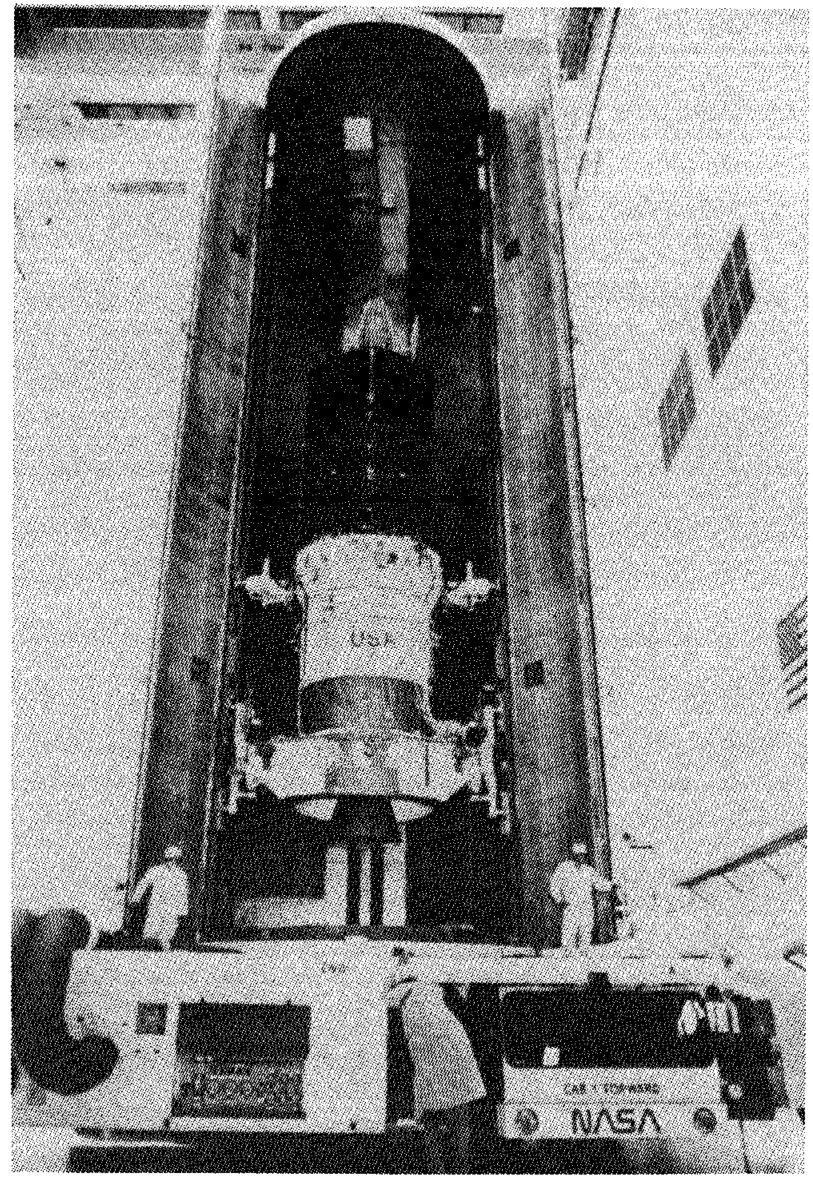
After the orbiter's payload bay doors are opened in Earth orbit, the orbiter maintains a preselected attitude to fulfill payload thermal requirements and constraints except during those operations that require special attitudes (e.g., orbital inertial measurement unit alignments, RF communications and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

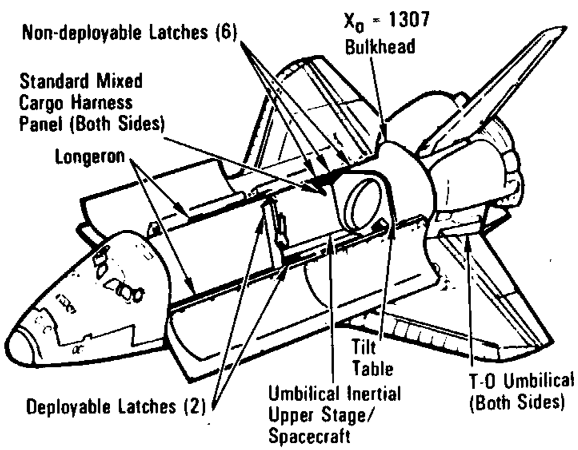
When the orbiter flight crew is given a go decision, the orbiter flight crew activates the ordnance that separates the IUS and spacecraft's umbilical cables. The flight crew then commands the electromechanical tilt actuator to raise the tilt table to a 50-degree deployment position. The orbiter's reaction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

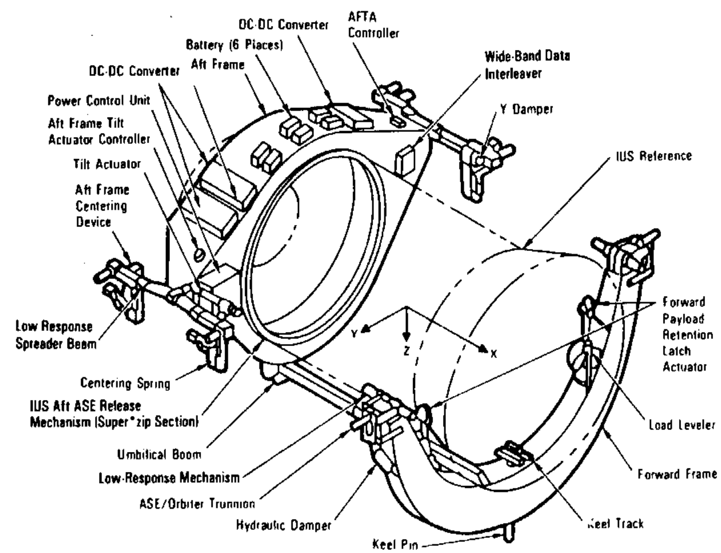


Inertial Upper Stage Airborne Support Equipment

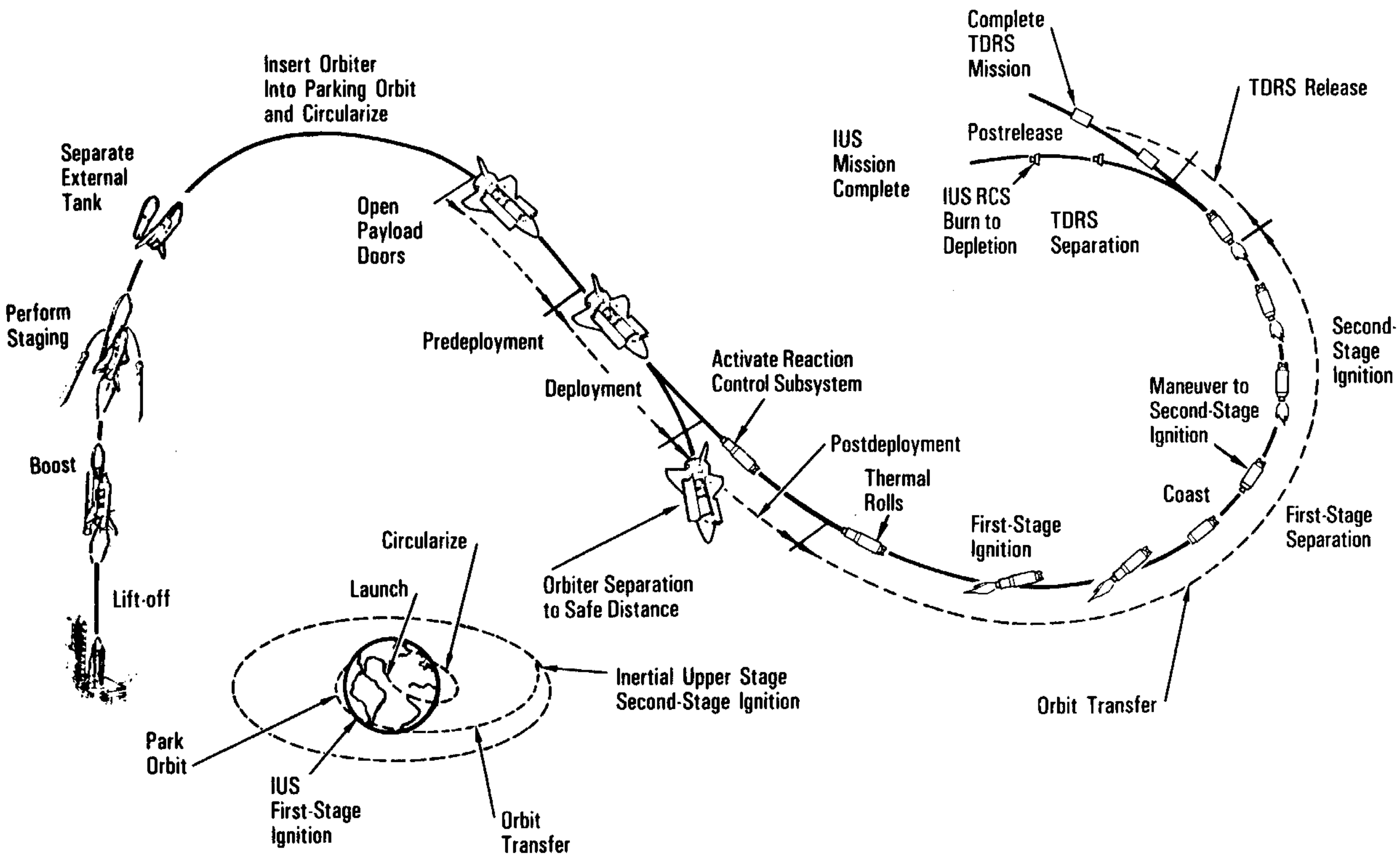
this time, the bottom of the orbiter is oriented toward the IUS and spacecraft to protect the orbiter windows from the IUS SRM-1 plume. The IUS then recomputes SRM-1 thrusting period. When the transfer orbit or planetary trajectory injection opportunity is reached, the IUS computer enables and applies 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

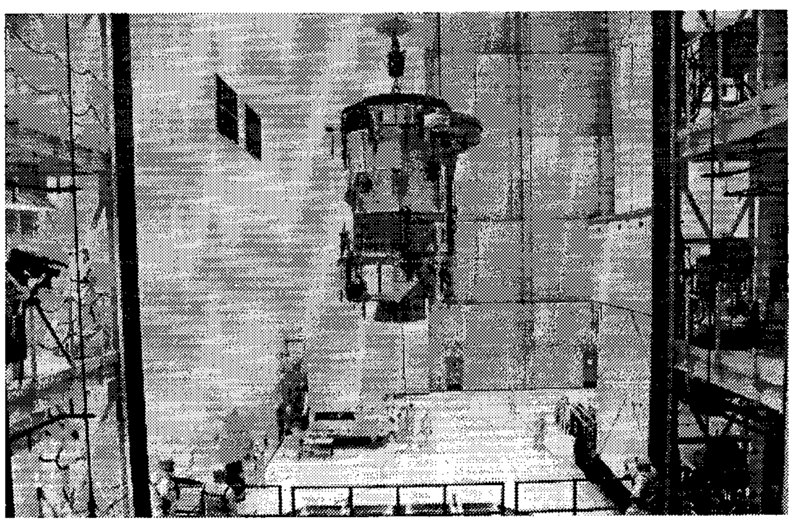


Sequence of Events For Typical Geosynchronous Mission seconds, which provides the final injection to geosynchronous orbit. The IUS then supports spacecraft separation and performs a final collision and contamination avoidance maneuver before deactivating its subsystems.

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 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.



Inertial Upper Stage Booster Testing

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 aft 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

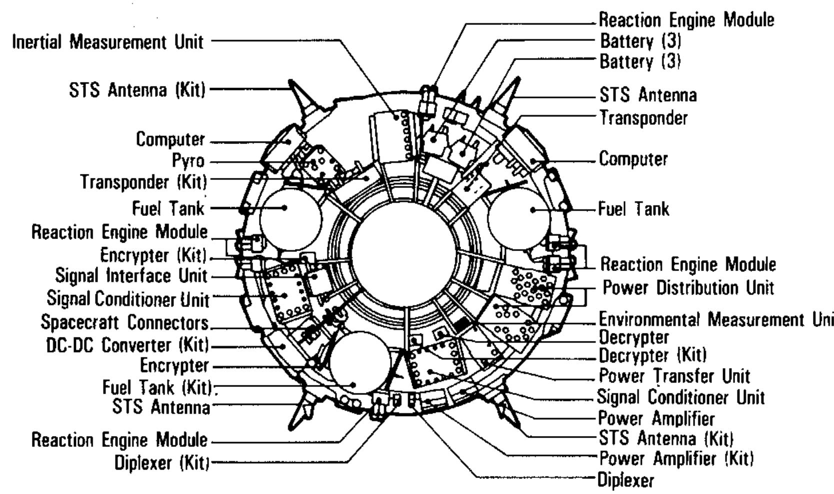
The ESS houses the majority of the IUS avionics and control subsystems. The top of the ESS contains the 10-foot-diameter interface mounting ring and electrical interface connector segment for mating and integrating the spacecraft with the IUS. Thermal isolation is provided by a multilayer insulation 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 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 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

Inertial Upper Stage Booster Testing

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 squiboperated 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.

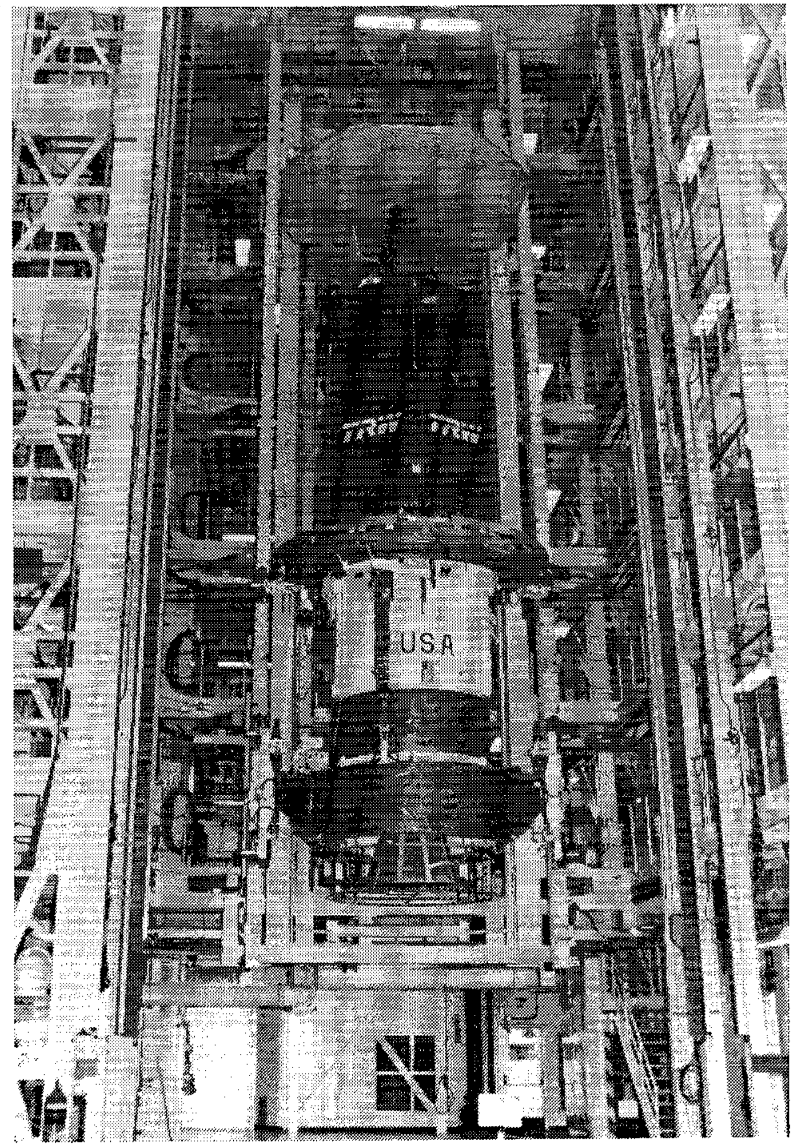
Power and data transmission to the spacecraft are provided by several IUS interface connectors. Access to these connectors can be provided on the spacecraft side of the interface plane or through the access door on the IUS equipment bay.

The IUS provides a multilayer insulation blanket of aluminumized 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.

The Tracking and Data Relay Satellite (TDRS)-E is the fifth communications spacecraft launched in the process of assembling a tracking and data relay network that provides continuous orbit determination and data acquisition support to Earth-orbiting spacecraft flying at altitudes from 750 miles to approximately 3,100 miles. At lower altitudes, such as those used by the space shuttle, there are brief periods when satellites or spacecraft over the Indian Ocean near the equator are out of view. Without the TDRS system (TDRSS) acting as a space-based relay, communications with satellites can be accomplished only when the spacecraft are in sight of a ground station, which is seldom more than 15 percent of an orbit. TDRSS achieved operational status in July 1989.

TDRSS was initiated following studies in the early '70s that showed that a system of telecommunication satellites operated from a single ground station could better support the space shuttle and scientific application mission requirements planned for the nation's space program. In addition, the system was seen as a means of halting the spiralling costs of upgrading and operating a network of tracking and communications ground stations located around the world.

The TDRSS network is currently composed of three satellites: TDRS-1 (TDRS-A), which is partially disabled and is functioning as part of TDRS-West at 171 degrees west longitude over the Pacific east of the Gilbert Islands; TDRS-3 (TDRS-C), which is also partially disabled and functioning as part of TDRS-West; and TDRS-4 (TDRS-D), which is functioning as TDRS-East at 41 degrees west longitude over the Atlantic just east of Brazil. TDRS-1 was deployed from the space shuttle Challenger on April 5, 1983 on mission STS-6. TDRS-3 was launched from Discovery on September 29, 1988 on STS-26. TDRS-4 was launched from Discovery on March 13, 1990 on STS-29. A fourth satellite, TDRS-B, was destroyed in the Challenger accident in January 1986.



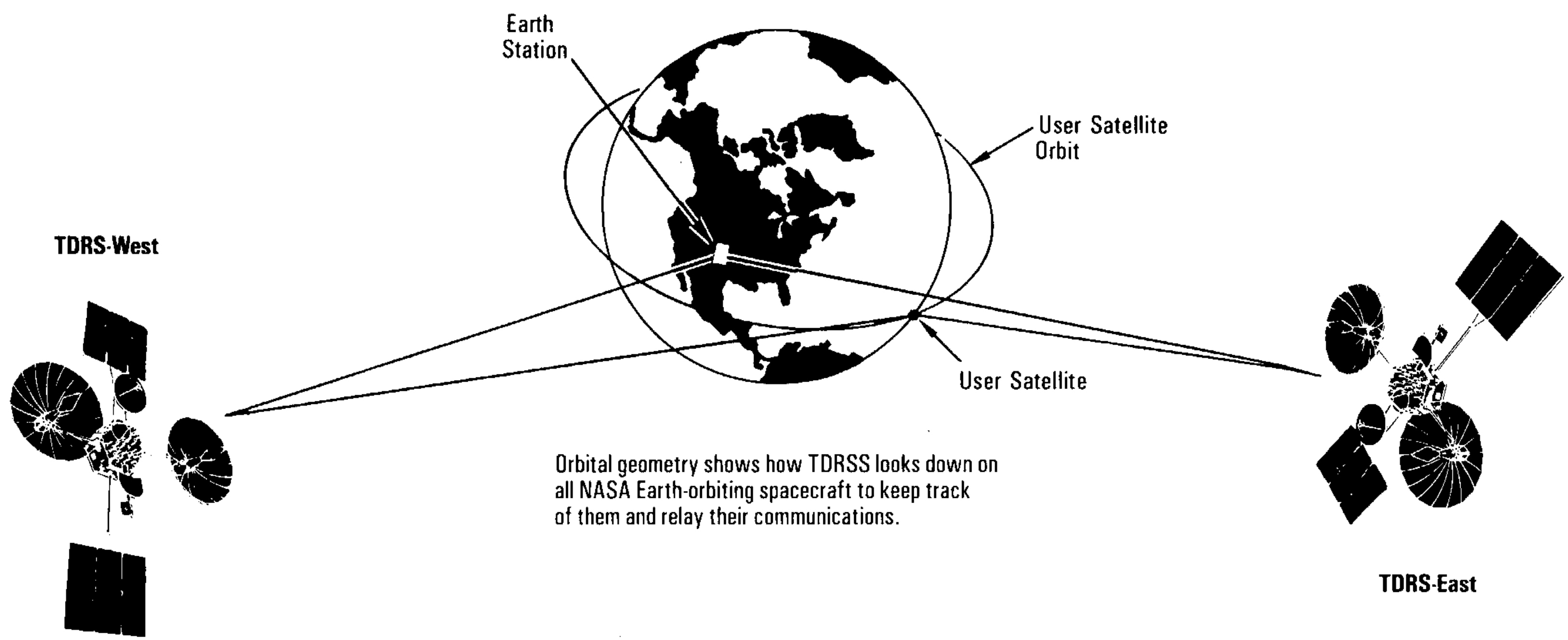
TDRS-E / IUS In Mated Configuration

TDRSS officials at NASA's Goddard Space Flight Center, which manages the TDRSS program, indicate that the TDRSS network requires three fully capable satellites in orbit. TDRS-E, which will be redesignated TDRS-5 once on orbit, will be positioned at 174 degrees west longitude after completion of on-orbit checkout, replacing TDRS-3, which will be repositioned at 62 degrees west longitude and will serve as a spare resource.

The satellites are positioned in geosynchronous orbits above the equator at an altitude of 22,300 statute miles by the Air-Force developed Inertial Upper Stage (IUS) booster. 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 positioning of TDRS-East and TDRS-West is 130 degrees apart instead of the usual 180-degree spacing. This 130-degree spacing reduces the ground station requirements to one station instead of the two stations required for 180-degree spacing.

The TDRS system does not process user traffic in either direction. Instead, it 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.

TDRSS is equipped to support up to 26 user spacecraft, including the space shuttle, simultaneously. It will provide two types of service: multiple access which can relay data from as many as 20 low data rate (100 bits per second to 50 kilobits per second) user satellites simultaneously, and single-access, which will provide two high data rate channels (to 300 megabits per second) from both the East and West locations. The latter is the equivalent of processing 300 14-volume sets of encyclopedias every minute.



Orbital geometry shows how TDRSS looks down on all NASA Earth-orbiting spacecraft to keep track of them and relay their communications.

Tracking and Data Relay Satellite System

TDRSS Ground Tracking Network

With TDRSS fully operational, virtually all communications between U.S. scientists and technicians and orbiting American spacecraft pass through the White Sands space network complex located in Southwest New Mexico.

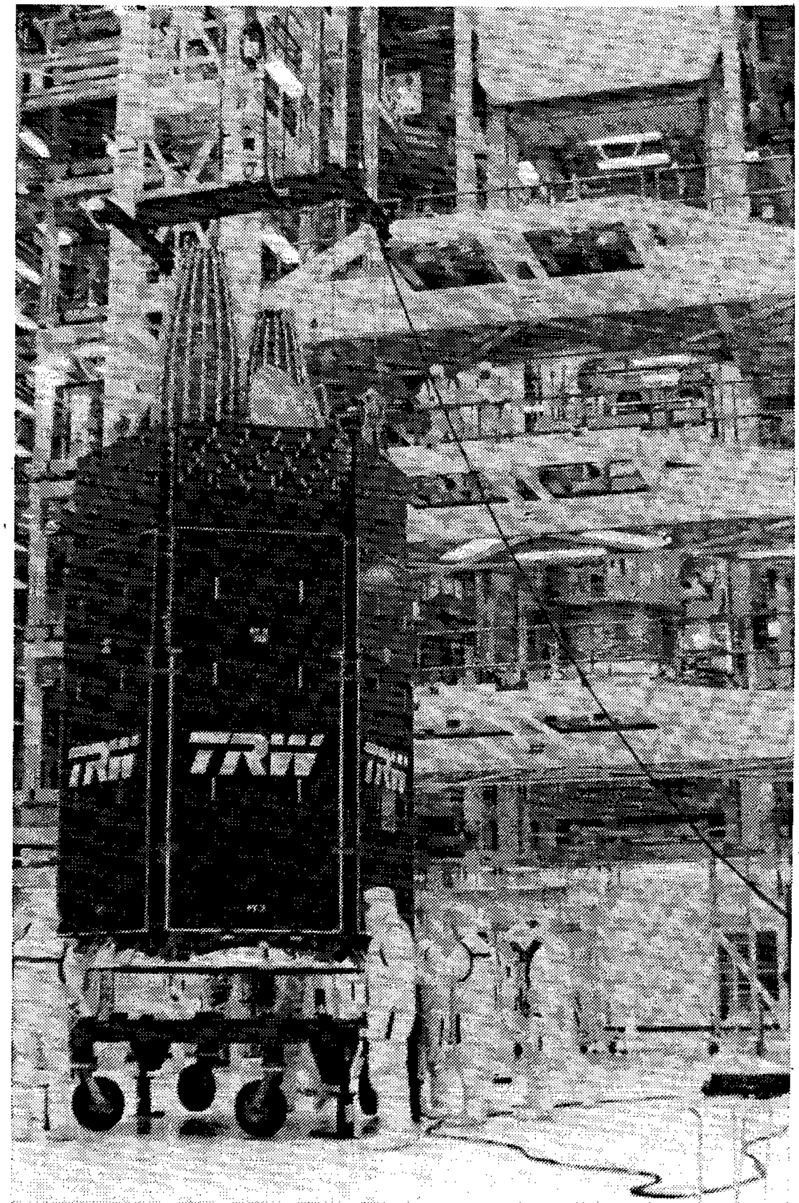
The White Sands space network complex consists of the White Sands Ground Terminal (WSGT), the NASA Ground Terminal (NGT) and the Second TDRSS Ground Terminal (STGT) all within the White Sands Missile Range near the Organ mountains. Situated just east of Las Cruces and surrounded by greasewood and mesquite, it has been in operation since 1983, when NASA launched its first TDRS.

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.

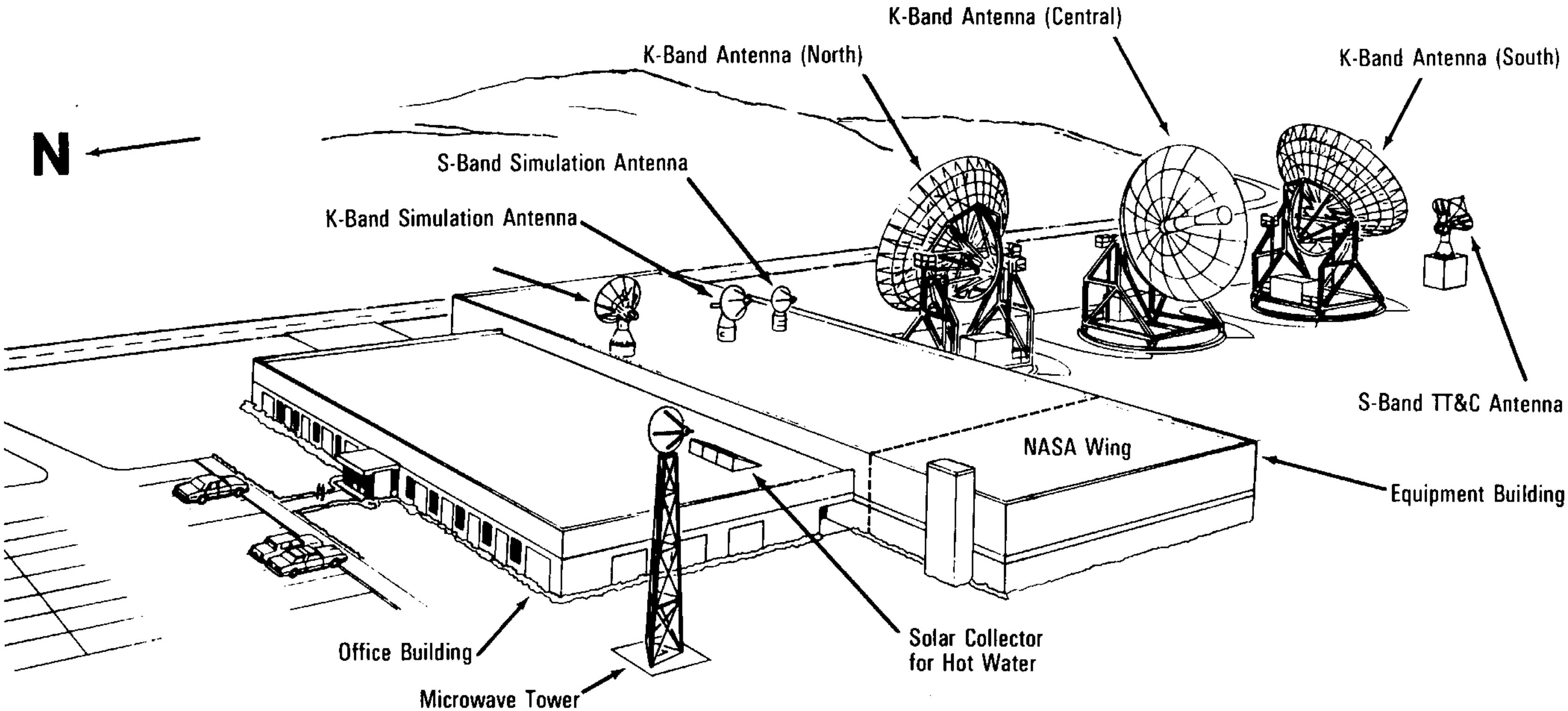
The most prominent features of the ground station are three 60-foot Ku-band dish antennas used to transmit and receive user traffic. Several other antennas are used for S-band and Ku-band communications. NASA developed sophisticated operational control facilities at GSFC and next to the WSGT to schedule 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,



TDRS-E

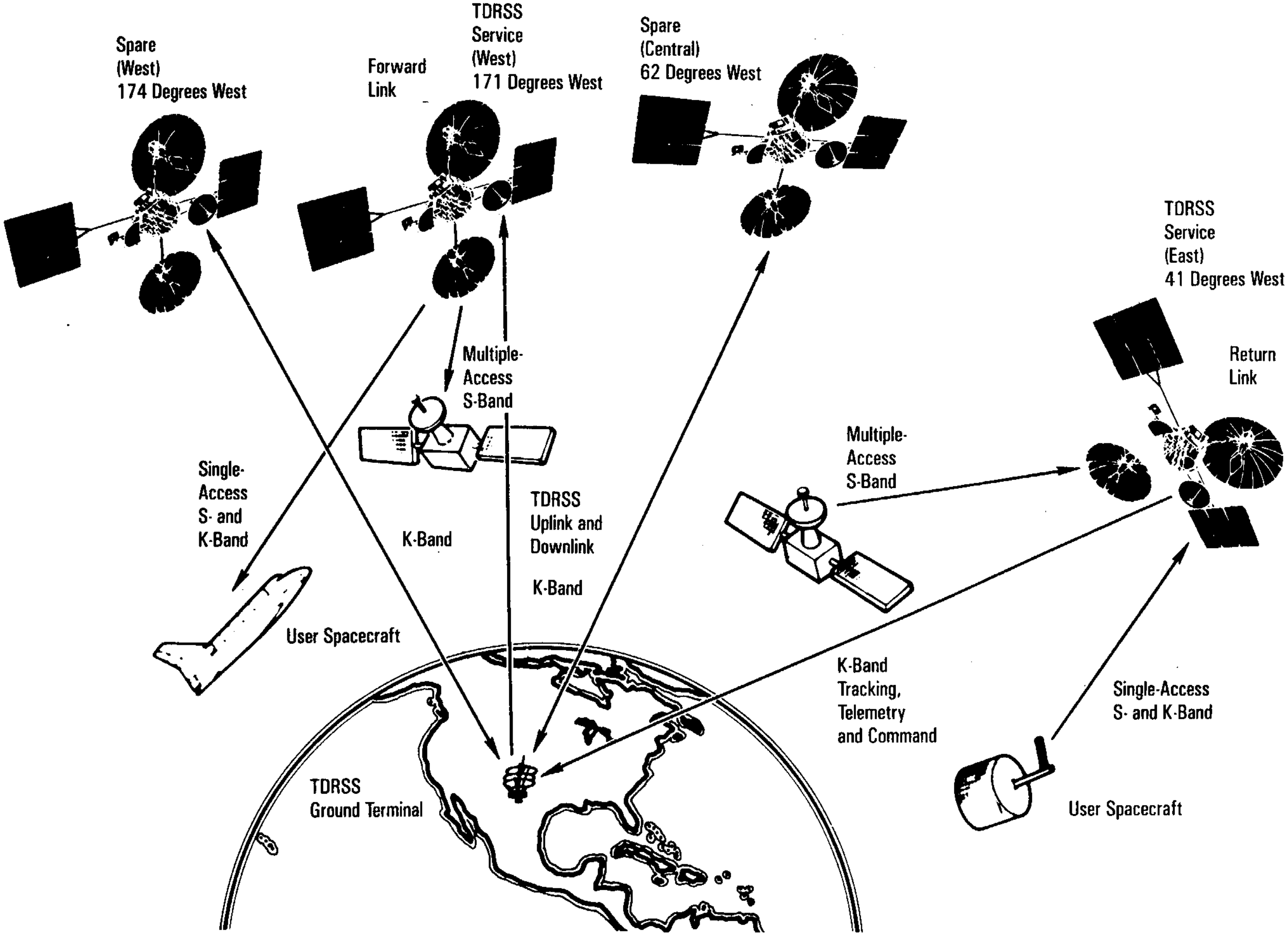


Tracking and Data Relay Satellite System Ground Station, White Sands, N.M.

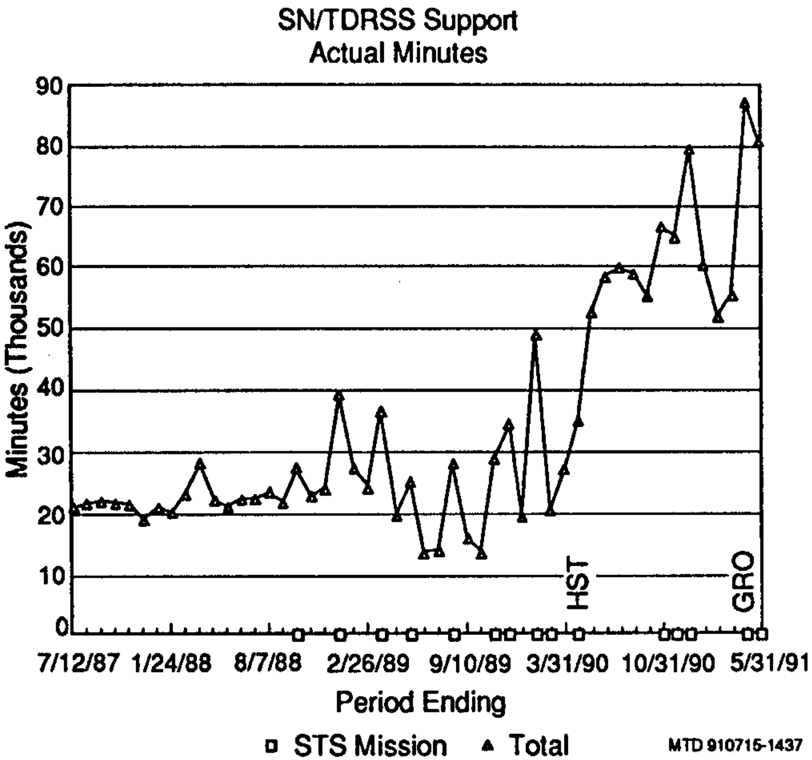
such as the formation and control of the receive beam of the TDRS multiple-access phased-array antenna and the control and tracking functions of the TDRS single-access antennas.

The WSGT and NGT ground stations, operated by Contel Federal Systems and Bexdix Field Engineering Corporation, respectively, under contract to NASA, send data to and receive data from TDRSS. In turn TDRSs relay instructions to and receive data from spacecraft orbiting at lower altitudes. 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, via the NGT, to Goddard Space Flight Center, Greenbelt, Md., which schedules TDRSS operations and controls a large number of satellites

Facilities at Goddard include the Network Control Center (NCC), which provides system scheduling and is the focal point for NASA communications and the WSGT and TDRSS users; the Flight Dynamics Facility (FDF), which provides the network with antenna pointing information for user spacecraft and the TDRSs; and the NASA Communications Network (NASCOM), which provides ground to ground communications through Earth terminals at Goddard, White Sands and the Johnson Space Center in Houston, Texas.



Linking Four Identical and Interchangeable Satellites With Earth Station



TDRSS Space Network Status

The Network Control Center console operators monitor the network performances, schedule emergency interfaces, isolate faults in the system, account for system use, test the system and conduct simulations. The user services available from the Space Network, which includes TDRSS and its supporting Goddard Space Flight Center elements, are provided through NASCOM, a global system that provides operational communications support to all NASA projects.

NASCOM offers voice, data, and teletype links with the Space Network, the Ground Spaceflight Tracking and Data Network (GSTDN), and the user spacecraft control centers.

A second TDRS ground terminal (STGT) at White Sands approximately 3 miles north of the initial ground station was dedicated in January 1990.

STGT is expected to be operational in 1993 and will house over $400 million in sophisticated computer and communications equipment. The facility is necessary as a backup to the WSGT and is needed to meet increased mission support requirements in the nation's space program in the 1990s.

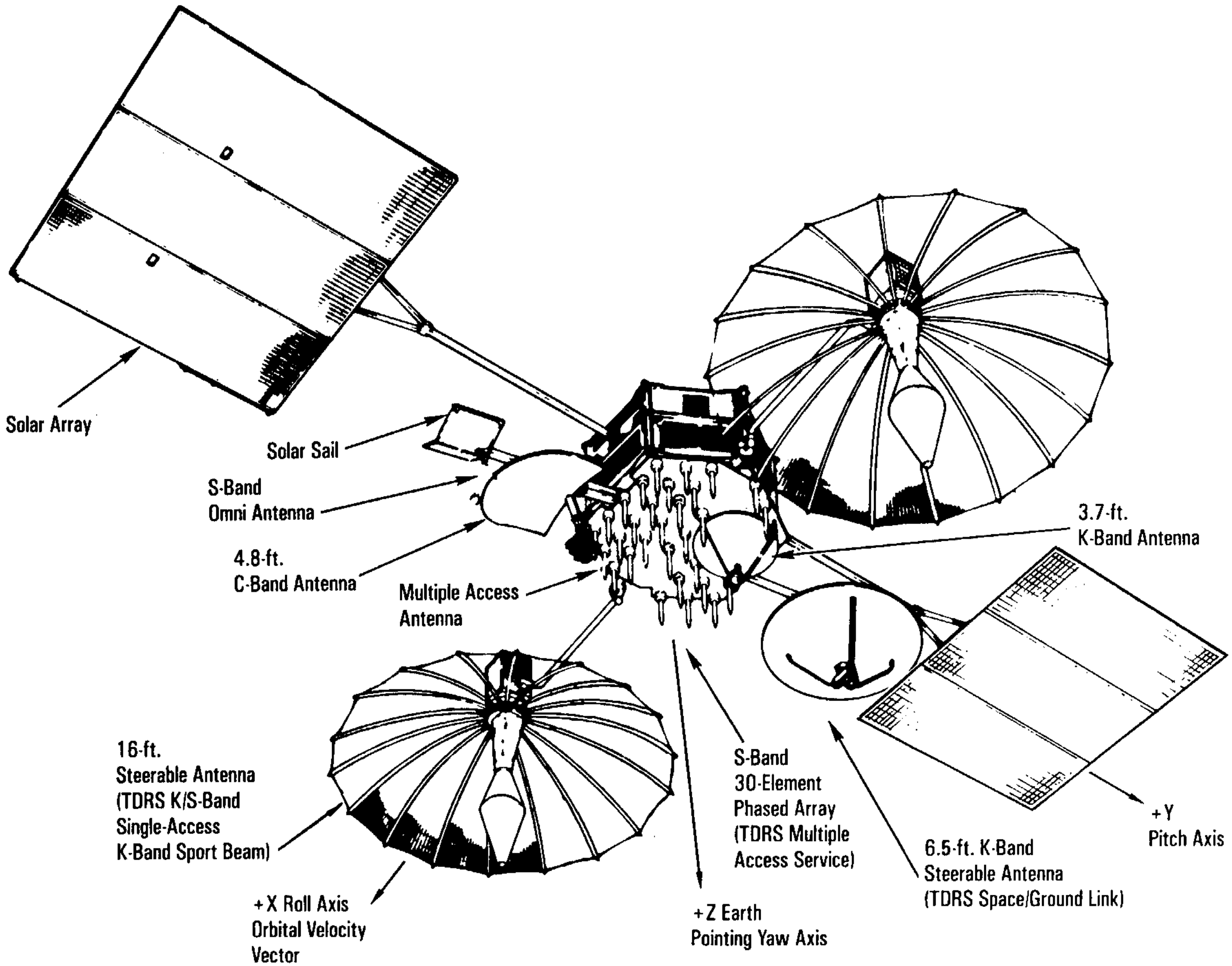
TDRSS has replaced many of the ground stations of the worldwide space flight tracking and data network, resulting in savings in personnel and operating and maintenance costs. However, the Merritt Island, Fla.; Ponce de Leon, Fla.; and Bermuda ground stations will remain open to support the launch of 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 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.)

The TDRS Satellite

To date, the TDRSs are the largest privately owned telecommunication satellites ever built. TDRS-E, which is essentially the same as TDRS-3 and -4, weighs approximately 4,900 pounds in orbit, including 1,200 pounds of hydrazine. 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.



Tracking and Data Relay Satellite

TDRS-E Characteristics

Parameter	Dimension
Height (Stowed)	19.25 ft
(Deployed)	57.2 ft
Diameter (Stowed)	9.5 ft
(Deployed)	42.6 ft
Weight (In Orbit)	4637 lb
Design Life	10 yr
Propellant (Hydrazine)	1212 lb

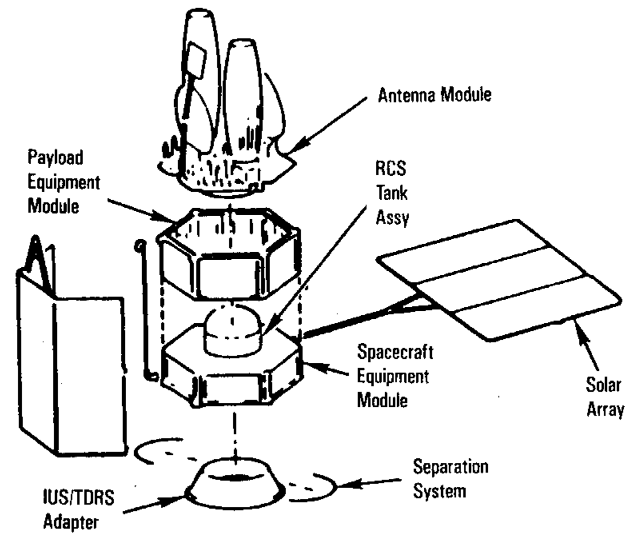
The TDRS single-access parabolic antennas deploy after the satellite separates from its inertial upper stage. After the TDRS acquires the sun and Earth, its sensors provide attitude and velocity control to achieve the final geostationary position.

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. Twenty-four monopropellant hydrazine thrusters are used for TDRS positioning and north-south, east-west stationkeeping.

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

The antenna module houses seven 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.

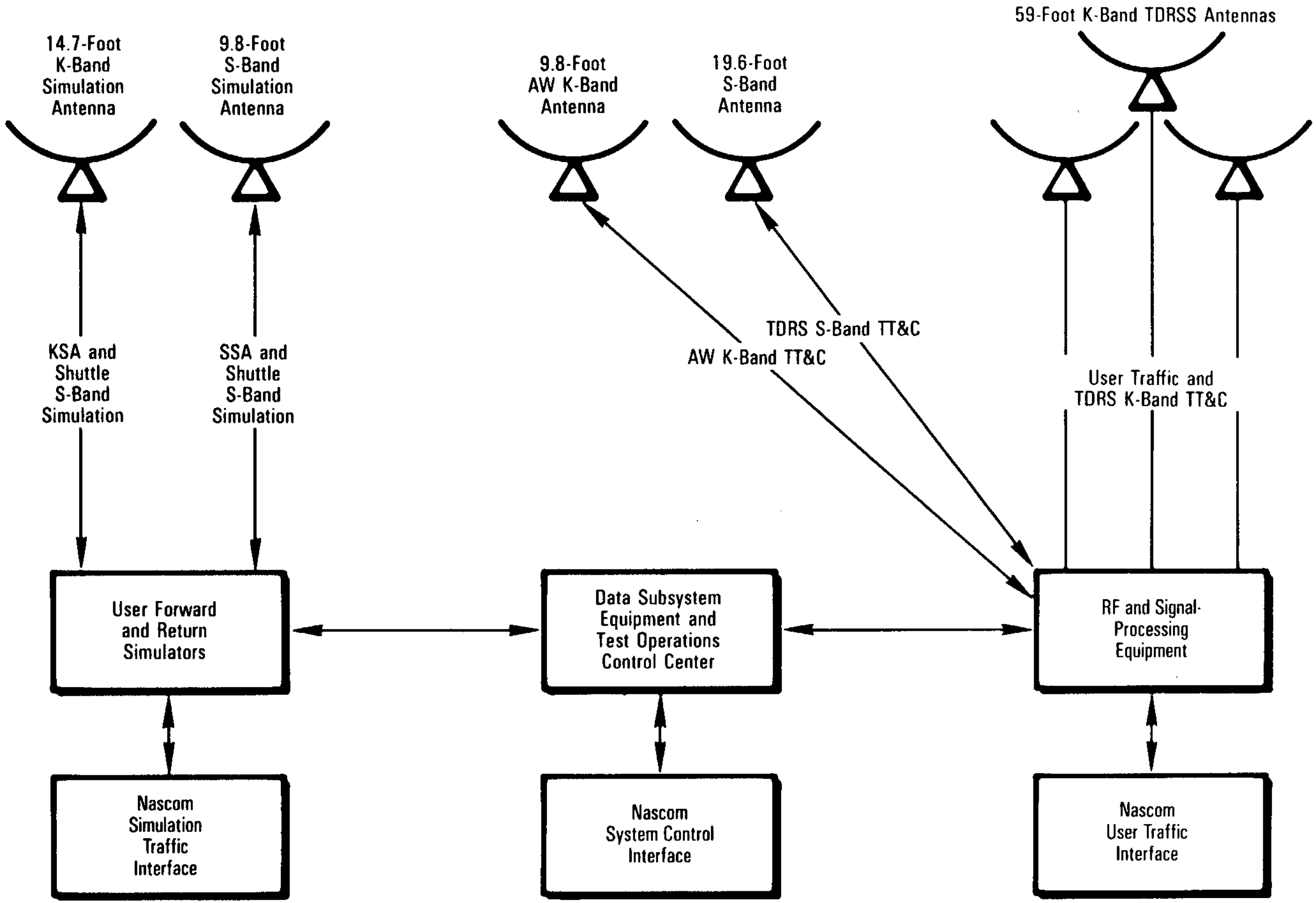
The antenna's primary reflector surface is a gold-clad molybdenum wire mesh, woven like cloth on the same type of machine used to make material for women's hosiery. When deployed, the antenna's 203 square feet of mesh are stretched



TDRS

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



Tracking and Data Relay Satellite System Antenna 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 WSGTs 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 6.5-foot parabolic reflector is the space-to-ground-link antenna that communicates all data and tracking information to and from the ground terminal on Ku-band. The S-band omni telemetry, tracking and communication antenna is used to control TDRS while it is in transfer orbit to geosynchronous altitude. Commercial K-band and C-band antennas round out the complement.

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 43 feet from tip to tip.

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 1,700 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.

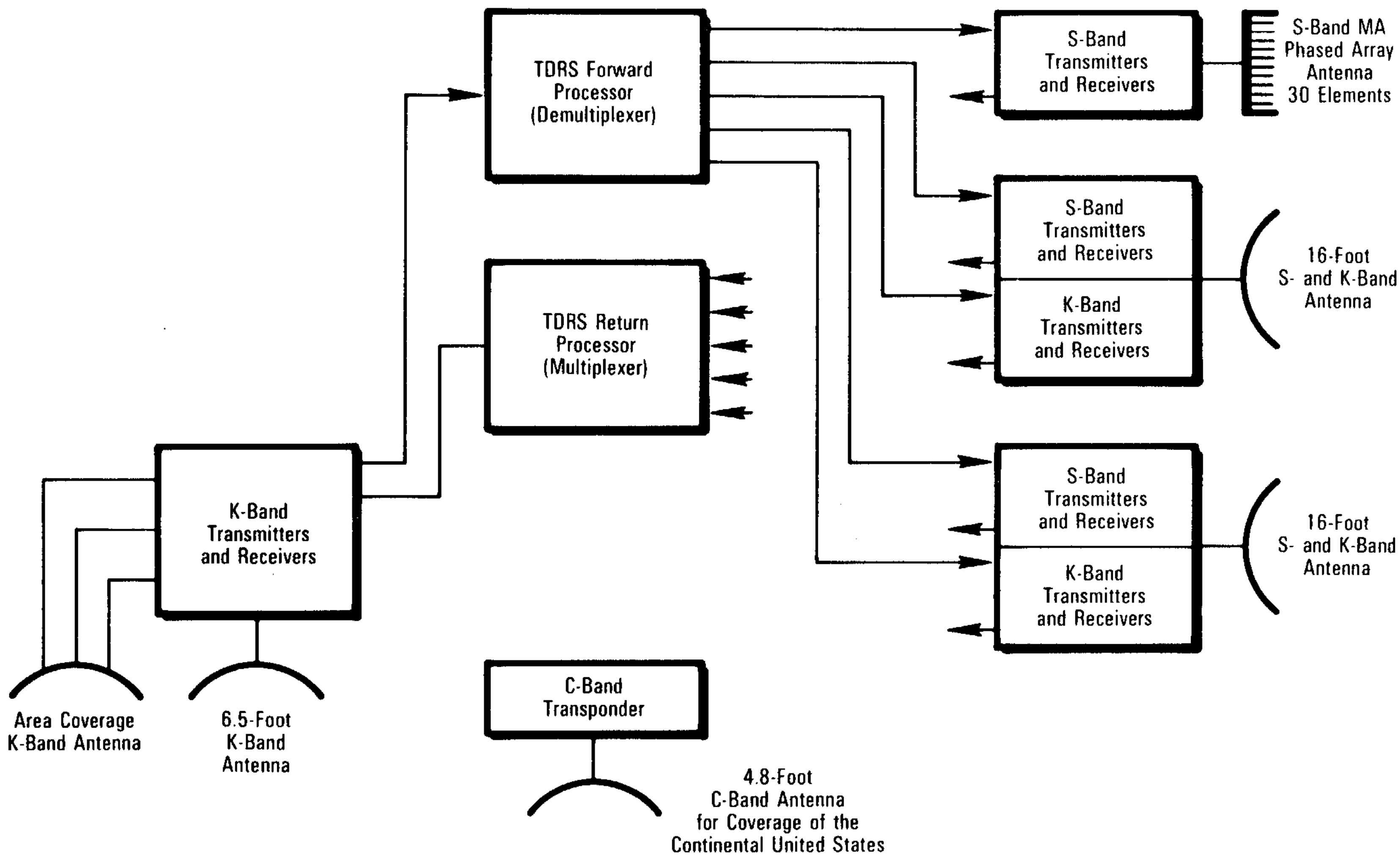
TDRSS Launch Chronology

TDRS-A (TDRS-1) 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, which was achieved on June 29, 1983. On orbit, TDRS-A was designated TDRS-1. 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-1 properly in spite of the thruster failures.

TDRS-1 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,



Tracking and Data Relay Satellite System Transmission and Receive System 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-1 in-orbit checkout was completed in December 1983. Service acceptance testing was completed in April 1985. Following testing, TDRS-1 was positioned at 41 degrees west longitude, serving as TDRS East. TDRS-D (TDRS-4) replaced TDRS-1 in 1989. TDRS-1 was then moved to 171 degrees west longitude as part of the TDRS west configuration. 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 STS-51-L mission in January 1986.

TDRS-C (TDRS-3) was carried into Earth orbit aboard Discovery on the STS-26 mission in September 1988. It achieved geosynchronous orbit on September 30, 1988. In-orbit checkout was completed in January 1989. On orbit, TDRS-C became TDRS-3 and was placed at 150 degrees west longitude for testing and support of STS-27. Following completion of the in-orbit checkout in January 1989, TDRS-3 was positioned at 171 degrees west longitude and was referred to as TDRS-West. TDRS-3 is currently operating as part of the TDRS-West configuration at 174 degrees west longitude. Following on-orbit checkout of TDRS-E, TDRS-3 will be repositioned at 62 degrees west longitude and will serve as a spare resource.

TDRS-D (TDRS-4) was carried aboard Discovery on the STS-29 mission in March 1989 and achieved geosynchronous orbit on March 14, 1989. In-orbit checkout was completed June 1989. On orbit, TDRS-D became TDRS-4 and was moved to an intermediate location for testing. Following completion of in-orbit checkout in June 1989, TDRS-4 was moved to the TDRS-East location at 41 degrees west longitude, replacing TDRS-1, which was moved to 171 degrees west longitude as part of the TDRS-West configuration.

TDRS-E Deployment Sequence

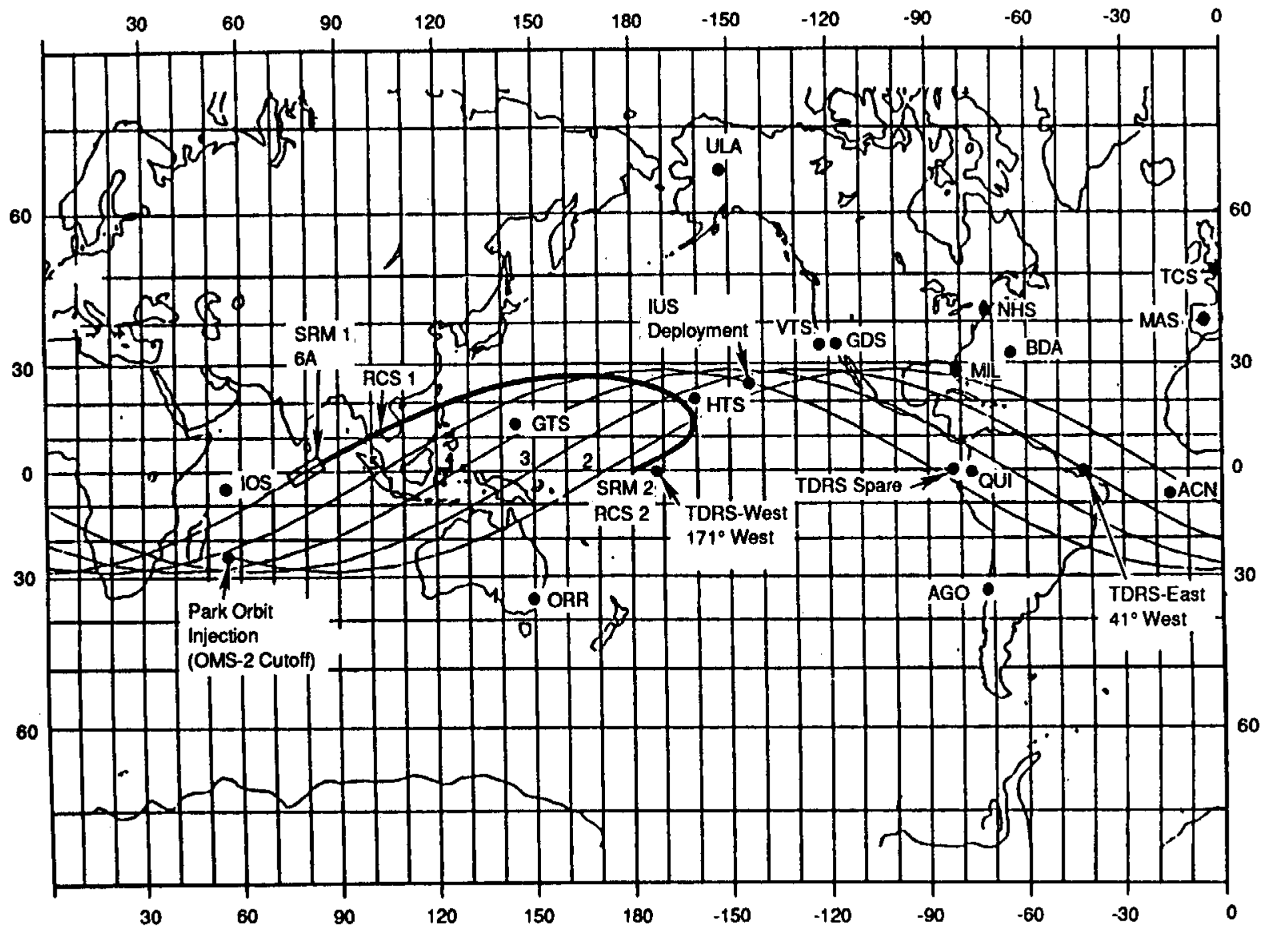
TDRS-E will be deployed from Atlantis approximately six hours after launch on Orbit five (over the Pacific south of Hawaii). Injection burn to geosynchronous orbit will be initiated at 77 degrees east longitude (Indian Ocean, south of India), placing the satellite in orbit at 178 degrees west longitude (over the Pacific near the Gilbert Islands).

The STS-43 crew elevates the IUS/TDRS to 29 degrees in the payload bay for preliminary tests and then raises it to 58 degrees for deployment. A spring-loaded ejection system is used for deploying the IUS/TDRS.

The first burn of the IUS booster will take place an hour after deployment, or about seven hours after launch. The second and final burn (to circularize the orbit) will take place five and one half hours after the first burn, approximately 12 and one half hours into the mission. Separation of the booster and satellite will occur at 13 hours after launch.

After the IUS second-stage thrusting is completed, the TDRSS mission team at White Sands will command deployment of the TDRS-E 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-E, the single-access booms will be released and the 16-foot-diameter single-access antennas will be deployed, unfurled and oriented toward Earth.

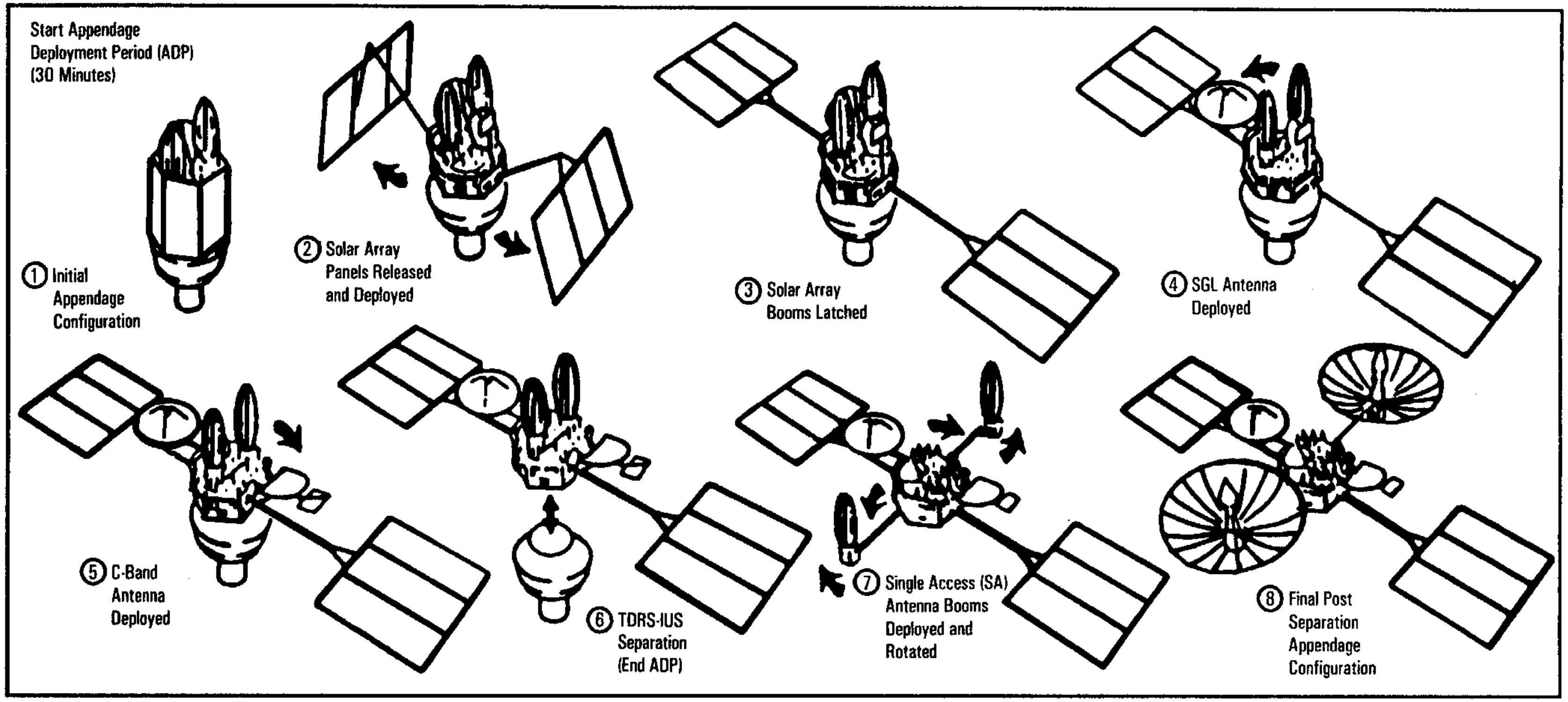
Testing of TDRS-E will be initiated; and after initial checkout, TDRS-E will drift westward to its operational location at 174 degrees west longitude, where it will be referred to as TDRS-West.



STS-43 Groundtrack for IUS / TDRS-E Deployment

Orbiter Ku-Band TDRS Signal Acquisition

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.



TDRS-E Appendage Deployment

MTD 910716-PBI-08

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.

The Future

Launch of TDRS-F (TDRS-5) is planned for 1993.

TDRS-G, also procured from TRW, will replace the destroyed TDRS-B. The spacecraft is now under construction.

Work is currently underway on the next generation (1997–2012) of TDRS, known as the Advanced TDRS (ATDRSS) program. ATDRS will support higher data rates in a new frequency band (Ka-band). Other features include backward compatibility to all TDRSS users, use of advanced technologies to save power, size, and weight, provisions for future service growth to accommodate evolving user needs, capability of supporting user spacecraft out of geosynchronous orbit, a higher data rate capability for multiple access users, and improved user tracking capabilities.

Phase A (conceptual) studies were completed by five contractors (Ford, GE, Hughes, Lockheed and TRW) in early 1989. Phase B (definition) studies are currently underway with GE, Hughes and TRW and will be completed this summer. The spacecraft design and development along with necessary modifications to the White Sands Complex for ATDRSS will be competitively procured in late 1991, with an award expected in September 1992, and a first spacecraft available for launch in 1997. The spacecraft network will grow from two plus a spare to four plus a spare in 1998 to accommodate expected increases in user data traffic.

Project Support and Staff

TRW Space and Technology Group in Redondo Beach, Calif., is the prime spacecraft contractor. Ground operations at the White Sands complex are conducted by Contel Federal Systems and Bexdix Field Engineering. The WSGT was build jointly by the team of TRW, Harris Corporation and Spacecom. Electronic hardware was jointly supplied by TRW and Harris' 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 TDRSS program is managed by NASA's Goddard Space Flight Center. The project manager for the Advanced Tracking and Data Relay Satellite Project is Charles Vanek; Nicholas G. Chrissotimos is TDRS manager for the spacecraft project; Daniel A. Spintman is chief, Networks Division; Wesley J. Bodin is associate chief for ground network; Phillip Liebrecht is assistant chief for TDRSS and Gary A. Morse is Goddard network director.

SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET INSTRUMENT

The SSBUV instrument was developed by NASA to calibrate similar ozone-measuring space-based instruments on the National Oceanic and Atmospheric Administration's TIROS satellites (NOAA-9 and -11) and Nimbus-7 satellites. The SSBUV was also flown aboard Atlantis in the STS-34 mission and Discovery in the STS-41 mission.

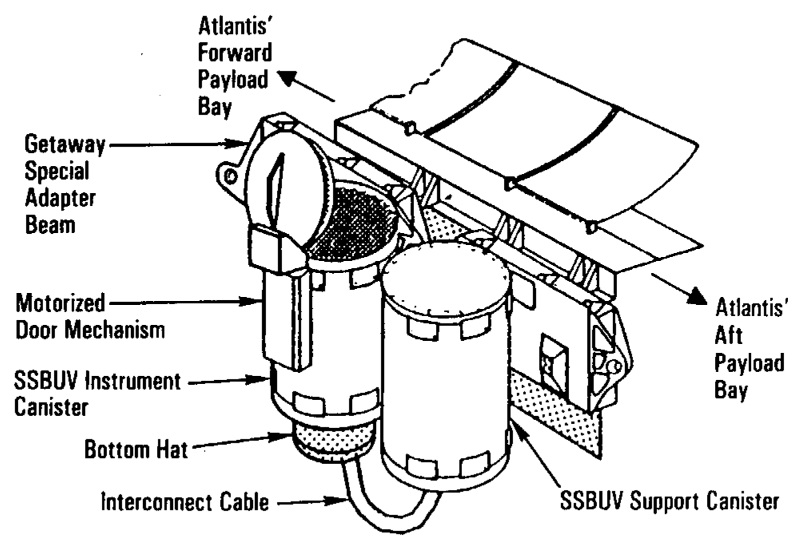
The SSBUV data will help scientists solve the problem of data reliability caused by calibration drift of solar backscatter ultraviolet instruments on orbiting spacecraft. The SSBUV instrument assesses instrument performance by directly comparing its atmospheric ozone and solar irradiance data with data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

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

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

The SSBUV missions are so important to the support of Earth science that seven additional missions are included on the shuttle manifest through 1995 to calibrate ozone instruments on future TIROS satellites, supporting a NASA commitment for making precise measurements of global ozone and solar irradiance. The SSBUV may be reflown every eight months.

The payload configuration consists of two canisters interconnected by cables mounted on a Get Away Special adapter beam on the starboard side of Atlantis' payload bay. The canister containing the SSBUV spectrometer and five supporting optical sensors is equipped with a motorized door assembly. The adjacent support canister contains data, command and power systems.

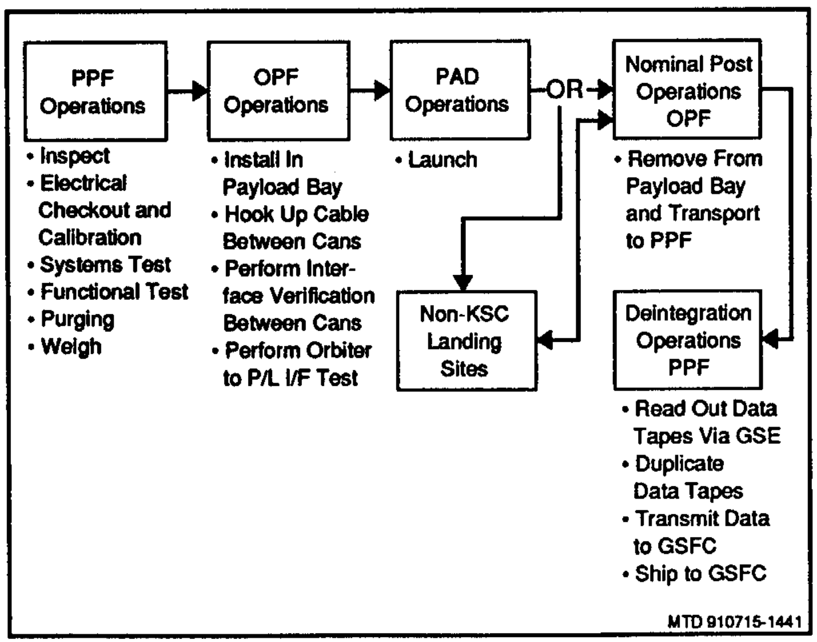


Shuttle Solar Backscatter Ultraviolet Experiment Configuration

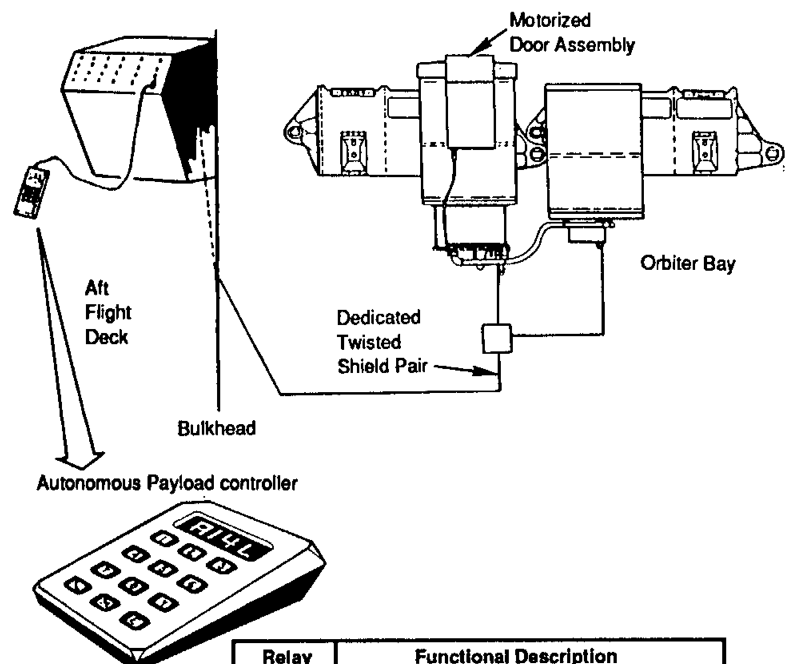
Together, they weigh approximately 1,200 pounds. The flight crew interface is through a GAS autonomous payload controller on the aft flight deck.

The SSBUV ozone-measuring instrument is identical to the SBUV/2 instruments which are flown operationally. It is a 1/4 mm double Ebert-Fastie spectrophotometer that uses a holographic grating and a single detector. The spectrophotometer will collect data when the lid of the GAS canister is opened by the motorized door mechanism. A "bottom hat" subcontainer has been added to the lower end plate.

After an outgassing period, the instrument will be operated in three modes: Earth viewing, solar viewing and calibration. Up to 29 orbits of Earth viewing observations will be made to measure backscatter radiances of the Earth horizon. In the solar view



SSBUV Processing



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

MTD 910716-1444

Shuttle Solar Backscatter Ultraviolet Experiment Command and Status Monitoring mode, observations of solar irradiance will be conducted for a 30-minute period at the beginning, middle and end of payload operation. Seventy-minute calibrations are also required at the beginning, middle, and end of SSBUV operation.

The SSBUV project is managed by NASA's Goddard Space Flight Center, Greenbelt, Md., for NASA's Office of Space Science and Applications. Ernest Hilsenrath is the principal investigator.

SPACE STATION HEATPIPE ADVANCED RADIATOR ELEMENT II

Space Station Heatpipe Advanced Radiator Element II (SHARE II) will demonstrate the on-orbit zero-gravity, thermal vacuum performance of high-capacity heatpipes under various thermal conditions to determine their suitability as a dependable, durable heat rejection system for Space Station Freedom (SSF). The experiment consists of two prototypical radiator panels for potential SSF application and an instrumentation and control system. Ground support equipment is located at Johnson Space Center.

The primary objectives of SHARE II are as follows:

- Demonstration of the passive priming of the heatpipes in a microgravity environment.
- Validation of the heat transport performance/capability in a microgravity environment (verify preflight ground predictions).

Background

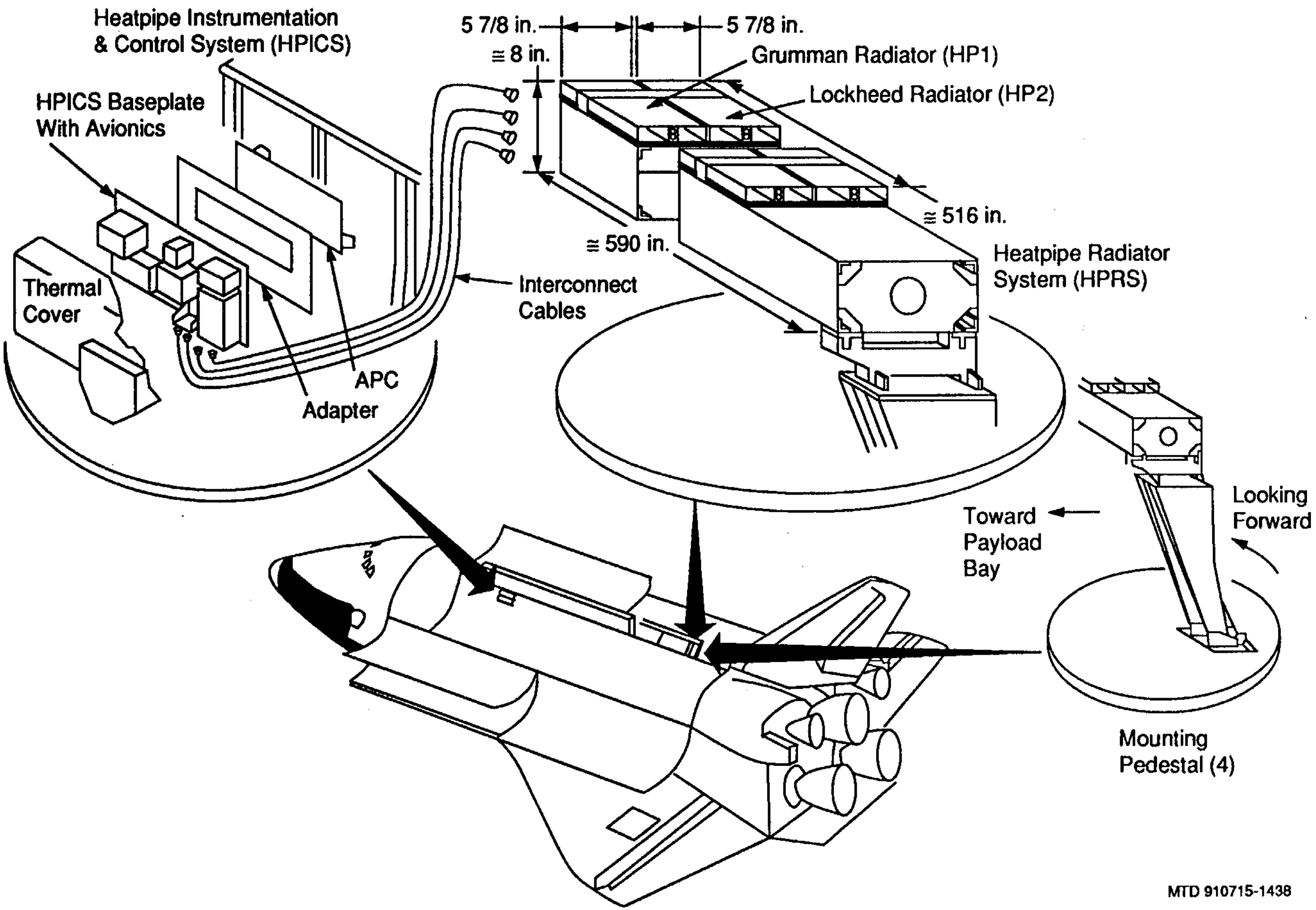
Throughout the manned spacecraft program, thermal management systems have relied on mechanically pumped liquid systems to collect, transport, and reject spacecraft waste heat. Although these systems, including the shuttle orbiter's Freon-21 loops, have performed with excellent reliability, their limitations for future applications have become apparent.

Presently, the primary means of heat rejection for orbiting spacecraft is by circulation of a fluid through a space radiator system. Because these mechanically-pumped systems are vulnerable to single-point failure by meteoroid or debris penetration of the fluid loop, system reliability is questionable for mission durations of greater than approximately 30 days. Reliability can be increased by the addition of redundant pumps, fluid lines, valving, and/or meteoroid and debris shielding, but the accompanying weight penalty is very large. Therefore, a need exists for the development of a long-life, high-reliability heat rejection system which can handle the projected heat loads for space station growth.

Heatpipe technology offers an attractive alternative to the limitations of existing systems. A heatpipe is a sealed vessel that contains a working fluid as both liquid and vapor. The working fluid evaporates in the evaporator, where the heat is added; is condensed in the condenser, where the heat is removed; and is pumped between the two by capillary forces. Heatpipe operation is limited by the capillary transport capability. When the amount of heat into the evaporator overwhelms the ability of the capillary forces to transport the fluid, the heatpipe capability has been exceeded. Heatpipe radiator panels consist of single or multiple heatpipes assembled in a fin structure. The fin structure, or panel, provides an extended surface area for the heatpipe(s) to radiate heat into space. Because a heatpipe radiator concept uses multiple, independent heatpipe sections, a meteoroid penetration causing the loss of a single heatpipe would be non-catastrophic. This approach eliminates the need for redundant heat rejection components and meteoroid protection.

Over the past ten years, the Crew and Thermal Systems Division (CTSD) at JSC has been involved in the development and testing of heatpipe radiators. Future SSF growth requirements dictate the need to develop a heatpipe of approximately 100 times higher capacity than standard heatpipes.

The SHARE program will culminate with the successful demonstration of prototypical high-capacity heatpipe radiator panels, for potential future SSF application, aboard STS-43.


Heatpipe Instrumentation
& Control System (HPICS)
HPICS Baseplate
With Avionics
Thermal
Cover
APC
Adapter
Interconnect
Cables
5 7/8 in.
5 7/8 in.
≅ 8 in.
Grumman Radiator (HP1)
Lockheed Radiator (HP2)
≅ 516 in.
≅ 590 in.
Heatpipe Radiator
System (HPRS)
Toward
Payload
Bay
Looking
Forward
Mounting
Pedestal (4)
MTD 910715-1438

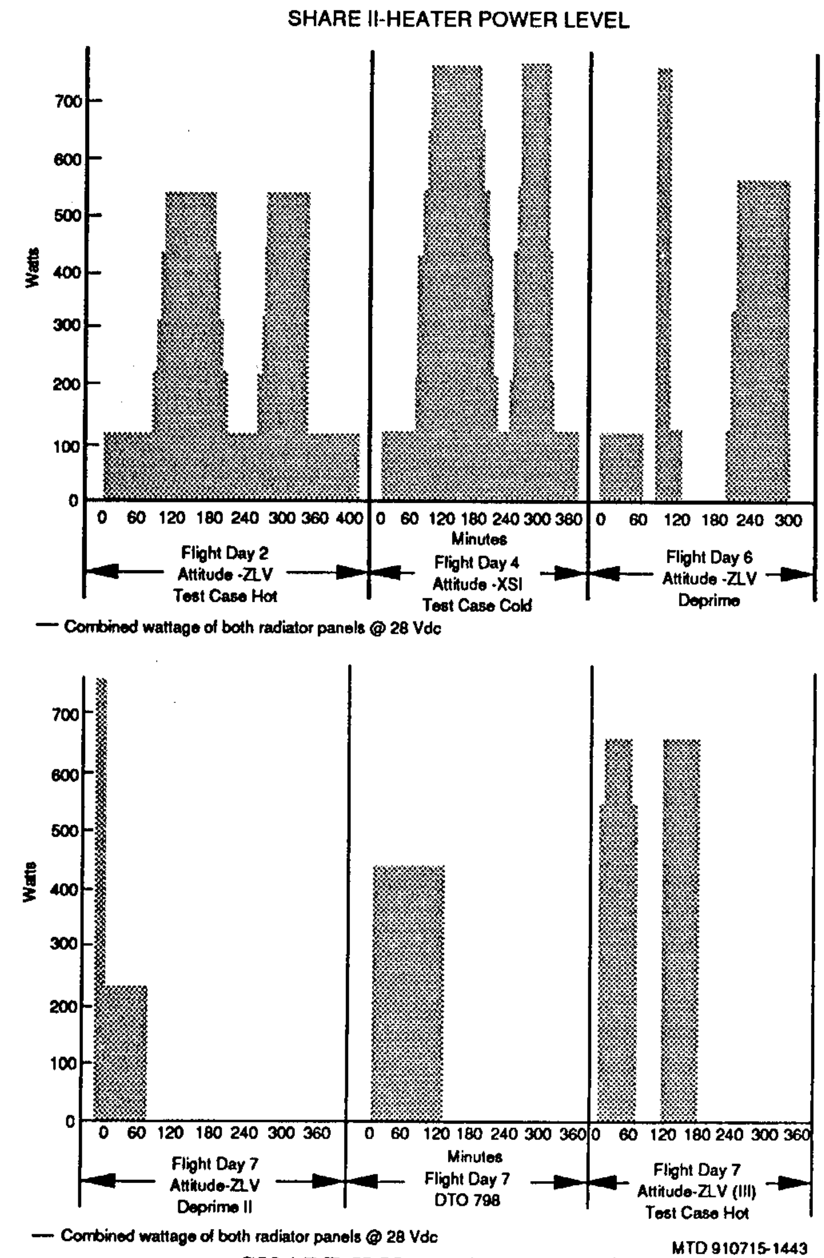
SHARE II

(temperature, current, and voltage), and converts the data for transmission to the experimenters on the ground. The raw measurements are processed by the various electronic subsystems to convert analog readings to digital signals and to convert the digital signals into an orbiter-compatible format for transmission to the Payload Operation Control Center (POCC) in Houston. All HPICS command circuits are activated by the flight crew using the orbiter's aft flight deck (AFD) standard switch panel (SSP). All orbiter interfaces remain consistent with the SHARE configuration.

Mission Sequence

The SHARE II mission sequence consists of six distinct data takes to be accomplished over the mission duration of nine days. Data takes were planned so that the heatpipe response to changing heat loads could be evaluated over extended periods of continuous operation. As the mission progresses, the ramp-up of the heat load becomes more and more severe in an attempt to test the limits of the heatpipe and approach a dryout condition.

Data take one involves six hours of operation in a -ZLV attitude (payload bay to Earth). This attitude places SHARE II in a relatively warm environment. Gradual ramp-up of the input heater wattage is begun at the start of the data take. Data take two is similar to the first, but in a cool space station-like, or -XSI, attitude (tail to sun), and also has a six-hour duration. Data take three purposely deprimes the heatpipe by initiating a forward shuttle acceleration that drives the fluid from the heatpipe evaporator. Data obtained from this testpoint will determine the amount of time required to return to a fully operational state following the deprime. This data will be used to allow prediction of the effects of SSF docking and reboost activities. Data take four is a repeat of data take three, with a more severe heat input. Data take five allows the heatpipe to operate at 220 watts during an orbiter DTO (Detailed Test Objective) that consists of various accelerations and vibrations of the shuttle. Data take six is a repeat of data take one with a more severe power profile in a -ZLV attitude.



SHARE-II Heater Power Level

Share II Payload Summary

HPRS: Mounted to orbiter using four pedestals. Occupies starboard RMS envelope.

Monogroove Heatpipe:

- Designed and built by Grumman Aerospace Corporation
- 5.87 in. x 1.3 in. x 22 ft
- 50 lb
- 6061 T6 aluminum
- NH_3 working fluid
- Spar panel construction
- Surface coating: Chemglaze A276 white paint
- Inputs: 55, 110, 220 watt—385 maximum at 28 Vdc
- 27 temperature measurements

Graded-Groove Heatpipe:

- Designed and built by Lockheed Missiles & Space Company/LTV Missiles and Space Company
- 5.85 in. x 1.3 in. x 22 ft
- 50 lb
- 6061 T6 aluminum
- NH_3 working fluid
- Honeycomb panel construction
- Surface coating: silver Teflon adhesively attached tape
- Inputs: 55, 110, 220 watt—385 maximum at 28 Vdc
- 27 temperature measurements

Box Beam:

- Designed and built by Johnson Space Center
- Provides structural support for radiator panels
- 6 in. x 12 in. x 50 ft
- 340 lb
- 6061 T6 aluminum

Pedestals:

- Designed and built by Johnson Space Center
- Quantity: 4
- Attach to 4 RMS MPM attach points on the starboard sill (provides structural interface with the orbiter)
- Allows beam assembly to rotate outboard for vertical payload installation
- 132 lb total weight
- 6061 T6 aluminum

HPICS:

- Designed by Lockheed Engineering and Sciences Company
- Built by Johnson Space Center
- Instrumentation and control package mounted in Bay 5
- Supplies power for heatpipe heaters
- Processes 64 data channels, converts electrical RTD signals to analog data and relays information to orbiter PDI data stream. Routes selected data to GPC for onboard display
- Six-hour on-board recording capacity
- 12 in. x 30 in. x 44 in.
- 157 lb

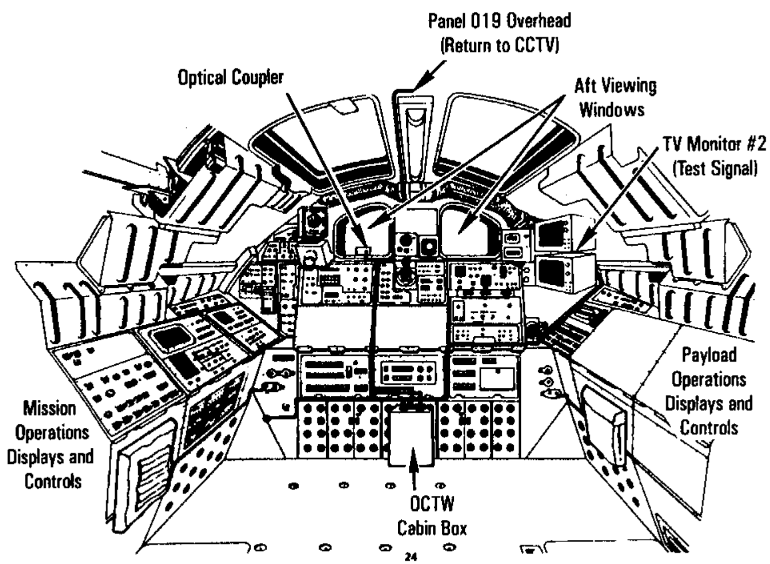
OPTICAL COMMUNICATIONS THROUGH THE SHUTTLE WINDOW

Optical Communications Through the Shuttle Window (OCTW) is a JSC-sponsored experiment designed to demonstrate the optical transmission of video and audio data from the crew cabin to the payload bay and back through the shuttle aft window by means of fiber optic technology rather than conventional radio frequency (RF) technology. If successful, optical communication could provide an alternative communication link between the orbiter interior and payload bay.

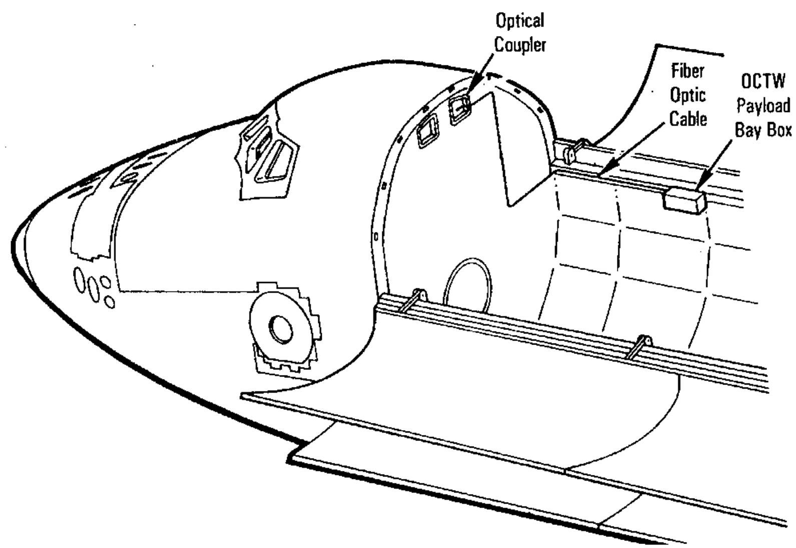
OCTW consists of two separate subsystem modules (an emitter coupled logic compatible digital system located in the orbiter crew cabin and a second module located in the payload bay) and two fiber optic cable bundles (one in the crew cabin and one in the payload bay). The experiment also requires the use of the onboard closed-circuit television system (CCTV).

The crew will transmit signals from the crew cabin module via an attached optical fiber bundle positioned near the AFD window. The signal will be picked up by an identical fiber bundle located near the AFD window on the outside starboard bulkhead in Bay 2. The outside fiber bundle will transmit the video and audio test signals back to the second module mounted on an adaptive payload carrier (APC) in the payload bay. The payload bay module will subsequently return the test signals to the cabin module that interfaces with the CCTV VTR in order to record signal performance information.

Payload activation requires the crew to manually switch the unit on via the small payload accommodations switch panel (SPASP) in the AFD. Four data takes of 15 minutes each will be conducted in flight.



OCTW Crew Compartment Configuration



OCTW Payload Bay Configuration

The crew cabin module houses an optoelectronic transmitter/receiver pair for both the video and digital test signals, test circuitry for the digital system, and interface circuitry required to obtain video test patterns from a CCTV monitor and record received video and measured digital signal integrity on the CCTV videotape recorder video and audio tracks, respectively. It is mounted near the AFD window and stows in a single middeck locker.

SOLID SURFACE COMBUSTION EXPERIMENT 02

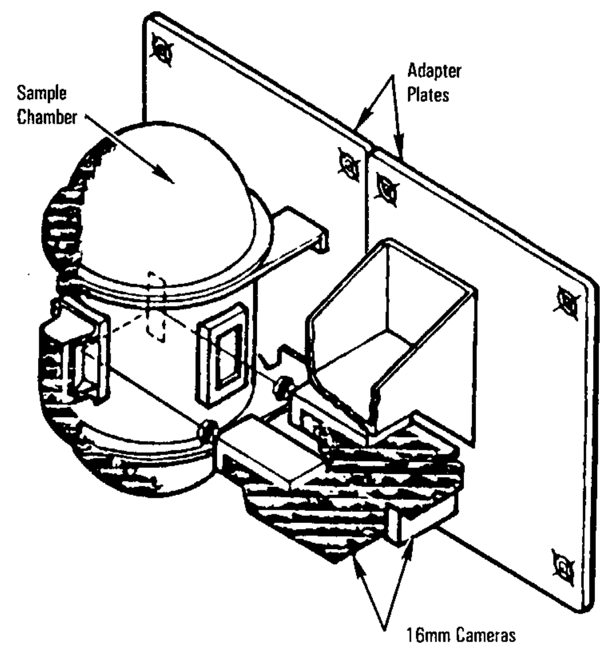
The primary objective of NASA's Solid Surface Combustion Experiment (SSCE)-02 is to supply information on flame spread over solid fuel surfaces in the reduced gravity environment of space. The experiment will measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds in low gravity. The data obtained will be used to validate flame spread models to improve fire safety of space travel.

For this flight, ashless filter paper, internally mounted in a pressurized chamber, has been selected as the "thin" fuel source. Polymethyl-methacrylate is the second source to test out "thick" fuel flame spread.

SSCE will take the place of four middeck lockers. The unit consists of a chamber assembly containing the samples, 16mm Photo-Sonics cameras, an electrical box, a 28-volt battery pack, and instrumentation consisting of thermocouples on or about the samples; a silicon ambient temperature sensor to measure the middeck air temperature; and pressure transducer to measure the internal chamber temperature and pressure. The chamber is designed with windows for camera viewing of the side edge and front of the samples, which are ignited by a hot filament wire coated with nitrocellulose. Crew activation is required for the seven-minute operation. The experiment must be conducted during a period of low orbiter accelerations.

Postflight, the 16mm film will be examined by the Lewis Research Center's photographic branch using a frame-by-frame analyzer to determine the flame spread rates. The data will determine if current science models are correct.

SSCE previously flew on STS-41. A total of eight SSCE flights are planned. SSCE is managed by NASA's Lewis Research Center.



SSCE

SPACE ACCELERATION MEASUREMENT SYSTEM

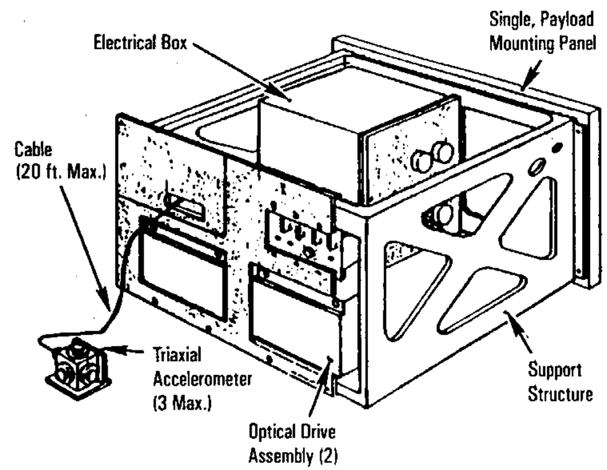
The primary objective of NASA's Space Acceleration Measurement System (SAMS) is to provide other shuttle payloads with data on the shuttle middeck and/or middeck-mounted experiments' acceleration environment.

SAMS consists of a main unit, up to three triaxial sensor heads, and sensor harnesses and optical disks. All SAMS components except for the optical disks are stowed in a middeck locker. The main unit consists of the data acquisition system (electrical box), two optical disk drives for data collection, and a control panel, all of which are mounted into a support structure with covers. The triaxial sensor heads are separated from the main unit by an umbilical cable (sensor harness) for remote positioning into another payload.

In operation, the triaxial sensor head produces output signals in response to acceleration inputs. The signals are amplified, filtered, and converted into digital data, which is then stored on optical disks. The data transfer and storage are controlled by the internal microprocessor.

The SAMS payload will be activated by the crew no sooner than 2.5 hours after launch. While in orbit, the crew must reset the central processing unit (CPU), activate the data recorder, and change out the optical disk. Acceleration data will be gathered throughout the flight and can be taken during specific events that require acceleration, such as OMS/RCS burns.

SAMS is sponsored by NASA's Lewis Research Center.



SAMS

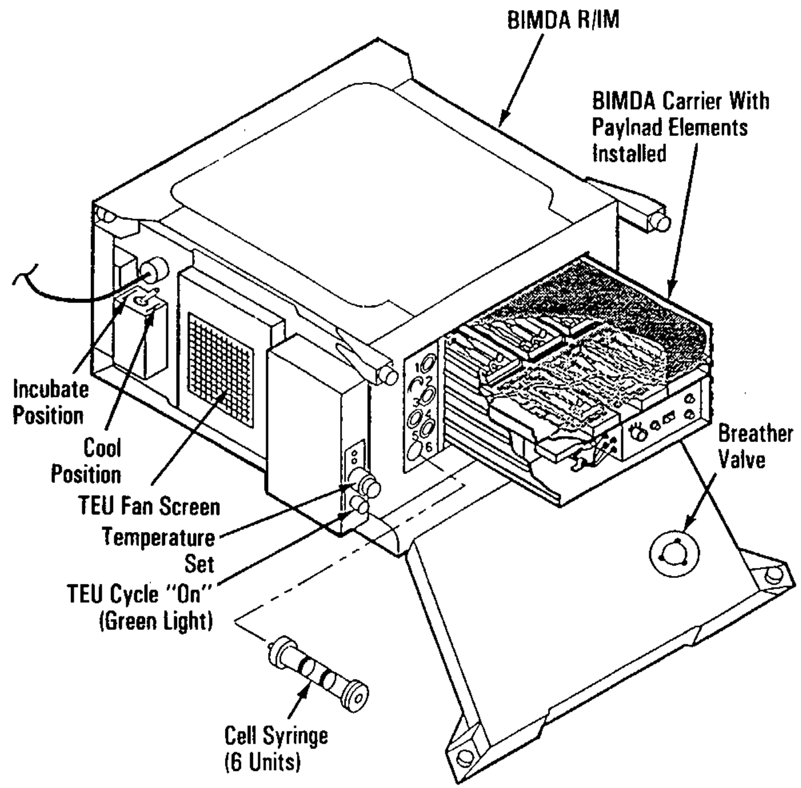
BIOSERVE-INSTRUMENTATION TECHNOLOGY ASSOCIATES MATERIALS DISPERSION APPARATUS

BIMDA-02 is a privately funded payload designed to investigate the scientific methods and commercial potential of biomedical and fluid science applications in the microgravity of space. Both basic and applied research will be conducted in three broad areas: bioprocessing, fluid science, and manufacturing technology. BIMDA-02 experiments focus on both synthetic and natural biological processes, including evaluations of current processes for growing large, high-quality protein crystals from macromolecules in microgravity; and cell and membrane (cell and artificial) processes.

BIMDA-02 is flown in a refrigerator/incubator module (R/IM) in an orbiter middeck locker. It consists of four materials dispersion apparatus (MDA) units; the MDA controller and power supply; six cell syringes (CSs) with twelve needle/valve sampling adapters and twelve sample vials; the bioprocessing testbed, which holds the six bioprocessing modules (BMs) and hardware needed to collect samples from the cell syringes; an automatic temperature recorder; a self-contained burst convection diffusion apparatus (BCDA); and the R/IM payload carrier. The experiment is dc powered. The R/IM will be operated at a constant 20 degrees Celcius.

The flight crew will activate and operate the protein crystal growing samples as soon as possible after orbital insertion and will document BIMDA-02's operation for postflight analysis by means of photographic documentation and audio observations. The temperature of the payload will be recorded automatically during flight.

The MDA has flown on NASA's KC-135 aircraft, the Consort rocket, and the space shuttle. Four MDA units were flown on BIMDA's first flight, STS-37. All operated properly. The biomedical, manufacturing process, and fluid sciences experiments generated 182 data samples. Highlights included growth of several classes of protein crystals (biomedical), growth of zeolite crystals (manufacturing processes), germination of alfalfa sprouts (applicable to the development of a "salad machine" on Space Station Freedom), conduction of fluid sciences diffusion experiments, and the development of a new technique for growing protein crystals called gradient diffusion. BIMDA-02



BIMDA Payload

will use gradient diffusion, along with osmotic dewatering and liquid-liquid diffusion, to grow protein crystals.

Data will be collected from 36 different experiments developed by scientists, engineers, and principle investigators. The researchers include private industry, universities, government research institutions, the NASA Centers for the Commercial Development of Space, and NASA JSC.

Potential Commercial Applications of Experiments To Be Conducted in the MDA Units on the BIMDA-2 Payload, STS-43

Experiment/ Category	General Field	Specific Application
Protein Crystal Growth	Pharmaceutical	Drug Design • AIDS Research • Neuromuscular Research
Clot Lysis	Biomedical	Cardiovascular Disease
Interferon Induction	Biomedical	Immune System Response
Collagen Assembly	Biomedical	Artificial Implants
Lipsome Formation	Biomedical	Pharmacology
Algae Metabolism	Microbiology	Environment
Magnetic Mixing for Cell Fixation	Microbiology	Baseline Data on Cell Fixation in Micro-g; Verify Magnetic Mixing Concept in MDA
E. Coli Bacteria Behavior	Microbiology	Biotechnology
Seed Germination	Agriculture	Space Station Garden
Zeolite Crystallization	Manufacturing Processes	Petroleum and Chemical Technology
Electrokinetic Transport	Fluid Sciences	Purification Technology
Interfacial Transport	Fluid Sciences	
Phase Reorientation	Fluid Sciences	Bioseparation Technology
Particle Diffusion	Fluid Sciences	Bioprocessing
Diffusion Coefficient	Fluid Sciences	

Specific MDA applications include the study of protein crystal growth in space, collagen polymerization, fibrin clot formation, liquid and solid diffusion, and the formation of thin film membranes. Other experiment areas include the following:

- Assembly of collagen, Human Immunodeficiency Virus (HIV) protease crystals, virus capsids, and liposomes
- Metabolism and reproduction of bacteria and algae
- Development of brine shrimp and plants
- Function of lymphocyte and macrophage immune cells
- Hardware assessments for mixing and casting

STS-43 is the last of the BIMDA development flight series. Instrumentation Technology Associates, Inc., intends to fly MDA units on subsequent shuttle flights as a commercial paying payload, leasing MDA test wells to users. Commercial operations would use 5 to 6 MDAs, each containing 50 to 100 samples, for a total of 300 to 600 data samples per middeck locker. ITA has submitted a Space Services Development Agreement to NASA for six shuttle flights of a single middeck locker to lease MDA test wells.

BIMDA-02 is a joint effort between Instrumentation Technology Associates, Inc., Exton, Pa., and BioServe Space Technologies, Boulder, Colo., a NASA Center for the Commercial Development of Space. BioServe is directed by Dr. Marvin W. Luttges of the University of Colorado. BIMDA-02 is managed by NASA JSC.

Refrigerator/Incubator Module

The R/IM provides a temperature-controlled environment for the payload from turnover prior to launch until return to the payload organization after landing. The R/IM serves as the structural interface to the shuttle for the payload elements located inside. It operates on 28 Vdc electrical power from the shuttle.

The R/IM is capable of providing a temperature environment of 0 to 37 degrees Celcius plus or minus two degrees. For this flight, the R/IM will be operated at 20 degrees Celcius. Later flights will be flown at either 4 degrees Celcius or 20 degrees Celcius.

The R/IM payload carrier provides a mechanical interface between the R/IM and most of the BIMDA payload elements. The carrier provides a mechanical attachment and a structural load path for the payload elements during launch and reentry. It is constructed of sheet aluminum and aluminum rails and is assembled as part of the payload integration operation.

After the carrier is assembled with the payload elements it is installed in the R/IM. The carrier is held in position with a close tolerance fit.

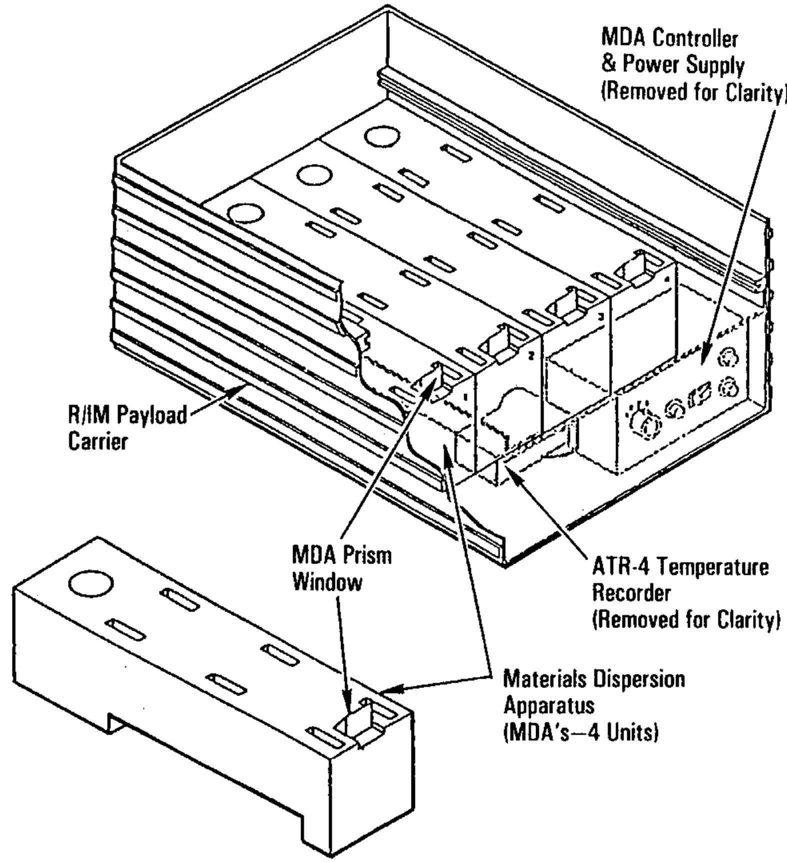
The R/IM payload carrier was designed and built by ITA.

Materials Dispersion Apparatus

The MDA Minilab is a compact automated fluid contacting device capable of mixing up to 140 samples of any two or three fluids in space.

Four MDA Minilabs will be flown as part of the STS-43 BIMDA-02 payload. The MDA units will provide 90 percent of the BIMDA data on STS-43, including 252 separate data samples from space collected from 30 separate experiments involving 20 principal investigators.

The MDA operates on the following principle: two blocks of inert material, each with sample wells in the upper and lower test half, are held together firmly with a sealing mechanism under a compressive load in a lightweight aluminum housing. The wells in the two blocks are misaligned at launch to separate the fluids to be



The MDA (Materials Dispersion Apparatus)

mixed. Once microgravity has been achieved, the blocks are moved into alignment using a motor-cam-follower mechanism, bringing the fluids into contact. Mixing occurs by liquid-to-liquid diffusion. A third fluid can be added to fix or quench the process under study. This is done by moving the blocks a second time. A type 2 or type 3 test well is designed to mix two or three fluids. A type 4 test well is designed to allow the MDA to cast a thin film membrane. A type 1 test well is a single cavity that does not mix with any other well, suitable for the "batch" method of protein crystal growth and for control samples that experience the low-gravity environment without mixing. All four types of test wells can be flown in the same MDA, providing multiple test data points in several technical disciplines. In addition, the MDA can be tailored to meet the experimenter's needs.

Ground experiments have validated a vapor diffusion method compatible with the MDA. Previous experiments have demonstrated that the MDA can grow lysozyme protein crystals via vapor diffusion using reverse osmosis membranes. Several test wells on the first BIMDA flight were used to validate this approach for use on subsequent flights.

MDA Controller and Power Supply

The MDA controller and power supply allow for the operation of the four MDA's by the astronaut crewmembers. It consists of printed circuit boards with board-mounted switches and a power supply mounted in a sheet aluminum housing. The electrical power is provided by ten Duracell DA-146 zinc-air batteries. The controller contains logic elements to assist in the operation of the MDA's by the crew.

The MDA controller and power supply was designed and built by ITA.

Automatic Temperature Recorder

The ATR will be used to record the temperature of the R/IM interior from payload turnover before launch until its return after landing. The data will be used by the various experimenters to correlate experiment results with the temperature. The ATR's operation is initiated by a command from software located on an IBM-compatible personal computer. Temperature data are recorded periodically at a pre-determined rate and stored on an EPROM chip for later analysis. The ATR can operate in a stand-alone mode and can accommodate up to four temperature sensors. The ATR can collect a finite set of temperature data points in a chronological manner. It is designed to operate in the -40 to 60 degrees Celcius temperature range with an accuracy of plus or minus one degree Celcius. The temperature sampling rate can be adjusted so that the temperature sampling is performed over various periods of time.

The ATR was developed by NASA's Ames Research Center for use on Spacelab missions.

Cell Syringes

The six cell syringes function to mix lymphocytes with target cells to test the immune function under microgravity conditions. This is done by pushing and pulling the syringe plunger to cause the mixing of two fluids separated by a septum through a bypass on the syringe's barrel. At pre-designated times after mixing, a sample of the mixture will be transferred to a sample vial containing a chemical fixative that will preserve the samples until they can be analyzed following return to Earth. This operation will be performed by the crew. The cell syringe is a modified commercially available syringe. Modifications include an extra level of containment to protect the crew while they operate the cell syringe. Each of the cell syringes will be sampled twice over a 24-hour period, producing 12 samples. The samples are transferred using 12 needle-valve adaptors and 12 sample vials designed to provide safe transfer of the experiment solution into the sample vials in the space environment.

The cell syringes are carried in a foam block located next to the payload carrier during launch and landing. The associated needle-valve adaptors, sample vials, and cell syringe plungers are carried in the bioprocessing testbed.

The cell syringes were developed by Bioserve Space Technologies.

Bioprocessing Modules

The bioprocessing modules are designed to allow a crewmember to mix an interferon activator or antigen solution with live lymphocytes to trigger an immune response under microgravity conditions and later fix the reaction. This is done with three 5 ml syringes connected to a three-way valve mechanism. In position zero, none of the syringes can communicate with each other. When the valve is switched to position one, the contents of syringe A are transferred to syringe B by depressing the syringe A plunger, thus stimulating a reaction in syringe B. After a pre-designated time period, the contents of syringe B are transferred to syringe C by switching the valve to position two and depressing the syringe B plunger. This last transfer is used to collect and fix the product of syringe B in syringe C.

The period between reaction initiation (the transfer of the contents from syringe A to syringe B) and reaction fixation (the transfer of the contents from syringe B to syringe C) can be varied.

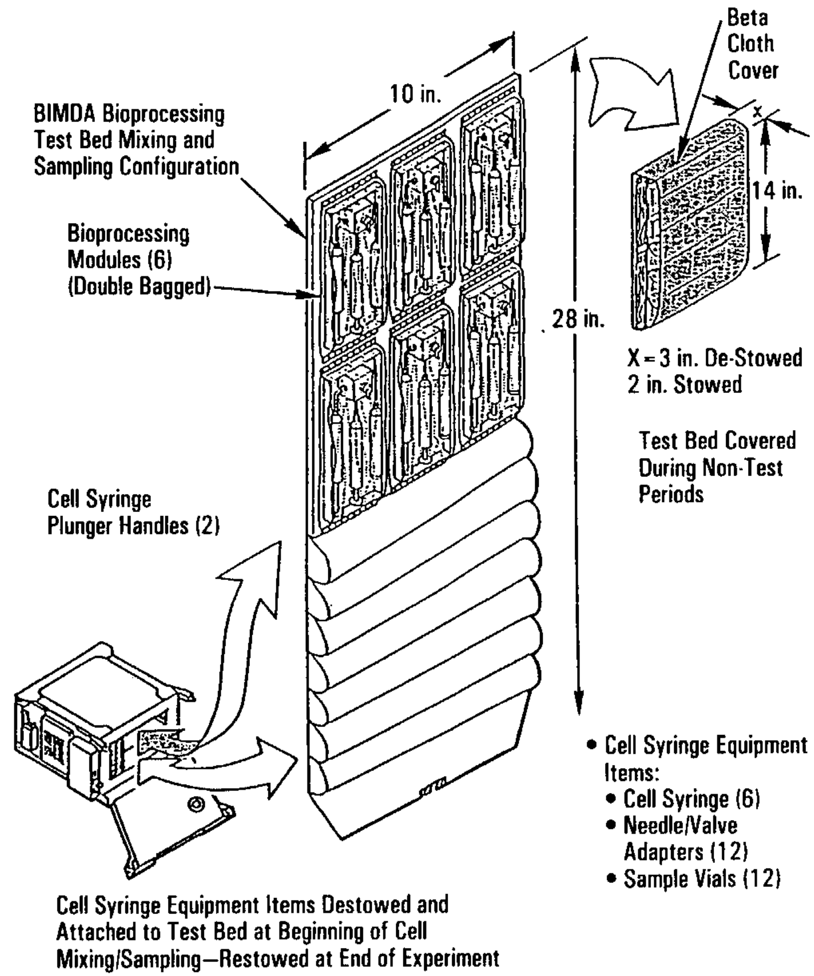
Bioprocessing modules, developed by NASA JSC, were previously flown on STS-7 and -37.

Bioprocessing Testbed

The bioprocessing testbed supports the cell syringe and bioprocessing module experiment operations. The testbed is made of an aluminum shelf that holds the six bioprocessing modules and the beta cloth carrier. The beta cloth carrier holds the hardware needed to collect the samples from the cell syringes.

Upon arrival in orbit, a crewmember will remove the bioprocessing testbed and the six cell syringes from the R/IM and attach them to a velcro mount in an available area in the orbiter middeck. This permits operation of the testbed without disturbing the temperature and microgravity environment of the R/IM containing the four MDA minilabs.

The bioprocessing testbed was designed and built by Bioserve Space Technologies.



The Bioprocessing Test Bed

BIMDA Payload Operations

The use of live cells and other labile fluids aboard BIMDA-02 necessitates late pre-launch and early post-launch access requirements to the shuttle and impacts the design of the pre- and postflight ground handling procedures.

The loading of the flight fluids into the various payload elements occurs within 24 hours of launch. Following assembly of the payload into the R/IM, the BIMDA-02 payload will be turned over to NASA for integration into Atlantis' middeck. Once in orbit, the crew will activate the BIMDA-02 payload.

Samples will be processed in the cell syringes and the bioprocessing modules. After the last samples are taken, the crew operations with the cell syringes and the bioprocessing modules are complete.

On Flight Day 8, the crew will deactivate the MDA's and configure the payload for return to Earth.

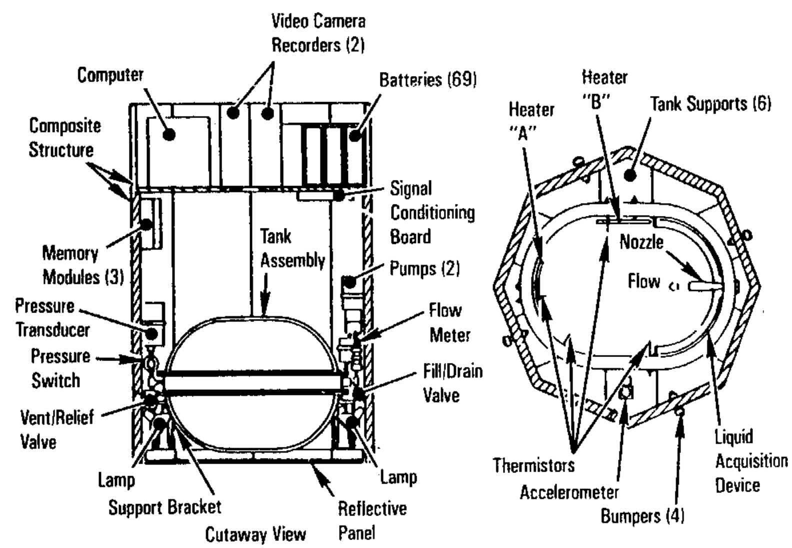
After the shuttle landing, the R/IM will be removed from the middeck within two hours of landing and the payload disassembled to allow for retrieval of the experiment fluids and/or products.

TANK PRESSURE CONTROL EXPERIMENT

The Tank Pressure Control Experiment (TPCE) is a NASA Goddard Space Flight Center (GSFC) Shuttle Small Payload Project (SSPP) designed to determine the effectiveness of jet mixing as a means of controlling tank pressures and equilibrating fluid temperatures. This experiment, flying for the first time, will provide thermodynamic data as well as visual information about the flow patterns found at various jet flow rates and with different liquid/vapor orientations. The data will be computed to produce a fluid dynamic model for validation of these techniques and guidance in their further development.

The TPCE is contained in a standard 5-cubic-foot Get Away Special (GAS) cylindrical canister, mounted on a GAS adapter beam in the payload bay. The payload will be controlled by a crew member from the aft flight deck (AFD) using a small handheld display encoder to signal the autonomous payload control system (APCS). Already established orbiter wiring from the AFD connects the GAS command encoder to the GAS control decoder located in the payload canister.

The experiment uses two strategically placed heaters to heat a partially full tank of refrigerant fluid (Freon-113) that is initially at its saturation pressure and temperature. The heat will create a thermal gradient and increase the tank pressure. A low-velocity jet mixer will be activated to provide forced convection mixing and heat transfer. After a short time, the pressure will have returned to near its initial value, and the temperatures within the liquid and vapor will be approximately equal. This sequence will be activated during ascent, and will be repeated for a total of 38 test runs over an 18- to 32-hour period. Several of the tests will be made while Atlantis is in a tail-into-the-velocity attitude, using orbital drag to keep the fluid at the heater end of the tank.



TPCE

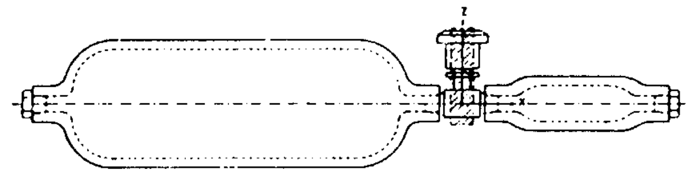
INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING 03

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

Polymer membranes have been used in the separation industry for many years for such applications as desalination of water, filtration during the processing of food products, atmospheric purification, purification of medicines and dialysis of kidneys and blood. The IPMP payload uses the evaporation casting method to produce polymer membranes. In this process, a polymer membrane is prepared by forming a mixed solution of polymer and solvent into a thin layer; the solution is then evaporated to dryness. The polymer membrane is left with a certain degree of porosity and can then be used for the applications listed above.

The IPMP investigation on STS-43 will evaporate mixed solvent systems in the absence of convection to control the porosity of the polymer membrane. Convective flows are a natural result of the effects of gravity on liquids or gases that are non-uniform in specific density. The microgravity of space will permit research into polymer membrane casting in a convection-free environment. This program will increase the existing knowledge base regarding the effects of convection in the evaporation process. In turn, industry will use this understanding to improve commercial processing techniques on Earth with the ultimate goal of optimizing membrane properties.

Experimenters are expecting to find that the absence of convection will leave very uniform spaces in the coating of the polymer membrane, thus leading to filtering advancements in processing procedures.



IPMP

The IPMP payload on STS-43 consists of two experimental units containing different solvent solutions that occupy a single small stowage tray (half of a middeck locker). Each unit consists of two 304L stainless steel sample cylinders measuring 4 inches and 2 inches in diameter. The cylinders are connected to each other by a stainless steel packless valve with an aluminum cap.

Pre-mission, a thin-film polymer membrane is swollen in a solvent solution, rolled and inserted into the smaller canisters and then sealed at ambient pressure (approximately 14.7 psia). The valves are sealed with Teflon tape. The larger canisters are evacuated and sealed with threaded stainless steel plugs using a Teflon tape threading compound.

During the mission, a crew member will turn the valves to the first stop to activate the evaporation process. Turning the valves opens the pathway between the large and sample cylinders, causing the solvents in the sample to evaporate into the evacuated larger cylinder. Both flight units are activated at the same time.

The STS-41 IPMP experiment investigated the effects of evaporation time on the resulting membranes by deactivating the two units at different times. A crew member terminated the evaporation process in the first unit after five minutes by turning the valve to its final position. This ended the process by flushing the sample with water vapor, which set the membrane structure. After the process was terminated, the resulting membrane was not affected by gravitational forces experienced during reentry, landing and postflight operations. The second unit was deactivated after seven hours.

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

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

The two most significant variables which remained in the experiment as originally configured were the time factor and the gravitational forces affecting the samples before the payload was retrieved. With the addition of a 75-cc cylinder containing a small quantity of distilled water pressurized with compressed air to greater than 14 psig, flight crew members will be able to terminate (or "quench") the vacuum evaporation process abruptly by flushing the sample with water vapor. After the process is terminated, the resulting membrane will not be further affected by gravity variations. The modifications will not alter the experimental objectives and, in fact, will contribute to a better understanding of the transport mechanisms involved in the evaporation casting process.

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

PROTEIN CRYSTAL GROWTH III BLOCK II

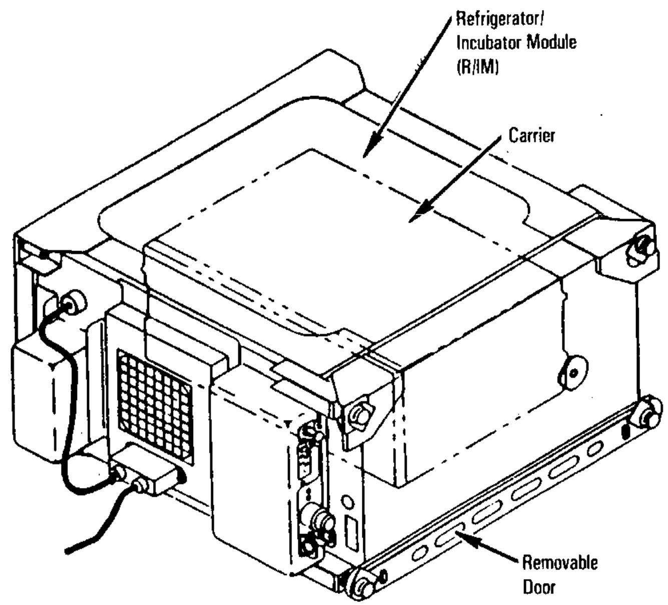
At the present time, protein crystallography is the only technique available for defining the atomic arrangements within complex biological molecules. Knowing the precise structure of the molecules provides the key to understanding their biological function. Discovering ways to alter or control their growth may result in new developments in the pharmaceutical industry.

Protein crystals grown on Earth are often small and are flawed by gravitational effects such as sediment drop out and convection. In addition, crystal growth is impeded due to the need for support by an attachment point. In contrast, PCG experiments flown on nine previous space shuttle missions (STS-51D, -51F, -61B, -61C, -26, -29, -32, -31, and -37) have already provided evidence that superior crystals can be obtained in the microgravity environment of space, where such effects are not present. These crystals have been larger, with more uniform morphologies, and were more highly ordered at the molecular level.

The primary objective of each PCG payload is to conduct experiments that will supply information on the scientific methods and commercial potential for growing high-quality protein crystals in a controlled microgravity environment that are of sufficient size to permit molecular analysis by diffraction techniques. Teams of industry, university, and government research investigators explore the potential advantages of using these crystals to determine the complex, three-dimensional structures of specific protein molecules.

The objectives of the STS-43 PCG III-Block II experiment are to grow protein crystals in large batches, and to use temperature as the means to initiate and control protein crystal growth. PCG III-Block II tests crystal size and quality as a function of the temperature gradients, which may vary with different proteins.

PCG III Block II will be contained in a refrigerator/incubator module (R/IM), which provides temperature control and automation for some of the processes. The R/IM replaces one middeck locker. The experiment operates on 28 Vdc electrical power from the shuttle orbiter.



PCG

The PCG III-Block II protein crystallization facility is made of polysulfone with neoprene O-rings. It consists of four insulated cylinders: 500 ml, 200 ml, 100 ml, and 50 ml, all of which have the same diameter with different heights. The four cylinder sizes will result in four different temperature gradients.

On-orbit, one of the mission specialists will initiate the crystal-growing process. The metal cap of each cylinder is apposed to the heating element of the R/IM and the temperature is decreased from 40 degrees Celsius to 22 degrees Celsius early in flight according to the following schedule:

L plus 2 hours:	40 to 36 degrees Celsius
L plus 10 hours:	36 to 32 degrees Celsius
L plus 18 hours:	32 to 28 degrees Celsius
L plus 26 hours:	28 to 22 degrees Celsius

Using temperature as a means of initiating and controlling protein crystal growth has various advantages: it allows dynamic control, is not invasive, and is the most subtle way to control protein solubility (no seeding is necessary, and no changes in protein, precipitant, or pH are necessary).

The Block I PCG has already had significant successes. Well-ordered crystals of many important animal and plant crystals have been grown that are impossible to grow on Earth. For example, purine nucleside phosphrylase (PNP) crystals have been grown, which have been found to be capable of destroying some anti-cancer drugs.

Bovine insulin, at 0.6 mg/ml, in a phosphate buffer, will be the protein used for the STS-43 crystal growth experiments.

PCG III-Block II is sponsored by NASA's Office of Commercial Programs, and is managed by NASA's Marshall Space Flight Center.

AIR FORCE MAUI OPTICAL SITE CALIBRATION TEST

The AMOS tests allow ground-based electro-optical sensors located on Mt. Haleakala in Maui, Hawaii, to collect imagery and/or signature data of the space shuttle orbiters during cooperative overflights.

This experiment is a continuation of tests made during the STS-29, -30, -34, -32, -31, -41, -35, and -37 missions. The scientific observations of the orbiters during those missions consisted of reaction control system thruster firings and water dumps or activation of payload bay lights. They were used to support the calibration of the AMOS ground-based infrared and optical sensors, using the shuttle as a well-characterized calibration target; and to validate spacecraft contamination models through observations of contamination/exhaust plume phenomenology under a variety of orbiter attitude and lighting conditions.

No unique on-board hardware is associated with the AMOS test. Crew and orbiter participation may be required to establish the controlled conditions for the Maui overflights.

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

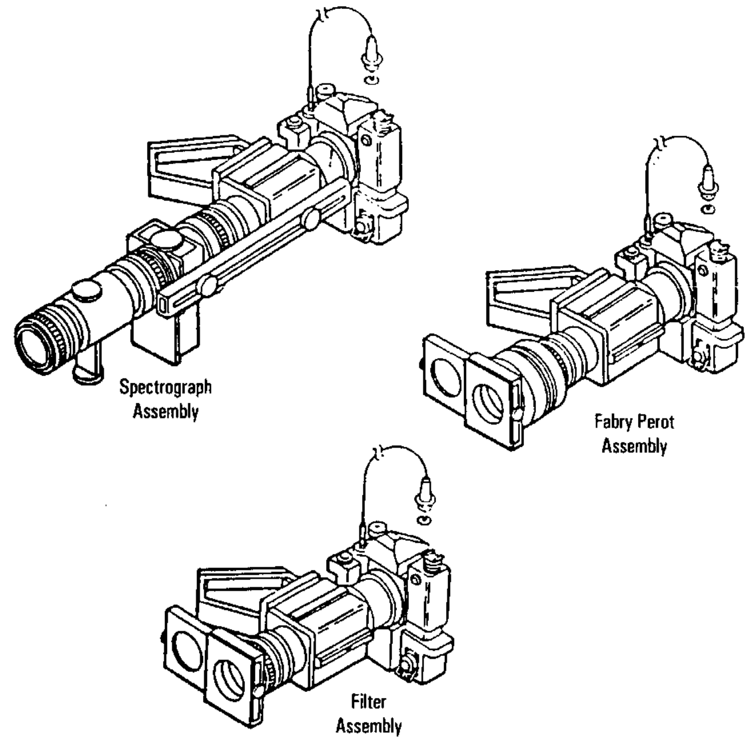
Flight planning and mission support activities for the AMOS test opportunities are performed by a detachment from AFSC's Space Systems Division at the Johnson Space Center in Houston. Flight operations are conducted at the JSC Mission Control Center in coordination with the AMOS facilities in Hawaii.

AURORAL PHOTOGRAPHY EXPERIMENT B

The Auroral Photography Experiment (APE)-B is an Air Force-sponsored payload designed to study airglow aurora, auroral optical effects, irradiation effects, the shuttle glow phenomena, and orbiter OMS exhaust plume emissions and port and starboard yaw thruster firings in the imaging, Fabry-Perot, and spectrometer modes of photography. The data collected during the experiment will be used to develop target acquisition models for space-based sensor systems.

APE-B hardware consists of a Nikon 35mm camera, 55mm lens, shroud adapter, image intensifier, Fabry-Perot filter/lens, spectrometer, filter carrier, filters, and film. The hardware will be mounted on the aft flight deck using the APE window mount. A "Witches Hat" shroud and shroud adapter will be used to block light from the crew compartment.

APE-B photography will occur with Atlantis in darkness and with minimal moonlight, payload bay lights off, and the crew cabin darkened or windows covered. No water dumps or fuel cell purges should be scheduled during any data collections and it is desirable that the orbiter flash evaporator system (FES) not be operated during photographic sessions. Shuttle glow and window effects data are collected for a number of different orientations of the window and orbiter surfaces relative to the orbiter ram and wake directions.



APE-B

ULTRAVIOLET PLUME INSTRUMENT

The Ultraviolet Plume Instrument (UVPI) is an instrument on the low-power atmospheric compensation experiment (LACE), an on-orbit SDIO satellite. Its objective is to view space shuttle OMS or RCS burns during orbital trajectory intersection. UVPI is sponsored by the U.S. Air Force and the Department of Defense.

FRCS FLIGHT TEST—EIGHT-SECOND PULSE (DTO 248)—If propellant available.

ASCENT STRUCTURAL CAPABILITY EVALUATION (DTO 301D). The purpose of this DTO is to collect data to expand the data base of ascent dynamics for various weights.

ASCENT FLUTTER BOUNDARY EVALUATION (DTO 309).

ET TPS PERFORMANCE—METHOD 2 (DTO 312).

HOT NOSEWHEEL STEERING RUNWAY EVALUATION (DTO 517).

EDWARDS LAKEBED RUNWAY BEARING STRENGTH ASSESSMENT FOR ORBITER LANDINGS (DTO 520)—If applicable.

COMBUSTION PRODUCTS ANALYZER (DTO 645). Should a thermodegradation event occur within the crew cabin the Combustion Products Analyzer (CPA) will ensure the safety of the crew by measuring possible resultant toxic gases. This DTO will verify the CPA function through in-flight checkout. Specifically, CPA operation and calibration stability will be tested.

VIBRATION RECORDINGS ON THE SHUTTLE TREADMILL USING AN ACCELEROMETER (DTO 652). The vibrational impact of the shuttle treadmill is sometimes a concern for material research experiments. This DTO will measure the magnitude and frequency of vibration at the source and on a middeck locker with the aid of the Space Acceleration Measurement System (SAMS). This will allow determination of whether the vibration is amplified or attenuated by the middeck structure. Ultimately, this will assist in the design of a treadmill isolation device or the determination of alternate exercise equipment.

TDRS S-BAND FORWARD LINK RF POWER LEVEL EVALUATION—POSTFLIGHT CALIBRATION INSTEAD OF PREFLIGHT (DTO 700-1). The agreed upon power level of the TDRS forward link is 46.0 dBW. Continued operation at the higher level is not guaranteed due to hardware constraints of the TDRS power amplifier and end-of-life degradation. During low activity periods of the time line, this DTO will test orbiter S-band reception at the lower power level.

ALTERNATE DAP MODE PERFORMANCE EVALUATION (DTO 798). This DTO will demonstrate the in-flight operation of the alternate mode of the on-orbit digital autopilot by performing representative control scenarios and thereby establishing an initial level of confidence in this system.

PGSC/PSDM/AIR/GROUND COMMUNICATIONS DEMO (DTO 799). This DTO will demonstrate the operational ability of the integrated payload and general support computer/portable audio data modem (PGSC/PADM) system to uplink and downlink STS and payload data files from the FAO MPSR via the orbiter voice communications link.

CROSSWIND LANDING PERFORMANCE (DTO 805).

SPACE STATION CURSOR CONTROL DEVICE EVALUATION (DTO 1208). This DTO will evaluate several hardware items and software concepts that are being considered for the space station. The evaluations include cursor control devices, portable computers, and electronic flight data file.

IN-FLIGHT AEROBIC EXERCISE (DSO 476). Daily in-flight aerobic exercise will (1) inhibit the decrease in cardiac dimensions observed during space flight and thus improve postflight orthostatic tolerance, and (2) minimize the loss of aerobic capacity after flight. The STS-43 crew is divided into two groups (exercisers and nonexercisers) who participate in daily measurements of resting heart rate. The exercisers will conduct detailed test protocols of aerobic exercise while measurement of ECG and heart rate are recorded. This research hopes to develop countermeasures that will provide complete prevention of post-spaceflight orthostatic intolerance.

IN-FLIGHT LOWER BODY NEGATIVE PRESSURE (LBNP) (DSO 478). Fluid loading via ingestion of salt tablets and water in association with lower body negative pressure (LBNP) treatment will protect tolerance to orthostasis (simulated in-flight by LBNP). The objective of this study is to evaluate the effectiveness of fluid loading during LBNP in improving tolerance of a LBNP stress protocol.

CHANGES IN BARORECEPTOR REFLEX FUNCTION (DSO 601).

VARIABILITY OF BLOOD PRESSURE AND HEART RATE DURING SPACE FLIGHT (DSO 602). The objective of this DSO is to determine whether arterial blood pressure and heart rate exhibit less variability in a microgravity environment than on Earth. The data will be used to investigate whether reduced blood pressure variability in flight, if any, is correlated with the extent of baroreflex attenuation that has been measured postflight. Integrity of the baroreceptor function is required for the appropriate blood pressure responses to the orthostatic stresses imposed by entry, landing, and egress. The crewmember will wear blood pressure and electrocardiograph equipment for two flight days on orbit.

ORTHOSTATIC FUNCTION DURING ENTRY, LANDING, AND EGRESS (DSO 603). The objective of this DSO is to measure the changes in orthostatic function of crewmembers during the actual stresses of entry, landing, and egress from the orbiter. Crewmembers will don equipment prior to donning the LES during deorbit preparation. Equipment consists of a blood pressure monitor, accelerometers, an impedance cardiograph, and transcranial Doppler hardware. The crewmember wears the equipment and records verbal comments through entry.

VISUAL VESTIBULAR INTEGRATION AS A FUNCTION OF ADAPTATION (DSO 604). The objective of this DSO is to investigate visual vestibular and perceptual adaptive responses as a function of mission duration. The operational impact of these responses on the crewmembers ability to conduct entry, landing, and egress procedures will also be investigated. For STS-43, four sessions will be scheduled where the crewmember performs head movements at a slow frequency while verbally recording self and surrounding motion sensations. The sessions are scheduled early on orbit, late in the flight, during entry, and immediately post landing.

POSTURAL EQUILIBRIUM CONTROL DURING LANDING EGRESS (DSO 605).

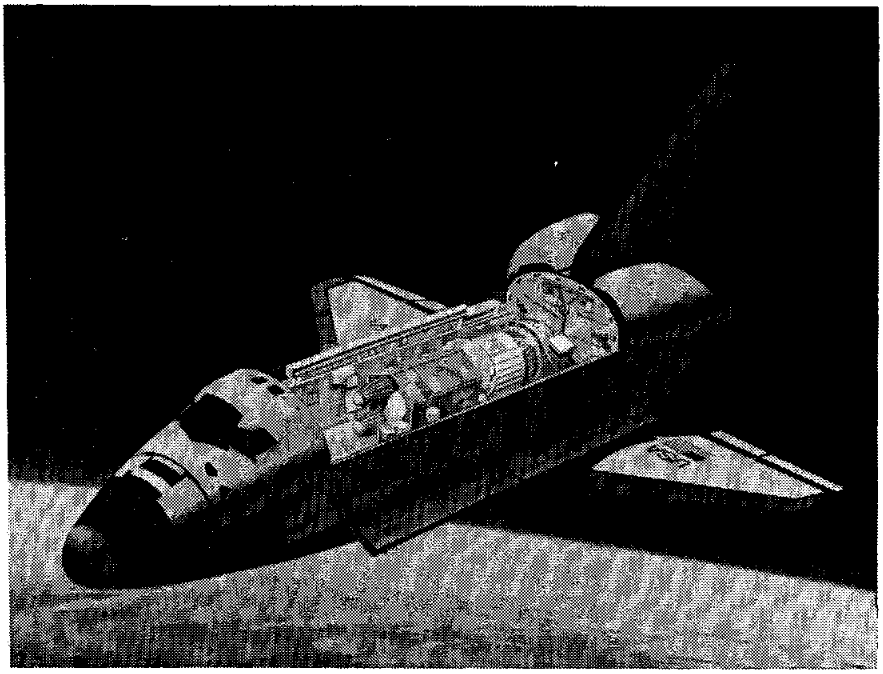
ENDOCRINE REGULATION OF ORTHOSTATIC TOLERANCE FOLLOWING SPACE FLIGHT (DSO 613).

EFFECT OF PROLONGED SPACE FLIGHT ON HEAD AND GAZE STABILITY DURING LOCOMOTION (DSO 614). This test will characterize head and body movement along with gaze stability during walking and running in association with regular treadmill exercise. These factors are relevant to egress from the shuttle and will be compared to baseline and postflight data.

DOCUMENTARY TELEVISION (DSO 901). This DSO requires live television transmission or VTR dumps of crew activities and spacecraft functions which include: payload bay views, TDRS predeploy, deploy, and separation activities, views of payload bay attached payloads, in-flight crew conference, views of middeck payload sessions, and unscheduled TV activities.

DOCUMENTARY MOTION PICTURE PHOTOGRAPHY (DSO 902). This DSO requires documentary and public affairs motion picture photography of significant activities which best depicts the basic capabilities of the space shuttle and key objectives. This DSO includes motion picture photography of IUS predeploy and deploy activities, middeck activities, and any unscheduled motion picture photography.

DOCUMENTARY STILL PHOTOGRAPHY (DSO 903). This DSO requires still photography of crew activities in the orbiter, spacecraft accommodations, and mission related scenes of general public and historical interest. Still photography with 70mm format for exterior photography and 35mm format for interior photography is required.



STS-43

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

July 1991

Rockwell International
Space Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the 9th flight of Atlantis and the 42nd for the space shuttle.

The flight crew for the STS-43 mission consists of commander John E. Blaha; pilot Michael (Mike) A. Baker; and mission specialists Shannon W. Lucid, G. D. (David) Low, and James (Jim) C. Adamson.

STS-43's primary mission objective is to successfully deploy NASA's Tracking and Data Relay Satellite (TDRS)-E using the Air Force's Inertial Upper Stage (IUS) booster.

TDRS-E is the fifth communications satellite launched in the process of assembling the Tracking and Data Relay Satellite System (TDRSS). TDRSS will provide a high-capacity communication and data link with the shuttle as well as other spacecraft and launch vehicles. The nominal IUS/TDRS-E deployment opportunity occurs on Orbit 5 at 0/6:13 Mission Elapsed Time (MET).

The IUS is a two-stage solid rocket, inertially stabilized upper stage that will place TDRS-E in a geosynchronous orbit. The IUS ignites its first stage (SRM-1) for transfer orbit insertion.

Twelve secondary objectives will be flown on STS-43: Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03, Space Station Heatpipe Advanced Radiator Element (SHARE)-II, Optical Communications Through the Shuttle Window (OCTW), Solid Surface Combustion Experiment (SSCE)-02, Space Acceleration Measurement System (SAMS), Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02, Tank Pressure Control Experiment (TPCE), Investigations Into Polymer Membrane Processing (IPMP)-03, Protein Crystal Growth (PCG)-III Block II, Air Force Maui Optical Site (AMOS), and Auroral Photography Experiment (APE)-B. In addition, a space-based experiment, the Ultraviolet Plume Instrument (UVPI), will be conducted using the orbiter as a data source.

The SSBUV-03 instrument is designed to provide calibration of backscatter ultraviolet (UV) instruments currently being flown on free-flying satellites. The payload configuration consists of two canisters interconnected by cables mounted on a Get Away Special (GAS) adapter beam in the orbiter payload bay. One canister contains the SSBUV spectrometer; the other contains data, command, and power systems. Crew interface is through a GAS autonomous payload controller (GAPC) on the aft flight deck. After an outgassing period, the instrument will operate in three modes: Earth view, solar view, and calibration.

SHARE-II will demonstrate the on-orbit zero-gravity thermal vacuum performance of high-capacity heatpipes under various thermal conditions to determine their suitability as a dependable, durable heat rejection system for Space Station Freedom (SSF). The experiment consist of two prototypical radiator panels and an Instrumentation and Control System. Ground support equipment is located at JSC. SHARE-II is a redesigned version of the SHARE experiment that flew on STS-29.

OCTW is a JSC-sponsored experiment designed to demonstrate the optical transmission of video and audio data from the crew cabin to the payload bay and back through the shuttle aft flight deck window by means of fiber optic technology rather than conventional radio frequency technology. It consists of two modules: one inside the orbiter crew cabin and one in the payload bay. The crew cabin module will house an optoelectronic transmitter/receiver pair for video and digital subsystems, test circuitry, and interface circuitry. The payload bay module serves as a repeater station. System performance will be measured by recording video test patterns and digital signal integrity on the orbiter closed-circuit television videotape recorder system. Four tests are planned under various payload bay temperature and lighting conditions.

The primary objective of SSCE-02 is to supply information on flame spread over solid fuel surfaces in the reduced gravity environment of space. The experiment will measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds in low gravity. The data obtained will be used to validate flame spread models to improve fire safety during space flight.

For this flight, ashless filter paper has been selected as the "thin" fuel source, with polymethyl-methacrylate as the "thick" fuel source. The samples are mounted in a pressurized chamber.

SAMS will provide other shuttle payloads with data on the shuttle middeck and/or middeck-mounted experiments' acceleration environment. The payload consists of three triaxial accelerometers connected to a digital encoder with an optical disk data recorder. SAMS is mounted in a single middeck locker. Accelerometer heads will be mounted to the treadmill and adjacent to the PCG and SSCE experiments.

BIMDA-02 is designed to investigate the methods and commercial potential of biomedical and fluid science applications in the microgravity environment of space. Both basic and applied research will be conducted in three broad areas: bioprocessing, fluid science, and manufacturing technology. BIMDA-02 consists of three experiments housed within a refrigerator/incubator module (R/IM). The payload elements are as follows: four materials dispersion apparatus (MDA) minilabs, six bioprocessing modules (BM), six cell syringes (CS), and one automatic temperature recorder. The BIMDA occupies the space of one middeck locker, and draws 28 Vdc power for the R/IM. The MDA, BIMDA-02's primary objective, will study protein crystal growth, collagen polymerization and several other phenomena. The BM and CS experiments will study the response of live cells to various stimulating agents.

TPCE will determine the effectiveness of jet mixing as a means of controlling tank pressures and equilibrating fluid temperatures. TPCE is installed in a sealed GAS canister attached to a GAS adapter beam in the payload bay.

The research objective of the IPMP-03 payload is to flash evaporate mixed solvent systems in the absence of convection to control the porosity of the polymer membrane. With at least 24 hours remaining before entry the crew will activate the experiment and log the MET.

PCG III Block II is designed to conduct experiments that will supply information on the scientific methods and commercial potential for growing large, high-quality protein crystals in microgravity. The PCG will be installed and operated on the orbiter middeck.

The primary objective of AMOS is to use the orbiter during cooperative overflights of Maui, Hawaii, to obtain imagery and/or signature data to support the calibration of the AMOS ground-based sensors and to observe orbiter plume phenomenology. No unique onboard hardware is associated with the AMOS test; crew and orbiter participation may be required to establish the controlled conditions for the Maui cooperative overflight.

The objective of APE-B is to photograph and record the spectra of the following aurora phenomena: shuttle glow, thruster emissions, aurora effects on the orbiter, aurora and airglow layer. APE-B equipment consists of a 35mm SLR camera, a 55mm lens, a 135mm lens, an image intensifier, spectrometer bar, filter holder and various filters.

The primary objectives of the UVPI activity are to use the orbiter during cooperative encounters of the low-power atmospheric compensation experiment (LACE) satellite to obtain imagery and/or signature data to support the calibration of UVPI space-based sensors and to observe orbiter events. No unique onboard hardware is associated with the UVPI tests; crew and orbiter participation are required to establish the controlled conditions for the cooperative passes.

Thirteen development test objectives and 12 detailed supplementary objectives are scheduled to be flown on STS-43.

MISSION STATISTICS

Vehicle: Atlantis (OV-104), 9th flight

Launch Date/Time:

7/23/91 10:54 a.m., EDT
9:54 a.m., CDT
7:54 a.m., PDT

Launch Site: Kennedy Space Center (KSC), Fla.--Launch Pad 39A

Launch Window: 4 hours, 20 minutes

Mission Duration: 8 days, 21 hours, 17 minutes

Landing: Nominal end of mission on Orbit 142

8/1/91 8:11 a.m., EDT
7:11 a.m., CDT
5:11 a.m., PDT

Runway: Nominal end-of-mission landing on runway 15, KSC, Fla. Weather alternates are Edwards Air Force Base (EAFB), Calif., and Northrop Strip (NOR), White Sands, New Mexico

Transatlantic Abort Landing: Banjul, Gambia; alternate is Ben Guerir, Morocco

Return to Launch Site: KSC

Abort-Once-Around: EAFB

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 orbit. This direct-insertion profile lofts the trajectory to provide the earliest opportunity for orbit in the event of a problem with a space shuttle main engine.

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 2 minutes is eliminated in this direct-insertion ascent profile. The OMS-1 thrusting maneuver is replaced by a 5-foot-per-second reaction control system maneuver to facilitate the main propulsion system propellant dump.

Altitude: 160 nautical miles (184 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,526,488 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 259,382 pounds

Payload Weight Up: Approximately 46,882 pounds

Payload Weight Down: Approximately 9,242 pounds

Orbiter Weight at Landing: Approximately 196,735 pounds

Payloads--Payload Bay (* denotes primary payload): Tracking and Data Relay Satellite (TDRS)-E/Inertial Upper Stage (IUS)*; Space Station Heatpipe Advanced Radiator Element (SHARE)-II; Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03; Optical Communications Through the Shuttle Window (OCTW)

Payloads--Middeck: Air Force Maui Optical Site (AMOS) Calibration Test; Auroral Photography Experiment (APE)-B; Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02; Investigations Into Polymer Membrane Processing (IPMP)-03; Protein Crystal Growth III Block II; Space Acceleration Measurement System (SAMS); Solid Surface Combustion Experiment (SSCE)-02; Tank Pressure Control Experiment (TPCE)

Flight Crew Members:
- Commander: John E. Blaha, third space shuttle flight
- Pilot: Michael (Mike) A. Baker, first space shuttle flight
- Mission Specialist 1: Shannon W. Lucid, third space shuttle flight
- Mission Specialist 2: G. D. (David) Low, second space shuttle flight
- Mission Specialist 3: James (Jim) C. Adamson, second space shuttle flight

Ascent Seating:
- Flight deck, front left seat, commander John E. Blaha
- Flight deck, front right seat, pilot Michael (Mike) A. Baker
- Flight deck, aft center seat, mission specialist G. D. (David) Low
- Flight deck, aft right seat, mission specialist Shannon W. Lucid
- Middeck, mission specialist James (Jim) C. Adamson

Entry Seating:
- Flight deck, aft center seat, mission specialist G. D. (David) Low
- Flight deck, aft right seat, mission specialist James (Jim) C. Adamson
- Middeck, mission specialist Shannon W. Lucid

Extravehicular Activity Crew Members, If Required:
- Extravehicular (EV) astronaut-1 is James (Jim) C. Adamson; EV-2 is G. D. (David) Low

Intravehicular Astronaut: Michael (Mike) A. Baker

Entry: Automatic mode until subsonic, then control-stick steering

Notes:

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

MISSION OBJECTIVES

- Primary Payload
  - Deployment of Tracking and Data Relay Satellite (TDRS)-E/Inertial Upper Stage (IUS)
- Secondary Payloads
  - Payload Bay
    - Space Station Heatpipe Advanced Radiator Element (SHARE)-II
    - Shuttle Solar Backscatter Ultraviolet (SSBUV) Instrument 03
    - Optical Communications Through the Shuttle Window (OCTW)
  - Middeck
    - Air Force Maui Optical Site (AMOS) Calibration Test
    - Auroral Photography Experiment (APE)-B
    - Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA)-02
    - Investigations Into Polymer Membrane Processing (IPMP)-03
    - Protein Crystal Growth (PCG)-III Block II
    - Space Acceleration Measurement System (SAMS)
    - Solid Surface Combustion Experiment (SSCE)-02
    - Tank Pressure Control Experiment (TPCE)
- Space-Based Experiment
  - Ultraviolet Plume Instrument (UVPI)
- Development Test Objectives (DTOs)/Detailed Supplementary Objectives (DSOs)

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
SAMS, PCG, TPCE, SSBUV, and BIMDA activation
TDRS/IUS deploy, Orbit 5
DSO: 476

Flight Day 2

TDRS/IUS backup deploy opportunity
BIMDA, PCG, SAMS, SSBUV, and SHARE operations
DTOs: 645, 652, and 799
DSOs: 476, 478, 602, and 604

Flight Day 3

BIMDA, SAMS, OCTW, SSBUV, and PCG operations
TPCE deactivation
DTOs: 645 and 1208
DSOs: 476, 478, and 602

Flight Day 4

SSBUV, SHARE, OCTW, PCG, and SAMS operations
DTOs: 645, 799, and 1208
DSOs: 476 and 602

Flight Day 5

SSBUV, OCTW, SAMS, SHARE, BIMDA, IPMP, AMOS, and PCG operations
DTOs: 645 and 1208
DSOs: 476 and 602

Flight Day 6

SHARE, PCG, SAMS, SSCE, and APE operations
DTOs: 645, 798, and 799
DSOs: 476 and 478

Flight Day 7

SAMS, PCG, SHARE, APE, and AMOS operations
DTOs: 645, 798, and 1208
DSOs: 476, 478, and 604

Flight Day 8

PCG, SAMS, SHARE, and APE operations
BIMDA stow
LBNP ramp, stow
Crew conference
RCS hot fire
FCS checkout
DTOs: 645, 799, and 1208
DSOs: 476, 478, 602, and 604

Flight Day 9

PCG operations
Cabin stow
DTO: 645 and 1208
DSOs: 476, 602, and 604
Deorbit preparation
Deorbit burn
Landing

Notes:

- An approved exemption authorizes a Flight Day 2 backup TDRS deployment unscheduled EVA, if necessary.

- An approved exemption provides details for the crew exercise protocol to support Extended Duration Orbiter (EDO) buildup.

- Each flight day includes a number of scheduled housekeeping activities. These include inertial measurement unit alignment, supply water dumps (as required), waste water dumps (as required), fuel cell purge, Ku-band antenna cable repositioning, and a daily private medical conference.

STS-43 CREW ASSIGNMENTS

Commander (John E. Blaha):

Overall mission decisions

Orbiter: DPS, MPS, OMS/RCS, APU/hydraulics, EPS, IV

Payload: IPMP-03, APE-B

DTOs/DSOs: DTO 798; DSOs 476 and 602

Pilot (Michael [Mike] A. Baker):

Orbiter: MPS, OMS/RCS, APU/hydraulics, EPS, IV, SPOC, IFM, FDF, flight rules, TAGS

Payload: SSBUV-03, SHARE-II, AMOS

DTOs/DSOs: DSOs 478 and 602

Other: Earth observations, geography, oceanography

Mission Specialist 1 (Shannon W. Lucid):

Orbiter: ECLSS (FES), communications/instrumentation, payload bay door open/close, medic, crew equipment, flight rules

Payload: IUS/TDRS-E, OCTW, PCG III Block II, BIMDA-02, SSCE-02, APE-B

DTOs/DSOs: DTOs 1208 and 799; DSOs 603 and 604

Mission Specialist 2 (G. D. [David] Low):

Orbiter: DPS, photo/TV, camcorder, EVA/EMU, SPOC, FDF

Payload: SAMS

DTOs/DSOs: DTOs 1208 and 799; DSOs 476, 478, and 602

Other: oceanography, meteorology

Mission Specialist 3 (James [Jim] C. Adamson):

Orbiter: ECLSS, communications/instrumentation, payload bay door open/close, photo/TV, camcorder, EVA/EMU, medic, crew equipment, IFM, TAGS

Payload: IUS/TDRS-E, SSBUV-03, SHARE-II, TPCE, OCTW, SAMS, SSCE-02, IPMP-03

DTOs/DSOs: DTOs 1208 and 798

Other: Earth observations, geography, meteorology

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- FRCS flight test--eight-second pulse (if propellant available) (DTO 248)
- Ascent structural capability evaluation (DTO 301D)
- Ascent flutter boundary evaluation (DTO 309)
- ET TPS performance--method 2 (DTO 312)
- Hot nosewheel steering runway evaluation (DTO 517)
- Edwards lakebed runway bearing strength assessment for orbiter landings (if applicable) (DTO 520)
- Combustion products analyzer (DTO 645)
- Vibration recordings on the shuttle treadmill using an accelerometer (DTO 652)
- TDRS S-band forward link RF power level evaluation--postflight calibration instead of preflight (DTO 700-1)
- Alternate DAP mode performance evaluation (DTO 798)
- PGSC/PADM air/ground communications demonstration (DTO 799)
- Crosswind landing performance (DTO 805)
- Space station cursor control device evaluation II and advanced applications, ac power (DTO 1208)

DSOs

In Flight:

- In-flight aerobic exercise (DSO 476)
- In-flight LBNP (DSO 478)
- Heart rate and blood pressure variability (DSO 602)
- Orthostatic function during entry, landing, and egress (DSO 603)
- Visual vestibular integration as a function of adaption, OI-1, OI-3 (DSO 604)
- Head and gaze stability during locomotion (DSO 614)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)

Pre- and Postflight Only:

- Baroreceptor reflex function (DSO 601)
- Postural equilibrium control during landing/egress (DSO 605)
- Endocrine regulation of orthostatic tolerance following space flight (DSO 613)

STS-43 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.
02:55:00	Flight crew departs Operations and Checkout (O&C) Building for launch pad.
02:25:00	Flight crew orbiter and seat ingress occurs.
02:10:00	Post ingress software reconfiguration occurs.
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	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	The flight crew starts the communications checks.
01:25:00	The SRB RGA torque test begins.
01:20:00	Orbiter side hatch is closed.
01:10:00	Orbiter side hatch seal and cabin leak checks are performed.
01:01:00	IMU preflight align begins. Flight crew functions from this point on will be initiated by a call from the orbiter test conductor (OTC) to proceed. The flight crew will report back to the OTC after completion.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
01:00:00	The orbiter RGAs and AAs are tested.
00:50:00	The flight crew starts the orbiter hydraulic auxiliary power units' (APUs') 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.
	The landing convoy status is again verified and the landing sites are verified ready for launch.
	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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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.
	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 Hold 10 Minutes	A planned 10-minute hold starts.
	NASA and contractor project managers will be formally polled by the deputy director of NASA, Space Shuttle Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records.
	All test support team members verify that they are "go for launch."
	Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins.
	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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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.
00:06:00	APU prestart occurs.
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.
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.
00:03:25	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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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.
00:02:30	The caution/warning memory is cleared.
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.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.
00:00:47	The liquid oxygen and liquid hydrogen outboard fill and drain valves are closed.
00:00:40	The external tank bipod heaters are turned off.
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.
	The SRB forward MDM is locked out.
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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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. The orbiter vent door sequence starts.
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. The SRB gimbal test begins.
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 sound suppression system water is activated.
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.
00:00:13	The aft SRB 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. SRB SRSS inhibits are removed. The SRB destruct system is now live.
00:00:12	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.
00:00:10	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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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 MPSs 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. 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 does 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.

STS-43 MISSION HIGHLIGHTS TIMELINE

Editor's Note: The following timeline lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-43 Flight Plan, Ascent Checklist, Post Insertion Checklist, Deorbit Prep Checklist, Entry Checklist, and IUS Deploy Checklist.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY ZERO	
0/00:00:07	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:09	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down (astronauts), wings level.
0/00:00:16	Roll maneuver ends.
0/00:00:24	All three SSMEs throttle down from 104 to 67 percent for maximum aerodynamic load (max q).
0/00:00:52	Max q occurs.
0/00:00:58	All three SSMEs throttle to 104 percent.
0/00:02:04	SRBs separate.
	When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:03:55	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:05:32	Single engine press to main engine cutoff (MECO).
0/00:07:27	All three SSMEs throttle down from 104 percent--vehicle acceleration capability no greater than 3g's.
0/00:08:20	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:25	MECO occurs at approximate velocity 25,873 feet per second, 36 by 157 nautical miles (41 by 180 statute miles).
0/00:08:44	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	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.
	--MPS vacuum inerting terminates.
0/00:42	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 22 seconds in duration, at 223 fps, 159 by 161 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.
0/00:59	MS configures aft flight station.
0/01:02	MS unstows, sets up, and activates PGSC.
0/01:06	Pilot activates payload bus (panel R1).
0/01:08	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive Y velocity vector attitude.
0/01:13	Orbit 2 begins.
0/01:17	Commander activates radiators.
0/01:19	If go for payload bay door operations, MS configures for payload bay door operations.
0/01:28	Pilot opens payload bay doors.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:30	Commander loads payload data interleaver decommutator format.
0/01:33	Commander switches star tracker (ST) power 2 (panel 06) to ON.
0/01:35	MS sets OCTW heater power to AUTO and experiment power to ON.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	Commander and pilot seat egress.
0/01:38	Commander and pilot clothing configuration.
0/01:39	MS clothing configuration.
0/01:50	Pilot initiates fuel cell auto purge.
0/01:51	MS activates teleprinter (if flown).
0/01:52	Commander begins post-payload bay door operations and radiator configuration.
0/01:55	MS removes and stows seats.
0/01:56	Commander starts ST self-test and opens door.
0/01:57	MS configures middeck.
0/01:58	Pilot closes main B supply water dump isolation circuit breaker, panel ML86B, opens supply water dump isolation valve, panel R12L.
0/02:00	MS activates PCP/CIU/SSP and performs checkout.
0/02:01	Pilot activates auxilary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:10	Commander configures for RCS vernier control.
0/02:12	Commander and pilot configure controls for on-orbit operations.
0/02:15	Commander clears star table.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/02:21	Pilot enables hydraulic thermal conditioning.
0/02:24	MS resets caution/warning (C/W).
0/02:25	MS unstows and installs treadmill.
0/02:26	Pilot switches APU coolant system (panel R2) fuel pump/valve A to OFF, B to AUTO.
0/02:28	Pilot plots fuel cell performance.
0/02:30	Unstow cabin.
0/02:30	Systems management cockpit initiation occurs.
0/02:30	P/TV02 activation.
0/02:30	Actuator engagement.
0/02:35	Aft controller checkout.
0/02:40	IUS predeployment checkout.
0/02:43	Orbit 3 begins.
0/02:45	Cryo oxygen tank heater sensor check.
0/02:55	IUS direct check.
0/03:05	IUS PI check.
0/03:15	TDRS PI check.
0/03:15	TDRS command check.
0/03:25	SAMS activation.
0/03:35	Maneuver vehicle to IMU alignment attitude.
0/03:35	P/TV03 setup (TDRS deployment).
0/03:40	APU heater deactivation.
0/03:50	IMU alignment: ST.
0/03:50	PCG activation.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/04:00	APU cool B.
0/04:05	Transfer SV.
0/04:13	Orbit 4 begins.
0/04:15	Maneuver vehicle to TDRS check attitude.
0/04:20	P/TV03 activation (TDRS deployment).
0/04:30	Elevate tilt table to 29 degrees.
0/04:40	Meal.
0/04:40	TDRS direct check.
0/04:55	IUS/PI lock.
0/05:20	Reconfigure APU heater gas generator/fuel pump B to AUTO.
0/05:33	Maneuver vehicle to TDRS deploy attitude.
0/05:40	P/TV03 activation (TDRS deployment).
0/05:44	Orbit 5 begins.
0/05:48	Deployment countdown begins.
0/06:13	TDRS/IUS deployment.
0/06:15	Maneuver vehicle to separation attitude.
0/06:20	Lower tilt table to -6 degrees.
0/06:28	OMS separation burn, approximately 16 seconds in duration, at 31 feet per second, 177 by 161 nm.
0/06:33	Maneuver vehicle to IUS viewing attitude.
0/06:50	Maneuver vehicle to protect attitude.
0/06:55	Closeout.
0/07:14	Orbit 6 begins.
0/07:14	SRM-1 ignition.
0/07:25	Maneuver vehicle to -ZLV, +YVV attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/07:40	Deploy Ku-band antenna.
0/07:45	VTR setup.
0/07:50	Ku-band antenna activation.
0/08:00	VTR playback.
0/08:00	Crew begins presleep activities.
0/08:15	APC unstow/setup.
0/08:15	Maneuver vehicle to IMU alignment attitude.
0/08:25	TPCE activation/checkout.
0/08:30	IMU alignment: ST.
0/08:35	SSBUV system verification.
0/08:35	Maneuver vehicle to -ZLV, -XVV attitude.
0/08:45	Orbit 7 begins.
0/08:50	Reconfigure APU heater gas generator/fuel pump A to AUTO.
0/08:50	P/TV06 setup (SSBUV).
0/09:10	P/TV06 activation (SSBUV).
0/09:20	Initiate SSBUV outgassing.
0/09:30	Private medical conference.
0/10:16	Orbit 8 begins.
0/11:00	Crew begins sleep period.
0/11:47	Orbit 9 begins.
0/13:17	Orbit 10 begins.
0/14:48	Orbit 11 begins.
0/16:18	Orbit 12 begins.
0/17:49	Orbit 13 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/19:00	Postsleep activities.
0/19:00	DSO 476--In-flight aerobic exercise (pulse rate).
0/19:20	Orbit 14 begins.
0/20:05	SSBUV outgas termination.
0/20:15	SSBUV activation.
0/20:50	P/TV05 setup (middeck activities).
0/20:50	Orbit 15 begins.
0/20:55	BIMDA test bed setup.
0/21:10	SSBUV MDA close.
0/21:10	BIMDA cell syringe activation.
0/21:15	SSBUV calibration initiation.
0/21:20	P/TV05 activation (middeck activities).
0/21:25	BIMDA bioprocessing modules activation.
0/21:40	BIMDA MDA activation.
0/21:45	Maneuver vehicle to IMU alignment attitude.
0/22:00	IMU alignment: ST.
0/22:00	SHARE II MDM verification.
0/22:05	Maneuver vehicle to solar view (-ZSI) attitude.
0/22:05	MDA activation.
0/22:10	SSBUV calibration termination.
0/22:15	PCG fan inlet cleaning/temperature check.
0/22:21	Orbit 16 begins.
0/22:25	SSBUV solar initiation.
0/23:15	SSBUV solar termination.
0/23:20	Maneuver vehicle to -ZLV, +XVV attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/23:45	VTR setup.
0/23:52	Orbit 17 begins.

MET DAY ONE

1/00:00	VTR playback.
1/00:00	DSO 604--Visual vestibular integration as a function of adaption, OI-3.
1/00:45	DSO 604--Visual vestibular integration as a function of adaption, OI-1.
1/00:45	P/TV06 setup (SSBUV).
1/00:55	SAMS disk check.
1/01:05	SHARE II -ZLV precondition activation.
1/01:05	P/TV06 activation (SSBUV).
1/01:15	SSBUV Earth view initiation.
1/01:22	Orbit 18 begins.
1/01:45	DSO 602--Blood pressure variability.
1/02:40	SHARE II -ZLV (I) heater activation.
1/02:53	Orbit 19 begins.
1/03:05	Meal.
1/04:05	Filter cleaning.
1/04:23	Orbit 20 begins.
1/04:40	SHARE II -ZLV (I) heater deactivation.
1/05:00	DTO 645--combustion products analyzer operations.
1/05:00	SAMS optical disk changeout.
1/05:24	Orbit 21 begins.
1/06:00	Commander and MS 2 perform DSO 476--In-flight aerobics.
1/06:00	P/TV05 setup (middeck activities).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/06:00	SHARE II -ZLV (II) heater activation.
1/06:15	PCG temperature check.
1/06:20	P/TV05 activation (middeck activities).
1/07:10	DTO 799--PGSC/modem demonstration.
1/07:15	SAMS disk check.
1/07:25	Orbit 22 begins.
1/07:30	SHARE II -ZLV (II) heater deactivation, step 1.
1/07:30	Crew begins presleep activities.
1/07:45	Private medical conference.
1/08:25	SHARE II -ZLV (II) heater deactivation, step 2.
1/08:30	Maneuver vehicle to IMU alignment attitude.
1/08:45	IMU alignment: ST.
1/08:50	COAS calibration: aft station.
1/08:55	Orbit 23 begins.
1/09:00	BIMDA cell syringe sample.
1/09:00	Maneuver vehicle to -ZLV, +XVV attitude.
1/10:26	Orbit 24 begins.
1/10:30	Crew begins sleep period.
1/11:56	Orbit 25 begins.
1/13:26	Orbit 26 begins.
1/14:57	Orbit 27 begins.
1/16:28	Orbit 28 begins.
1/17:58	Orbit 29 begins.
1/18:30	Postsleep activities.
1/18:30	DSO 476--In-flight aerobics (pulse rate).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/19:30	Orbit 30 begins.
1/20:00	SAMS optical disk changeout.
1/20:15	SSBUV Earth view termination.
1/20:30	Maneuver vehicle to IMU alignment attitude.
1/20:45	IMU alignment: ST.
1/20:50	Maneuver vehicle to -ZSI (solar view) attitude.
1/20:55	BIMDA cell syringe sample.
1/20:59	Orbit 31 begins.
1/21:05	SSBUV solar initiation.
1/21:10	BIMDA bioprocessing module sample.
1/21:30	DTO 799--PGSC/modem powerdown.
1/21:30	DSO 478--lower-body negative pressure setup.
1/21:45	PCG fan inlet cleaning/temperature check.
1/21:55	SSBUV solar view termination.
1/22:00	P/TV05 setup (middeck activities).
1/22:05	Maneuver vehicle to -ZLV, +YVV attitude.
1/22:05	SSBUV calibration initiation.
1/22:20	P/TV05 activation (middeck activities).
1/22:31	Orbit 32 begins.
1/23:05	SSBUV calibration termination.
1/23:15	DSO 478--lower-body negative pressure test preparation.
1/23:45	DSO 478--lower-body negative pressure ramp setup.

MET DAY TWO

2/00:02	Orbit 33 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/00:15	DSO 478 egress/reconfiguration.
2/00:30	Meal.
2/01:00	TPCE deactivation.
2/01:30	P/TV05 setup (middeck activities).
2/01:33	Orbit 34 begins.
2/01:45	DSO 602--blood pressure variability equipment doff.
2/02:00	P/TV05 activation (middeck activities).
2/02:15	SAMS disk check.
2/02:30	Supply water dump using FES.
2/02:35	DSO 478--lower-body negative pressure test preparation.
2/02:45	Maneuver vehicle to biased -ZLV, +XVV attitude.
2/03:00	DSO 478--lower-body negative pressure ramp test (pilot).
2/03:00	SSBUV Earth view initiation.
2/03:03	Orbit 35 begins.
2/03:30	DTO 645--combustion products analyzer operations.
2/03:30	DSO 478 egress/reconfiguration.
2/04:00	DSO 476--In-flight aerobics (commander, MS 2).
2/04:33	Orbit 36 begins.
2/05:40	DTO 1208--Mac modem data transfer setup.
2/05:50	SAMS optical disk changeout.
2/05:55	PCG temperature check.
2/06:00	Presleep activities.
2/06:04	Orbit 37 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/06:30	Private medical conference.
2/07:10	Maneuver vehicle to IMU alignment attitude.
2/07:25	IMU alignment: ST.
2/07:35	Orbit 38 begins.
2/07:35	Maneuver vehicle to -ZLV, +XVV attitude.
2/08:30	Supply water dump using FES.
2/09:00	Crew begins sleep period.
2/09:05	Orbit 39 begins.
2/10:36	Orbit 40 begins.
2/12:06	Orbit 41 begins.
2/13:37	Orbit 42 begins.
2/15:08	Orbit 43 begins.
2/16:38	Orbit 44 begins.
2/17:00	Postsleep activities.
2/17:00	DSO 476--In-flight aerobics (pulse rate).
2/17:35	SSBUV Earth view termination.
2/17:55	Maneuver vehicle to IMU alignment attitude.
2/18:09	Orbit 45 begins.
2/18:10	IMU alignment: ST.
2/18:15	Maneuver vehicle to -ZSI (solar view) attitude.
2/19:00	P/TV04 setup (OCTW).
2/19:15	SAMS disk check.
2/19:25	P/TV04 activation (OCTW).
2/19:35	Unstow OCTW.
2/19:40	Orbit 46 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/19:50	OCTW powerup.
2/19:50	DTO 1208--Mac modem transfer powerdown.
2/19:50	SSBUV solar view initiation.
2/20:05	OCTW hot test.
2/20:30	PCG fan inlet cleaning/temperature check.
2/20:40	SSBUV solar view termination.
2/20:50	SSBUV calibration initiation.
2/20:55	Maneuver vehicle to -XSI attitude.
2/21:10	Orbit 47 begins.
2/21:25	BIMDA cell syringe sample.
2/21:30	Cabin temperature control reconfiguration.
2/21:50	DTO 1208--cursor control evaluation II.
2/21:50	SSBUV calibration termination.
2/21:55	BIMDA bioprocessing module sample.
2/22:15	SSBUV data transfer.
2/22:30	Supply water dump using FES.
2/22:35	SSBUV deactivation.
2/22:41	Orbit 48 begins.
2/22:55	P/TV04 setup (OCTW).
2/23:10	SAMS optical disk changeout.
2/23:15	P/TV04 activation (OCTW).
2/23:25	OCTW powerup.
2/23:45	OCTW cold test.

MET DAY THREE

3/00:10	SHARE II -XSI (I) heater activation, step 1.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/00:10	SAMS disk check.
3/00:11	Orbit 49 begins.
3/00:15	Meal.
3/01:25	SHARE II -XSI (I) heater activation, steps 2-7.
3/01:42	Orbit 50 begins.
3/02:00	DSO 476--In-flight aerobics (commander).
3/02:00	P/TV04 setup (DTO 1208).
3/02:20	P/TV04 activation (DTO 1208).
3/02:30	DTO 1208--cursor control evaluation II.
3/03:13	Orbit 51 begins.
3/03:30	DTO 645--combustion products analyzer operations.
3/03:30	SHARE II -XSI (I) heater deactivation.
3/04:10	Private medical conference.
3/04:10	SAMS optical disk changeout.
3/04:30	PCG temperature check.
3/04:30	DSO 476--In-flight aerobics (MS 2).
3/04:40	SHARE II -XSI (II) heater activation.
3/04:43	Orbit 52 begins.
3/05:40	DTO 799--PGSC/modem demonstration.
3/05:45	SHARE II -XSI (II) heater deactivation, step 1.
3/06:00	Crew begins presleep activities.
3/06:09	Orbit 53 begins.
3/06:15	P/TV06 setup (SSBUV).
3/06:35	P/TV06 activation (SSBUV).
3/06:35	SHARE II -XSI (II) heater deactivation, step 2.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/06:35	Maneuver vehicle to -ZLV, +XVV attitude.
3/06:45	SSBUV activation.
3/07:00	Supply water dump using FES.
3/07:25	Maneuver vehicle to IMU alignment attitude.
3/07:40	IMU alignment: ST.
3/07:45	Orbit 54 begins.
3/07:45	Maneuver vehicle to -ZLV, +XVV attitude.
3/07:50	SSBUV Earth view initiation.
3/09:00	Crew begins sleep period.
3/09:15	Orbit 55 begins.
3/10:46	Orbit 56 begins.
3/12:16	Orbit 57 begins.
3/13:47	Orbit 58 begins.
3/15:17	Orbit 59 begins.
3/16:48	Orbit 60 begins.
3/17:00	Postsleep activities.
3/17:00	DSO 476--In-flight aerobics (pulse rate).
3/18:00	Maneuver vehicle to IMU alignment attitude.
3/18:15	IMU alignment: ST.
3/18:19	Orbit 61 begins.
3/18:25	Maneuver vehicle to -ZLV, +XVV attitude.
3/19:30	DSO 602--blood pressure variability.
3/19:45	Humidity separator reconfiguration.
3/19:50	Orbit 62 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/20:00	DTO 799--PGSC/modem powerdown.
3/20:15	SAMS disk check.
3/20:30	PCG fan inlet cleaning/temperature check.
3/20:30	RCS regulator reconfiguration.
3/20:40	P/TV04 setup (OCTW).
3/20:50	Heater reconfiguration--Configuration B.
3/21:00	ECLSS checkout.
3/21:00	P/TV04 activation (OCTW).
3/21:10	OCTW powerup.
3/21:20	Orbit 63 begins.
3/21:30	PCS 1 (2) configuration.
3/21:30	OCTW day test.
3/22:00	DTO 1208--cursor control evaluation II.
3/22:40	SSBUV Earth view termination.
3/22:45	Maneuver vehicle to -ZSI attitude.
3/22:50	Orbit 64 begins.
3/23:00	DTO 1208--cursor control evaluation II.
3/23:00	SSBUV solar view initiation.
3/23:20	P/TV06 setup (SSBUV).
3/23:40	P/TV06 activation (SSBUV).
3/23:50	SSBUV solar view termination.
3/23:55	Maneuver vehicle to -ZLV, +YVV attitude.

MET DAY FOUR

4/00:05	SSBUV calibration initiation.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/00:10	SAMS optical disk changeout.
4/00:10	Meal.
4/00:21	Orbit 65 begins.
4/01:00	Filter cleaning.
4/01:05	SSBUV calibration termination.
4/01:30	SSBUV data transfer.
4/01:45	SSBUV deactivation.
4/01:52	Orbit 66 begins.
4/01:55	APC stow.
4/02:15	Humidity separator reconfiguration (B).
4/02:20	P/TV04 setup (OCTW).
4/02:25	DTO 645--combustion products analyzer.
4/02:35	SAMS disk check.
4/02:35	DSO 476--In-flight aerobics (commander, MS 2).
4/02:40	P/TV04 activation (OCTW).
4/02:50	OCTW powerup.
4/03:10	OCTW night test.
4/03:23	Orbit 67 begins.
4/03:30	OCTW stow.
4/04:30	PCG temperature check.
4/04:40	DTO 1208--Mac modem data transfer setup.
4/04:53	Orbit 68 begins.
4/05:00	Crew begins presleep activities.
4/05:15	SAMS optical disk changeout.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/05:15	Private medical conference.
4/05:55	Maneuver vehicle to IMU alignment attitude.
4/06:05	IMU alignment: ST.
4/06:05	Maneuver vehicle to COAS calibration attitude.
4/06:24	Orbit 69 begins.
4/06:25	COAS calilbration--forward station.
4/06:30	Maneuver vehicle to -ZLV, +YVV attitude.
4/06:45	Waste dump initiation.
4/07:30	Waste dump termination.
4/07:54	Orbit 70 begins.
4/08:00	Crew begins sleep period.
4/09:25	Orbit 71 begins.
4/10:55	Orbit 72 begins.
4/12:26	Orbit 73 begins.
4/13:56	Orbit 74 begins.
4/15:28	Orbit 75 begins.
4/16:00	Crew begins postsleep activities.
4/16:00	DSO 476--In-flight aerobics (pulse rate).
4/16:57	Orbit 76 begins.
4/17:55	Maneuver vehicle to IMU alignment attitude.
4/18:00	MDA deactivation.
4/18:10	IMU alignment: ST.
4/18:15	Maneuver vehicle to -ZLV, +YVV attitude.
4/18:28	Orbit 77 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/18:30	SHARE II deprime heater activation.
4/19:00	SHARE II two-second X-axis burn.
4/19:00	DTO 1208--Mac modem data transfer powerdown.
4/19:00	SAMS disk check.
4/19:10	PCG fan inlet cleaning/temperature check.
4/19:35	P/TV05 setup (IPMP).
4/19:40	DTO 1208--cursor control evaluation II.
4/19:55	P/TV05 activation (IPMP).
4/19:59	Orbit 78 begins.
4/20:00	SHARE II eight-second X-axis burn.
4/20:05	IPMP.
4/21:00	DSO 602--blood pressure variability equipment doff.
4/21:30	Orbit 79 begins.
4/22:00	BIMDA bioprocessing module activation.
4/22:15	DTO 1208--cursor control evaluation II.
4/22:30	P/TV05 setup (SSCE).
4/22:55	Maneuver vehicle to -ZLV, +XVV attitude.
4/23:01	Orbit 80 begins.
4/23:10	AMOS RCS test.
4/23:10	SAMS optical disk changeout.
4/23:20	Maneuver vehicle to -ZLV, +YVV attitude.
4/23:35	Meal.

MET DAY FIVE

5/00:25	P/TV05 activation (SSCE).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/00:32	Orbit 81 begins.
5/00:35	SSCE activation.
5/01:00	DSO 476--In-flight aerobics (commander, MS 2).
5/01:10	P/TV07 setup (APE-B)--spectrometer mode.
5/01:20	DTO 645--combustion products analyzer operations.
5/01:30	Maneuver vehicle to +ZLV, -XVV attitude.
5/01:45	APE RCS test.
5/01:45	P/TV07 activation (APE-B)--thruster emission (far field).
5/02:03	Orbit 82 begins.
5/03:10	APE RCS test.
5/03:20	P/TV07 stow (APE-B).
5/03:30	PCG temperature check.
5/03:30	Maneuver vehicle to -ZLV, +YVV attitude.
5/03:33	Orbit 83 begins.
5/03:40	DTO 799--PGSC/modem demonstration.
5/04:00	Private medical conference.
5/04:00	Crew begins presleep activities.
5/04:40	Maneuver vehicle to IMU alignment attitude.
5/04:55	IMU alignment: ST.
5/05:00	Maneuver vehicle to -ZLV, +YVV attitude.
5/05:04	Orbit 84 begins.
5/05:40	SAMS disk check.
5/06:34	Orbit 85 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/07:00	Crew begins sleep period.
5/08:04	Orbit 86 begins.
5/09:35	Orbit 87 begins.
5/11:06	Orbit 88 begins.
5/12:36	Orbit 89 begins.
5/14:07	Orbit 90 begins.
5/15:00	Postsleep activities.
5/15:00	DSO 476--In-flight aerobics (pulse rate).
5/15:37	Orbit 91 begins.
5/16:45	Maneuver vehicle to IMU alignment attitude.
5/17:00	IMU alignment: ST.
5/17:05	Maneuver vehicle to -ZLV, +YVV attitude.
5/17:08	Orbit 92 begins.
5/17:30	Supply water dump initiation.
5/17:30	P/TV05 setup (LBNP).
5/17:50	LBNP preparation.
5/17:55	DTO 799--PGSC/modem powerdown.
5/17:55	SAMS optical disk changeout.
5/18:00	PCG fan inlet cleaning/temperature check.
5/18:00	P/TV05 activation (LBNP).
5/18:15	DSO 478--lower-body negative pressure soak (MS 2).
5/18:20	Supply water dump termination.
5/18:38	Orbit 93 begins.
5/19:30	DTO 798--alternate mode DAP tests 1-4.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/20:09	Orbit 94 begins.
5/20:55	DTO 798--alternate mode DAP tests 10-13.
5/21:00	SHARE II heater activation.
5/21:10	SAMS disk check.
5/21:40	Maneuver vehicle to alternate DAP set 3 attitude.
5/21:40	Orbit 95 begins.
5/21:50	DTO 798--alternate mode DAP tests 5-9.
5/22:15	LBNP egress.
5/22:40	Maneuver vehicle to alternate DAP set 4 attitude.
5/22:55	Meal.
5/23:10	Orbit 96 begins.
5/23:25	LBNP preparation.
5/23:45	P/TV05 activation (LBNP).
5/23:50	DTO 798--alternate mode DAP tests 14-17.

MET DAY SIX

6/00:00	DSO 478--lower-body negative pressure soak (pilot).
6/00:40	DTO 798--alternate mode DAP tests 18-21.
6/00:41	Orbit 97 begins.
6/00:50	VTR setup.
6/01:00	VTR playback.
6/01:05	Maneuver vehicle to -ZLV, +YVV attitude.
6/01:10	SHARE II heater deactivation.
6/01:10	SAMS optical disk changeout.
6/01:20	SHARE II -ZLV (III) heater activation/deactivation, steps 1 and 2.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/01:20	DTO 645--combustion products analyzer operations.
6/02:12	Orbit 98 begins.
6/02:15	SHARE II -ZLV (III) heater activation/deactivation, steps 3-4.
6/02:30	PCG temperature check.
6/03:10	DTO 1208--Mac modem data transfer setup.
6/03:15	Crew begins presleep activities.
6/03:20	SHARE II -ZLV (III) heater activation/deactivation, step 5.
6/03:42	Orbit 99 begins.
6/04:00	LBNP egress.
6/04:20	SHARE II -ZLV (III) heater activation/deactivation, step 6.
6/04:25	Private medical conference.
6/04:50	Maneuver vehicle to IMU alignment attitude.
6/05:05	IMU alignment: ST.
6/05:10	Maneuver vehicle to -ZLV, +YVV attitude.
6/05:13	Orbit 100 begins.
6/06:30	Crew begins sleep period.
6/06:43	Orbit 101 begins.
6/08:14	Orbit 102 begins.
6/09:45	Orbit 103 begins.
6/11:15	Orbit 104 begins.
6/12:45	Orbit 105 begins.
6/14:17	Orbit 106 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/14:30	Postsleep activities.
6/14:30	DSO 476--In-flight aerobics (pulse rate).
6/15:47	Orbit 107 begins.
6/17:00	Maneuver vehicle to IMU alignment attitude.
6/17:15	IMU alignment: ST.
6/17:17	Orbit 108 begins.
6/17:20	Maneuver vehicle to +ZLV, -YVV attitude.
6/17:30	PCG fan inlet cleaning/temperature check.
6/17:30	DTO 1208--Mac modem data transfer powerdown.
6/17:35	DTO 1208--cursor control evaluation II.
6/17:40	SAMS disk check.
6/17:55	P/TV07 setup (APE-B)--spectrometer mode.
6/18:30	APE RCS test.
6/18:30	P/TV07 activation (APE-B)--thruster emission (near field).
6/18:45	P/TV05 setup (middeck activities).
6/18:48	Orbit 109 begins.
6/18:50	LBNP preparation.
6/19:05	P/TV05 activation (middeck activities).
6/19:15	DSO 478--lower-body negative pressure ramp test (MS 2).
6/19:45	LBNP egress.
6/20:00	P/TV07 activation (APE-B)--orbiter surfaces.
6/20:10	Maneuver vehicle to -ZLV, -YVV attitude.
6/20:10	P/TV07 stow (APE-B).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/20:19	Orbit 110 begins.
6/20:25	P/TV05 setup (middeck activities).
6/20:25	LBNP preparation.
6/20:45	P/TV05 activation (middeck activities).
6/20:50	DSO 478--lower-body negative pressure ramp test (pilot).
6/21:20	LBNP egress.
6/21:40	SAMS optical disk changeout.
6/21:45	Maneuver vehicle to -ZLV, +XVV attitude.
6/21:49	Orbit 111 begins.
6/22:00	AMOS RCS test.
6/22:15	Maneuver vehicle to -ZLV, +YVV attitude.
6/22:30	Meal.
6/23:20	Orbit 112 begins.
6/23:35	SAMS disk check.
6/23:50	DSO 604--Visual vestibular integration OI-1 (MS 1).

MET DAY SEVEN

7/00:00	P/TV05 setup (DSO 1208).
7/00:00	SHARE II deprime II.
7/00:15	SHARE II two-second burn.
7/00:20	P/TV05 activation (DSO 1208).
7/00:30	DTO 1208--cursor control evaluation II.
7/00:50	Orbit 113 begins.
7/01:00	DTO 645--combustion products analyzer operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/01:00	DSO 476--In-flight aerobics (commander, MS 2).
7/01:10	PCG temperature check.
7/01:30	P/TV07 setup (APE-B)--spectrometer mode.
7/01:50	Maneuver vehicle to +ZLV, -YVV attitude.
7/02:05	APE RCS test.
7/02:05	P/TV07 activation (APE-B)--thruster emission (near field).
7/02:20	P/TV05 setup (DSO 476).
7/02:21	Orbit 114 begins.
7/02:40	P/TV05 activation (DSO 476).
7/03:10	DTO 799--PGSC/modem demonstration.
7/03:30	SAMS optical disk changeout.
7/03:30	Crew begins presleep activities.
7/03:35	P/TV07 activation (APE-B)--orbiter surfaces.
7/03:45	Maneuver vehicle to +ZLV, -YVV attitude.
7/03:50	P/TV07 stow (APE-B).
7/03:52	Orbit 115 begins.
7/04:00	Private medical conference.
7/05:05	Maneuver vehicle to IMU alignment attitude.
7/05:20	IMU alignment: ST.
7/05:22	Orbit 116 begins.
7/05:25	Maneuver vehicle to -ZLV, +YVV attitude.
7/06:30	Crew begins sleep period.
7/06:53	Orbit 117 begins.
7/08:23	Orbit 118 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/09:54	Orbit 119 begins.
7/11:25	Orbit 120 begins.
7/12:55	Orbit 121 begins.
7/14:26	Orbit 122 begins.
7/14:30	Postsleep activities.
7/14:30	DSO 476--In-flight aerobics (pulse rate).
7/15:40	Maneuver vehicle to IMU alignment attitude.
7/15:55	IMU alignment: ST.
7/15:56	Orbit 123 begins.
7/16:00	Maneuver vehicle to -ZLV, +YVV attitude.
7/16:15	DSO 602--blood pressure variability.
7/16:30	APU heater activation.
7/17:27	Orbit 124 begins.
7/17:30	FCS checkout.
7/17:30	DTO 799--PGSC/modem powerdown.
7/17:30	P/TV05 setup (BIMDA).
7/17:35	PCG fan inlet cleaning/temperature check.
7/17:50	P/TV05 activation (BIMDA).
7/18:00	MDA deactivation.
7/18:20	BIMDA stow.
7/18:50	RCS hot fire.
7/18:50	LBNP preparation.
7/18:57	Orbit 125 begins.
7/19:15	DSO 478--lower-body negative pressure ramp test (MS 2).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/19:25	APU heater reconfiguration.
7/19:30	APU cool A.
7/19:40	DSO 604--visual vestibular integration OI-3.
7/19:45	LBNP egress.
7/20:00	LBNP preparation.
7/20:25	DSO 478--lower-body negative pressure ramp test (pilot).
7/20:28	Orbit 126 begins.
7/20:55	LBNP egress.
7/21:15	LBNP stow.
7/21:15	P/TV08 setup (crew press conference).
7/21:30	Maneuver vehicle to crew conference attitude.
7/21:35	P/TV08 activation (crew press conference).
7/21:45	Conference audio/TV check.
7/21:58	Orbit 127 begins.
7/22:00	Meal.
7/23:00	Supply water dump using FES.
7/23:10	P/TV08 activation (crew press conference).
7/23:20	Crew press conference.
7/23:30	Orbit 128 begins.
7/23:35	Maneuver vehicle to -ZLV, +YVV attitude.
7/23:50	DSO 476--In-flight aerobics (commander).
7/23:50	SAMS deactivation.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
MET DAY EIGHT	
8/00:30	Cabin stow.
8/00:59	Orbit 129 begins.
8/01:20	DTO 645--combustion products analyzer operations.
8/01:35	PCG temperature check.
8/02:31	Orbit 130 begins.
8/03:00	Ku-band antenna stow.
8/03:10	DTO 1208--Mac modem data transfer powerdown.
8/03:25	Private medical conference.
8/03:25	SAMS dummy disk loading.
8/03:30	Crew begins presleep activities.
8/03:45	Maneuver vehicle to IMU alignment attitude.
8/04:00	IMU alignment: ST.
8/04:00	Supply water dump using FES.
8/04:02	Orbit 131 begins.
8/04:05	Maneuver vehicle to -ZLV, +YVV attitude.
8/04:20	Waste dump initiation.
8/05:20	Waste dump termination.
8/05:32	Orbit 132 begins.
8/06:30	Crew begins sleep period.
8/07:03	Orbit 133 begins.
8/08:33	Orbit 134 begins.
8/10:04	Orbit 135 begins.
8/11:34	Orbit 136 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/13:00	Postsleep activities.
8/13:00	DSO 476--In-flight aerobics (pulse rate).
8/13:05	Orbit 137 begins.
8/14:00	Private medical conference.
8/14:20	Maneuver vehicle to IMU alignment attitude.
8/14:35	IMU alignment: ST.
8/14:36	Orbit 138 begins.
8/14:40	Maneuver vehicle to -XSI attitude.
8/15:00	DSO 602--blood pressure variability equipment doff.
8/15:35	DSO 604, 603 entry preparation.
8/16:00	DTO 1208--Mac modem data transfer powerdown.
8/16:05	Cable reconfiguration.
8/16:06	Orbit 139 begins.
8/16:17	Begin deorbit preparation.
8/16:17	CRT timer setup.
8/16:21	Commander initiates coldsoak.
8/16:21	Stow radiators, if required.
8/16:39	Commander configures DPS for deorbit preparation.
8/16:42	Mission Control Center updates IMU star pad, if required.
8/16:51	MS configures for payload bay door closure.
8/17:07	Maneuver vehicle to IMU alignment attitude.
8/17:19	MCC-H gives "go/no-go" command for payload bay door closure.
8/17:27	Pilot and MS close payload bay doors.
8/17:37	Orbit 140 begins.
8/17:37	IMU alignment: ST/payload bay door operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/17:47	Commander and pilot configure dedicated displays for entry.
8/18:00	MCC gives the crew the go for OPS 3.
8/18:03	Maneuver vehicle to deorbit burn attitude.
8/18:07	Pilot starts repressurization of SSME systems.
8/18:12	Commander and pilot perform DPS entry configuration.
8/18:21	MS deactivates ST and closes ST doors.
8/18:23	All crew members verify entry payload switch list.
8/18:38	All crew members perform entry review.
8/18:40	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
8/18:53	Commander and pilot configure clothing.
8/19:07	Orbit 141 begins.
8/19:08	MS configure clothing.
8/19:18	Commander and pilot seat ingress.
8/19:20	Commander and pilot set up heads-up display (HUD).
8/19:22	Commander and pilot adjust seat, exercise brake pedals.
8/19:30	Final entry deorbit update/uplink.
8/19:36	OMS thrust vector control gimbal check is performed.
8/19:37	APU prestart.
8/19:52	Close vent doors.
8/19:56	MCC-H gives "go" for deorbit thrusting period.
8/20:02	Manuever vehicle to deorbit thrusting attitude.
8/20:03	MS ingress seats.
8/20:11	First APU is activated.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/20:17	Deorbit thrusting period, approximately two minutes, 46 seconds in duration, at 315.4 fps, 174 by 161 nm.
8/20:22	Initiate post-deorbit thrusting period attitude.
8/20:26	Terminate post-deorbit thrusting attitude.
8/20:34	Dump forward RCS, if required.
8/20:37	Orbit 142 begins.
8/20:42	Activate remaining APUs.
8/20:46	Entry interface, 400,000 feet altitude.
8/20:49	Enter communication blackout.
8/20:51	Automatically deactivate RCS roll thrusters.
8/20:58	Automatically deactivate RCS pitch thrusters.
8/21:00	Initiate first roll reversal.
8/21:01	Exit communications blackout.
8/21:05	Initiate second roll reversal.
8/21:06	Initiate ammonia boilers.
8/21:07	Initiate preprogrammed test inputs.
8/21:09	Initiate third roll reversal.
8/21:10	Initiate air data system (ADS) probe deploy.
8/21:11	Begin entry/terminal area energy management (TAEM).
8/21:11	Initiate payload bay venting.
8/21:13	Automatically deactivate RCS yaw thrusters.
8/21:15	Begin TAEM/approach/landing (A/L) interface.
8/21:16	Initiate landing gear deployment.
8/21:17	Vehicle has weight on main landing gear.
8/21:17	Vehicle has weight on nose landing gear.
8/21:17	Initiate main landing gear braking.
8/21:18	Wheel stop.

GLOSSARY

AA	accelerometer assembly
ADS	air data system
A/L	approach and landing
AMOS	Air Force Maui Optical Site
APC	adaptive payload carrier
APE-B	auroral photography experiment-B
APU	auxiliary power unit
BFS	backup flight control system
BIMDA	Bioserve-Instrumentation Technology Associates Materials Dispersion Apparatus
BM	bioprocessing module
CDMS	command and data management system
CIU	computer/controller interface unit
COAS	crewman optical alignment sight
CRT	cathode ray tube
CS	cell syringe
C/W	caution/warning
DAP	digital autopilot
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
EDO	extended duration orbiter
EMU	extravehicular mobility unit
EOM	end of mission
EPS	electrical power system
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FCS	flight control system
FES	flash evaporator system
FDF	flight data file
FPS	feet per second
FRCS	forward reaction control system
GAPC	GAS autonomous payload controller
GAS	get away special
GBA	GAS bridge assembly
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GSFC	Goddard Space Flight Center

HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
IPMP	investigations into polymer membrane processing
IUS	inertial upper stage
IV	intravehicular
JSC	Johnson Space Center
KSC	Kennedy Space Center
LACE	low-power atmospheric compensation experiment
LBNP	lower-body negative pressure
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
MCC-H	Mission Control Center--Houston
MDA	materials dispersion apparatus
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merritt Island
MLP	mobile launcher platform
MM	major mode
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NMI	nautical miles
NOR	Northrup Strip
O&C	operations and checkout
OAA	orbiter access arm
OCTW	optical communications through the shuttle window
OEX	orbiter experiments
OMS	orbital maneuvering system
OTC	orbiter test conductor
PADM	portable audio data modem
PASS	primary avionics software system
PCG	protein crystal growth
PCP	power control panel
PCS	pressure control system
PGSC	payload and general support computer
PI	payload interrogator
PIC	pyro initiator controller
PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV

RCS	reaction control system
RF	radio frequency
RGA	rate gyro assembly
R/IM	refrigerator/incubator module
RMS	remote manipulator system
RSLS	redundant-set launch sequencer
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SAMS	space acceleration measurement system
SHARE	space station heatpipe advanced radiator element
SM	statute miles
SMMI	small mass measurement instrument
SPOC	shuttle portable on-board computer
SRB	solid rocket booster
SRM	solid rocket motor
SSCE	solid surface combustion experiment
SRSS	shuttle range safety system
SSBUV	shuttle solar backscatter ultraviolet instrument
SSF	Space Station Freedom
SSME	space shuttle main engine
SSP	standard switch panel
ST	star tracker
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TCD	timing control distributor
TDRS	tracking and data relay satellite
TDRSS	tracking and data relay satellite system
TI	thermal phase initiation
TIG	time of ignition
TPCE	tank pressure control experiment
TPS	thermal protection system
TSM	tail service mast
TV	television
UVPI	ultraviolet plume instrument
VTR	videotape recorder
WCS	waste collection system