STS-8

PRESS

INFORMATION

August 1983

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The STS-8 flight of *Challenger* in its third flight into space will chalk up another first—the first night launch and landing of the Space Shuttle. Proper placement in geostationary orbit of the Indian Communications Satellite (INSAT) -1B dictates the night launch of *Challenger* in STS-8 from Kennedy Space Center, Florida and the night landing at Edwards Air Force Base, California.

On May 27, 1983 NASA announced that the Tracking and Data Relay Satellite (TDRS) -B would not be flown on the STS-8 mission due to the problem encountered with the Inertial Upper Stage (IUS) in the deployment of TDRS-A. It was also announced that the Payload Deployment and Retrieval System (PDRS)/Payload Flight Test Article (PFTA) originally scheduled to be flown on STS-11 would be flown on STS-8 along with the originally manifested INSAT-1B/PAM (Payload Assist Module) -D.

The PFTA has a total of four different grapple fixture locations, however only two will be used for grappling of the PFTA by the Remote Manipulator System (RMS) in unberthing and berthing the PFTA in on orbit testing of the RMS/PFTA, *Challenger* response.

The Development Flight Instrumentation (DFI) pallet (minus the DFI instrumentation used in flights of *Columbia*) would be placed in the payload bay of *Challenger* for STS-8, (in front of the PFTA). The experiments on the DFI are; — Evaluation of Oxygen Interaction with Materials (EOIM); two diced Low Temperature Reusable Surface Insulation (LRSI) tiles; two Advanced Flexible Reusable Surface Insulation (AFRSI) blankets; one AFRSI outer blanket layer fabric material segment; and a High Capacity Heat Pipe demonstration experiment. These experiments, except for the High Capacity Heat Pipe, will be subjected to atomic oxygen within the low Earth orbital environment of 121 by 121 nautical miles (139 x 139 statute miles) and the experiments (payload bay) oriented in the direction of *Challenger's* velocity vector around Earth.

Challenger's Ku-band system along with its S-band system, will be used to test performance, navigation and proficiency of the communications system with the Tracking and Data Relay Satellite System (TDRSS).

The Continuous Flow Electrophoresis System (CFES) is flown again in the STS-8 mission, however in this mission six live cells are used.

Twelve Getaway Special (GAS) canisters are flown on STS-8, four of the GAS canisters are for experiments and the eight remaining canisters carry U.S. Postal Service covers. Two mail boxes are mounted on the DFI pallet and carry additional U.S. Postal Service Covers.
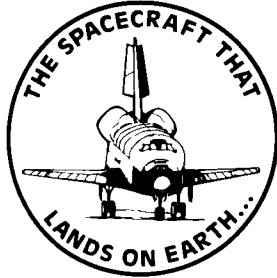
NEWS About Space Flight

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STS-8 MISSION STATISTICS

Launch: Tuesday, August 30, 1983
2:15 A.M. E.D.T.
1:15 A.M. C.D.T.
11:15 P.M. P.D.T.

Mission Duration: 144 hours (6 days) 1 hour, 10 minutes

Landing: Monday, September 5, 1983
3:25 A.M. E.D.T.
2:25 A.M. C.D.T.
12:25 A.M. P.D.T.

Inclination: 28.45 degrees

SSME Throttling: 100 to 70 to 100 to 3 "g" limit to 65 percent

Spacecraft Altitudes in Orbit: 1) 160 x 160 nautical miles (184 x 184 statute miles); 2) 166 x 160 nautical miles (191 x 184 statute miles); 3) 166 x 121 nautical miles (191 x 139 statute miles); 4) 121 x 121 nautical miles (139 x 139 statute miles)

Payload Weight "Up": Approximately 10,255 kilograms (26,609 pounds)

Payload Weight "Down": Approximately 8,692 kilograms (19,164 pounds)

Payloads: INSAT (Indian Communications Satellite) -1B PAM (Payload Assist Module) -D, PFTA (Payload Flight Test Article), DFI (Development Flight Instrumentation) Pallet, 12 GAS (Getaway Specials), CFES (Continuous Flow Electrophoresis System) experiment

Entry Angle of Attack: 40 degrees

Maximum Q (aerodynamic pressure): 712 pounds per square foot

Crew Members:
    Commander (CDR) Richard H. Truly
    Pilot (PLT) Daniel C. Brandenstein
    Mission Specialist (MS) Guion S. Bluford, Jr.
    Mission Specialist (MS) Dale A. Gardner
    Mission Specialist (MS) William E. Thornton

Crew Seating: Dale Gardner will be in the flight deck center seat during ascent and entry. William Thorton will be in the mid-deck during ascent and entry

Crew Attire: Blue intravehicular activity (IVA) flight suits, helmets will be worn for launch and entry. Anti "g" (gravity) suit worn (lower extremity) for entry over IVA flight suit

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Cross Range: 475 nautical miles (546 statute miles)

Runway: Edwards Air Force Base (concrete runway 22)

Note: No chase plane will be used in the landing sequence on this flight. *Challenger* will probably not be visible until 30 to 15 meters (100 to 50 feet) above the runway at landing

FLIGHT TEST AND MISSION OBJECTIVES

FLIGHT TEST

- External tank and solid rocket booster ascent performance

- Solid rocket booster recovery

- POGO stability performance

- *Challenger* OV-099 cold canopy test, tail to sun attitude for 16 hours

- Cabin atmosphere verification

- Payload deployment retrieval system (PDRS) payload handling performance

- S-band/Tracking Data Relay Satellite (TDRS) -A communication link performance test No. 2

- TDRSS navigation test

- Ku-band communication link performance test No. 2

- Ku-band communications and tracking performance

- *Challenger* S-band and Ku-band/TDRS-A operations proficiency test No. 2

- Ku-band side lobe detection

- *Challenger* Remote Manipulator System (RMS) dynamic interaction test using Payload Flight Test Article (PFTA)

- On-orbit TACAN (Tactical Air Navigation) navigation

- Mid-deck locker temperature survey

- Crew module thermal evaluation

- Entry aerodynamic test No. 4 (pre-programmed test inputs [PTI's]), a total of nine

- TPS(Thermal Protection System) entry heating evaluation

- SLSS (Shuttle Launch Support System) communications performance, ground tests over two Merritt Island, Florida

- Validation of predictive tests and countermeasures for space motion sickness

- Cardiovascular deconditioning countermeasure assessment

- Head and eye motion monitoring during ascent and entry

- On-orbit head and eye tracking tasks, performed by MS William Thornton

- Acceleration detection sensitivity, performed by MS William Thornton

- Kinesthetic repeatability, performed by MS William Thornton

- Photographic documentation of body fluid shifts, performed by MS William Thornton

- Near vision ability, twice per crew-member

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- Microbiology screening test

- Audiometry with cabin noise, performed by MS William Thornton

- Simple mass measurement

- Treadmill photography, performed by MS William Thornton

- Ophthalmoscopy performed, by MS William Thornton twice, on each crew-member

- Tissure pressure-tonemeter, performed by MS William Thornton

- Ambulatory monitoring with and without skeletal loading and other maneuvers, performed by MS William Thornton

- Inflight countermeasures for Space adaptation syndrome with objective measurements, performed by MS William Thornton

- Eye hand coordination, performed by MS William Thornton

- Verification of the mid-deck animal enclosure module, performed by MS William Thornton

- Anatomical observation, performed by MS William Thornton

- Study of inflight fluid changes, performed by MS William Thornton

- Evoked potentials demonstration, performed by MS William Thornton

- Intraocular pressure, performed by MS William Thornton

- Soft contact lens application test, performed by MS William Thornton

- Engineering test of carry-on incubator

MISSION OBJECTIVES

- First night launch and night landing

- Deployment of INSAT-1B/PAM-D

- DFI (Development Flight Instrumentation) structure
    Heat pipe evaluation
    Evaluation of oxygen interaction with materials

- PFTA (Payload Flight Test Article)/PDRS (Payload Deployment Retrieval System) unberth, interaction with *Challenger* and berth

- CFES (Continuous Flow Electrophoresis System) experiment

- 12 GAS (Getaway Special) canisters

- Investigation of STS (Space Transportation System) atmospheric luminosities (ISAL)

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STS-7 TO STS-8 SPACE SHUTTLE DIFFERENCES

- **Solid Rocket Boosters**

High performance solid rocket motors with light weight shaved casings. The high performance solid rocket motors increase the initial thrust by four percent, adding about 1,360 kilograms (3,000 pounds) to the Space Shuttle's payload carrying capability. The increase in thrust was achieved by lengthening the exit cone of the solid rocket motors nozzles by 254 millimeters (10 inches) and decreasing the solid rocket motors nozzles throat diameter by 101 millimeters (4 inches) which increases the velocity of the solid rocket motors gases as they exit through the nozzle.

Also, some of the solid rocket motors propellant inhibitor used in the four motor segments in each solid rocket motor is omitted, thus causing the propellant to burn faster. These high performance motors will be used on future flights. The shaved light weight casings were first used in the STS-6 mission which reduced the weight of each solid rocket booster by 1,814 kilograms (4,000 pounds)

- **Lightweight External Tank**

Weighs approximately 4,536 kilograms (10,000 pounds) less than the last heavy weight tank used in the STS-7 flight

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MODIFICATIONS TO *CHALLENGER* FROM STS-7 TO STS-8

- Addition of nine additonal quick shoe camera mounts in crew compartment for Government Furnished Equipment (GFE) cameras

- Deletion of suction foot restraints in crew compartment and orbiter's floor finish associated with suction cups

- Modification of hydraulic bootstrap accumulator seals

- Redesign of TV camera stabilizer bracket in crew compartment aft flight deck station

- Installation of a deeper pile thermal barrier (monkey fur) at the aft edge of the payload bay doors nearest the hinge line and X_0 1307 bulkhead for both right and left hand doors

- Stow start/sustaining heater wires for fuel cell No. 1

- Reset of the flapper angle of the liquid oxygen 17 inch disconnect to accommodate the light weight external tank

- Addition of non-standard payload retention guides to accommodate payload flight test article (PFTA). These guides will be 17 and 19 inches long to be compatible with the envelopes at the PFTA longeron location

- Routing of signal wiring for two temperature measurements through the orbiter, from the external tank/orbiter interface to the orbiter/ground system interface for observing the external tank feedline temperatures during liquid oxygen loading operations

- Change of glareshield light assemblies from a 3.6 volt lamp to a 1.8 volt lamp and adjusting the output filament voltages to be compatible with the 1.8 volt lamp

- Addition of eight remote manipulator system measurements in the operational instrumentation for use with the PFTA for math model validation

- Provide new Heads-up Display (HUD) format-software. Spare HUD carried onboard as HUD is mandatory for a night landing

- Addition of buttons on keel area for payload blanket

- Redesign of purge, vent and drain filter frame

- Provision for flight data file removal for in-flight maintenance capability

- Change 50 foot tether in payload bay to 35 feet

- Deletion of external tank separation camera

- Modification of standard mixed cargo harness (SMCH)

- 76 thermal protection system tiles were removed and replaced after the STS-7 mission due to flight damage

- Re-waterproofing of thermal protection system tiles internally except for diced tiles which are sprayed. The upper surface of the body flap, aft heat shield and aft end of Orbital Maneuvering System/Reaction Control System (OMS/RCS) are not water proofed as these areas do not get wet

- On STS-7, there were a total of 50 Advanced Flexible Reusable Surface Insulation (AFRSI) blankets on the Orbital Maneuvering System/Reaction Control System (OMS/RCS) pods. Of these 50 blankets, 44 were removed, four blankets were reworked, two blankets were retained as is, and eight new blankets were installed for a total of 14 blankets, for both OMS/RCS pods. The remaining area of AFRSI blankets not installed was covered with a total of 170 Low Temperature Reusable Surface Insulation (LRSI) tiles for both OMS/RCS pods. Some of the small transition areas from the LRSI tiles to the AFRSI blankets utilize Felt Reusable Surface Insulation (FRSI). Approximately

40 square feet of FRSI is used for both OMS/RCS pods.

- Four areas of LRSI tiles on *Challenger* were removed and replaced with AFRSI blankets to establish confidence in locations of AFRSI applications on *Discovery* Orbiter-103. The AFRSI test panels are installed on the left hand side of the forward fuselage canopy, left hand side of forward fuselage, left hand side of mid-fuselage and left hand side of upper wing. Each test panel location consists of two AFRSI blankets 304 millimeters (12 inches) in length by 406 millimeters (16 inches) in width, one in front of the other, with total length in flow of the wind of 609 millimeters (24 inches)
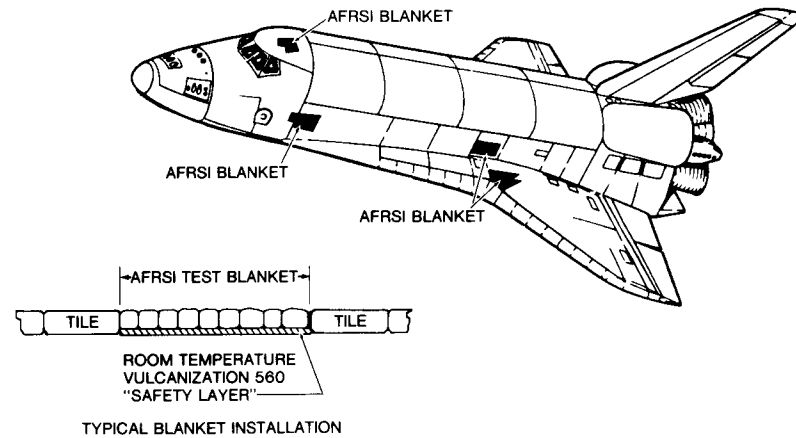
Advanced Flexible Reusable Surface Insulation (AFRSI) Blankets Flown on Challenger on STS-8 as a Flight Test Program

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LINE REPLACEABLE UNITS

- Removed and replaced right hand Orbital Maneuvering System (OMS) propellant gauging totalizer

- Removal and replacement of text and graphics unit

- Removal and replacement of Cathode Ray Tube (CRT) No. 3

- Removal and replacement of Display Driver Unit (DDU) No. 2

- Removal and replacement of hydraulic system No. 2 accumulator/transducer

- Removal and replacement of hydraulic system No. 2 unloader valve

- Removal and replacement of Space Shuttle Main Engine (SSME) No. 3 and No. 2 gaseous hydrogen pressurization outlet pressure sensor

- Removal and replacement of Auxiliary Power Unit (APU) No. 3. Will hot fire on launch pad

- Removal and replacement of waste collection system

- Removal and replacement of mid-deck ACCU (Audio Central Control Unit)

- Removal and replacement of MDM (multiplexer/demultiplexer) FF (Flight forward) No. 4

- Removal and replacement of outer pane window No. 5

- Removal and replacement UHF (ultra high frequency) receiver

- Removal and replacement of WSB (Water Spray Boiler) No. 3 valve actuator motor

- Removal and replacement of main landing gear uplock linkage

- Removal and replacement of SSME No. 1 and No. 2 heat shield flexible blankets

- Removal and replacement of four main landing gear brake assemblies, wheels, and tires

- Removal and replacement of RA (Radar altimeter) No. 1

- Removal and replacement of SSME No. 3 high pressure fuel turbopump

- Removal and replacement of 1-1/2 inch hydrogen high point disconnect

- Removal and replacement of SSME No. 3 flange F4 seal

- Removal and replacement of left wing vent box relief door

- Removal and replacement of left OMS gaseous nitrogen regulator

- Removal and replacement of ascent thrust vector control (AVTC) No. 4

PAYLOAD ASSIST MODULE (PAM)

The Payload Assist Module (formerly called the Spinning Solid Upper Stage — SSUS) is designed as a higher altitude booster of satellites deployed in near Earth orbit but operationally destined for higher altitudes.

The INSAT-1B will be boosted to geosynchronous orbit (35,887 kilometers — 22,300 miles) by PAM-D.

There are two versions of the PAM — the "D" which is utilized to launch lighter weight satellites and the "A" which is capable of launching satellites weighing up to 1,995 kilograms (4,400 pounds) into a 27-degree geosynchronous transfer orbit after being deployed from the Shuttle spacecraft's cargo bay.

The PAM-D is capable of launching satellite weights up to 1,247 kilograms (2,750 pounds) into a 27 degree geosynchronous orbit following deployment. A requirement for a 1,361 kilogram (3,000 pound) transfer orbit capability requires about a 10-percent increase in the PAM-D motor performance, which can be accomplished by adding more length to the motor case, but reducing the nozzle length the same amount to retain the overall stage length. The motor case extension is about 137 milimeters (5.4 inches). This uprating will require other changes, namely the strengthening and addition of cradle members so that the system structural dynamic frequency will avoid the Space Shuttle forcing frequencies.

The PAM-A and PAM-D have deployable (expendable) stage consisting of a spin stabilized solid rocket fueled motor (SRM), a payload attach fitting (PAF) to mate with the unmanned spacecraft, and the necessary timing, sequencing, power and control assemblies.

The reusable airborne support equipment (ASE) consists of the cradle structure for mounting the deployable system in the Space Shuttle orbiter payload bay, a spin system to provide the stabilizing rotation, a separation system to release and deploy the stage and unmanned spacecraft, and the necessary avionics to control, monitor, and power the system.

The PAM-A and PAM-D stages are supported through the

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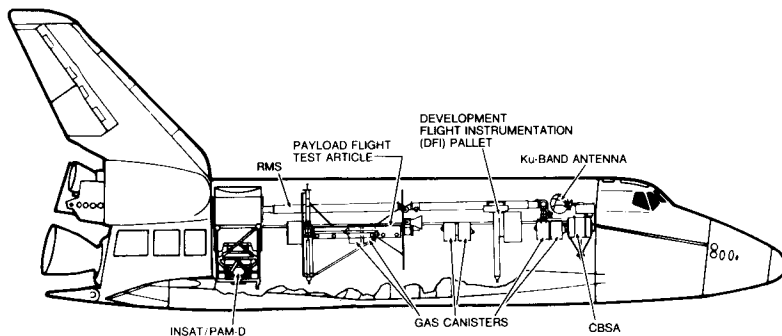
STS-Payload Configuration (Side View)
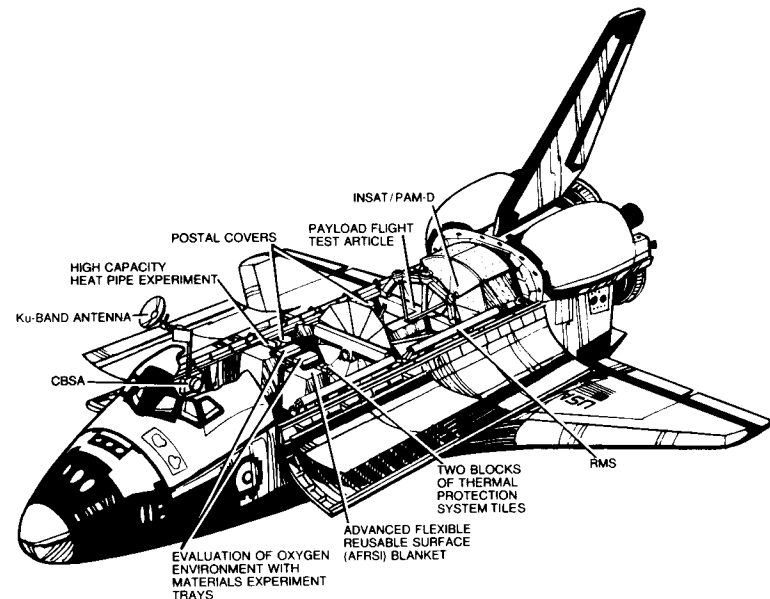
STS-Payload Configuration (Top View)

spin table at the base of the motor and through restraints at the PAF. The forward restraints are retracted before deployment.

The PAM-D also provides a sunshield for thermal protection of the satellite when the Space Shuttle orbiter payload bay doors are open.

PAM-D Airborne Support Equipment and Orbiter Installation. The PAM-D Airborne Support Equipment (ASE) consists of all the reusable hardware elements that are required to mount, support, control, monitor, protect, and operate the PAM-D expendable hardware and unmanned spacecraft from liftoff to deploymenmt from the Space Shuttle. It will also provide the same functions for the safing and return of the stage and spacecraft in case of an aborted mission. The ASE is designed to be as self-contained as possible, thereby minimizing dependence on orbiter or flight crew functions for its operation. The major ASE elements include the cradle for structural
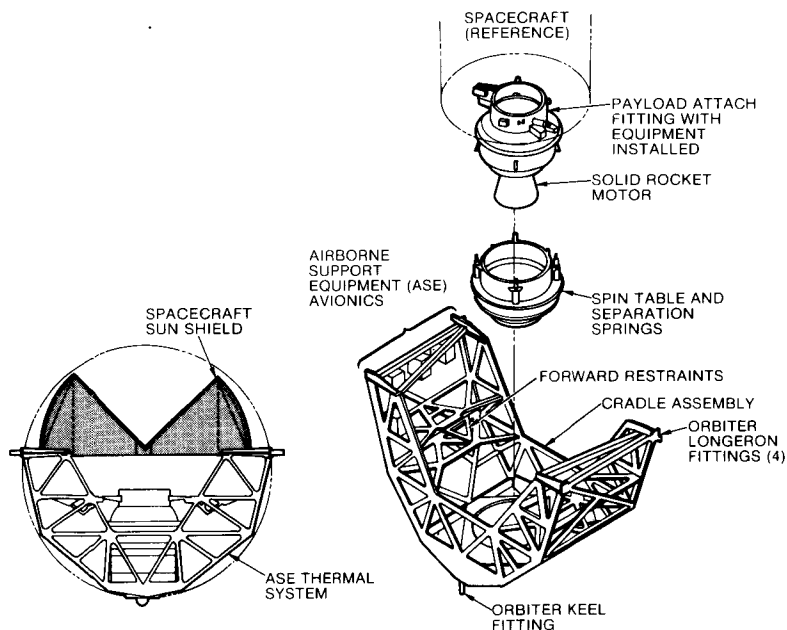
PAM-D System

STS-Payload Configuration (Top View)

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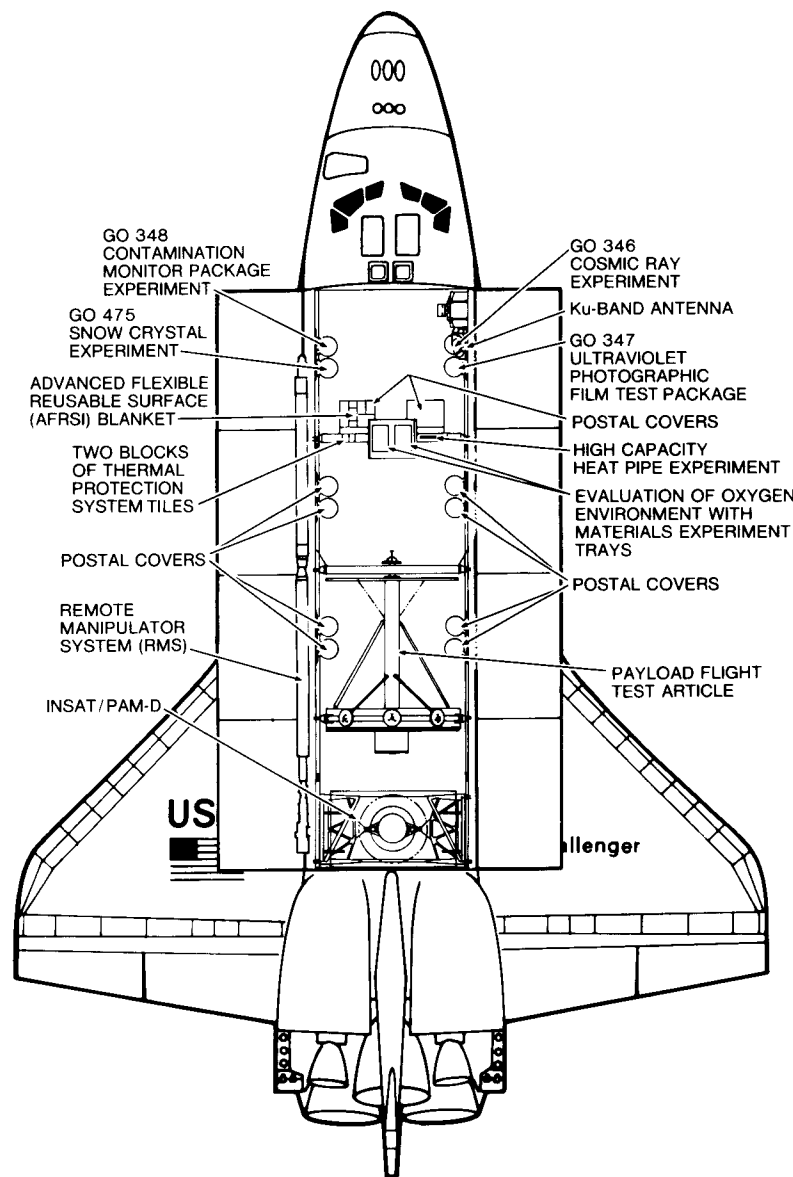
mounting and support, the spin table and drive system, the avionics system to control and monitor the ASE and the PAM-D vehicle and the thermal control system.

The cradle assembly provides a vertical structural mounting support for the PAM-D/unmanned spacecraft assembly in the orbiter payload bay. The nominal envelope for the PAM-D vertical installation provides a cylindrical volume 2,562 millimeters (100.88 inches) in height on the centerline and a diameter of 2,184 millimeters (86 inches). The diameter limitation applies to all early unmanned spacecraft that require the capability to use the Delta launch vehicle as a backup to the Space Shuttle. After full transition to the Space Shuttle is complete, the unmanned

spacecraft configuration may use the extra volume available within the Space Shuttle payload bay, a maximum diameter of 2,743 millimeters (108 inches) inside the cradle, 3,048 millimeters (120 inches) above the cradle. The cradle is 4.5 meters (15 feet) wide. The length of the cradle is 2,362 millimeters (93 inches) static and 2,438 millimeters (96 inches) dynamic. The open truss structure cradle is constructed of machined aluminum frame sections and chrome plated steel longeron and keel trunnions.

The spacecraft-to-cradle lateral loads are reacted by forward retractable retraction fittings between the payload attach fitting and cradle, which are driven by redundant dc electrical motors. After the reaction fittings are retracted, the spin table is free to spin the PAM unmanned spacecraft when commanded.

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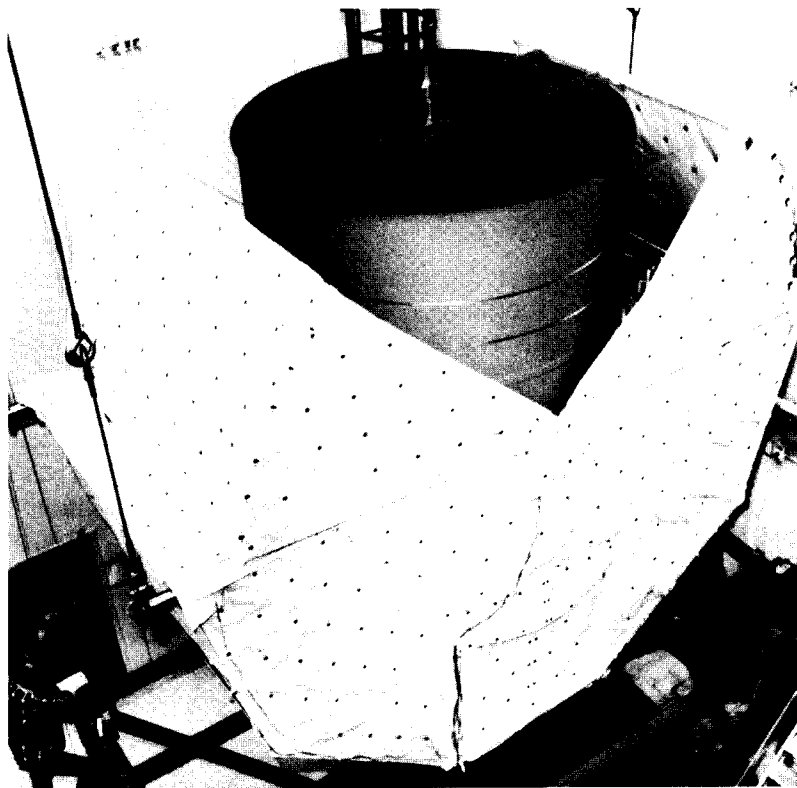
PAM-D Sunshield Open
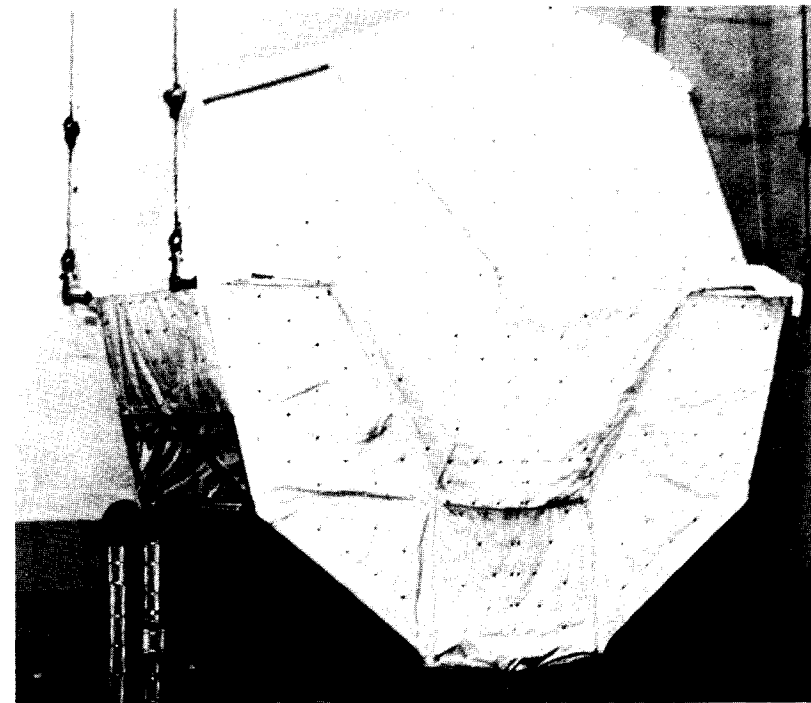
PAM-D Sunshield Closed

The spin table consists of three subsystems, spin, separation, and electrical interface. The spin subsystem consists of the spin table, the spin bearing, the rotating portion of the spin table, a gear and gear support ring, two redundant drive motors, a despin braking device, and a rotational index and locking mechanism. The separation subsystem includes four compression springs mounted on the outside of the rotating spin table, each with an installed preload of 635 kilograms (1,400 pounds) and a Marman-type clamp band assembly.

The electrical interface subsystem is composed of a slip-ring assembly to carry electrical circuits for PAM-D and spacecraft across the rotating spin bearing. The electrical wiring from the slip ring terminates at electrical disconnects at the spin-cable separation point. The slip-ring assembly is used to carry safety-critical command and monitor functions and those commands required before separation from the spin table.

The system provides a capability for spin rates between 45 and 100 rpm. In this flight, the spin rate is approximately 40 rpm. Upon command, the spin table will be spun up to the nominal rpm by two electric motors, either of which can produce the required torque. When the spin table rpm has been verified and the proper point is reached in the parking orbit, redundant debris-free explosive bolt cutters are fired upon command from the electrical ASE to separate the band clamp (which is mechanically retained on the spin table) and the springs provide the thrust to attain a separation velocity of approximately 0.9 meters per second (3 feet per second).

In case of an abort mode after spinup, the multiple-disc-stack friction-type braking device will despin the PAM-D unmanned spacecraft assembly and the spin drive motor will slowly rotate the assembly until the solenoid-operated indexing and locking device is engaged. Upon confirmation by the ASE that the spin table is properly aligned and locked, the restraint pins will be re-engaged.

PAM-D Mounted Thermal Control System. The PAM-D thermal control system is provided to alleviate severe thermal
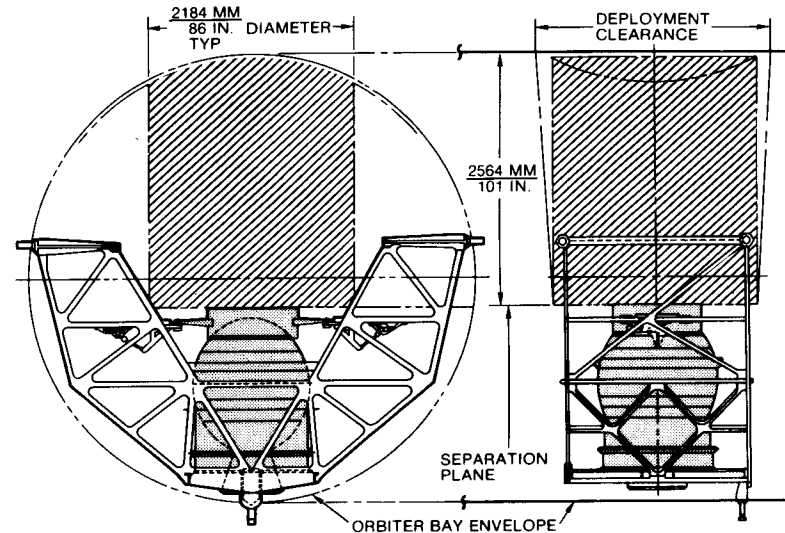
PAM-D Orbiter Vertical Installation
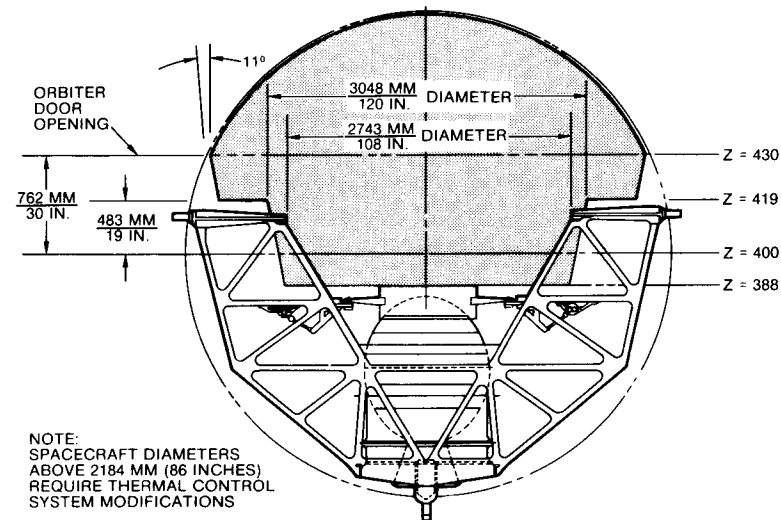
Maximum Spacecraft Envelope With STS PAM-D

stresses on both the unmanned spacecraft and the PAM-D system.

The system consists of thermal blankets mounted on the cradle to provide thermal protection for the PAM-D system, and a passive sunshield mounted on the cradle to control the solar input to and heat loss from the payload when the orbiter payload bay doors are open.

Thermal blankets consisting of multilayered insulation mounted to the forward and aft sides of the cradle protect the PAM-D from thermal extremes. On the sides and the bottom, the orbiter payload bay liner protects the PAM-D from the environmental extremes.

PAM-D / Telesat-F

A sunshield, consisting of multilayered, Mylar lightweight insulation supported on a tubular frame, mounts to the cradle and protects the unmanned spacecraft from environmental extremes. The sunshield panels on the sides are fixed and stationary. The portion of the shield covering th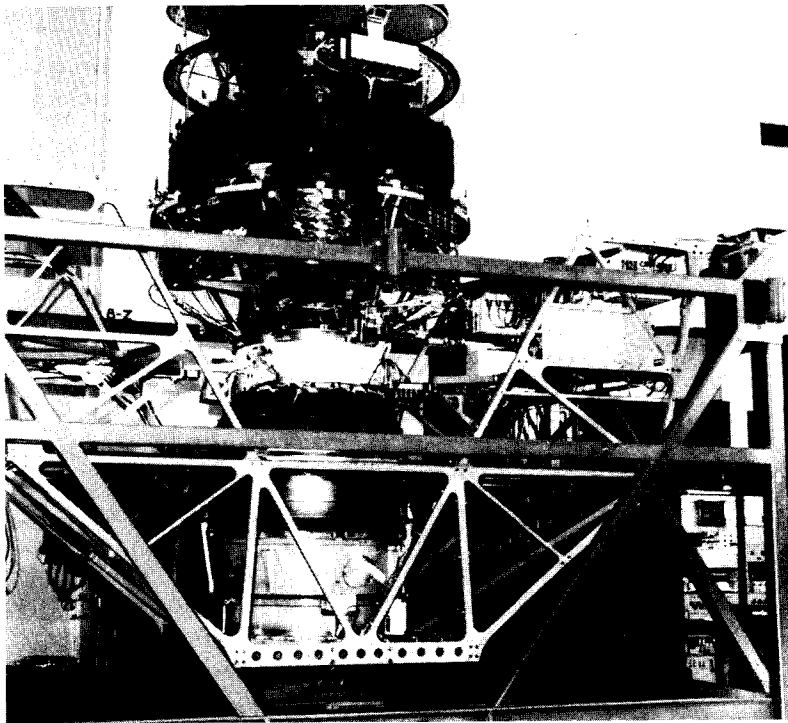e top of the unmanned spacecraft is a clamshell structure that remains closed to protect against thermal extremes when the orbiter payload bay doors are open. The sunshield resembles a two-piece baby buggy canopy. The clamshell is opened by redundant electric rotary actuators operating a control-cable system.

The sunshield required for the PAM-D growth will have a width adjustment capability to accommodate spacecraft up to 2,901 millimeters (115 inches) in diameter.

PAM-D Vehicle Configuration. The PAM-D expendable vehicle hardware consists of a Thiokol Star-48 solid-fueled rocket motor, the payload attach fitting and its functional system. The Star-48 motor features a titanium case, an 89-percent solid propellant, a carbon-carbon throat insert, and a carbon-carbon exit cone. Maximum loading of propellant is 1,998 kilograms (4,405 pounds) with a nominal of 1,738 kilograms (3,833 pounds). The motor is 1,239 millimeters (48.8 inches) in diameter and is 1,828 millimeters (72 inches) long.

The payload attach fitting (PAF) structure is a machined forging and provides the subsystem mounting installations and mounts on the forward ring of the motor case. The two cradle reaction fittings provide structural support to the forward end of the PAM-D stage and unmanned spacecraft, and transmit loads to the ASE cradle structure. The forward interface of the PAF provides the spacecraft mounting and separation system. One steel band is preloaded to approximately 2,585 kilograms (5,700 pounds) and separation is achieved by redundant bolt cutters. Four separation springs, mounted inside the PAF provide the impetus for clear separation. The installed preload for each spring is approximately 90 kilograms (200 pounds) with a spring stroke of 133 millimeters (5.25 inches), providing a spacecraft separation velocity of about 0.9 meters per second (3 feet per second). The electrical interface connectors between the PAM-D

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and the spacecraft are mounted on brackets on opposite sides of the PAF. Other subsystems mounted on the PAF include the redundant safe-and-arm device for motor ignition, and telemetry components (if desired) and the S-band transmitter.

PAM-D Avionics. The electrical ASE minimizes the number of operations to be performed by the flight crew so that greater attention can be paid to monitoring functions that are critical to safety and reliability.

Flight crew control functions include system power on, SRM arming, deployment ordnance arming, emergency deployment and sequence control assembly (SCA) control.

The electrical ASE performs control and monitoring of restraint withdrawal, spin-table spin and deployment functions; arms (and disarms, if necessary) the SRM; controls and monitors the PAM-D vehicle electrical sequencing system (and telemetry system, when used); generates system status information for display to the flight crew (cathode ray tube) via the data lens and from the orbiter keyboard panel; and provides wiring to carry required spacecraft functions. And, as a mission option, it provides control and monitoring of spacecraft systems.

The Payload Assist Modules are designed and built by McDonnell Douglas Astronautics, Co., Huntington Beach, California.

PAM-D Interfaces
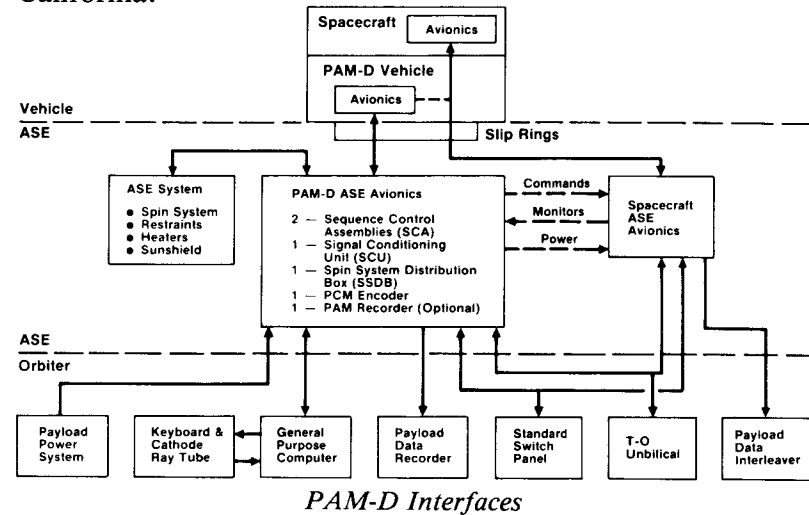
INDIAN NATIONAL SATELLITE (INSAT) -B

INSAT-1B is the second in a series of the most complex civil operational satellites ever to be launched. INSAT's design combines in one package its three separate missions: (1) telephone and data communications over India's million square miles; (2) direct television broadcasting to receivers nationwide, including thousands of remote villages and (3) comprehensive weather services, including continuous observations in both visible and infrared bands, relay of meteorological data from unattended stations, disaster warnings and radio program distribution to communities throughout India.

The three-in-one satellite provides for over 8,000 two-way long distance telephone circuits, supplementing India's existing communications system. Accessibility to long distance telephone will be available to even the remotest part of the country. The system will be tied to 35 satellite earth stations.

The direct broadcast radio and television will be beamed to approximately 100,000 Indian-built receive-only, small S-band earth terminals 3 to 3.6 meters (10 to 12 feet) in diameter placed in rural communities across the vast country. Social and agricultural education programs are among those planned for broadcast.

INSAT's meteorological capability via the INSAT two channel Very High Resolution Radiometer (VHRR) and Data Collection Platform (DCP) subsystem will benefit many segments of the country's economy, such as agriculture and aviation. Flood control, irrigation planning and disaster warning are important spin-offs anticipated. The spacecraft will transmit weather photos every half hour, 24 hours a day through the Delhi Telecommunications earth station to India's Meteorological Data Utilization Center (MDUC) in New Delhi. The Very High Resolution Radiometer (VHRR) data analysis will reveal cloud motion derived winds, sea surface, snow fields, cloud top and large water body temperatures which will be merged with other meteorological data collected by the Data Collection Platform's (DCP's). From up to 800 small
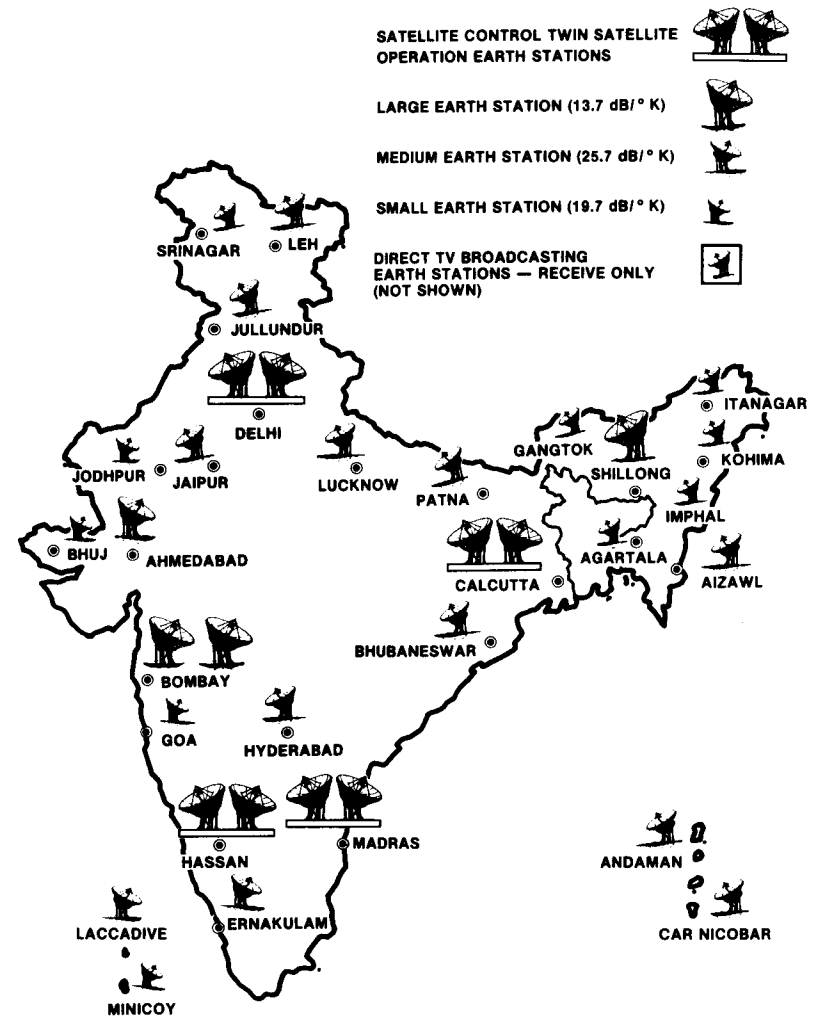
INSAT-1 Ground Facilities

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unattended land and ocean DCP's are selected on a random basis three times each hour to INSAT at Ultra High Frequency (UHF-INSAT - four dipole antennas) and re-transmitted at C-band to the MDUC in New Delhi.

India is one of the largest and most populous nations on earth, with a population of 613,000,000 million and a land area of one and a quarter million square miles. In addition, it embraces an enormous diversity of language, culture, and community life.

The INSAT program is a joint venture of India's Department of Space; the Ministry of Communications, Posts and Telegraph Department; and the Ministry of Information and Broadcasting. The Department of Space will establish and operate the space segment of the system, while the Ministries of Communications, Tourism and Civil Aviation, and Information and Broadcasting will establish and operate their respective ground segment facilities. Interagency coordination is managed by the INSAT coordination committee.
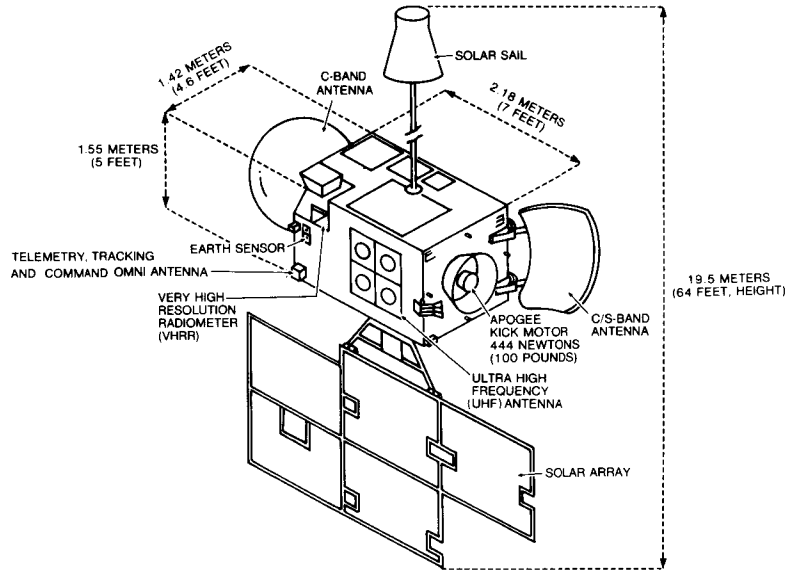
Ford Aerospace and Communications Corporation, Western Development Laboratories Division at Palo Alto, Calif., built INSAT-1B for India's Department of Space. In addition to building the INSAT-1 satellites (INSAT-1B, the first of two satellites), Ford Aerospace participated in a project with India's Department of Space to design and develop the Mission Control Center at Hassan, India. During the launch and checkout of the INSAT-1B satellite, Ford Aerospace personnel will be responsible for all operations. In the ensuing three-month period after satellite launch, operational responsibility will be transferred from Ford Aerospace to India's Department of Space personnel.

INSAT-1B has 12 transponders, each having the capacity for 1,200 voice/data channels or two television channels at 6/4 GHz (Gigahertz). A 1.4 meters (4.5 feet) diameter C-band reflector will receive at 6 GHz and transmit six of the twelve 4 GHz channels. A 1.5 by 1.6 meter (4.9 by 5.2 feet) C/S-band reflector provides the capability for transmitting the direct

15
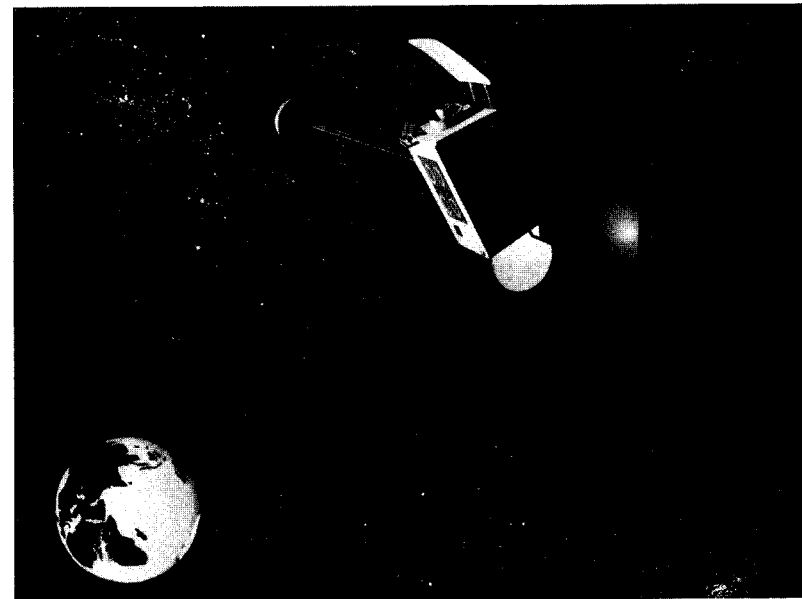
INSAT-1B

INSAT-1B Geosynchronous Orbit

INSAT-1
SYSTEM CONCEPT

DIRECT TV
BROADCASTING
TO RURAL
COMMUNITIES

NETWORK
OPERATIONS
CONTROL CENTER
(NOC) DELHI

LARGE EARTH STATION

DUAL ANTENNA
AT FOUR STATIONS

INTERMAIN AND MAIN
PRIMARY TRUNK
TELEPHONY

REMOTE AREA
COMMUNICATIONS

TV UPLINK FOR FEEDING
TV CHANNELS

RECEPTION OF
METEOROLOGICAL DATA
FROM SATELLITE AT
NEW DELHI STATION

MASTER CONTROL FACILITY
(HASSAN, KARNATAKA)

ON-ORBIT CONTROL OF SATELLITES
HEALTH MONITORING OF SATELLITES
ORBIT RAISING CONTROL

2.5 GHz

4 GHz

6 GHz

4 & 6 GHz

4 & 6 GHz

400 MHz

4 & 6 GHz

4 & 6 GHz

400 MHz

400 MHz

6/4/2.5 GHz

6/4/2.5 GHz

2.5 & 4 GHz

4 & 6 GHz

REMOTE AREA TERMINALS
TELEPHONY ONLY

MEDIUM EARTH STATIONS
TRUNK TELEPHONY
(MAIN PRIMARY)
TV UPLINK FEED

METEOROLOGICAL
DATA COLLECTION AND
REPLAY PLATFORMS

VHRR AND
DCP DATA
RECEIVED
AT DELHI
EARTH STATION

METEOROLOGICAL
DATA UTILISATION CENTER
(MDUC) (DELHI)
VHRR AND DCP DATA PROCESSING
DATA ANALYSIS DISSEMINATION

EMERGENCY COMMUNICATION TERMINALS
JEEP-TRANSPORTABLE AND AIR-LIFTABLE
FOR MEETING SHORT NOTICE
EMERGENCY DISASTER REQUIREMENTS

TRANSPORTABLE TERMINALS
FOR MEETING EMERGENT NEEDS
TELEPHONY TV UPLINK FEED

REDIFFUSION OF SATELLITE TV
BY TERRESTRIAL TRANSMITTERS
NATIONAL NETWORKING

16

INSAT-1 System Concept

broadcast signals at 2.5 GHz and the other six telecommunications channels at 4 GHz.

INSAT-1B Attitude Control Subsystem design is a momentum-bias type with two momentum wheels. A reaction wheel is provided for redundancy in achieving three-axis satellite control. Attitude information is provided by redundant scanning infrared earth sensors and non-scanning sun sensors which are used both, in the transfer orbit and synchronous orbit operations. The subsystem also interfaces with the propulsion subsystem to perform thruster operation of attitude control during acquisition, apogee boost, momentum wheel unloading, and station-keeping maneuvers. A solar sail extending 12.6 meters (41 feet) from INSAT's main body is used to provide passive compensation of the solar pressure torque about the satellite main body due to the single-wing solar array. The single-wing solar array is used to avoid interference with the radiometer cooler field of view. A body-mounted magnetic torquing coil provides an additional reaction torque for attitude control and momentum wheel speed unloading.

A single 445-Newton (100 pound) thruster is utilized for apogee boost. The thruster utilizes hypergolic propellants, nitrogen tetroxide as the oxidizer and monomethylhydrazine as the fuel. Attitude control and station keeping are accomplished with redundant sets of 22 Newton (5 pound) thrusters; each of the two sets contain six thrusters. Propellant storage consists of two titanium tanks equipped with surface tension propellant management devices. Both tanks are pressurized with helium and have a capacity for a calculated life of seven years.

A single wing, five panel planar solar array of aluminum honeycomb with graphite-epoxy face skins converts solar energy into electrical power. Energy storage for solar eclipse operations is supplied by two 12 ampere-hour, 28-cell-nickel-cadmium batteries. Control of the electrical power subsystem is provided by the power control electronics consisting of the power control unit and sequential shunt unit. A direct-energy transfer dual-bus system provides electrical power.

India is paying NASA approximately $4 million and the value of each satellite is approximately $50 million. Total cost for the two satellites, PAM-D's and launch is approximately $140 million. INSAT-1C is the backup for INSAT-1B. Each satellite is designed for a nominal seven year life.

The satellite will be controlled after ejection and PAM-D motor firing by the Satellite Control Center located in Hassan, India. The final parking orbit will be at geosynchronous orbit over the equator at 74 degrees East longitude.

INSAT-1B/PAM-E EJECTION

To prepare for cargo ejection, the orbiter flight crew verifies the spacecraft through a series of checks and configures the payload for deployment. The orbiter is approximately 160 nautical miles (184 statute miles) altitude for spacecraft deployment. The satellite is spun up (up to 40 rpm) on the cradle's spin table, communications and other subsystems are checked by means of an electrical and communications harness to the flight crew cabin, and the payload ordnance items are armed. All the checks are performed remotely from the flight crew cabin, and payload data are transmitted from the orbiter to the Mission Control Center in Houston (MCC-H) for analysis.

During a final pre-ejection sequence lasting approximately 30 minutes, the orbiter is maneuvered into a deployment attitude with the payload bay facing the direction desired for the PAM motor firing.

Ejection will occur, nominally on mission elapsed time of day one, one hour and 17 minutes, on a descending node, orbit 17. A Marman clamp is released by explosive bolts, and the spinning payload pops out of the payload bay at approximately 0.9 meters per second (3 feet per second).

At ejection from the orbiter cargo bay, the INSAT-1B spacecraft has completed only the first of several critical launch events. At this point it is in an orbit similar to the orbiter's with

an altitude of about 160 nautical miles (185 statute miles) and a velocity of about 27,835 kilometers (17,300 mph).

To perform its intended communications service, the spacecraft must be raised to an altitude of about 36,851 kilometers (22,898 statute miles), with a velocity of about 10,941 kilometers per hour (6,800 mph).

The first in a series of major in-orbit events is the firing of the solid-propellant motor aboard the payload's PAM. At ejection, this motor is armed to automatically fire in 45 minutes. Spacecraft sensors and thrusters automatically maintain the payload's correct attitude for firing.

The PAM motor firing raises the apogee (high point) of the orbit to about 35,887 kilometers (22,300 statute miles). Now the spacecraft is in a highly elliptical transfer orbit with a perigee of about 158 nautical miles (182 statute miles). The PAM motor casing is jettisoned after firing.

NASA's responsibility for the launch of INSAT-1B is completed upon INSAT-1B/PAM-D ejection from *Challenger*, except for tracking of the payload until the PAM is fired.

The INSAT-1B liquid fueled apogee kick motor (AKM) is
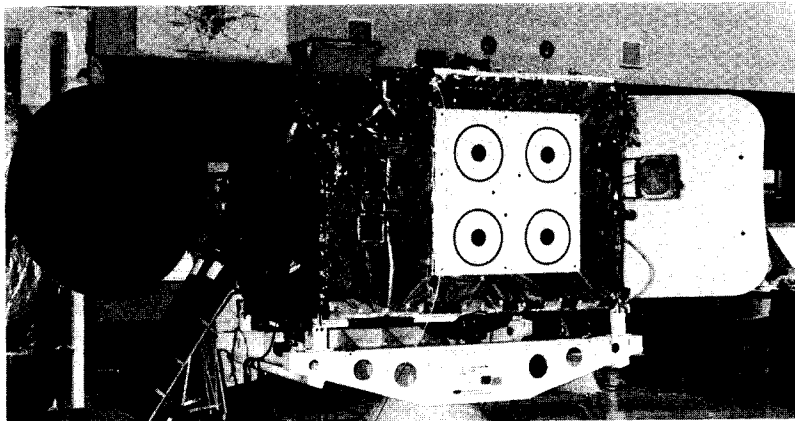
INSAT-1B

fired to raise the perigee of the orbit. This puts INSAT-1B into a near circular orbit at near-geosynchronous altitude. The apogee kick motor is fired on command from Indian Satellite Control in Hassan, India. This is followed by a series of INSAT-1B thruster firings by Indian Satellite Control to refine the orbit
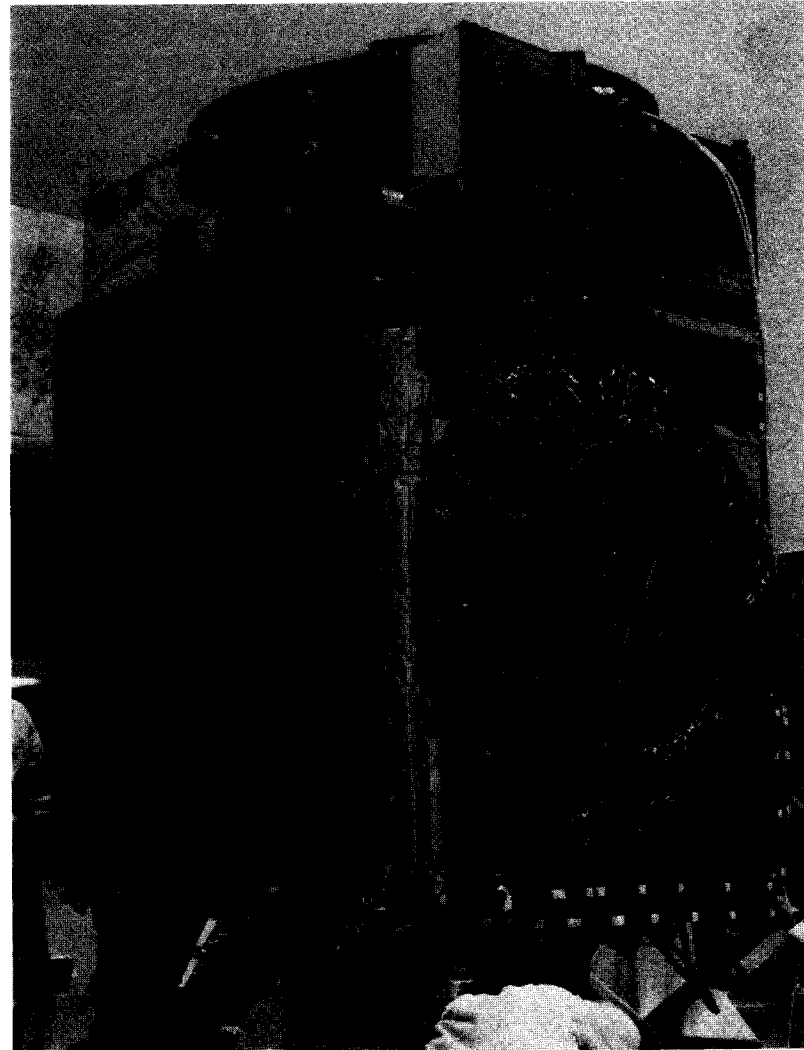
INSAT-1B in Stowed Position

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and adjust INSAT-1B velocity so that a controlled drift will bring it to its final destination. When the maneuvers are completed, Indian Satellite Control conducts a series of on-orbit tests and verification of spacecraft subsystems, before service is begun.

PAYLOAD RETENTION MECHANISMS

Nondeployable payloads are retained by passive retention devices, whereas, unberthing and berthing of the PFTA (Payload Flight Test Article) are secured by motor-driven, active retention devices.

Payloads are secured in the orbiter payload bay by means of the payload retention system or are equipped with their own unique retention systems.

The orbiter payload retention system provides three-axis support for up to five payloads per flight.

The payload retention mechanisms secure the payloads during all mission phases and provides for installation and removal of the payloads when the orbiter is either horizontal or vertical.

Attachment points in the payload bay are in 99-millimeter (3.933-inch) increments along the left- and right-side longerons and along the bottom centerline of the bay. Of the potential 172 attach points on the longerons, 48 are unavailable because of the proximity of spacecraft hardware. The remaining 124 may be used for carrier/payload attachment: of these, 16 may be used for deployable payloads. Along the centerline keel, 89 attach

20

Payload Retention

Orbiter Retention Rigging

Split Bearing Retained in Bearing Housing Cap

Trunnion

Swings Aft

Trunnion

Bearing Housing Cap

Z_0 414

Z_0 414

Z_0 410

Typical Attach Location

Longeron

Bridge

Split Bearing

Longeron Bridge

NONDEPLOYABLE PAYLOAD ATTACH FITTING

Hammer-Head Latch

Latch

Actuator

Bridge

Split Bearing

Trunnion
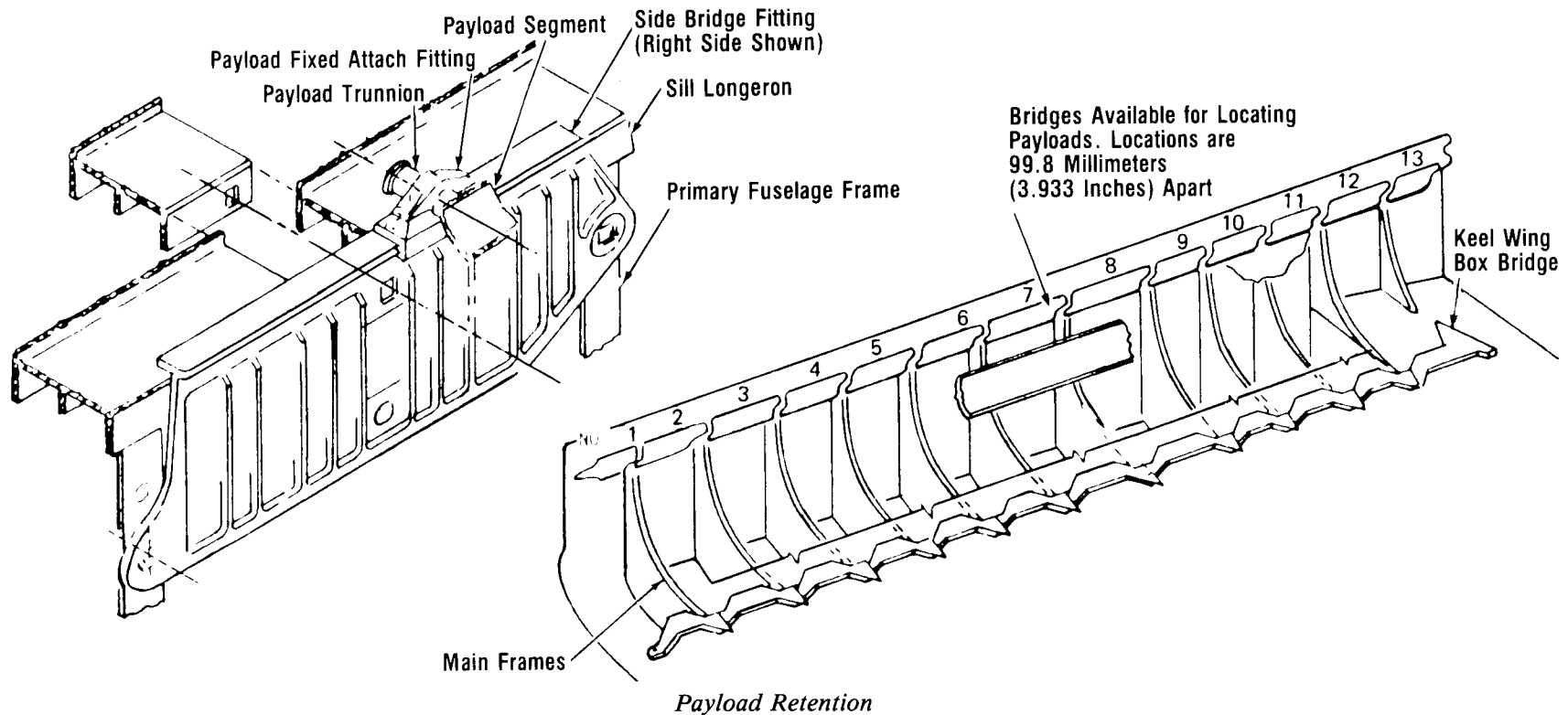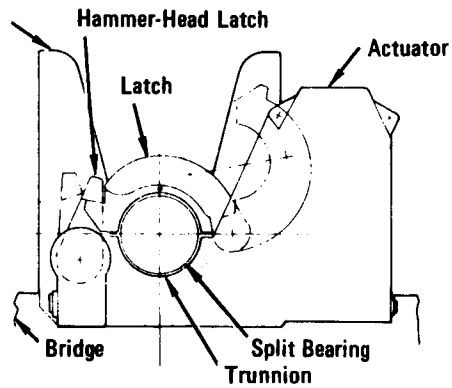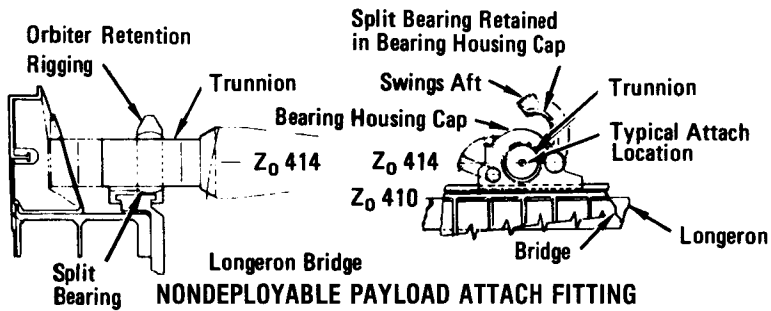
DEPLOYABLE PAYLOAD ATTACH FITTING/MECHANISM

$Y_0 = 0$

Keel Attach Points

Fuselage Frame

Sliding Keel Fitting (Bolted Onto Keel Bridge Track)

Self-Aligning Bearing

Carrier/Payload Keel

$Z_0 = 305$

CARRIER/PAYLOAD KEEL FITTING
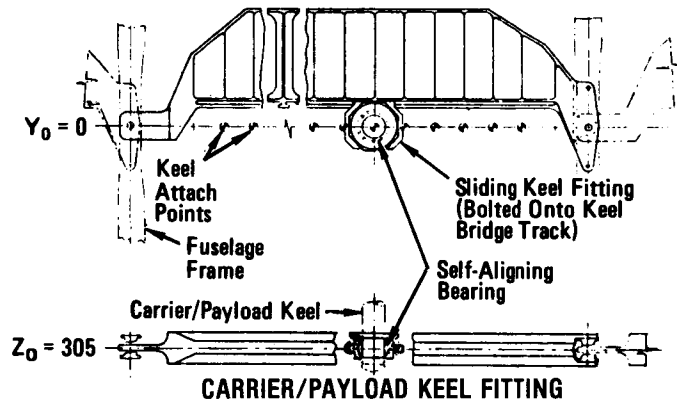
Standard Attach Fittings for Payloads

Latch

Gear Motor

Sill Longeron

Main Frame

Bridge Pin 3 Payload

Bridge Fitting

Primary Fittings X and Z Loads

Stabilizer Fitting Z Loads

Keel Fitting Y Loads
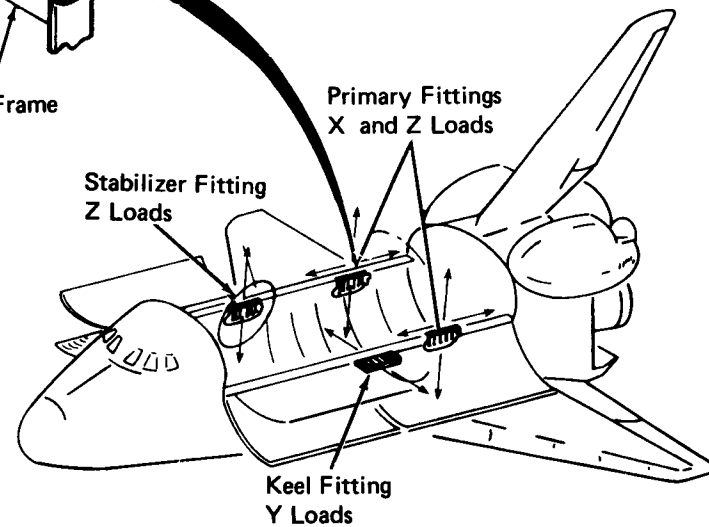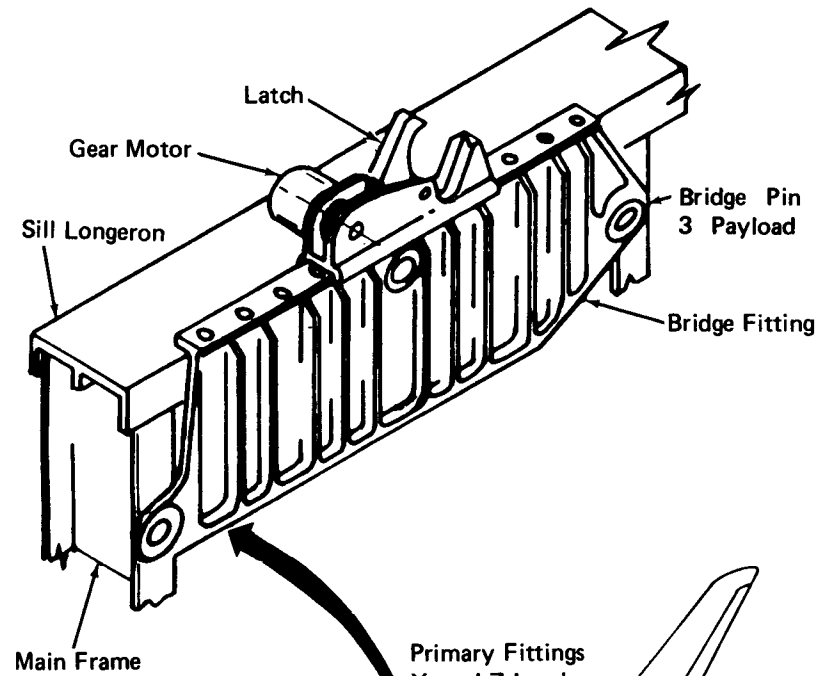
Active Payload Retention System

21

points are available, 75 of which may be used for deployable payloads. There are 13 longeron bridges per side and 12 keel bridges available per flight. Only the bridges required for a particular flight are flown. The bridges are not interchangeable because of main frame spacing, varying load capability, and subframe attachments.

The longeron bridge fittings are attached to the payload bay frame at the longeron level and at the side of the bay. Keel bridge fittings are attached to the payload bay frame at the bottom of the payload bay.
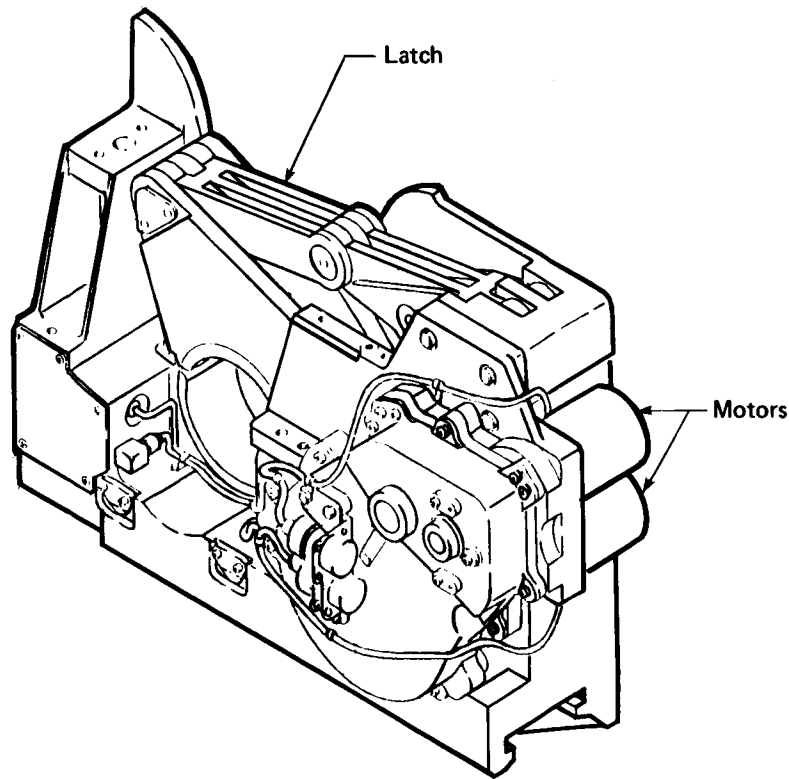
The payload trunnions are the interfacing portion of the payload with the orbiter retention system. The trunnions that interface with the longeron are 82 millimeters (3.25 inches) in diameter and 177.8 or 222.2 millimeters (7 or 8.75 inches) long, depending upon where they are positioned along the payload bay. The keel trunnions are 76.2 millimeters (3 inches) in diameter and vary in length from 101.6 to 292.1 millimeters (4 to 11.5 inches), depending upon where they fit in the payload bay.

The orbiter/payload attachments are the trunnion/bearing/journal type. The longeron and keel attach fitting have a split, self-aligning bearing for nonrelease-type payloads in which the hinged half is bolted closed. For on-orbit unberth and berthing of the PFTA, the hinged half fitting releases or secures the payload by latches that are driven by dual redundant electric motors.

Payload guides and scuff plates are used to assist in unberthing and berthing the PFTA in the payload bay. The payload is constrained in the X direction by guides and in the

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Payload Retention Latch

Active Keel Fitting

Y₀ 92.5 → $Y_0\ 92.5$

$Z_0\ 438$

**82 Millimeters
(3.25 Inches)**

$Y_0\ 89.5$

Scuff Plate

Guide

Payload Trunnion

← Y Axis →

→ Payload

Skirt

Orbiter
Structure

$Z_0\ 410$

Longeron

Retention
Fitting

Bridge
Fitting

$Y_0\ 105$

114 Millimeters
(4.5 Inches)

114 Millimeters
(4.5 Inches)

50 Millimeters
(2 Inches)

330
Millimeters
(13 Inches)

Aft

609
Millimeters
(24 Inches)

101
Millimeters
(4 Inches)

203
Millimeters
(8 Inches)

50 Millimeters
(2 Inches)

$Z_0\ 414$

Latch
Envel

23

Orbiter Payload Guide and Trunnion/Scuff Plate (Nominal)

Orbiter Active Latch Guide

Y direction by scuff plates and guides. The guides are mounted to the inboard side of the payload latches and interface with the PFTA trunnions and scuff plates. The scuff plates are attached to the PFTA trunnions and interface with the PFTA guides.

The guides are V shaped with one part of the V being 50.8 millimeters (2 inches) taller than the other part. Parts are available to make either the forward or aft guide, the tallest. This difference enables the operator monitoring the unberthing or berthing operations through the aft bulkhead TV cameras to better determine when the PFTA trunnion has entered the guide. The top of the tallest portion of the guide is 609.6 millimeters (24 inches) above the centerline of the payload trunnion when it is all the way down in the guide. The top of the guide has a 228.6-millimeter (9-inch) opening. These guides are mounted to the 203.2-millimeter (8-inch) guides that are a part of the longeron payload retention latches.

The payload scuff plates are mounted to the PFTA structure. There are two longeron latches and a keel latch for on-orbit unberthing and berthing of the PFTA. These latches are controlled by dual redundant electric motors with either or both motors releasing or latching the mechanism. The operating time of the latch is 30 seconds with both motors operating or 60 seconds with one motor operating. The latch/release switches on the aft flight deck display and control panel station control the latches. Each longeron latch has two microswitches sensing the ready-to-latch condition. Only one is required to control the ready-to-latch talkback indicator on the aft flight deck display and control panel station. Each longeron latch also has two microswitches to indicate latch and two to indicate release. Only one of each is required to control the latch or release talkback indicator on the aft flight deck display and control panel station. The keel latch also has two microswitches that sense when the keel latch is closed with the trunnion in it. Only one of the switches is required to operate the talkback indicator on the aft flight deck display and control panel station. The keel latch also has two microswitches that verify if the latch is closed or open, with only one required to control the talkback indicator on the aft flight station display and control panel station.

It is noted that the keel latch centers the PFTA in the yaw direction in the payload bay; therefore the keel latch must be closed before the longeron latch is closed. The keel latch can float plus or minus 69 millimeters (plus or minus 2.75 inches) in the X direction.

PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM

The remote manipulator system (RMS) is the mechanical arm portion of the payload deployment and retrieval system (PDRS) that maneuvers the PFTA (Payload Flight Test Article) from the payload bay for unberthing and berthing.

The basic RMS configuration consists of a manipulator arm, an RMS display and control panel (including rotation and translation hand controls), and a manipulator controller interface unit which interfaces with the orbiter computer. The manipulator arm is installed on the port (left) side longeron of the orbiter payload bay.

The fifth onboard computer controls the RMS. The RMS takes up 32 percent of the CPU (computer processor unit) in the one computer for RMS operation and 30 percent for manual augmented operation. The RMS is a simple software package (computer programs) and a simple set of display and control panel hardware at the flight deck aft station.

The manipulator arm is 15 meters, 76.2 millimeters (50 feet, 3 inches) in length, 381 millimeters (15 inches) in diameter, and has six degrees of freedom. In conjunction with handling aids, it can remove and install a 4.5-meter (15-foot diameter), 18-meter (60-foot) long, 29,484-kilogram (65,000-pound) payload. The arm weight is 410 kilograms (905 pounds) and the total system weight is 450 kilograms (994 pounds). The RMS will rotate 31.36 degrees towards the payload bay doors when opened and rotates 31.36 degrees towards the payload bay so the payload bay doors can be closed.

The RMS arm consists of joint housing, electronics housing, arm booms, and shoulder brace. There are two booms: the upper, which connects the shoulder and elbow joints, and the lower, which connects the elbow and wrist joints. The booms are made of graphite/epoxy, 330 millimeters (13 inches) in

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BDA — Backup Drive Amplifier
D&C — Display and Controls
EEEU — End Effector Electronics Unit
GPC — General-Purpose Computer
JPC — Joint Power Conditioner
MCIU — Manipulator Controller Interface Unit
MM/SCU — Motor Module/Signal Conditioning Unit
RHC — Rotational Hand Controller
SPA — Servo Power Amplifier
THC — Translational Hand Controller

RMS Components
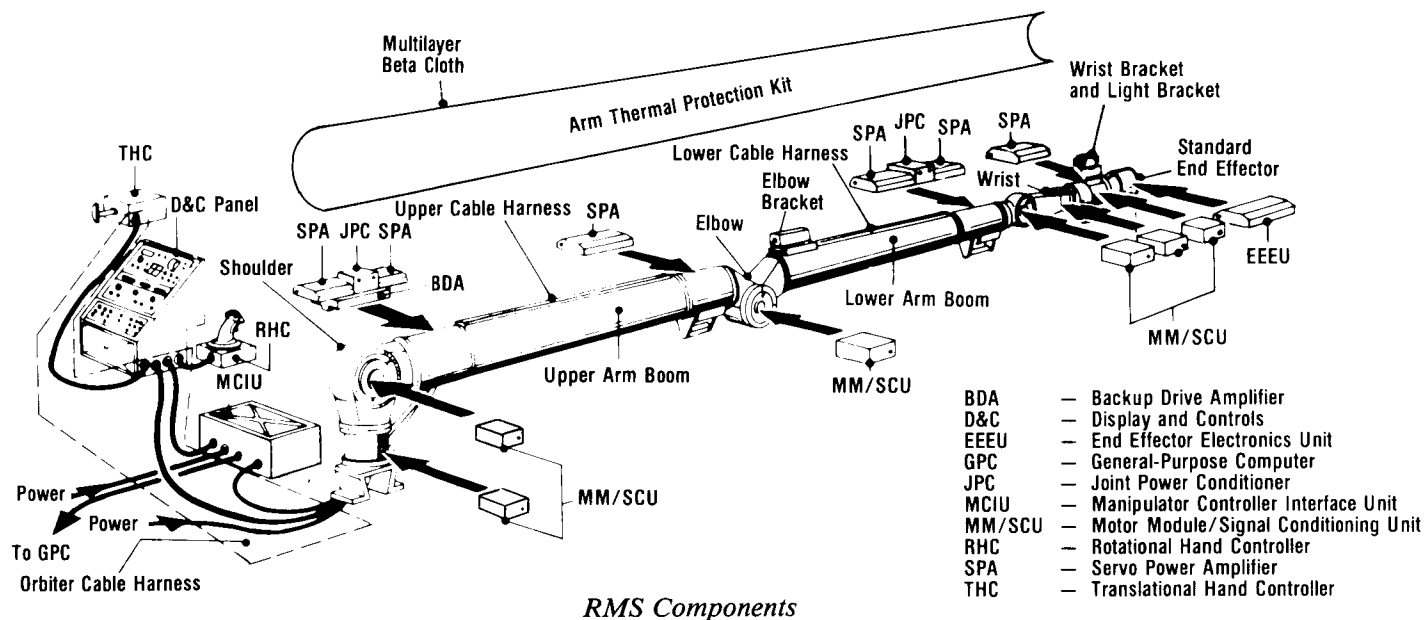
diameter, by 5 meters (17 feet) and 6 meters (20 feet) respectively, attached by metallic joints. The composite weight in one arm is 42 kilograms (93 pounds). The joint and electronic housings are made of aluminum alloy. A shoulder brace, used only during launch, minimizes high pitch axis moment loading on the shoulder pitch gear train. The shoulder brace is unlatched by a switch located on the aft flight deck display and control panel.

The RMS operates with a standard end effector. The standard end effector can grapple the PFTA, keep it rigidly attached as long as required, and then release it after berthing it.

The standard end effector has two functions: capture/release and rigidize/derigidize. Capture/release is accomplished by rotating an inner cage assembly containing three wire snares to open and close around the PFTA mounted standard grapple fixture. A switch on the back of the RMS rotation hand controller (RHC) commands capture or release. Rigidize/derigidize is accomplished by drawing the snare assembly into the rear of the end effector or moving the snares forward toward the open end of the effector. In the automatic mode, rigidization is automatic; when manually operated, a switch on the aft flight deck station display and control panel is used to rigidize or derigidize the effector.

The end effector generates six data signals corresponding to the following indications: snares fully open, snares full closed, payload present, carriage fully extended, maximum tension level crossed, and zero tension crossed.

The arm has a closed-circuit TV camera and a viewing light on the wrist section, as well as closed-circuit TV camera and a pan and a tilt unit at the elbow lower arm transition.

The RMS operator controls arm position and attitude by viewing it through the aft or overhead windows at the aft flight deck station, as well as by using closed-circuit TV from both the arm and payload-bay-mounted cameras. Two closed-circuit TV monitors at the aft flight deck station have split-screen capability.

26
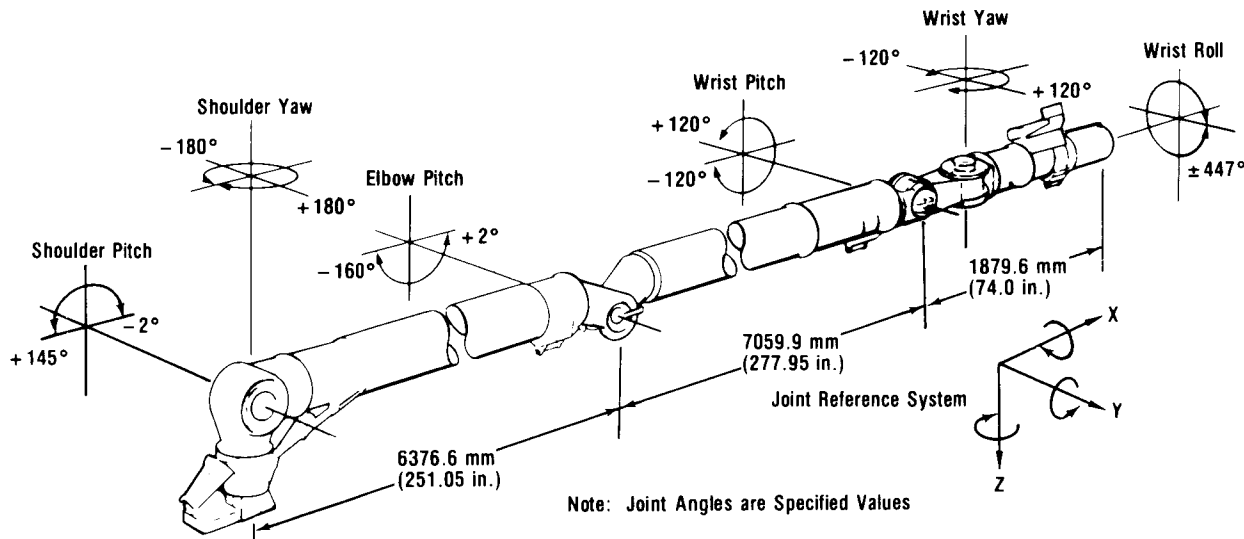
Mechanical Arm—Stowed Position and Movement Configuration
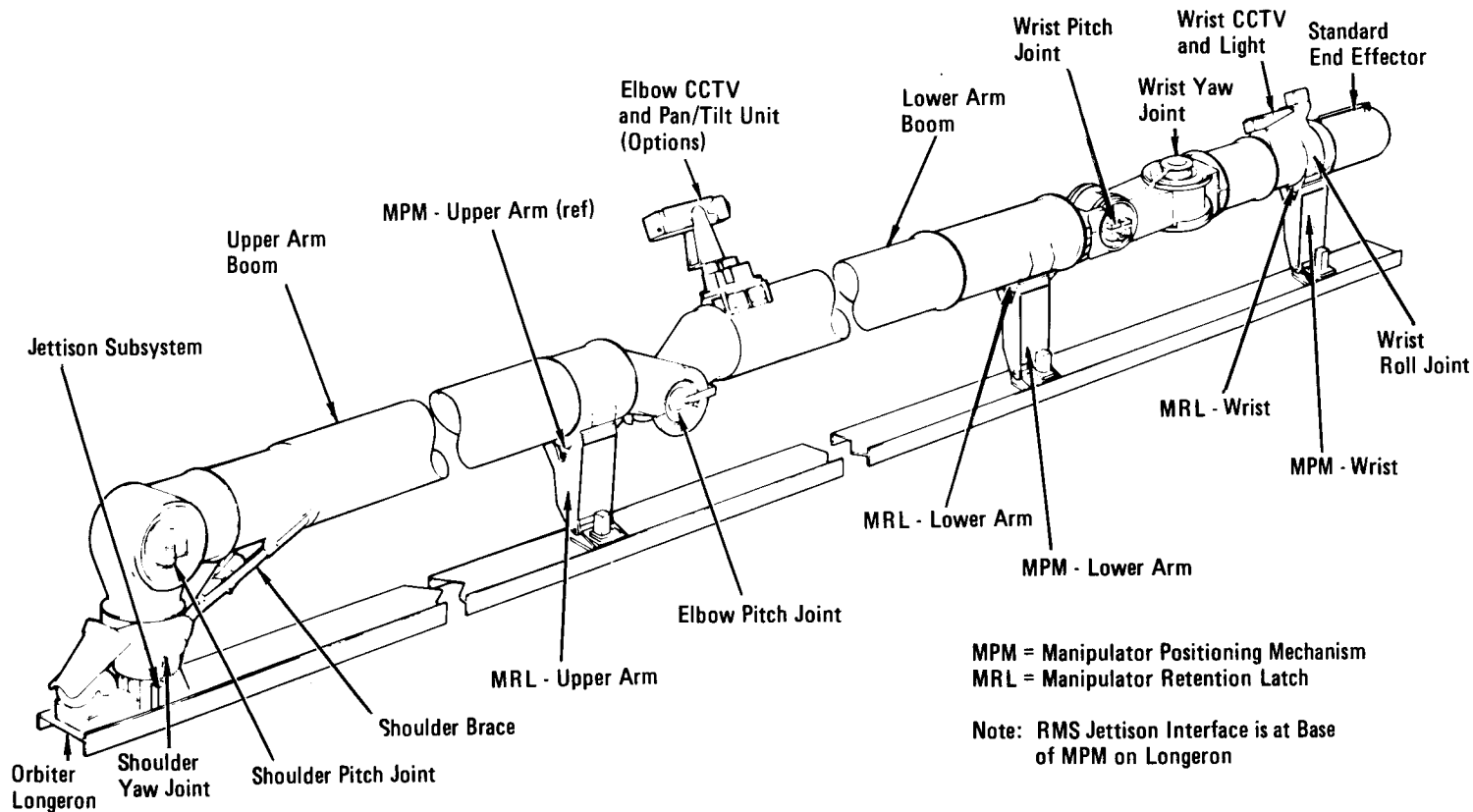
Mechanical Arm—Stowed Position and General Arrangement

The RMS has both passive and active thermal control systems. The passive system consists of multilayer insulation blankets and thermal coatings. The active system consists of 26 heaters on each arm that supply 520 watts of power at 28 Vdc. The heater system uses redundant buses on each arm, so if a failure occurs on one, the other is capable of supplying full heater power. The heaters operate automatically to maintain the temperature within the joints above -25 °C (-14 °F). Heater circuits are individually switched off as the corrsponding temperature reaches 0 °C (32 °F). Twelve temperature thermisters per arm monitor the temperatures, which can be displayed at the aft flight deck station.

Every joint of the arm is driven electromechanically. The joint drive train consists of a dc drive motor providing joint actuation, an output gear train that controls output speeds from the motor input, an optical encoder on the gearbox output shaft, and a mechanical brake on the motor output shaft.

The end effector drive train consists of a dc drive motor, a brake and clutch associated with the snare system, brake and clutch associated with the rigidization carriage and a differential unit. A spring mechanism is used for backup release.

The joint motor tachometers are the prime means of motion sensing, augmented by optical encoders. Tachometer

27
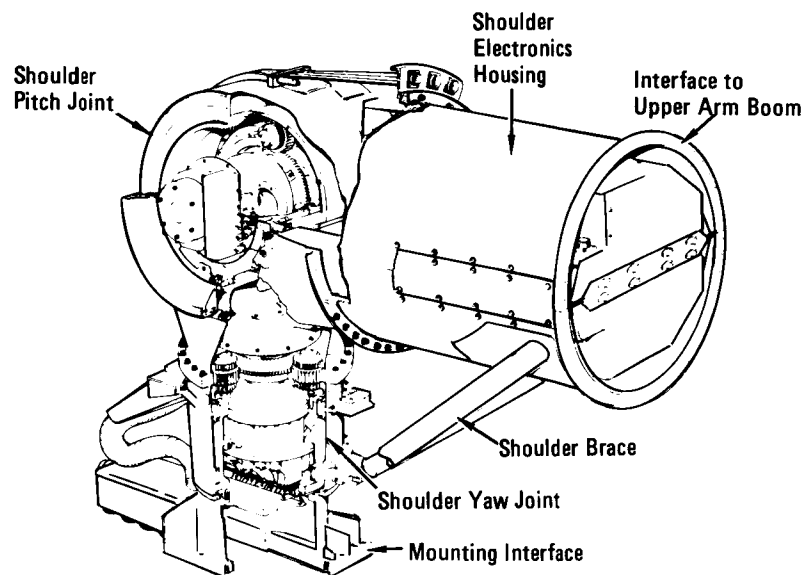
Overall Configuration of the Shoulder Joint

Shoulder Pitch Joint
Shoulder Electronics Housing
Interface to Upper Arm Boom
Shoulder Brace
Shoulder Yaw Joint
Mounting Interface
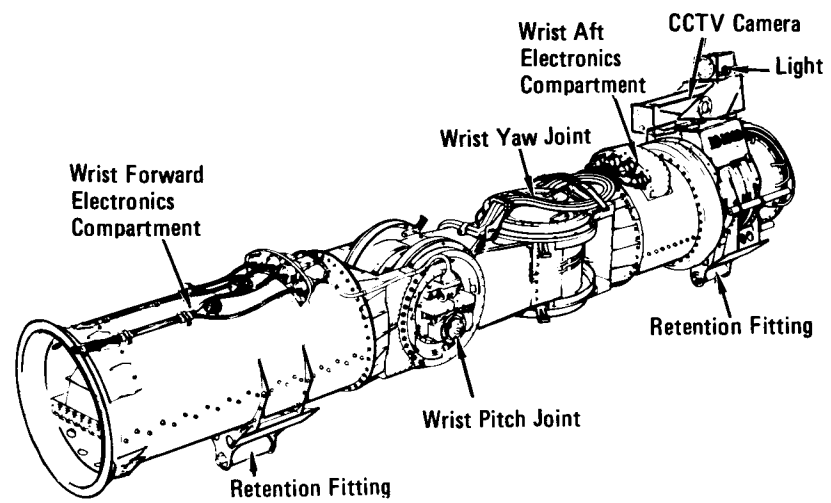
Overall Configuration of Wrist Joint

Wrist Aft Electronics Compartment
CCTV Camera
Light
Wrist Yaw Joint
Wrist Forward Electronics Compartment
Retention Fitting
Wrist Pitch Joint
Retention Fitting

28
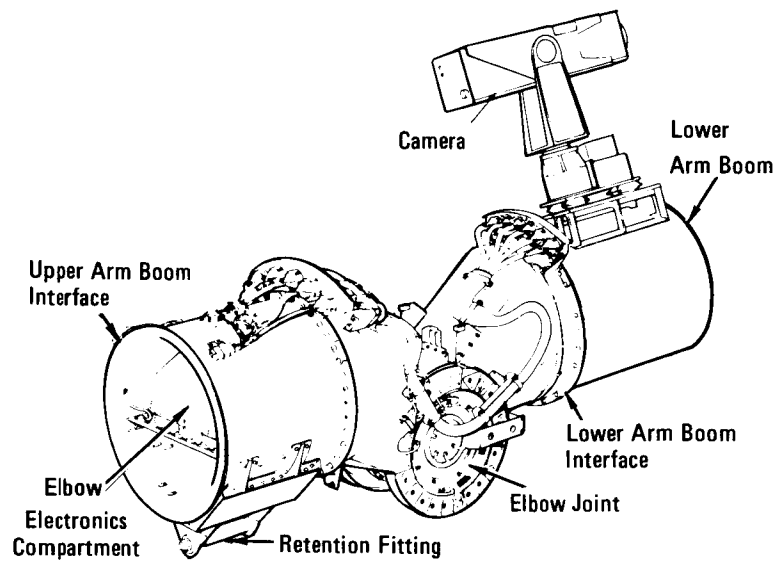
Overall Configuration of the Elbow Joint

Camera
Lower Arm Boom
Upper Arm Boom Interface
Lower Arm Boom Interface
Elbow Electronics Compartment
Elbow Joint
Retention Fitting
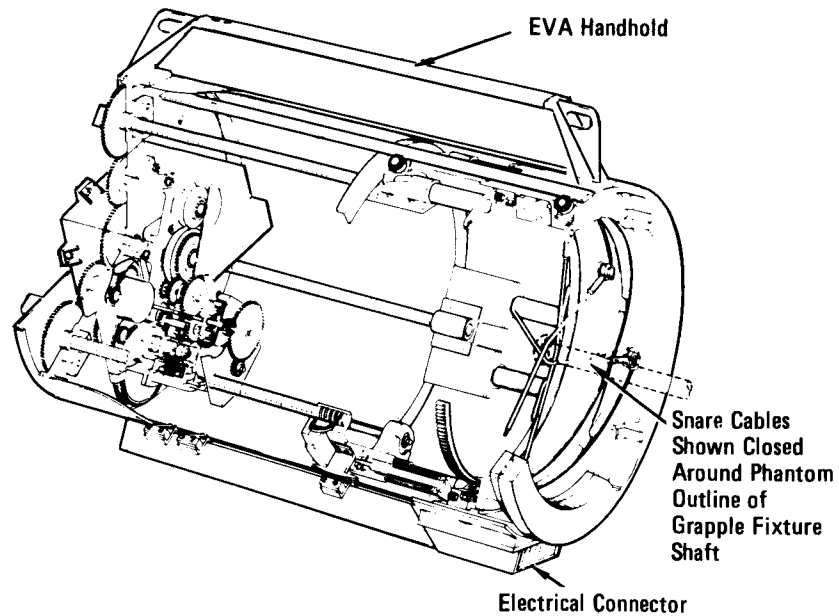
Standard Snare Type End Effector

EVA Handhold
Snare Cables Shown Closed Around Phantom Outline of Grapple Fixture Shaft
Electrical Connector
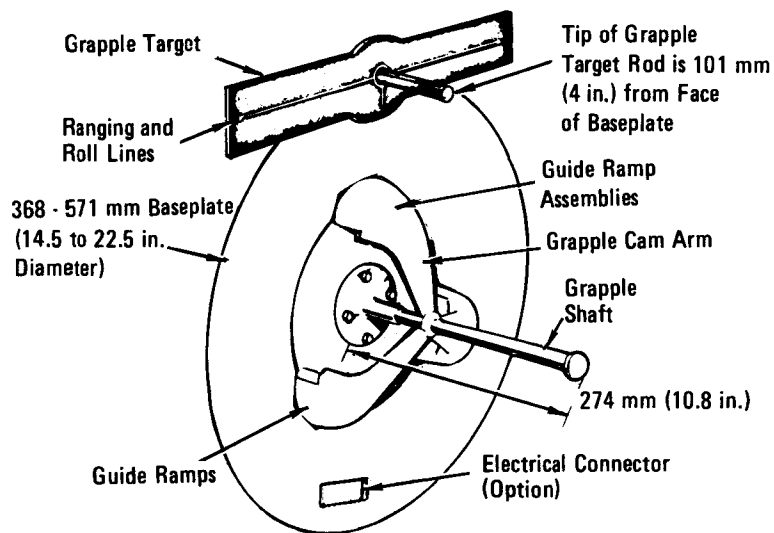
Grapple Fixture/Target Assembly on PFTA

Grapple Target

Tip of Grapple
Target Rod is 101 mm
(4 in.) from Face
of Baseplate

Ranging and
Roll Lines

Guide Ramp
Assemblies

368 - 571 mm Baseplate
(14.5 to 22.5 in.
Diameter)

Grapple Cam Arm

Grapple
Shaft

274 mm (10.8 in.)

Guide Ramps

Electrical Connector
(Option)
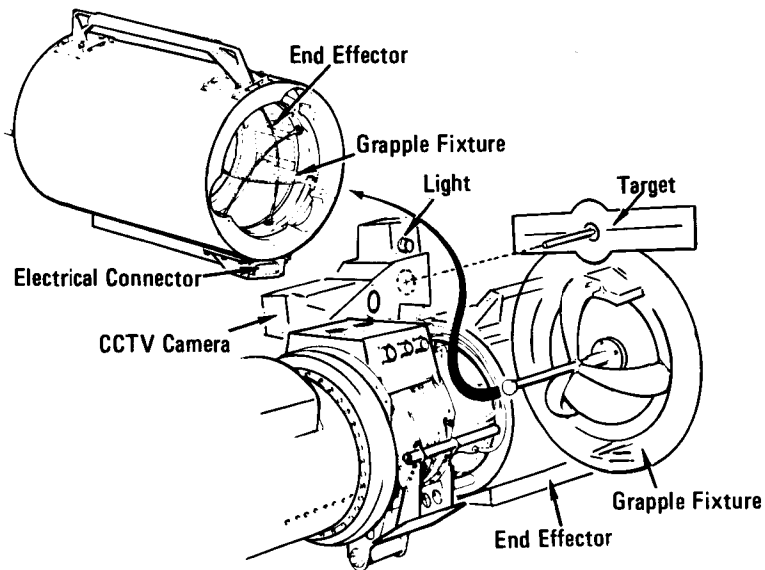
End Effector/Grapple Fixture Interface

End Effector

Grapple Fixture

Light

Target

Electrical Connector

CCTV Camera

Grapple Fixture

End Effector

data is supplied to control algorithms, which convert input drive commands to an output rate demand resolved for each joint of the arm. The algorithms output this rate demand within limits defined according to arm and individual joint loading conditions present at the time of computation. The algorithms supply the rate demand to control either end effector speed or position. The maximum attainable commanded velocity for the end effector and individual joints is limited by arm loading conditions, as is the maximum torque that can be applied to an individual joint under certain conditions. The aspect of arm control is provided by end effector velocity, joint rate, and motor current limiting within the software system under normal operating conditions. Joint velocity is limited during software-supported control modes by specifying a rate limit for each joint by the software system. Current limiting by the computer occurs during capture/rigidization operations. When the capture command is detected, the software commands zero current to all joint servos, except for the wrist roll joint servo; thus, for a short period, there is a "limp" arm, except for the wrist roll joint. This is to allow for constrained motion adjustment during deployment.

Normal braking is accomplished by motor deceleration, while the joint brakes are used for emergency or driving contingency operations only. Backdriving occurs when the payload or moving arm transmits kinetic energy into the drive train.

The RMS can be operated in any one of five different modes: automatic, manual augmented, manual single-joint drive, direct drive, and manual backup drive.

The normal loaded arm movement rate is up to 0.06 meters per second (0.2 feet per second) and the unloaded arm movement rate is up to 0.60 meters per second (2 feet per second), no payload for the latter. Rate of movement can be controlled within 0.009 meters per second (0.03 feet per second) and 0.09 degrees per second.

The manual augmented mode can be used to grapple PFTA, maneuver it into or out of the payload retention fittings

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or handling aids, and grapple or stow it in orbit. The manual augmented mode enables the operator to direct the end-point of the arm using two 3-degree-of-freedom hand controllers to control end effector translation and rotation rate. The control algorithms process the hand controller signals into a rate demand to each joint of the arm. The operator can carry out manual augmented control of the arm using any four coordinate systems: orbiter, end effector, payload, or orbiter loaded.

When the manual orbiter mode is selected, rate commands through the aft flight deck station RMS translation hand control (THC) result in motions at the tip of the end effector which are parallel to the orbiter-referenced coordinate frame and compatible with the up/down, left/right, in/out direction of the THC. Commands from the aft flight deck station RHC result in rotation at the tip of the end effector, which are also about the orbiter-referenced coordinate frame.

Rate Hold
(2-Position Pushbutton)

Rate Limit
Vernier/Coarse
(2-Position Slide Switch)

End Effector
Capture/Release
(3-Position Rocker)
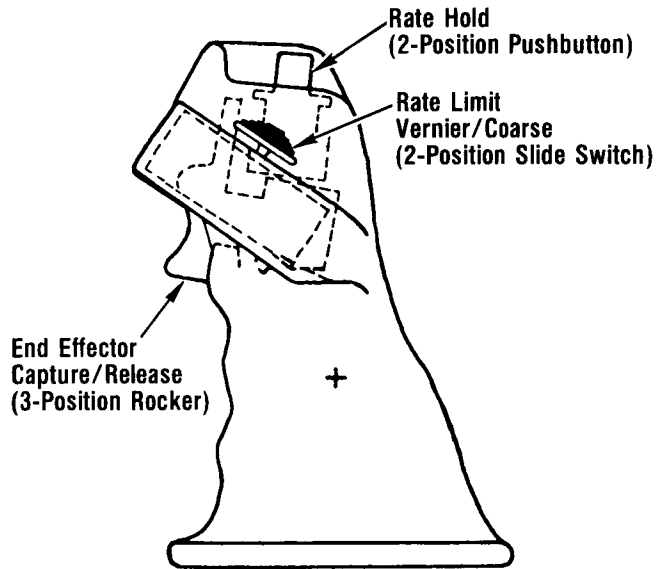
RMS Rotation Hand Control Switches
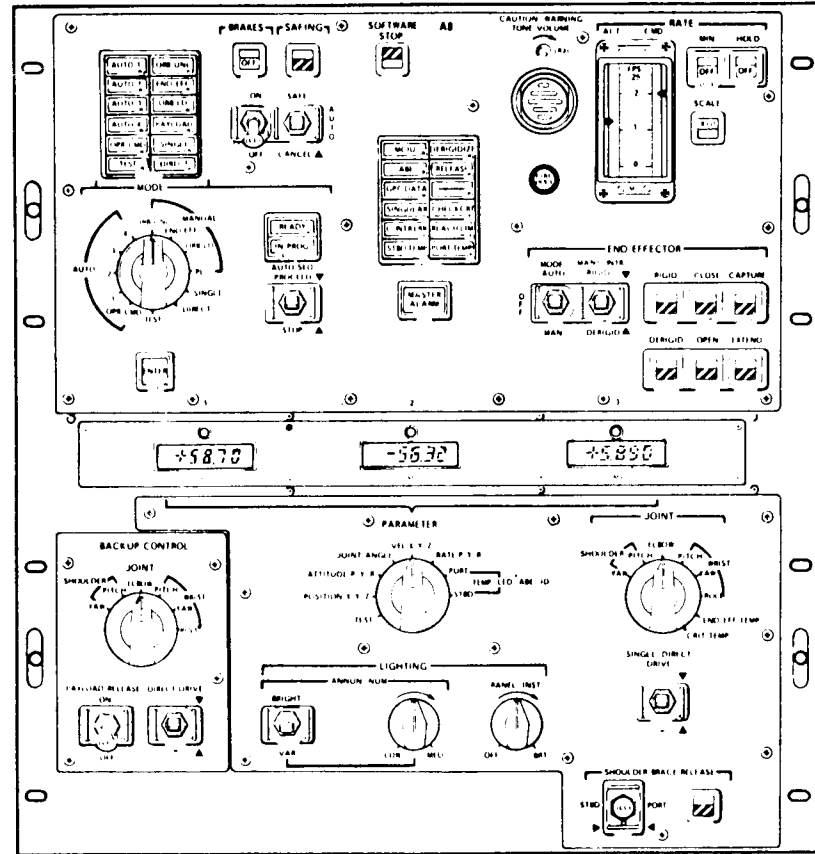
The manual end effector mode is to maintain compatibility at all times between rate commands at the THC and RHC and the instantaneous orientation of the end effector. The end effector mode is used primarily for grappling operations in conjunction with a wrist-mounted CCTV camera which is oriented with the end effector coordinates and rolls with the end effector. The CCTV scene presented on the television monitor has viewing axes which are oriented with the end effector coordinate frame. This results in compatible motion between the rate commands applied at the hand controllers and movement of the background image presented on the television monitor.

Payload Grapple

Snared Position

PFTA
Payload

Payload
Grapple

Wires Stored
End Effector

Outer Ring   Inner Rotating Ring

① With ring in forward
position, wires stored,
payload grapple enters
open end of effector

②
Payload grapple
inside open end
of end effector;
wires stored

31

③
End effector ring
begins to rotate;
wires begin to close
onto payload grapple

80   80

④
End effector ring
fully rotated;
wires closed on
payload grapple,
centering it and
capturing payload

80

⑤ Operation of ball screw and nut
withdraws wires, pulling payload
into full contact and keyed orientation;
further operation tensions wires to
rigidize contact

Snare Capture and Rigidization Sequence

Up/down, left/right, in/out motions of the THC results in the same direction of motion of the end effector as seen on the television monitor, except that the background in the scene will move in the opposite direction. Therefore, the operator must remember to use a "fly to" control strategy and apply commands to the THC and RHC that are toward the target area in the television scene.

The manual orbiter loaded mode is to enable the operator to translate and rotate a payload about the orbiter axis with the point of resolution of the resolved rate algorithm being at a predetermined point within the payload, normally the center of

geometry. This allows for pure rotations of the payload, which is useful for berthing operations.

There are two types of automatic modes, preprogrammed and operator commanded. The preprogrammed auto mode can store up to 20 automatic sequences in the computer, four of which can be assigned for selection at the aft flight deck station.

In the automatic modes, the payload is maneuvered to different locations for data taking according to a preprogrammed sequence.

Each automatic sequence is made up of a series of positions and attitudes of the end effector which define a trajectory of motion. The series may have from one to 199 points to define the trajectories. Pauses may be preprogrammed into the trajectory at any point. These will automatically cause the arm to come to rest, from which it may be able to proceed with the automatic sequence through the auto sequence

Aft Flight Deck RMS Crew Station/Crew Interface

RMS Controls and Displays

32

Upper Observation Windows

35° 45°

Fields of View

30°

32°

Aft Observation Windows

Flight Deck

Payload Bay Mounted Floodlights (3 per Side)

TV Cameras Mounted on Pan/Tilt Mechanism

TV Camera Pan/Tilt Mechanism

TV Camera and Spotlight
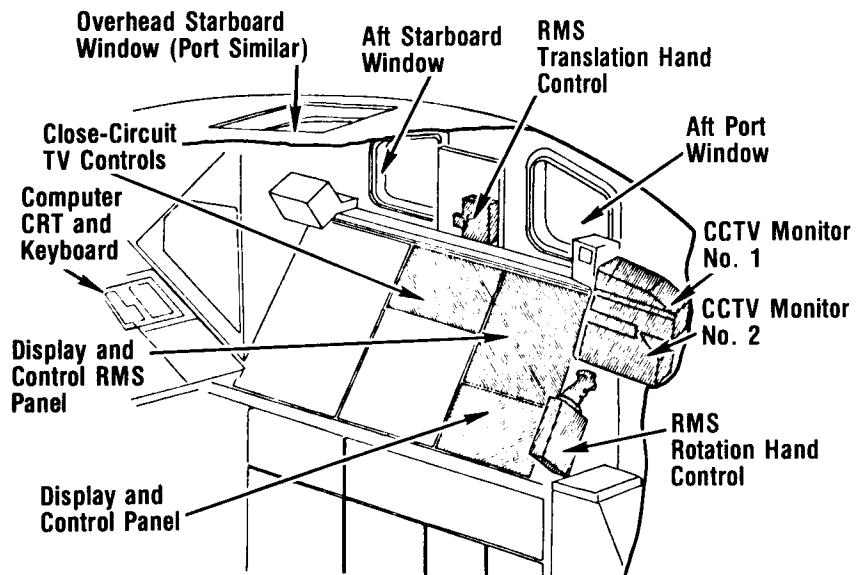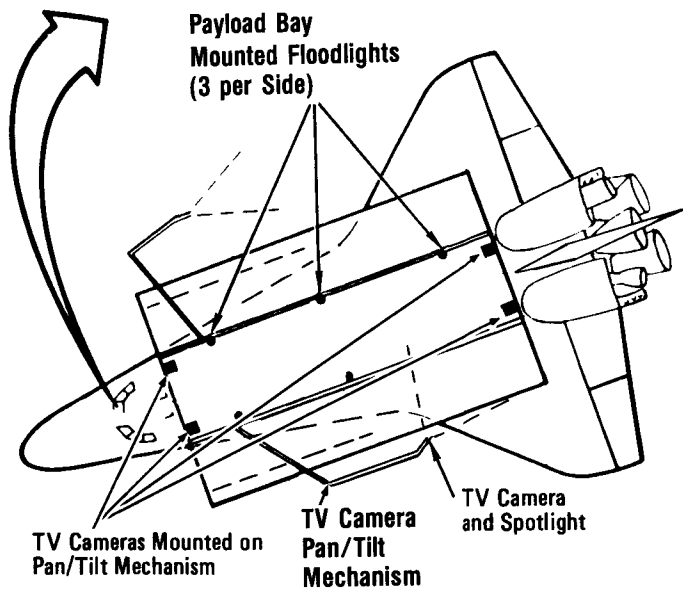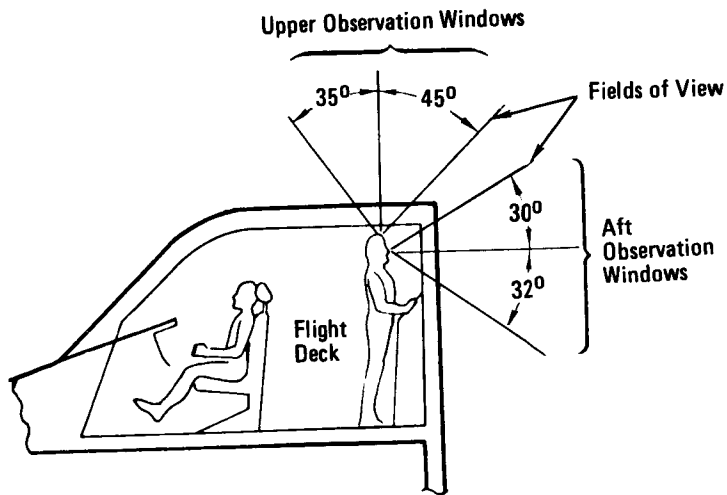
Payload Bay Television Cameras and Floodlights

Orbiter Unloaded—Point of Resolution at Tip of End Effector

X Roll

Y

Z Pitch

Yaw

Y

X

Z

Orbiter Body Axis System
(Origin as Orbiter Structural System)

Orbiter Loaded—Point of Resolution Within Payload Is Pre-Designated

X Roll

Y

Z Pitch

Yaw

Orbiter Operating System

Wrist
TV Camera

Point of Resolution at Tip of End Effector

X Roll

Y
Pitch

Z Yaw

End Effector Operating System

X Roll

Point of Resolution at Tip of End Effector

Y

Z Pitch

Yaw

Payload Operating System

Control Coordinate Operating Systems

33

"Proceed/Stop" switch on the aft flight deck station display and control panel. The operator can use the "Stop" position to halt the automatic sequence. This will bring the arm to rest, the switch is positioned to "Proceed" to resume the automatic sequence. When the last point in the sequence is reached, the computer will terminate the movement of the arm and enter a position hold mode. The speed of the end effector between points in a sequence is governed by the individual joint rate limits set in the RMS software.

The operator-commanded automatic mode moves the end effector from its present position and orientation to a new one defined by the operator to the computer via the keyboard and RMS cathode ray tube (CRT) display. After the data is keyed in, the RMS software verifies that the acquired position and orientation are "legal" with respect to arm configuration and reach envelope. The outcome of this check is displayed on the CRT. After the check, a "Ready" light will be displayed and the operator can execute the automatic sequence by placing the automatic sequence switch to "Proceed." The end effector will move in a straight line to the required position and orientation and then enter the hold mode. The operator can stop and start the sequence through the automatic sequence switch.

The single-joint drive control mode enables the operator to move the arm on a joint-by-joint basis with full computer support, thereby enabling full use of joint drive characteristics on a joint-by-joint basis. The operator supplies a fixed drive signal to the control algorithms via a toggle switch at the aft flight deck station. The algorithms supply joint rate demands to the selected joint while holding position on the other joints. The single-joint drive mode is used to stow and unstow the arm and drive it out of joint travel limits.

Direct-drive control is a contingency mode. It bypasses the manipulator control interface unit (MCIU), computer, and data buses to send a direct command to the motor drive amplifier (MDA) via hardwires. The direct-drive mode is used when the MCIU or computer has a problem that necessitates arm control by the direct drive mode to maneuver the loaded arm to a safe

payload release position or to maneuver the unloaded arm to the storage position. The operator must place the brake on and select direct drive on the mode select switch. Since this is a contingency mode, full joint performance characteristics are not available. Computer-supported displays may or may not be available, depending on the fault that necessitated use of direct drive.

Back drive control is a contingency mode used when the prime channel drive modes are not available. The backup is a degraded joint-by-joint drive system. It meets the fail-safe requirement of the RMS by using only the drive train of the prime channel.

Safing and braking are the two methods available for bringing the arm to rest. Safing can be accomplished by the operator from the aft flight deck station or by the MCIU in receipt of certain failure indications. Operator-initiated safing is sent on hardwires to the input latches, setting them to zero and thus resulting in zero current to each joint independent of computer commands.

The RMS has a built-in test capability to detect and display critical failures. It monitors the arm based electronics (ABE), display and controls, and the MCIU software checks in the computer monitor computations. Failures are displayed on the aft flight deck station panel and on the CRT and also are available for downlinking through orbiter telemetry.

All of the major systems of the ABE are monitored by built-in test equipment. The MCIU checks the integrity of the communications link between itself and the ABE, display and control, and the orbiter computer. It also monitors end effector functions, thermistor circuit operation, and its own internal consistency. The computer checks cover an overall check of each joint's behavior through the consistency check, encoder data validity, and end effector behavior, as well as the proximity of the arm to reach limits, soft stops, and singularities.

The caution/warning annunciators are located on the aft

flight deck station display panel. There are six caution annunciators (port temperature, starboard temperature, reach limit, singularity, control error, and check CRT) and five warning annunciators (release, derigidize, ABE, GPC data, and MCIU). A "Master Alarm" light and an audio signal attract the flight crew member's attention whenever a fault condition is detected.

A jettisoning system is installed within the Rockwell-provided manipulator positioning mechanism in the event the RMS cannot be stowed. Three floodlights are installed on each side of the payload bay. A portion of the orbiter closed circuit television (CCTV) system supports the payload deployment retrieval operations. The payload deployment retrieval operator uses the four payload bay TV cameras, the remote manipulator arm cameras, the TV monitors, and the TV controls and displays to assist in all phases of the payload deployment retrieval system operations. There are six TV cameras on STS-8 positioned in the following locations, arm wrist, arm elbow, forward port bulkhead, forward starboard bulkhead, aft port bulkhead and aft starboard bulkhead.

The wrist TV camera is mounted on the roll joint of the arm; the elbow TV camera is mounted on the lower arm boom next to the elbow joint. The payload bay bulkhead TV camera brackets are attached to the aft and forward bulkheads. The TV monitors and the displays and controls are mounted on the aft flight deck display and control panel station.

The TV cameras used for payload deployment and retrieval operations are identical and, therefore, interchangeable. They are black and white cameras. The cameras have a pan/tilt unit, which provides plus or minus 170° in pan and tilt, except when used on the arm's wrist or in the payload keel.

There are two black and white monitors. The monitors' electronic crosshairs have both vertical and horizontal components at the electrical center of the image. They are used to align the cameras with targets and sighting aids. The crosshairs are also used to align overlays with the monitor image. Alphanumerics are available on the monitors. The pan and tilt

Remote Manipulator System
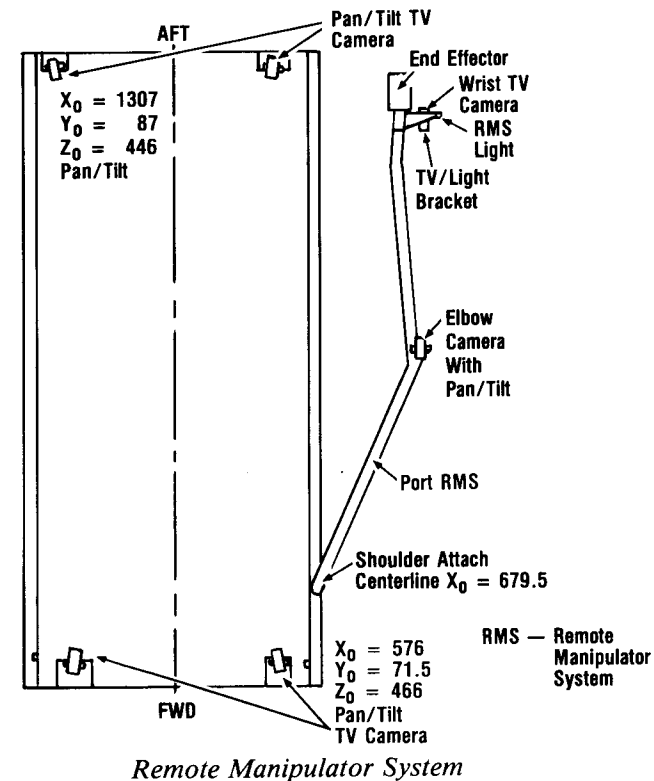
angles are displayed in degrees and tenths of degrees when the monitors display full scene images. The alphanumerics can be turned off. Each monitor can display two images simultaneously. The right or left half of the monitor will display the center half of the selected camera scene when the split screen mode is used.

Spar Aerospace Limited, Toronto, Canada, is the prime contractor to the National Research Council for development of the RMS for NASA. CAE Electronics Ltd, Montreal is responsible for the displays and controls in the orbiter. RCA Ltd, Montreal is responsible for the electronic interfaces, provides servo amplifiers and power conditioners. Dilworth, Secord, Meagher and Assoc. Ltd (DSMA), Toronto is responsible for the end effector.

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PAYLOAD FLIGHT TEST ARTICLE

The remote manipulator system is used in STS-8 for unberthing and berthing the PFTA, placing it in numerous positions while operating *Challenger's* attitude control system in various modes including free drift to determine the response in flight, for comparison with ground data and verification of ground computer simulations. This data will be used in determining the response of the remote manipulator system as well as the orbiter in handling larger payload in future missions, such as the Long Duration Exposure Facility (LDEF), which weighs approximately 9,072 kilograms (20,000 pounds).

The PFTA weighs approximately 3,383 kilograms (7,460 pounds) and is attached to *Challenger's* Cargo bay, four longeron trunnions and one keel trunnion. This is the first demonstration of a five point payload attachment system. The forward and aft screens of the PFTA simulate a "full-volume" cylinderical payload and are used to demonstrate the ability to unberth/berth the PFTA without a direct view of the four

longeron trunnions and one keel trunnion. There are four grapple fixtures on the PFTA, No. 2 through No. 5, however only No. 2 and No. 5 will be used to provide a different arm geometry and mass property. The majority of the weight of the PFTA is located at the aft end where the lead ballast is located. The beams are hollow aluminum and the screens are aluminum. Grapple fixture No. 5 provides the larger moment of inertia. The various tests will determine that the remote manipulator system can position a payload within 50 millimeters (2 inches) and one degree of accuracy in respect to *Challenger's* axes.

The following tests will be performed using the remote manipulator system (RMS) and PFTA:

- Nominal unberth/berth of the PFTA using the RMS in a six degree-of-freedom mode with closed circuit television and RMS position and altitude data.
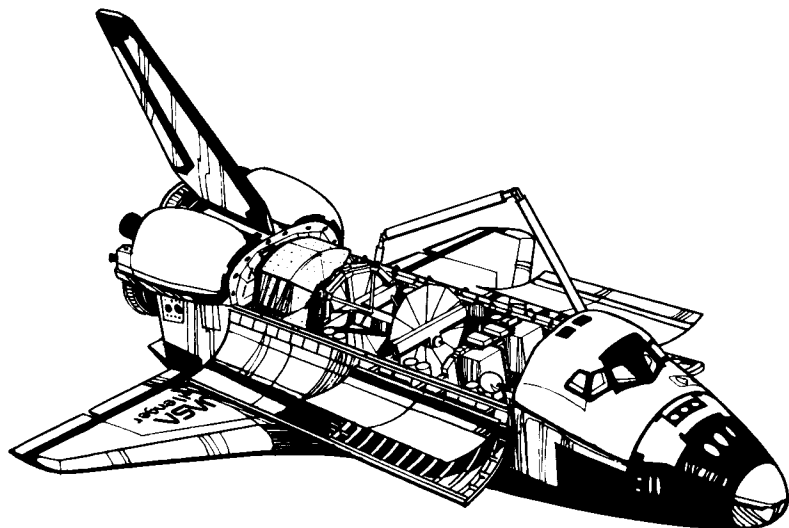
RMS (Remote Manipulator System) Using PFTA (Payload Flight Test Article) No. 2 Grapple Fixture in Payload Bay
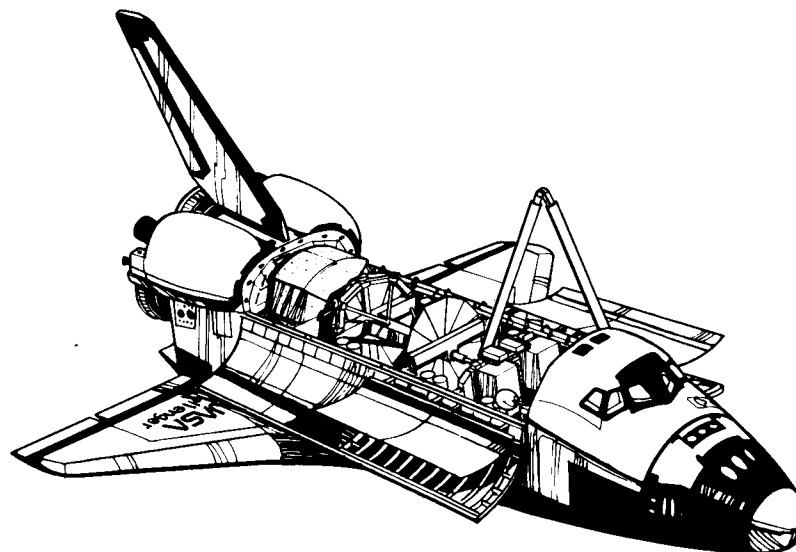
RMS (Remote Manipulator System) Using PFTA (Payload Flight Test Article) NO. 5 Grapple Fixture in Payload Bay

Z~TA~

−Y~TA~

+Y~TA~   X~TA~
          AFT

BALLAST

③ ②

Weight: 3,383 kilograms (7,460 pounds)

④

**FOUR
LONGERON
TRUNNIONS**

FORWARD SCREEN
Screen Diameter
3.8 meters (12.5 ft)

AFT SCREEN
Diameter
4.16 meters (13 ft, 8 in.)

**ONE
KEEL
TRUNION**

SMALL SCREEN (2)

⑤

**Overall Length
6.03 meters
(19 ft, 9 in.)**

**NOTE:
Numbers in Circles
Refer to Grapple
Fixture Locations
Grapple Fixture
2 and 5 Will Be
Only Ones Used**

**Width
4.77 meters
(15 ft, 8 in.)**

FORWARD

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Payload Flight Test Article (PFTA)

SINGLE AND MANUAL CONTROL SYSTEM EVALUATION
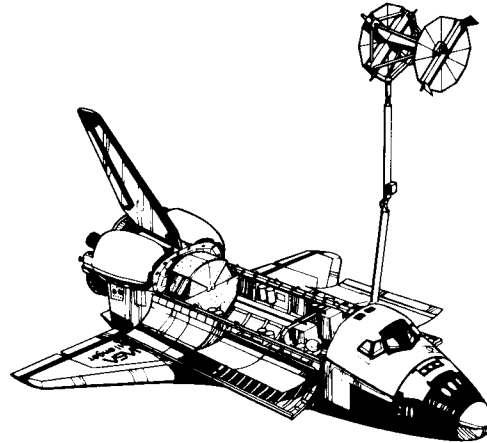
RMS (REMOTE MANIPULATOR SYSTEM)/PRCS (PRIMARY REACTION CONTROL SYSTEM) INTERACTION AND LSS (LARGE SPACE STRUCTURE) DAMPING TEST. POSITIVE/NEGATIVE ROLL AND POSITIVE/NEGATIVE PITCH PULSES FOR PRCS INTERACTION TEST. POSITIVE/NEGATIVE ROLL PULSES. FOR LSS VIBRATION DAMPING TEST
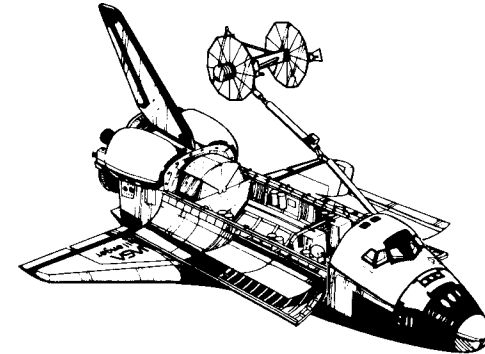
SINGLE JOINT CONTROL SYSTEM EVALUATION

38
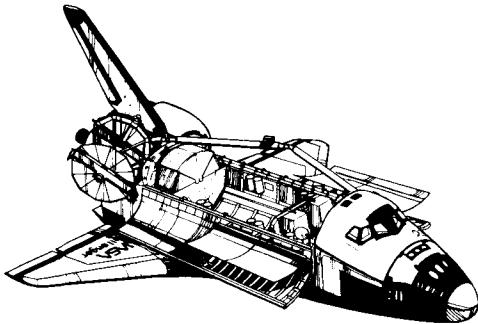
MANUAL AUGMENTED CONTROL SYSTEM EVALUATION
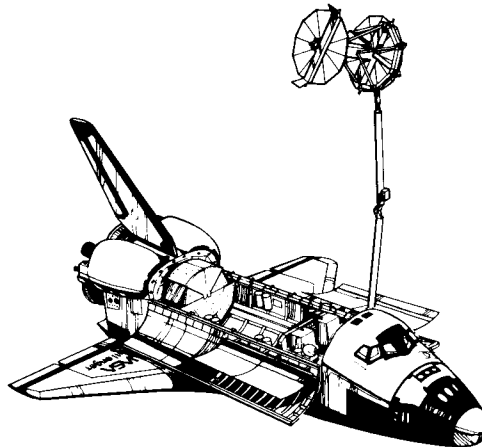
RMS/PRCS INTERACTION TEST. ORBITER LONGERON STIFFNESS TEST. POSITIVE/NEGATIVE ROLL AND POSITIVE/NEGATIVE PITCH PULSES
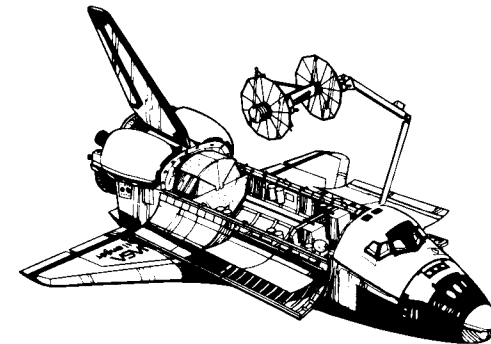
LSS VIBRATION DAMPING TEST. PRCS ROLL PULSES

RMS (Remote Manipulator System) Using PFTA (Payload Flight Test Article) No. 2 Grapple Fixture per Validation Runs

REMOTE MANIPULATOR SYSTEM (RMS)/PAYLOAD FLIGHT TEST ARTICLE (PFTA) OPERATIONS USING GRAPPLE FIXTURE NO. 2

MISSION ELAPSED TIME DAY 2, 01:00 HOURS TO 07:20 HOURS

OPERATIONS CHECKLIST	DURATION
Power Up	10
Nominal Unberth Using 6 Degree of Freedom Mode	15
FCS (Flight Control System)/RMS Test Using Vernier Reaction Control System (VRCS)	30
Control System Evaluation	45
RMS/PRCS Interaction	45
LSS (Large Space Structure) Test	45
Auto Sequence	20
Nominal Berth Using 6 Degree of Freedom Mode	20
Direct Drive Unberth Using One Joint at a Time	20
Direct Drive Berth Using One Joint at a Time	30
Unloaded Auto Sequence	20
Power Down	10
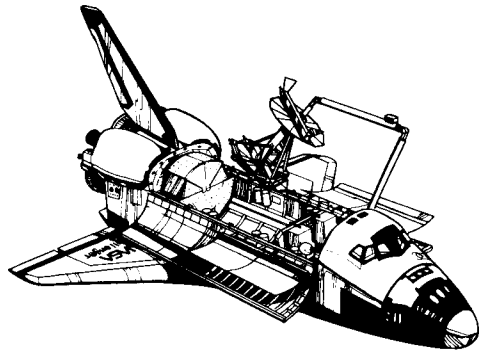
SINGLE JOINT CONTROL SYSTEM EVALUATION
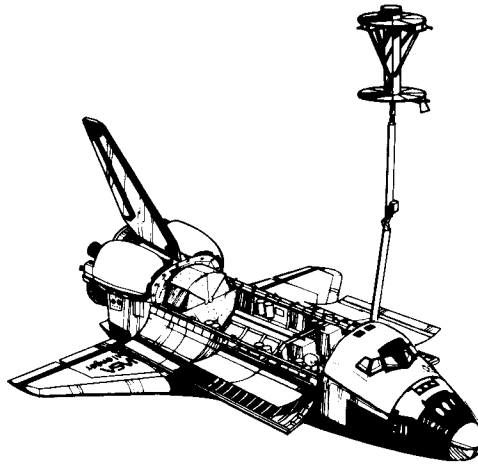
RMS (REMOTE MANIPULATOR SYSTEM)/PRCS (PRIMARY REACTION CONTROL SYSTEM) INTERACTION TEST. POSITIVE/NEGATIVE ROLL AND POSITIVE/NEGATIVE PITCH PULSES.
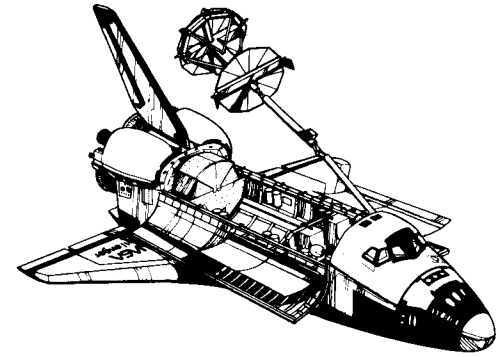
SINGLE AND MANUAL CONTROL SYSTEM EVALUATION
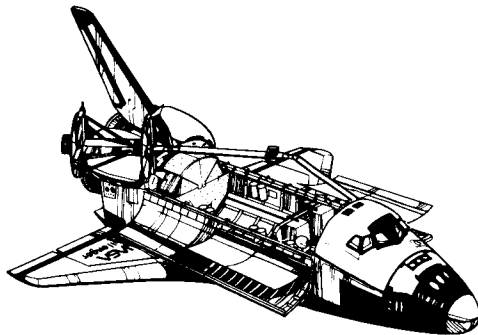
40

MANUAL AUGMENTED CONTROL SYSTEM EVALUATION

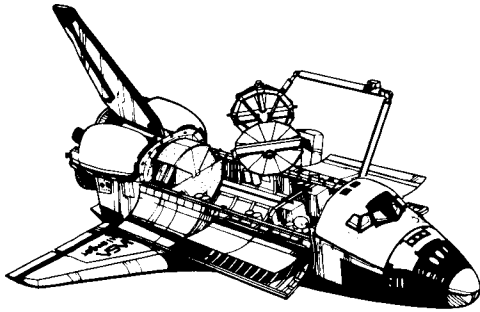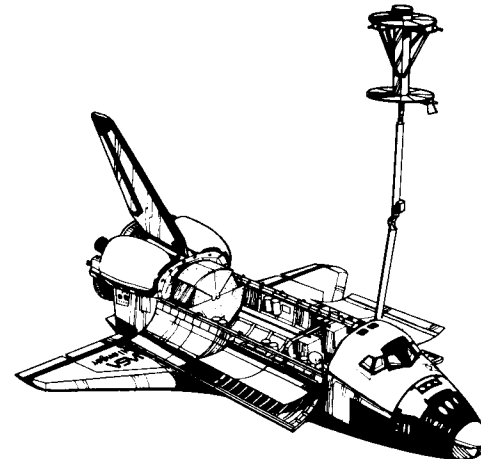**RMS/PRCS INTERACTION TEST — POSITIVE/NEGATIVE ROLL AND POSITIVE/NEGATIVE PITCH PULSES**

RMS (Remote Manipulator System) Using PFTA (Payload Flight Test Article) No. 5 Grapple Fixture per Validation Runs.

REMOTE MANIPULATOR SYSTEM (RMS)/PAYLOAD FLIGHT TEST ARTICLE (PFTA) OPERATIONS USING GRAPPLE FIXTURE NO. 5

MISSION ELAPSED TIME DAY 3, 02:20 HOURS TO 06:40 HOURS

OPERATIONS CHECKLIST	DURATION
Power Up	10
Nominal Unberth Using 6 Degree of Freedom Mode	15
FCS (Flight Control System)/RMS Test Using Vernier Reaction Control System (VRCS)	45
Control System Evaluation	45
RMS/PRCS Interaction	45
Orbiter/RMS Dynamic Interaction in Free Drift	15
Auto Sequence	20
Nominal Berth Using 6 Degree of Freedom Mode	20
Direct Drive Unberth Using One Joint at a Time	20
Direct Drive Berth Using One Joint at a Time	30
Power Down	10

- Direct unberth/berth of the PFTA using RMS one joint at a time with closed circuit television as visual cues only (most degraded mode of operation of RMS).

- Monitor *Challenger's* vernier reaction control system/flight control attitude control system during RMS/PFTA operations.

- Gather data on RMS natural frequencies, damping characteristics, and *Challenger* longeron stiffness during PFTA handling operations and interactions with *Challenger's* primary reaction control system in operation.

- Gather dynamic data on the RMS and payload damping to be used in design of large space structures (LSS)

- Verification of the ability of the RMS to follow a pre-programmed automatic sequence path and stop at the desired position and attitude.

- Gather data on the effects of loaded RMS dynamic interaction on the *Challenger* by maneuvering the RMS and observe *Challenger's* response while in free drift.

- Confirmation of the control system evaluation with loaded RMS in respect to performance envelopes.

DEVELOPMENT FLIGHT INSTRUMENTATION (DFI) PALLET

The Development Flight Instrumentation (DFI) pallet will be flown on STS-8 minus the instrumentation that was carried on the earlier flights of *Columbia*. In the STS-8 mission, the DFI pallet will be used to mount two experiments and two boxes of U.S. Postal covers. The two experiments are the Evaluation of Oxygen Interaction with materials and the High Capacity Heat Pipe Demonstration.

The Evaluation of Oxygen Interaction with materials was carried on the DFI pallet in Columbia during the STS-3 and 5 missions, but was passive with incident atomic oxygen flux dependent on vehicle attitude. Shadowing by spaceflight hardware in those flights within *Columbia's* payload bay complicated post-flight analysis and the low values of atomic oxygen fluence made extrapolation of degration effects for long-duration mission uncertain. Tests during the STS-8 mission will obtain quantative rates of oxygen interaction with materials used on the orbiter and advanced payloads, such as Space Telescope and Space Station.

Atomic oxygen within the low Earth orbit environment is known to be extremely reactive when in contact with solid surfaces. Chemical changes can occur for spacecraft materials at orbital altitudes which alter optical and electrical properties and in some cases, even remove layers of material. If the atoms impinge with kinetic energy of orbital speed, chemical reactions are accelerated and the mass loss for many materials becomes more pronounced. Advanced payloads, such as Space Telescope and Space Station, will use materials which react chemically with oxygen. Although the reaction rates are low at altitudes where these advanced spacecraft will operate, long duration missions may result in significant mass erosion for solar arrays, optical overcastings, light baffles and thermal control coating films. The objective of this experiment is to obtain quantative rates of atomic oxygen interaction with these materials. The materials, ion-repulsion cells and solar ultraviolet sample array are mounted on trays on the DFI with thermal plates that are provided with 28 vdc and controlled by on/off switching by the flight crew.

The second objective of the experiment is to flight test specimens of Advanced Flexible Reusable Surface Insulation (AFRSI) and Thermal Protection System (TPS) tiles in an atomic oxygen environment. AFRSI on *Challenger's* Orbital Maneuvering System/Reaction Control System (OMS/RCS) pods failed during the STS-6 mission after entry and the orbiter TPS tiles show significant loss of waterproofing and strength after each Shuttle mission. These anomalies may result from atomic oxygen interacting with waterproofing agents on the AFRSI outer quartz fabric and the TPS tile interior. The results of these flight tests and subsequent laboratory tests will enable technologists to resolve these issues. There are two diced low temperature reusable surface insulation (LRSI) tiles, 203 by 203 millimeters (8 by 8 inches) and approximately 25.4 millimeters (one inch) thick, specimens. There are several advanced flexible reusable surface insulation (AFSI) specimens. There are two 355 by 431 millimeter (14 by 17 inch) AFRSI blankets, six 152 by 152 millimeter (6 by 6 inch) AFRSI blankets, and one segment of AFRSI approximately 0.18 cubic meters squared (two square feet) of outer AFRSI blanket layer fabric material.
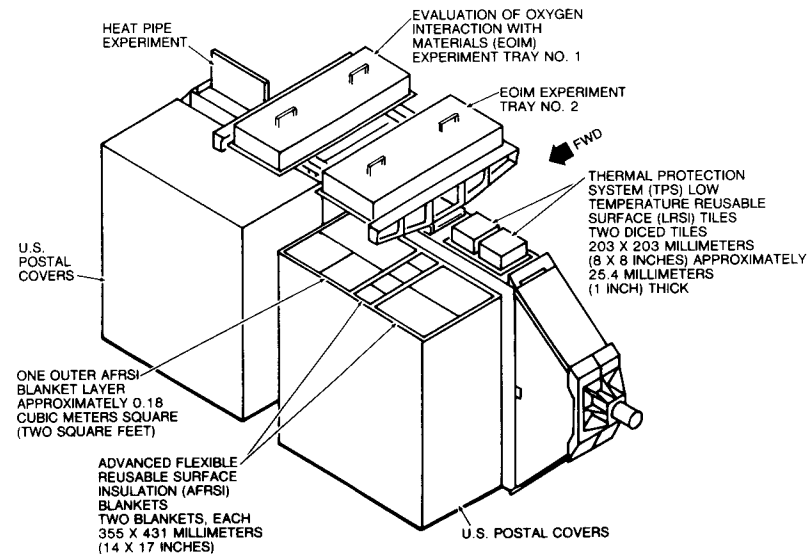
Development Flight Instrumentation (DFI) Pallet Experiments

When *Challenger* descends to 121 nautical miles (139 statute miles) altitude for the Atomic Oxygen Interaction Experiment, *Challenger* will be oriented so the DFI experiment trays, AFRSI, and TPS tiles are normal to *Challenger's* velocity vector with *Challenger's* starboard side to the sun and tail pointed northward. The remotely controller thermal plates and sample fixtures are actuated after *Challenger* acquires direct impingement attitude. The specimens are subjected to atomic oxygen bombardment for 26 hours to obtain an atomic oxygen fluence of 1.8×10^{20} atoms/centimeter^2. Power will be secured to the thermal plates after completion of the exposure period.

Also, five material specimens are placed on the upper arm of the remote manipulator system (RMS) to obtain data of oxygen interaction with materials (surface glow phenomena) during night time pass(es). Photographs will be taken from *Challenger's* aft flight deck during the night time pass(es) at 121 nautical mile (139 statute mile) altitude.

The High Capacity Heat Pipe Demonstration experiment mounted on the DFI pallet will provide in-orbit demonstration of the thermal performance of a high capacity heat pipe designed for future spacecraft heat rejection systems. One flight crew member at the aft flight station will activate a heater power switch, photograph with a 35 millimeter camera with telephoto lens, temperature sensitive tape and then deactivate the heater power switch. The experiment heater power switches will be turned on during the tail-to-sun orbiter attitude and time of operation will be a minimum of 45 minutes and a maximum of two hours.

Approximately 260,000 Special Philatelic covers will be flown on the STS-8 flight. Some of these are specially packaged in the two large storage (mail) boxes mounted on the DFI. The remaining covers are located in eight of the Getaway Special (GAS) canisters mounted in the payload bay. For a description of the covers, refer to the GAS section within this booklet.

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CHALLENGER, S-BAND, Ku-BAND AND TRACKING DATA RELAY SATELLITE (TDRS-A)

The STS-8 flight of *Challenger* will be used as a test flight to establish the ability of the TDRS-A communications satellite to maintain communications with *Challenger*. This will be the percusor to the use of the TDRS-A operationally for the flight of STS-9 *Columbia* with Spacelab-1.

All modes of TDRS-A communications will be exercised during the STS-8 mission such as performance navigation and proficiency tests of *Challenger's* S-band system with TDRS-A in addition to *Challenger's* Ku-band system with TDRS-A

The Ku-band antenna is a 914 millimeter (36 inch) diameter antenna mounted on the starboard forward portion of *Challenger's* payload bay. The Ku-band antenna is stowed in this area and after payload bay door opening on-orbit, the Ku-band antenna is deployed. If the Ku-band antenna cannot be stowed, provisions are incorporated to jettison the assembly so the payload bay doors can be closed for entry.

The orbiter Ku-band system operates in the Ku-band portion of the RF spectrum, which is 15,250 MHz to 17,250 MHz. The Ku-band provides a much higher gain signal with a smaller antenna than the S-band system. The S-band system can be used to communicate via the TDRS, but the low-data-rate mode must be used because of limited power since the S-band does not have a high enough signal gain to handle the high data rate. A test will be conducted during STS-8 to try the high data rate through TDRS-A. With Ku-band system, the higher data rates can be used.

One drawback of the Ku-band system is its narrow pencil beam, which makes it difficult for the antennas on the TDRS to lock on to the signal. The S-band will be used to lock the antenna into position first because it has a larger beam width. Once the S-band signal has locked the antenna into position, the Ku-band signal will be turned on.

The Ku-band antenna is gimbaled, which permits it to acquire the TDRS for communications acquisition or radar search for other space hardware. The Ku-band system is first given the general location of the space hardware from the orbiter computers. The antenna then makes a spiral scan of the area to pinpoint the target.

With communications acquisition, if the TDRS is not detected within the first eight 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.

TDRS-A is positioned over the equator at 67 degrees West longitude over Brazil and is referred to as TDRS-East. Next

S-Band/TDRS Communications

45
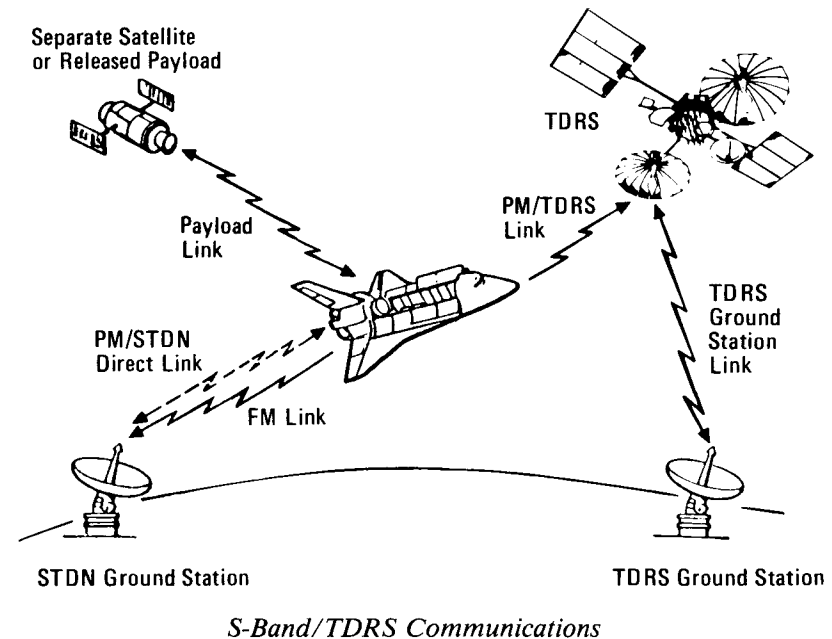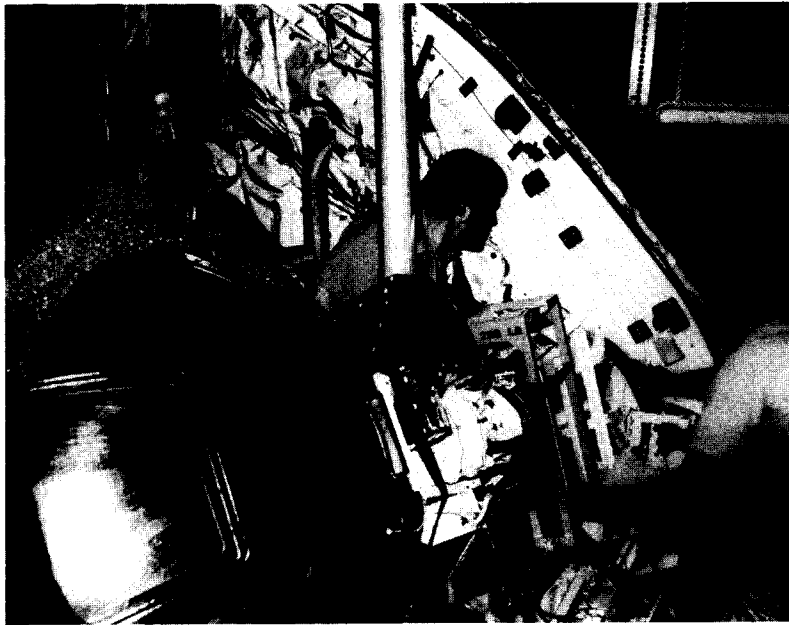
Ku-Band Antenna Installation in Challenger

year, TDRS-B will be carried into earth orbit aboard the Space Shuttle and launched from the spacecraft and positioned over the Pacific Ocean at the equator southwest of Hawaii at 171 degrees West longitude and will be referred to as TDRS-West. TDRS-C is scheduled to be positioned at the central station as a backup just west of South America over the Pacific Ocean at 79 degrees West longitude. The TDRS satellites are positioned at geosynchronous orbit above the equator at an altitude of 35,880 kilometers (22,300 statute miles). At this altitude, because the speed of the satellite is the same as the rotational speed of earth, they remain "fixed" in orbit over one location. The eventual positioning of two TDRS satellites will be 130 degrees apart at geosynchronous orbit — instead of the usual 180 degrees spacing. This 130 degree spacing reduces the ground station to one instead of two if the satellites were spaced at 180 degrees.

When the TDRSS is fully operational (including the in-orbit spare), ground stations of the worldwide Spaceflight Tracking and Data Network (STDN) will be closed or consolidated in savings in personnel, operating and maintenance costs with the exception of Bermuda and Merritt Island, Fla., which will remain open to support the launch of the Space Transportation System. Moreover, much of the equipment at the ground stations is almost 20 years old and inadequate to meet the demands of the Space Shuttle and today's advanced spacecraft.

Instead of the existing worldwide network of ground stations which can provide coverage up to only 20 percent of a satellite's or a spacecraft's orbit, limited to the brief periods when the satellite or spacecraft are within the sight of the tracking station. Each tracking station in the network can handle at most two satellites or spacecraft at one time and most stations can handle but one.

The TDRSS operational system can provide continuous global coverage of earth orbiting satellites above 1,200 kilometers (750 miles) up to an altitude of about 5,000 kilometers (3,100 miles). At lower altitudes there will be brief periods when satellites or spacecraft over the Indian Ocean near the equator will be out of view. The TDRSS operational system will be able to provide almost full-time coverage not only for the Space Shuttle but up to 26 other near earth-orbiting satellites or spacecraft simultaneously.

Deep space probes and earth orbiting satellites above approximately 5,000 kilometers (3,100 miles) will use the three ground stations of the Deep Space Network (DSN) operated for NASA by the Jet Propulsion Laboratory, Pasadena, CA. The STDN stations that were co-located with the three DSN stations, Goldstone, CA, Madrid, Spain, and Orroral, Australia will be consolidated with the DSN.

In the STS-8 mission the liftoff and ascent phase of the mission will use *Challenger's* S-band system through Merritt Island (MILA), Florida, Bermuda (BDA) and Dakar (DKR) ground stations, transmitting/receiving in the high data rate mode. After passing Dakar (DKR), *Challenger's* S-band system

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will transmit/receive through TDRS-A until loss of signal, thus the White Sands, New Mexico TDRS station in the low data rate mode until out of view of TDRS-A. When *Challenger* is not in view of TDRS-A, *Challenger's* S-band system will transmit/receive through the applicable ground station in view in the high data rate mode.

When *Challenger* is on orbit and the payload bay doors are opened, *Challenger's* Ku-band antenna is deployed. When *Challenger* is in view of TDRS-A. *Challenger's* Ku-band antenna will transmit/receive through TDRS-A in the high data rate mode, thus the TDRS ground station at White Sands, New Mexico. When *Challenger* is not in view of TDRS-A, *Challenger's* S-band system will be used to transmit/receive through the applicable ground station in the high data rate mode.

There are times when in view of TDRS-A, that transmission/receiving will be interrupted due to *Challenger* blocking the Ku-band antenna view to TDRS-A because of an *Challenger* attitude requirement or when certain payloads cannot allow Ku-band radiation to be hit by the main beam of the Ku-band antenna. The main beam of *Challenger's* Ku-band antenna produces 340 volts per meter at the antenna but decreases in distance, such as to 200 volts per meter 20 meters (65 feet) away from the antenna. Dependent upon the payload, a program, can be instituted into the Ku-band control system which would limit the azimuth and elevation angle which would inhibit the Ku-band antenna from directing its beam into the area of that payload. This is referred to as an obscuration zone. This program would be instituted from Mission Control Houston. In other cases such as the deployment of INSAT-1B in STS-8, the Ku-band antenna would be turned off during deployment and turned on after deployment.

In preparation for entry, the Ku-band antenna is stowed and the payload bay doors are closed. When *Challenger* is not in view of TDRS-A, *Challenger's* S-band system will transmit/receive in the high data rate mode through the applicable ground station in view. When *Challenger* is in view of

TDRS-A, *Challenger's* S-band system will transmit/receive through TDRS-A in the low data rate mode and during the blackout period of entry, transmission/reception is at present a question mark. After blackout, *Challenger* will continue to operate with TDRS-A to as low a view as possible until reaching the Buckhorn (BUC) California ground station at which time *Challenger's* S-band system would transmit/receive through Buckhorn (BUC) in the high data rate mode through landing, rollout, and safing at the Edwards Air Base, California landing site.

It is noted that the S-band system forward link (previously referred to as uplink), consists of a high data rate of 72 kbps (kilo-bits-per-second) and a low data rate of 32 kbps through TDRS-A. The high data rate, 72 kbps, consists of two air to ground voice channels at 32 kbps, each and one command channel at eight kbps. The low data rate 32 kbps consists of one air to ground voice channel at 24 kbps and one command channel at eight kbps. The return link (previously referred to as downlink), consists of a high data rate of 192 kbps and a low data rate of 96 kbps. The high data rate, 192 kbps consists of two air to ground voice channels at 32 kbps, each and one telemetry link at 128 kbps. The low data rate, 96 kbps consists of one air to ground voice channel at 32 kbps and one telemetry link at 64 kbps.

The Ku-band system forward link, consists of a mode one and mode two through TDRS-A. Mode one consists of 72 kbps data (two air to ground voice, 32 kbps, each and 8 kbps command) and 128 kbps text and graphics (used in place of teleprinter) and 16 kbps synchronization. Mode two consists of 72 kbps operational data (two air to ground voice, 32 kbps, each and 8 kbps command).

The Ku-band system return link, consists of channel one mode one and two, plus one channel two mode one and two, and one of channel three through TDRS-A. Channel one mode one and two consists of 192 kbps operational data (128 kbps operational data telemetry/payload data interleaver plus two air to ground voice at 32 kbps) plus one of channel two mode one

and two selection of four; payload digital data from 16 kbps to 2 mbps (mega): or payload digital data from 16 kbps to 2 mbps; or operations recorder playback from 60 kbps to 1,024 kbps: or payload recorder playback from 25.5 kbps to 1,024 kbps; plus one of the following from channel three; mode one attached payload digital data (real-time or playback) from 2 mbps to 50 mbps; or mode two television (color or black/white) composite video; or mode a real time attached payload analog data or payload analog data.

The data acquired by the TDRS satellites is relayed to a single centrally located ground terminal at NASA's White Sands Test Facility in New Mexico. From New Mexico, the raw data will be sent directly by domestic communications satellite (DOMSAT) to NASA control centers at Johnson Space Center, Houston, TX, for Space Shuttle operations and the Goddard Space Flight Center, Greenbelt, MD, which schedules TDRSS operations and controls a large number of unmanned satellites. To increase system reliability and availability, there will be no signal processing done onboard the TDRS satellites, they will act as repeaters, relaying signals to and from the ground stations or to and from user satellites or spacecraft. No user signal processing is done onboard the TDRS satellites.

The TDRSS will serve as a radio data relay, carrying voice, television, analog, and digital data signals. It will be the first telecommunications satellite to simultaneously offer three frequency band service: S-band, C-band, and high capacity Ku-band. The C-band transponders operate at 4-6 gigahertz and the Ku-band TDRS transponders operate at 12-14 gigahertz.

The highly automated ground station is located at NASA's White Sands Test Facility, New Mexico, and is owned and managed by Spacecom, which NASA also leases. The ground station provides a location at a longitude with a clear line-of-sight to the TDRS satellites and a location where rain conditions are very remote, as rain can interfere with the K-band uplink and downlink channels. It is one of the largest and most com-

plex communication terminals ever built. All satellite or spacecraft transmissions are relayed by the TDRS satellites and funneled through the White Sands ground station. The most prominent features of the ground station are three 18 meter (59 feet) Ku-band antennas used to transmit and receive user traffic. Several other smaller antennas are used for S-band and Ku-band communications. NASA is developing a sophisticated operational control system to schedule the use of the system. These control facilities located at Goddard Space Flight Center and adjacent to the ground terminal at White Sands, will enable NASA to schedule the TDRSS support of each user and to distribute the user's data directly from White Sands to the user.

Automatic data processing equipment at the White Sands Ground Terminal aids in making user satellite tracking measurements, controls and communications, equipment in the TDRS and in the ground station, and collects system status data for transmission along with user satellite or spacecraft data to NASA.

Initially the TDRSS will be used to support the Space Shuttle missions, Spacelab missions and the Landsat 4 earth resources satellite program. The TDRSS operational system will provide data from Landsat 4 in near real time, thus eliminating the need to rely upon onboard tape recorders. DOMSAT satellites will be used to transmit Landsat 4 data from White Sands to the data processing facility at the Goddard Space Flight Center and subsequently to the Landsat data distribution center at the Earth Resources Observation System (EROS) Data Center at Sioux Falls, South Dakota.

It is noted, that after completion of the STS-8 mission, TDRS-A will be moved to its operational location at 41° West longitude, northeast corner of Brazil.

The orbiter ku-band system includes a rendezvous radar which will be used to skin-track satellites or payloads that are in orbit. This makes it easier for the orbiter to rendezvous with any

satellite or payload in orbit. For large payloads that will be carried into orbit, one section at a time, the orbiter will rendezvous with the payload that is already in orbit to add on the next section.

Radar search for space hardware may use a wider spiral can, up to 60 degrees. Objects may be detected by reflecting the radar beam off the surface of a target (passive mode) or by using the radar to trigger a transponder beam on the target (active mode).

RADAR RENDEZVOUS RANGE

PASSIVE SKIN TRACK

RANGE 30 meters (100 feet) to 12 nautical miles (13 statute miles)

RANGE rate is 45 meters (148 ft) per second opening maximum to 22 meters (75 ft) per second closing maximum

ACTIVE (TRANSPONDER ON THE VEHICLE BEING TRACKED)

RANGE 30 meters (100 ft) to 300 nautical miles (345 statute miles)

RANGE rate is 457 meters (1,500 ft) per second opening maximum to 91 meters (300 ft) per second closing maximum

It is noted that the Shuttle program has not baselined a transponder, however TRW has a transponder that can be placed on a payload.

Payload

Tracking and Data Relay Satellite (TDRS)

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Optional

Ku-Band Deployed Assembly

Ku-Band Radar/ Communication Electrical Assembly

Avionics Bay 3A

$Z_0 = 332$

Ku-Band Signal Processor

TDRS Ground Station
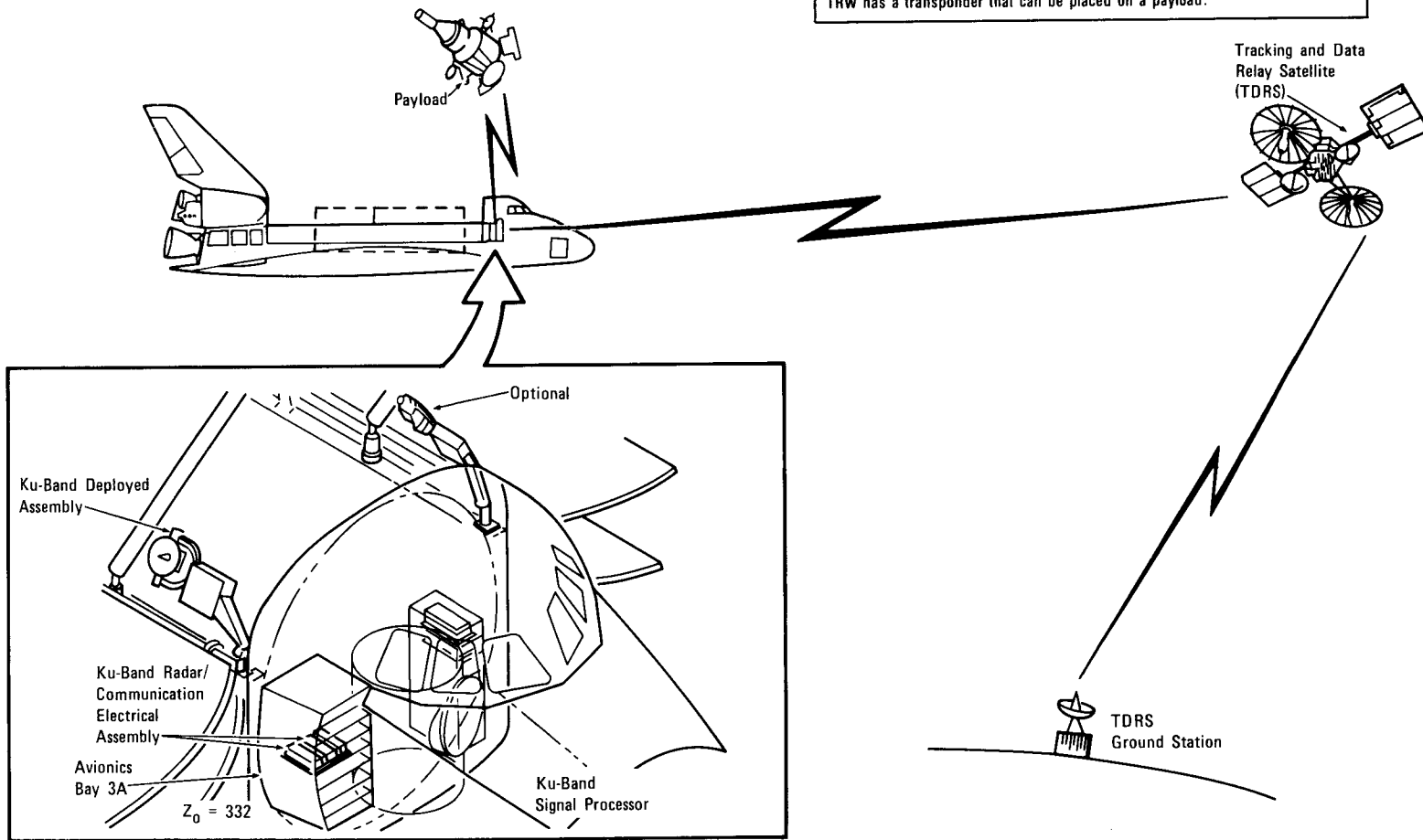
Ku-Band Radar Communication System

GETAWAY SPECIAL

The getaway special (GAS), officially titled small self contained payloads (SSCP's), is offered by NASA to provide anyone who wishes the opportunity to fly a small experiment aboard the Space Shuttle.

Since the offer was first announced in the fall of 1976, more than 326 GAS reservations have been made by over 197 individuals and groups. Payload spares have been reserved by several foreign governments and individuals: United States industrialists, foundations, high schools, colleges and universities, professional societies, service clubs and many others. Although many reservations have been obtained by persons and groups having an obvious interest in space research, a large number of spaces have been reserved by persons and organizations entirely outside the space community.

There are no stringent requirements to qualify for space flight, but the payload must meet safety criteria and must have a scientific or technological objective. A person who wishes to fly items of a commemorative nature, such as medallions for later resale as "objects that have flown in space," would be refused.

GAS requests must first be approved at NASA Headquarters, Washington, DC, by the Director, Space Transportation Systems Utilization Office, Code OT6. It is at this point that requests for Space Shuttle space are screened for propriety, and scientific or technical aim. These requests must be accompanied or preceded by the payment of $500 earnest money.

Requests approved by the Space Transportation Systems Utilization Office are given a payload identification number and referred to the GAS Team at the Goddard Space Flight Center, Greenbelt, MD. The center has been designated the lead center or direct manager for the project.

The GAS Team screens the proposal for safety and provides advice and consultation for payload design. The GAS Team certifies that the proposed payload is safe, that it will not harm or interfere with the operations of the Space Shuttle, its crew, or other experiments on the flight. If any physical testing must be done on the payload to answer safety questions prior to the launch, the expense of these tests must be borne by the customer.

In flight, the flight crew will turn on and off up to three payload switches, but there will be no opportunity for flight crew monitoring of GAS experiments or any form of in-flight servicing.

The cost of this unique service will depend on the size and weight of the experiment; Getaway Specials of 90 kilograms (200 pounds) and 0.14 cubic meter (5 cubic feet) may be flown at a cost of $10,000; 45 kilograms (100 pounds) and 0.07 cubic meter (2.5 cubic feet) for $5,000, and 27 kilograms (60 pounds) and 0.07 cubic meter (2.5 cubic feet) at $3,000. These prices remain fixed for the first three years of Space Shuttle operations.

The GAS container provides for internal pressure which can be varied from near vacuum to about one atmosphere. The bottom and sides of the container are always thermally insulated and the top may be insulated or not depending on the specific experiment; an opening lid or one with a window may be required. These may be offered as additional cost options.

The weight of the GAS container, experiment mounting plate and its attachment screws, and all hardware regularly supplied by NASA is not charged to the experimenter's weight allowance.

The GAS container is made of aluminum and the circular end plates are 15 millimeters (5/8 inch) thick aluminum. The bottom 76 millimeters (3 inches) of the container are reserved for NASA interface equipment such as command decoders and pressure regulating systems. The container is a pressure vessel capable of evacuation prior to launch, or evacuation during launch and repressurization during reentry, or maintaining

about one atmosphere pressure at all times, evacuation and repressurization during orbit as provided by the experimenter. The experimenters' payload envelopes in the 0.14 cubic meter (5 cubic feet) container are 501 millimeters (19.95 inches) in diameter and 717 millimeters (28.25 inches) in length. The payload envelope in the 0.07 cubic meter (2.5 cubic feet) container is 501 millimeters (19.95 inches) in diameter and 358 millimeters (14.13 inches) in length.

The GAS program is managed by the Goddard Space Flight Center. Project manager is James S. Barrowman. Clarke Prouty, also of Goddard, is technical liaison officer, and queries can be addressed to him at Code 741, Goddard Space Flight Center, Greenbelt, MD, 20771. Program manager at NASA Headquarters, Washington, DC, is Donna S. Miller.

Beginning with the STS-7 mission, the GAS team has inaugurated a new facility dedicated to the preparation of GAS payloads. The facility is located in the old Delta third-stage facility on the Cape Canaveral Air Force, Fla., station.

Twelve 0.14 cubic meter (5 cubic feet) GAS canisters are aboard *Challenger* for the STS-8 mission. Four of the GAS canisters are involved with experiments and the remaining eight canisters carry postal covers for the U.S. Postal Service. The U.S. Postal Service is paying NASA for carrying the postal covers.

Prior to the STS-8 mission, twelve GAS canisters were flown, one on STS-4, one on STS-5, three on STS-6, seven on STS-7 and with the inclusion of STS-8, a total of 24 GAS canisters will have been flown.

GAS canisters experiment G475 is a follow-on to a similar experiment conducted on STS-6. This experiment is an artificial snow crystal experiment sponsored by the Asahi Shimbun newspaper, one of the largest in Japan, with a circulation of eight million. Post flight investigation of the STS-6 experiment showed that the temperature of the upper endplate of the GAS canister went down to minus seven degrees Celsius (19 degrees Fahrenheit), much lower than engineers had expected. The engineers had designed the equipment to warm up the water in two tanks up to 20 degrees Celsius (68 °F) to get water vapor enough to make snow crystals. With the colder endplate, and the colder temperatures inside the canister, the water had frozen and the heaters in the water tanks could not heat up the water enough to generate water vapor.

For the STS-8 mission, engineers have increased the power of the heaters three-fold. They suspect that the weightlessness in space resulted in no convection current in the cold chamber, causing the water vapor supplied from the water tanks not to be transported efficiently to the fields of view of the TV cameras in the GAS canister. The engineers have added a small auxiliary fan to stir up the gas in the cold chambers. The mode of the fan will be changed in every snow-making experiment, which will be repeated for four times. In the first experiment, the fan will be activated for the first one-third of the full experiment time, and in the second experiment the fan will be activated from the beginning to the end of the experiment. In the third experiment, the fan will be activated for the latter half of the experiment. For the last experiment, the fan will be activated just for a short time at the beginning and at the end of the experiment. Thus, the experimenter can see the influence of the weightlessness on the snow crystal growth.

The experiment was selected from 17,000 ideas solicited from its readers. The idea of the artificial snow was proposed by two Japanese high school boys, Haruhiko Oda and Toshio Ogawa.

The heart of the experiment consists of two identical small copper boxes 38 millimeters (1.5 inches) by 38 millimeters (1.5 inches) by 99 millimeters (3.9 inches). The semiconductor cooling modules are attached to each box to cool down the inside of the boxes to minus fifteen degrees Celsius (5 °F). Then water vapor will be supplied from the small water tanks which are made of porous sintered metal and store about twenty grams of water. When enough vapor is supplied, a very small platinum heater on which a few milligrams of silver iodine is attached will

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be heated up. The small particles of the sublimated silver iodine will serve as seeds for artificial snow crystals. The crystals formed in the cold chambers will be recorded on videotape with four TV cameras and four video tape recorders in the GAS canister. This experiment desires a Vernier Reaction Control System (VRCS) attitude control period of five hours early in the flight. The payload was designed by NEC Corporation, which is the leading satellite manufacturer in Japan. Principle investigator for the experiment is Shigeru Kimura, Asahi Shimbun newspaper, Japan.

GAS canister experiment G348 is a similar experiment to the one successfully flown on the OSS (Office of Space Sciences)-1 pallet on STS-3. This Contamination Monitor Package (CMP) is the first GAS payload mounted on the outside of the canister lid. The CMP experiment is to determine the effect of atomic oxygen within *Challenger's* environment. The experiment is built entirely with recycled or reusable parts.

The dramatic effect of atomic oxygen seen after most of the past Space Shuttle flights sparked interest in understanding the mechanisms and the orbital environment itself. The STS-8 altitudes and attitudes provide an opportunity to look at these effects in an accelerated environment. This experiment has been designed to measure the atomic oxygen flux in two directions 90 degrees apart in a unique way. The experiment will measure the rate of mass loss of two materials known to readily oxidize, carbon and osmium. The information learned from this experiment will not only help future Space Shuttle missions, but also will provide insights to material behavior and environmental effects at higher altitudes for future missions like Space Telescope.

The CMP flown on OSS-1 on STS-3 is used on STS-8 with modifications to fly independently on the top of the GAS canister. Besides being the support structure, the GAS canister provides the electrical power (battery), storage of commands (in a read-only-memory) and data storage (tape recorder). As with the OSS-1 flight on STS-3, the CMP contains four temperature-controlled quartz crystal microbalances (TQCMs) as its only sensors. TQCMs are very sensitive instruments which accurately measure mass changes of a crystal. TQCMs have traditionally been used to measure mass build ups of contamination of a crystal to determine molecular contamination levels. In this application, they will be used to measure the mass loss of a material (carbon and osmium) deliberately deposited before the flight. One sensor is left uncoated as a reference. The uncoated TQCM along with one coated with carbon and another coated with osmium will face out of the bay, and the fourth TQCM with carbon will face aft. The mass loss of carbon and osmium will indicate the atomic oxygen flux as a function of time which can be correlated to altitude, attitude, and direction. Laboratory studies of reaction rates for these coatings will yield absolute rate determination. The experiment is prepared by Goddard Space Flight Center and the principal investigator is Jack J. Triolo of Goddard Space Flight Center, MD.

GAS canister experiment G-347 is similar to one flown on the STS-7 mission. The ultraviolet photographic film test package is to evaluate the affect of *Challenger's* gaseous environment on ultraviolet sensitive photographic emulsions planned for flight in the orbiter, initially in the High Resolution Telescope and Spectrograph (HRTS) being built by the Naval Research Laboratory for Spacelab 2 and eventually in the Goddard Space Flight Center Solar Extreme Ultraviolet Telescope and Spectrograph (SEUTS) planned for a future Space Shuttle flight.

The STS-8 flight is particularly well suited to investigate the extent of film degradation due to an ion environment in the vicinity of ultraviolet-sensitive photographic emulsions due to STS-8 providing the opportunity to face the instrument in the direction of velocity vector, producing a ram effect, while *Challenger* is in sunlight.

This will permit better studies into the extent of film degradation due to an ion (charged particles) environment. Laboratory tests have shown that the presence of ions produces chemical reactions that can blacken these emulsions, as if they were exposed to light. Clouds of ions that can produce this effect can be produced in space through the action of solar

ultraviolet radiation on a residual cloud of gas emanating from the payload or vehicle. If, in addition, an instrument opening, such as telescope apertures, face in the direction of motion of the spacecraft, these ions can be scooped up and "rammed" into the interior portions of an instrument where they can interact with sensitive photographic materials.

Six sets of emulsions will be exposed for varying amounts of time for the experiment. The shortest exposure allowed by the electronics is three minutes. Longer exposures of 9, 27, and 50 minutes will examine the effects of longer duration exposures.

The experiment is prepared by the Naval Research Laboratory/Goddard Space Flight Center and the principle investigator is Dr. Werner M. Neupert of Goddard Space Flight Center.

GAS canister experiment G346 is a Cosmic Ray Upset Experiment (CRUX) to determine how charged particles might upset or change the logic state of a memory cell. This is the first flight of this experiment designed to resolve many of the questions concerning upsets caused by single particles. An upset or change in logic state, of a memory cell can result from a single, highly energetic particle passing through a sensitive volume in a memory cell. In doing so, it deposits or loses energy, and if enough energy is deposited, the memory cell can change state. In some technologies, enough energy can be deposited to cause another effect, called "latchup", which can result in the device destroying itself by drawing excessive current.

Positive determination of the cause of an upset in flight is difficult because of other influences, such as electromagnetic interference (EMI), noise on power supply lines, or voltage dropouts, can result in the same device behavior as if induced by cosmic rays.

The experiment is prepared by the Goddard Space Flight Center and the principle investigator is John W. Adolphsen of Goddard Space Flight Center.

Approximately 260,000 special Philatelic covers for the U.S. Postal Service are flown in the STS-8 mission. Some are located in the storage (mail) boxes mounted on the DFI pallet in the payload bay and the remainder are located in eight of the twelve GAS canisters located in the payload bay of *Challenger*.

NASA and the U.S. Postal Service jointly announced that these special cacheted postal covers would be flown on STS-8. The cachet design on the front of each cover will be a full color replica of NASA's crew patch for the STS-8 mission and on the back will be a cachet of NASA's 25th anniversary logo. The cacheted covers will bear the recently announced $9.35 postage stamp, intended primarily for Express Mail. The pictorial cancellation on the front of each cover will carry the originally scheduled STS-8 launch day of August 14, 1983, which is also the issue date of the stamp. Upon the completion of the flight, the actual date of launch will be noted on the cover. Another cancellation will be applied to each cover, indicating the STS-8 landing date and site.

Following the flight of STS-8, each of the covers will be placed in souvenir folders featuring photographs of the *Challenger* before they are sold. Each cover is imprinted with a special serial number. Under no circumstances will a serial number be duplicated and requests for specific numbers will not be honored. The folder will be sold for $15.35 each and the proceeds (exclusive of the postage affixed) from the sale of the Shuttle Flight Folder will be divided equally between NASA and the U.S. Postal Service.

Mail orders only for the item (designated as Item Number C572) will be accepted no earlier than the date *Challenger* returns from its mission. Orders postmarked prior to that date will be returned unopened. Orders and remittance should be sent to: Shuttle Flight Folder, Philatelic Sales Division, Washington, D.C. 20265-9997. Personal checks in the exact amount will be accepted for orders up to the folder limit. Do not send cash or postage stamps. If any covers are still available 30 days after *Challenger* returns, there will be restrictions on quantities ordered.

Although the covers have been specially packaged to withstand the rigors of space travel, some minor damage may occur. Some covers are extremely tightly bundled and stacked in the two large storage (mail) boxes on the DFI container. The remaining covers are in the eight GAS cylindrical canisters that are sealed and pressurized with pure nitrogen. Both containers and canisters will be exposed to the temperature extremes encountered in space when the payload bay doors are opened. Despite all precautions, some of the covers may show evidence of the voyage into space. Because of the limited number of covers, the U.S. Postal Service cannot offer replacements for covers damaged in flight or during processing, but will refund the purchase price upon receipt of the damaged cover.

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CONTINUOUS FLOW ELECTROPHORESIS SYSTEM (CFES)

The Continuous Flow Electrophoresis System (CFES) that has purified mixtures of proteins in cultures on the STS-4, 6, and 7 flights will be used in the STS-8 mission with live cells for the first time. A total of six living cell samples will be carried on this flight.

Two samples for McDonnell Douglas, under the terms of a new agreement with Washington School of Medicine, St. Louis, Missouri, are pancreas cells to be used in research for purification techniques that could lead to new treatments for diabetes.

NASA's Lyndon B. Johnson Space Center is sending two samples of kidney cells. Two pituitary cell samples are carried for Pennsylvania State University in conjunction with the NASA project.

Because of the difficulties in maintaining the viability of live cells, one of the goals in the STS-8 mission is to demonstrate handling techniques for keeping these cells alive before and after separation. The CFES hardware remains the same as in previous flights, except for the addition of tray on which samples are carried aloft on the surface of microcarrier beads in a fluid compatible with live cells. The mission specialists operating CFES will transfer the cells to syringes before insertion into the separation chamber. An additional requirement for maintenance of live materials is activation of CFES soon after *Challenger* has reached orbit. Seven hours of CFES operation is planned on launch day of the flight followed with another seven hours of operation on the following day. The samples will be removed and checked for viability shortly after landing.

The McDonnell Douglas, Washington School of Medicine pancreas cells will be used to try to separate insulin-producing cells from dogs in greater quantity and purity than on the ground.

Islet cells — which make insulin — separated on Earth and transplanted into four dogs appeared to cure them of their diabetes, however caution is urged against too much expectation that human transplantation would result in a cure.

Insulin regulates blood sugar levels in the body. In diabetics, the islet cells production of insulin is either diminished or virtually non-existent. Most diabetics must take regular doses of the hormone, orally or by injection, and monitor their food intake carefully.

The goal of this experiment in this flight, is to study insulin-producing cells in their pure form, not to transplant them. Another goal is to separate out the immune cells which cause rejection of transplanted tissue.

Scientists hope this test will lead to permanent transplants of insulin producing cells for diabetics, when diabetics could produce sufficient insulin on their own. Diabetes affects an estimated 10 million Americans and is the fifth leading cause of death by disease. It causes widespread complications, including heart disease, kidney disease, blindness and damage to the nervous system.

The investigators for Washington University are Dr. Paul Lacy and Dr. David Scharp.

The NASA Johnson Space Center investigator is Dr. Dennis Morrison and the investigator for Pennsylvania State University is Dr. Wesley Humer.

In the STS-7 flight, CFES was used by McDonnell Douglas for separation tests to identify other materials that might be candidates for commercial development.

In the STS-7 flight, NASA's Marshall Space Flight Center Space Sciences Laboratory used the CFES for their research. NASA's use of CFES is part of the consideration provided to the space agency under terms of the NASA/McDonnell

Douglas joint Endeavor Agreement. This agreement provides a vehicle for private enterprise and NASA to work together to promote the utilization of space where a technological advancement is needed and there is a potential commercial application. The Commercial Materials Processing in Low Gravity Office at Marshall manages NASA's effort under the joint endeavor agreement. In the STS-7 flight CFES was used to run samples of dyed polystyrene latex particles to further investigate the concentration limitations of CFES in space and to calibrate the experiment hardware.

The continuous flow electrophoresis experiment (CFES) in the STS-6 flight achieved four times better purification of biological materials and also demonstrated that it can separate over 700 times the quantity obtainable in similar ground-based units here on earth. In order to achieve the greater purity in the STS-6 flight, two changes were made. The voltage applied across the chamber was increased from 140 to 400 volts and the amount of time the materials remained in the chamber was increased by 60 percent. Three samples were run on each of two days in the flight. The samples separated were a laboratory standard mixture of rat and egg albumins, a cell culture fluid containing many types of proteins and two samples of hemoglobin. The hemoglobins were tested for NASA's Marshall Space Flight Center. One sample contained only hemoglobin and a second sample containing a mixture of hemoglobin and polysaccharide (a complex sugar). The hemoglobin sample, at 10 times the concentration that can be processed in an earth-based laboratory was designed to explore the concentration limits of electrophoresis in space. The results are still being analyzed, although scientists did note some unexpected broadening of the sample flow. The sample of a mixture of hemoglobin and a polysaccharide was separated to determine the quality of separations in a space-based electrophoresis device. The sample with a lower concentration of hemoglobin, provided data showing a good separation of the biological materials.

The 249 kilogram (550 pound), 1.8 meter (6 feet) high electrophoresis operations in space (EOS) device is scheduled to be flown two more times in the mid-deck of the spacecraft to iden-
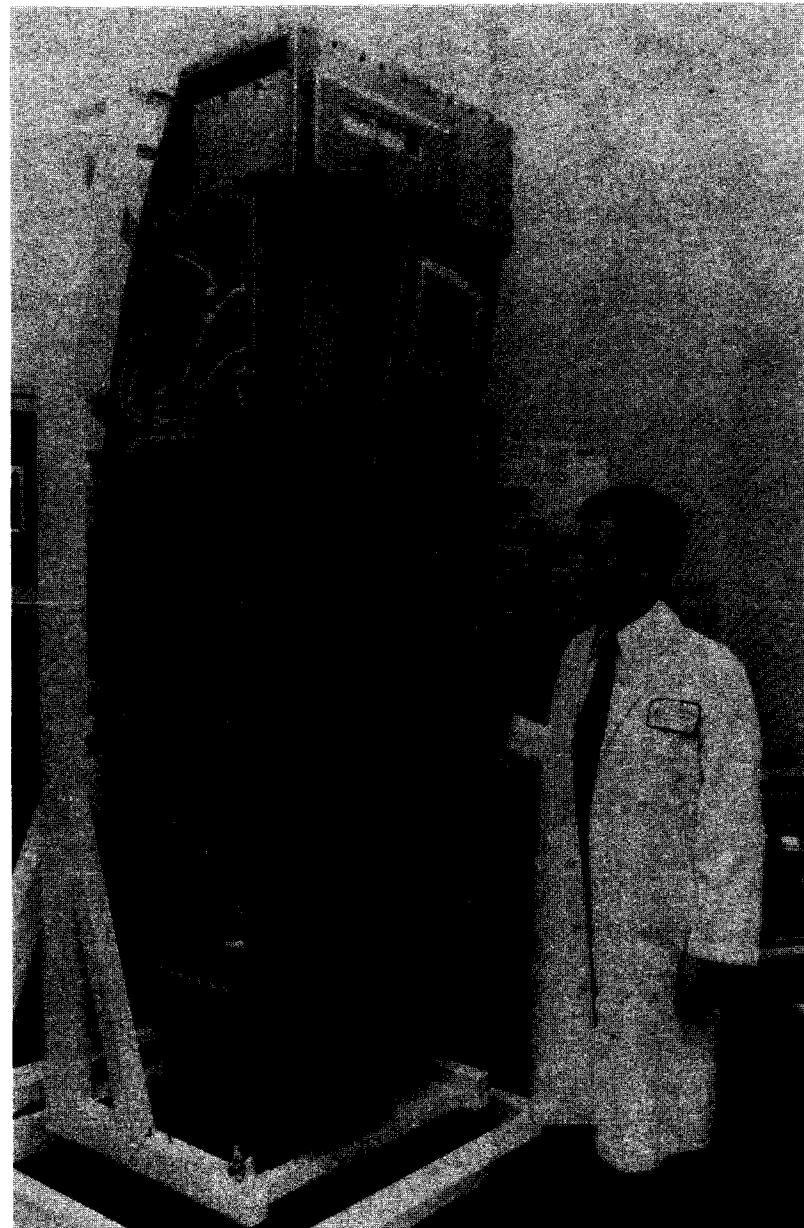
Continuous Flow Electrophoresis System

tify materials that might be candidates for commercial development. After the completion of these flights, McDonnell Douglas plans to install a 2,268 kilogram (5,000 pound), 1 meter (3.5 foot) long and 4.2 meter (14 feet) long prototype production unit to be carried in the spacecraft's payload bay on two future Space Shuttle flights in 1985 and 1986. The fully automated system will have 24 separation chambers, compared with one that is flown in the mid-deck. The next step would be to install a production EOS in an earth-orbiting satellite to be serviced by the Space Shuttle spacecraft on a six-month schedule by the late 1980's. Proposed satellites under consideration include the Space Platform, the Space Operations Center, and the Multimission Modular Spacecraft.

The continuous flow electrophoresis system experiment is a pharmaceutical producing device designed to demonstrate that pharmaceuticals of marketable purity can be produced in quantity in the zero gravity of space. This is the first of many steps leading to possible commercial operation in space of "space factories." It provides a processing system which can segregate biological samples using a separation process based on the relative motion of charged particles through an electric field (electrophoresis).

The U.S. materials processing in space (MPS) program is designed to accommodate applied research payloads on economically viable materials, technology, and industrial processes in space and is part of a space processing applications program. It is hoped that this technology will develop products that cannot be produced on earth, or that can be improved greatly by being processed in space. NASA is confident that these payloads will advance new product technology and make significant contributions to American industry for many years.

On earth, people accept the pull of gravity and the atmosphere as essential elements in their existence. Weight is the balance between the earth's gravitational attraction and the centrifugal force caused by the earth's constant high-speed rotation. It is commonly thought of as a force pulling the body or object downward; we refer to it as a force of one-g at sea level.

In space (earth orbit), the gravitational attraction of earth to an object is reduced as the object moves away from earth, while centrifugal force increases as it moves faster. In a stable orbit, the two forces equal and cancel each other. This is referred to as zero-g or weightlessness.

Until orbital space flights became possible, a zero-gravity environment could be produced only for very short periods in free fall. Drop towers, aircraft nose-overs, and sounding rocket coast periods could provide periods of zero or reduced gravity lasting from a few seconds to six minutes.

Gravity and the atmosphere often pose serious problems in the manufacturing of certain very important products. The space environment, with its zero gravity and almost perfect vacuum, offers interesting possibilities for large-scale manufacturing of products.

Space processing can provide advantages by lowering costs through the more efficient processing available in space. More frequently, it provides the capability for producing substances or devices that cannot be produced in the presence of gravity and an atmosphere.

Examples of the difference between earth and space environments are the effects of gravity on the processes of sedimentation and convection. An example of sedimentation is fruit gelatin dessert; the gelatin must be allowed to thicken to a certain extent before adding fruit or the fruit will settle to the bottom. Sedimentation is caused by the effect of gravity on mixtures of solid particles in liquids.

Convection is either the upward movement of part of a gas or liquid that is heated, or the downward movement of a gas or liquid that is cooled. It is caused by the difference in gravity force-weight or buoyancy which occurs at different temperatures. Wind is an example of natural convection of the air; the currents observed in a heated glass pot of water is another example.

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In space, sedimentation and convection are virtually absent. A liquid mixture containing materials of greatly differing densities can be solidified without the materials separating. Without convection, some parts of the liquid mixture will get much hotter or colder than on earth. This enables control of the way liquids solidify and thereby control of the product produced. The lack of gravitational forces in space also allows liquids to levitate, or float freely, so that processes can be conducted in space that are impossible on earth because the liquids to be processed would react with their containers.

In earth's one-g environment, it is almost impossible to process useful quantities of some pure biological (such as vaccines). Pharmaceutical companies are presently spending millions of dollars a year on research to improve biological processing. A method called electrophoresis may be used in zero-g to obtain quantities of highly superior, purer biological substances than those that can be produced on earth.

The electrophoresis method separates biological materials, such as human cells, by means of an electrical field (electrical voltage force). In zero-g, the cells will separate because each cell reacts in a different degree to the electrical field. Electrophoresis is not a new process. It has been widely used in blood and urine analysis. However, sedimentation becomes a serious problem in electrophoresis on earth if the particles to be separated are large and heavy, since the gravitational forces on the particles become large relative to the electrophoresis forces. Convection also causes currents that tend to remix the separate factions.

In recent years, scientists have determined that cures or greatly improved treatments for a number of diseases might be possible using certain cells, enzymes, hormones or proteins. One problem has been that these substances are not available in the quantity or purity needed.

In the electrophoresis process, gravity limits the concentration of starting material to be used and thus the output of the process itself. On earth the starting must be diluted to only about 0.1 percent by weight in order for its density to equal that of the carrier fluid a condition necessary for proper suspension and successful separation. In space, these concentrations can be increased to at least 10 percent and as high as 40 percent, and still remain suspended in the carrier fluid. This increased concentration means that an electrophoretic chamber in space could turn out 100 to 400 times as much as a chamber on the ground in the same length of time, thereby providing the premise that marketable quantities of the product can be obtained.

Processing in space offers the additional benefit of improved product purity. On earth, as the starting material separates into individual streams, gravity acts on the density differences between them and the carrier fluid. This phenomenon causes the streams to widen and overlap, which in turn limits the purity of the output product. Because this overlapping phenomenon does not occur as extensively in the microgravity of space, product purity will increase. Analysis indicate that product purity will increase by a factor of about five.

Extensive analytical and experimental work has been accomplished by a skilled team of engineers and scientists representing such disciplines as fluid dynamics, thermodynamics, microbiology, and biochemistry. They continued to develop improved laboratory electrophoresis units so that, by optimizing earth performance, they could understand the limitations of the process. When gravity effects are removed, they predict a significant improvement of the process and thus larger quantity and greater purity.

The electrophoresis program is the result of a unique joint endeavor agreement between McDonnell Douglas Corporation and NASA. In addition, McDonnell Douglas Corporation has an agreement with the Ortho Pharmaceutical Division of Johnson & Johnson to collaborate in studying the commercial feasibility of production in space.

The CFES is comprised of three equipment modules in the orbiter crew compartment mid-deck.

The fluid systems module is installed in lieu of the galley location in the mid deck of the orbiter crew compartment. The fluid systems module contains all fluid systems associated with control of the electrophoretic process. The flow control/conditioning subsystem of the fluid systems module provides functional control of buffer and sample flow rates and system pressures, and is comprised of buffer pumps, flow thermal electronic cooling unit and internal cooling blower.

The buffer reservoir subsystem of the fluid system module provides a depletable supply of process buffer liquid, 35 liters (9.2 gallons) and also serves as a return loop waste tank and the other reservoir provides a fixed volume supply of process buffer 10 liters (2.6 gallons).

The separation column of the fluid system module provides the equipment item within which a sample stream of biological material is separated and contains the carrier buffer/sample separation flow chamber, electrode chambers, fluid supply manifold, sample fraction collection tubing bundle and instrumentation for sensing system parameters of temperature, pressure, differential pressures, and separation chamber voltage gradients.

The degassing subsystem of the fluid system module provides the removal of the hydrogen product of electrolysis generated within the cathode chamber of the separation column and is comprised of three membrane deaeration/degassing columns, vacuum systems, solenoid isolation valves, liquid sensors and a catalytic converter.

The fraction collecting subsystem of the fluid system module provides valving control of all effluent fractions from the separation column and the positioning control for sample cartridge collectors. The cartridge positioning mechanism is contained in a housing that isolates its interior from the interior of the fluid system module. A latched door on the front of the housing enclosure provides access for installing and removing sample collection cartridges for each separation run collection cycle.

The fluid system module structure is equipped with gasketing to contain liquids within the fluid systems module interior in the event of system leakage. The fluid system module interior tracks cabin pressurization profiles via air exchange through hydrophobic breather panels installed in the fluid systems module enclosure panels.

The sample storage module is a separate insulated enclosure mounted in the module locker area of the mid-deck equipped with a thermal electric cooling unit and shelving for stowing sample supply syringes and sample collection cartridges. The experiment command and monitoring module is a separate module from the fluid systems module located above the sample storage module, which provides autonomous control of the electrophoresis system and is comprised of dedicated experiment processor, power supplies computer peripherals, fusing, displays and electrophoresis to orbiter power interface connectors.

The total weight of all three modules and cables is 299 kilograms (660 pounds). The fluid system module is 1.8 meters (6 feet) in height and is 457 millimeters (18 inches) in width.

CARRY ON INCUBATOR

This experiment is an inflight engineering test and evaluation of the performance of the incubator hardware and temperature control capability in the microgravity environment.

Separation of human embryonic kidney (HEK) cells in the Continuous Flow Electrophoresis System (CFES) experiment will be conducted during the STS-8 mission. HEK cells after separation, must attach to a substrate within 24 hours to survive. Microcarrier beads (coated with collagen [a fibrous protein]) are a suitable substrate. In a one "g" environment, the cells and beads settle and the cells readily attach. In microgravity, it is not known if there is sufficient time of contact between cells and beads to allow attachment. The carry-on incubator is a suitable controlled temperature container to

evaluate the cell attachment mechanics in microgravity.

On orbit, a flight crew member will inject a suspension of beads into each of the four cell culture chambers in the carry-on incubator. Each chamber will contain HEK cells. Immediately after this, the flight crew member will inject fixative (making it permanent) into the first chamber containing cells and beads, requiring 10 minutes. At 12, 24, and 36 hours after injection of the beads, the flight crew member will inject fixative into successive cell containing chambers requiring a minimum of two minutes, each.

After landing the carry-on incubator with cells will be delivered to the principle investigator.

The objective of this experiment is to determine if cells will attach to microcarrier beads in microgravity, in order to assess cell handling procedure for use in bioprocessing; to test mixing characteristics to fluids, cells and microcarrier beads in future STS flights.

The carry-on incubator is 246 by 302 by 83 millimeters (9.7 by 11.9 by 3.3 inches) in size and weighs 3.2 kilograms (7 pounds). The temperature controlled environment of the incubator is 37 plus or minus 0.5 degrees Celsius (98.6 plus or minus 32.9 degrees F). The incubator requires 28 vdc power.

INVESTIGATION OF STS (SPACE TRANSPORTATION SYSTEM) ATMOSPHERIC LUMINOSITIES (ISAL)

The ISAL experiment attempts to determine the spectral content of the STS induced atmospheric luminosities which are relevant to many aspects of payload operations. Part one of the two part experiment will investigate the glow about *Challenger's* tail and will include intensity measurements from different combination of the *Challenger's* Reaction Control System (RCS) vernier thrusting firings. Part two consists of five material specimens placed on the upper arm of the remote manipulator system (RMS) to obtain data of oxygen interaction on materials (surface glow phenomena) during night time pass(es). Photographs will be taken from *Challenger's* aft flight deck

during the night time pass(es) at the 121 nautical mile (139 statute mile) altitude.

ANIMAL ENCLOSURE MODULE

An animal enclosure module with rats is flown in the mid-deck of the crew compartment and is mounted among the modular storage lockers. The animal enclosure is to determine qualification of the enclosure for carrying animals into space for future student experiments. The enclosure provides the capabilities of supplying food and water as well as cycling lights on and off and is provided with the same atmosphere as that of the pressurized crew compartment.

STUDENT EXPERIMENT—BIOFEEDBACK

This experiment SE81-1, is a student experiment to determine the effectiveness of controlling a crew member's body parameters in zero gravity biofeedback. Four different parameters to be monitored include skin conductance, skin surface temperature, heart rate, and respiration. A microcomputer will record all data for post flight analysis. Two or three sessions will be conducted on orbit totaling approximately 45 minutes of crew time. The student is Wendy A. Angelo of Poughkeepsie, New York. She attends Franklin Delano Rossevelt High School, Hyde Park, New York. Her teacher is Mr. Jan L. Stoutenburgh. Her sponsor is Brooks Air Force Base School of Aviation Medicine, Texas.

RADIATION MONITORING EQUIPMENT (RME)

The RME experiment is designed to measure radiation levels in *Challenger's* middecks at various times throughout the flight. Experiment equipment includes the Handheld Radiation Monitor (HRM-III), a gamma and electron dosimeter and the Pocket REM Meter (PRM), a neutron and proton dosimeter. The HRM-III will operate four times during the mission for durations of 55 minutes, while the PRM will operate twice for durations of eight hours.

Two extravehicular mobility units (EMU's) are stowed in the airlock of *Challenger* for the STS-8 mission in the event a contingency extravehicular activity (EVA) is required in STS-8. If an EVA is required, mission specialists Richard Truly and Dale Gardner will perform the EVA.

The airlock and airlock hatches permit the EVA flight crew members to transfer from the mid-deck crew compartment into the payload bay without depressurizing the orbiter crew cabin.

The EMU's are an integrated space suit assembly and life support system which provides the capability for the flight crew to leave the orbiter pressurized crew cabin and work outside the cabin in space.

The airlock in this flight is located inside the mid-deck of the spacecraft's pressurized crew cabin. It has an inside diameter of 1,600 millimeters (63 inches), is 2,108 millimeters (83 inches) long, and has two 1,016 millimeter (40 inch) diameter D-shaped openings, 914 millimeters (36 inches) across, plus two pressure sealing hatches and a complement of airlock support systems. The airlock volume is 4.24 cubic meters (150 cubic feet).

The airlock is sized to accommodate two fully suited flight crew members simultaneously. The airlock support provides airlock depressurization and repressurization, EVA equipment recharge, liquid cooled garment water cooling, EVA equipment checkout, donning and communications. All EVA gear, checkout panel, and recharge stations are located against the internal walls of the airlock.

The airlock hatches are mounted on the airlock. The inner hatch is mounted on the exterior of the airlock (orbiter crew cabin mid-deck side) and opens in the mid-deck. The inner hatch isolates the airlock from the orbiter crew cabin. The outer hatch is mounted in the interior of the airlock and opens in the

airlock. The outer hatch isolates the airlock from the unpressurized payload bay when closed and permits the EVA crew members to exit from the airlock to the payload bay when open.

Airlock

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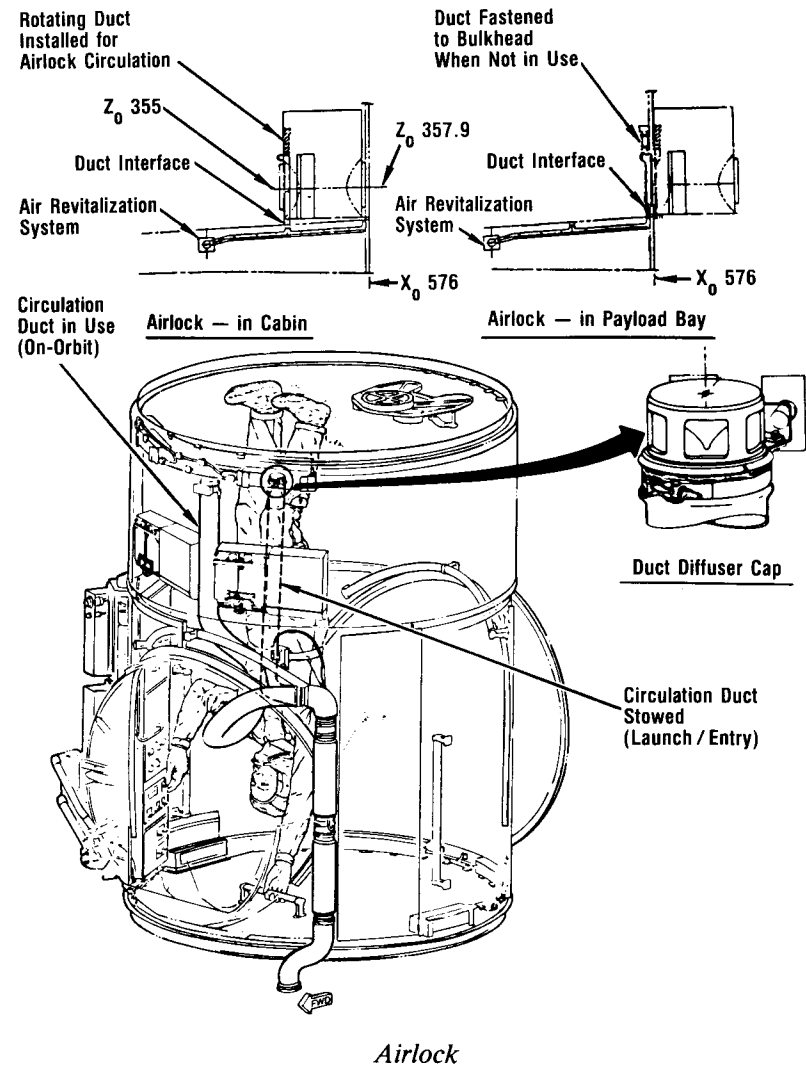
Airlock repressurization is controllable from inside the orbiter crew cabin mid-deck and from inside the airlock. It is performed by equalizing the airlock and cabin pressure with airlock hatch-mounted equalization valves mounted on the inner hatch. Depressurization of the airlock is controlled from inside the airlock. The airlock is depressurized by venting the airlock pressure overboard. The two D-shaped airlock hatches are installed to open toward the primary pressure source, the orbiter crew cabin, to achieve pressure assist sealing when closed.

Each hatch has six interconnected latches with a gearbox/actuator, a window, a hinge mechanism and hold-open device, a differential pressure gage on each side, and two equalization valves.

The window in each airlock hatch is 101 millimeters (4 inches) in diameter. The window is used for crew observation from the cabin/airlock and the airlock/payload bay. The dual window panes are made of polycarbonate plastic and mounted directly to the hatch using bolts fastened through the panes. Each hatch window has dual pressure seals with seal grooves located in the hatch.

Each airlock hatch has dual pressure seals to maintain pressure integrity for the airlock. One seal is mounted on the airlock hatch and the other on the airlock structure. A leak check quick disconnect is installed between the hatch and the airlock pressure seals to verify hatch pressure integrity prior to the flight.

The gearbox with latch mechanisms on each hatch allows the flight crew to open and/or close the hatch during transfers and EVA operation. The gearbox and the latches are mounted on the low pressure side of each hatch, with a gearbox handle installed on both sides to permit operation from either side of the hatch.

Three of the six latches on each hatch are double acting. They have cam surfaces which force the sealing surfaces apart

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Extravehicular Mobility Unit (EMU)

SCU Stowage Connector

Airlock Adapter Plate (AAP)

Avionics Panel

Straps

SCU

Lower Torso Restraint

ECLSS Panels
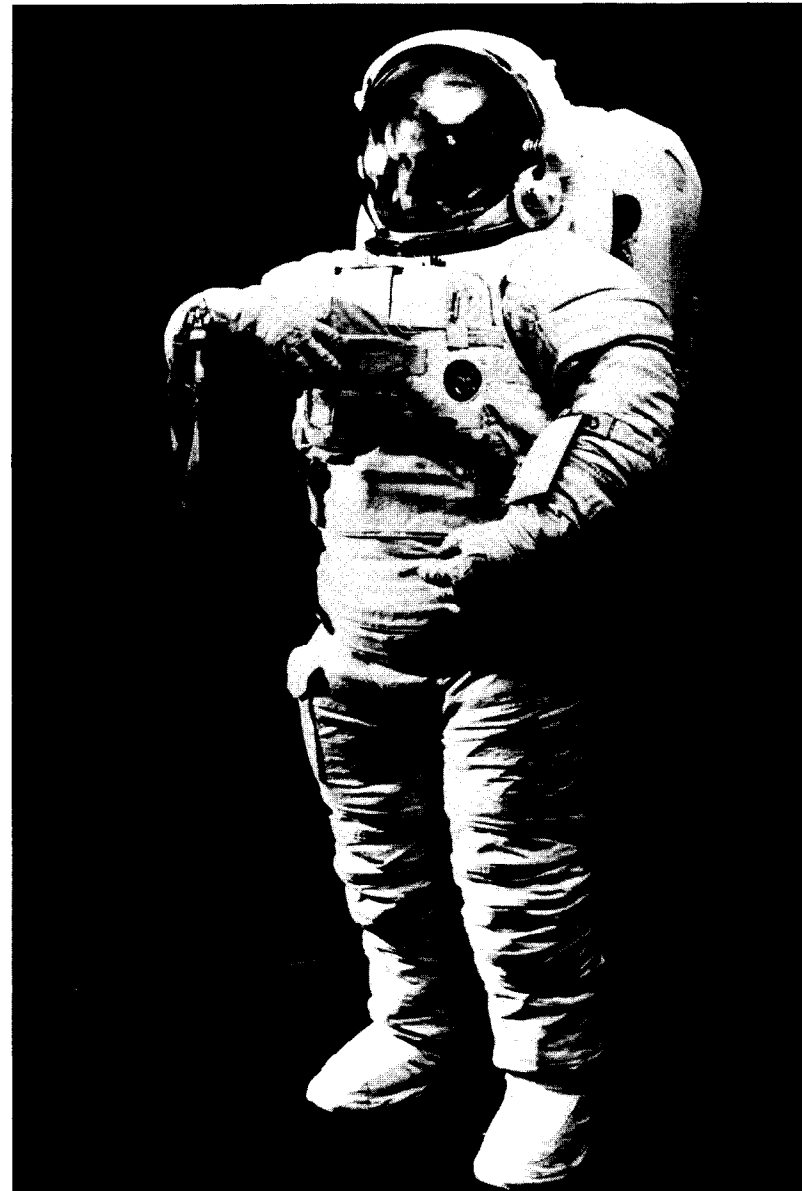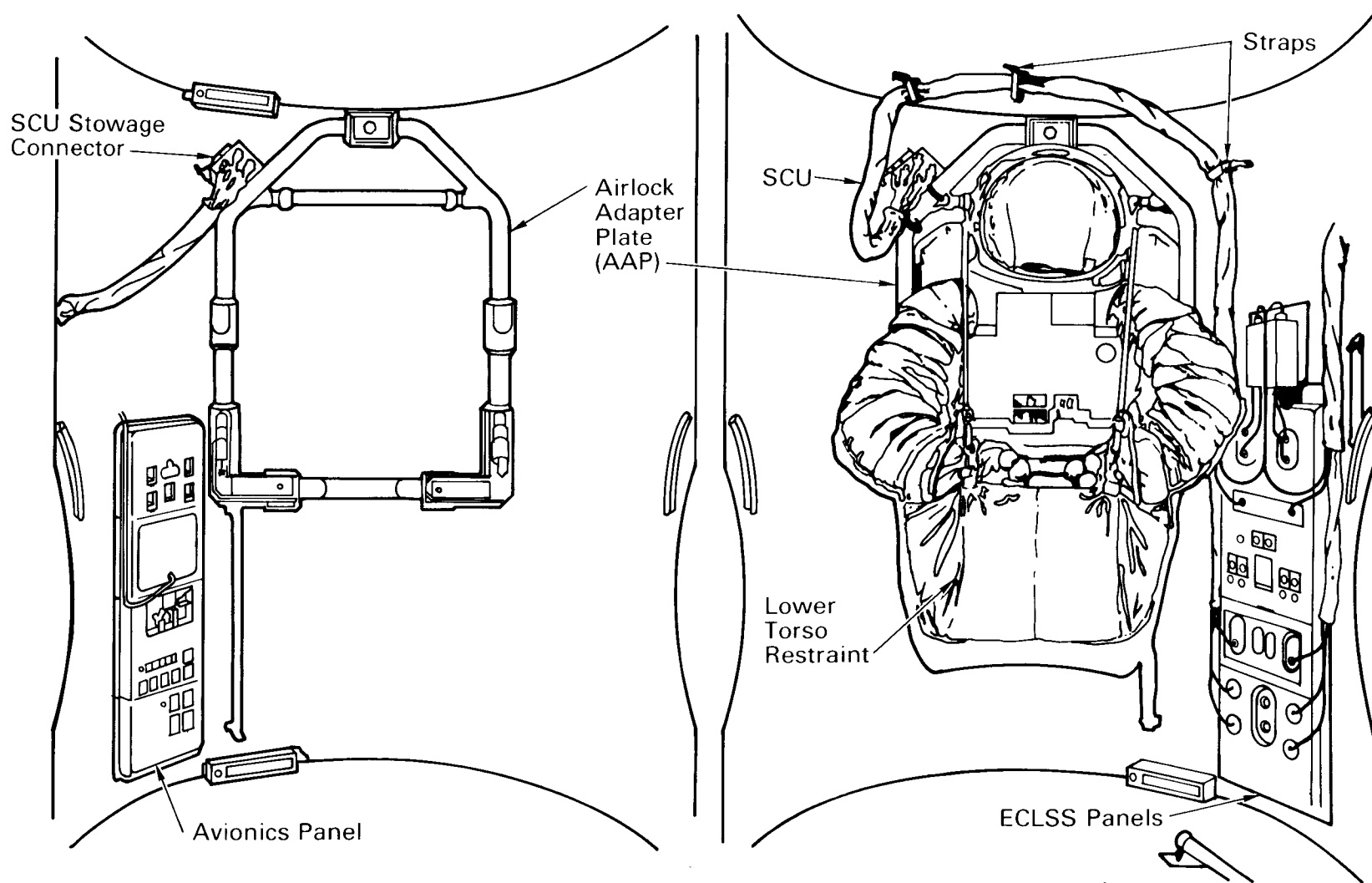
Extravehicular Mobility Unit (EMU)
Service and Cooling Umbilical (SCU)

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Airlock Stowage Provisions

To Open

Δ Pressure Gage

20 15 10 5 | 0 1 5 10 15 20

PSID

Equalization Valve

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Vent → High-Pressure Side

Norm Off

Emer

Emer

Norm Off

Vent

Press Handle
to Rotate (Both Ends)

Cap
Vent

Press to Vent Cap

Airlock Repressurization

DOUBLE ACTING LATCH
- HAS KICKER CAM TO BREAK SEAL
- USED FOR LATCHES 2, 4, AND 6

SINGLE ACTING LATCH
- USED FOR LATCHES 1, 3, AND 5

LATCH HANDLE LATCHED/LOCK INDICATOR

DOUBLE ACTING LATCH

UNLATCHED

ACTUATOR 440° HANDLE TRAVEL TO OPEN

PUSH-PULL ROD SELF-ALIGNING BEARINGS

DOUBLE ACTING LATCH

IDLER BELL CRANK

BELLCRANK SUPPORT BRACKET

HATCH SUPPORT STRUT (2)

DOUBLE ACTING LATCH

Airlock Hatch Latches

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when the latches are opened, thereby acting as crew assist devices. The latches are interconnected with "push-pull" rods and an idler bellcrank installed between the rods for pivoting the rods. Self-aligning dual rotating bearings are used on the rods for attachment to the bellcranks and the latches. The gearbox and hatch open support struts are also connected to the latching system, using the same rod/bellcrank and bearing system. To latch or unlatch the hatch, a rotation of 440 degrees on the gearbox handle is required.

The hatch actuator/gearbox is used to provide the mechanical advantage to open/close the latches. The hatch actuator lock lever requires a force of 35 to 44 Newtons (8 to 10 pounds) through an angle of 180 degrees to unlatch the actuator. A rotation of 440 degrees minimum with a force of 133 Newtons (30 pounds) maximum applied to the actuator handle is required to operate the latches to their fully unlatched positions.

The hinge mechanism for each hatch permits a minimum opening sweep into the airlock or the crew cabin mid-deck. The inner hatch (airlock to crew cabin) is pulled/pushed forward to the crew cabin approximately 152 millimeters (6 inches). The hatch pivots up and to the starboard (right) side. Positive locks are provided to hold the hatch in both an intermediate and a full open position. To release the lock, a spring-loaded handle is provided on the latch hold-open bracket. Friction is also provided in the linkage to prevent the hatch from moving if released during any part of the swing.

The outer hatch (in airlock to payload bay) opens and closes to the contour of the airlock wall. The hatch is hinged to be first pulled into the airlock and then pulled forward at the bottom and rotated down until it rests with the low pressure (outer) side facing the airlock ceiling (mid-deck floor). The linkage mechanism guides the hatch from the closed/open, open/closed position with friction restraint throughout the stroke. The hatch has a hold-open hook which snaps into place over a flange when the hatch is fully open. The hook is released

by depressing the spring-loaded hook handle and by pushing the hatch toward the closed position. To support and protect the hatch against the airlock ceiling, the hatch incorporates two deployable struts. The struts are connected to the hatch linkage mechanism and are deployed when the hatch linkage mechanism and are deployed when the hatch linkage is rotated open. When the hatch latches are rotated closed, the struts are retracted against the hatch.

The airlock hatches can be removed in-flight from the hinge mechanism via pip pins, if required.

Airlock air circulation system provides conditioned air to the airlock during non-EVA operation periods. The airlock revitalization system duct is attached to the outside airlock wall at launch. Upon airlock hatch opening in-flight, the duct is rotated by the flight crew through the cabin/airlock hatch and installed into the airlock and held in place by a strap holder. The duct has a removable air diffuser cap installed on the end of the flexible duct which can adjust the airflow from 0 to 97 kilograms per hour (216 pounds per hour). The duct must be rotated out of the airlock prior to closing the cabin/airlock hatch for airlock depressurization. During the EVA preparation period, the duct is rotated out of the airlock and can be used as supplemental air circulation in the mid-deck.

To assist the crew member in pre- and post-EVA operations, the airlock incorporates handrails and foot restraints. Handrails are located alongside the avionics and ECLSS panels. A handhold is mounted on each side of the hatches. They are aluminum alloy and oval configurations 19.05 by 33.52 millimeters (0.75 by 1.32 inches) and are painted yellow. The handrails are bonded to the airlock walls with an epoxyphenolic adhesive. Each handrail provides a handgrip clearance of 57 millimeters (2.25 inches) from the airlock wall to the handrail to allow gripping operations in a pressurized glove. Foot restraints are installed on the airlock floor nearer the payload bay side and the ceiling handhold installed nearer the cabin side of the airlock was removed for stowage of the third EMU. The foot restraints

can be rotated 360 degrees by releasing a spring-loaded latch and will lock in every 90 degrees. A rotation release knob on the foot restraint is designed for shirt sleeve operation, and therefore must be positioned before the suit is donned. The foot restraint is bolted to the floor and cannot be removed in flight and is sized for the EMU boot. The crew member ingresses by first inserting the foot under the toe bar and then the heel is pressed down by rotating the heel from inboard to outboard until the heel of the boot is captured.

There are four floodlights in the airlock. The lights are controlled by switches in the airlock on panel AWI8A; light 2 can also be controlled by a switch on mid-deck panel M013Q, allowing illumination of the airlock prior to entry. Lights 1, 3, and 4 are powered by buses MNA, B, and C respectively and light 2 is powered by ESS1BC. The circuit breakers are on panel ML86B.

In preparation for an EVA, the mission specialists will first don a liquid cooled and ventilation garment (LCVG). It is similar to "long-john" underwear into which have been woven many feet of flexible tubing that circulates cooling water. The liquid cooled and ventilation garment is worn under the pressure and gas garment to maintain desired body temperature.

A urine collection device (UCD) is worn for collection of urine in the suit. It stores approximately 0.9 liter (approximately one quart) of urine. It consists of adapter tubing, storage bag and disconnect hardware for emptying after an EVA into the orbiter waste water system.

The airlock provides stowage for two Extravehicular Mobility Units (EMU's) and two service and cooling umbilicals (SCU's) and various miscellaneous support equipment.

Both EMU's are mounted on the airlock walls by means of an airlock adapter plate (AAP).

The prime contractor to NASA for the space suit/life support system is United Technologies' Hamilton Standard Division in Windsor Locks, Conn. Hamilton Standard is program systems manager for the space suit/life support system in addition to designer and builder. Hamilton Standard's major subcontractor is ILC Dover of Frederica, Del., which fabricates the space suit.

The EMU's provide the necessities for life support, such as oxygen, carbon dioxide removal, a pressurized enclosure, temperature control and meteoroid protection during EVA.

The EMU space suit comes in various sizes so that prior to launch, flight crew members can pick their suits "off the rack." Components are designed to fit male and female from the 5th to the 95th percentiles of body size.

The life support system is self contained and contains seven hours of expendables such as oxygen, battery power for electrical power, water for cooling, and lithium hydroxide for carbon dioxide removal and a 30 minute emergency life support system during an EVA.

The airlock adapter plate in the airlock also provides a fixed position for the EMU's to assist the crew member during donning, doffing, checkout and servicing. Each EMU weighs approximately 102 kilograms (225 pounds) and the overall storage envelope is 660 by 711 by 1,016 millimeters (26 by 28 by 40 inches). For launch and entry, the lower torso restraint, a cloth bag attached to the airlock adapter plate (AAP) with straps, is used to hold the lower torso and arms securely in place.

To don the EMU, the crew member enters the airlock and dons the lower torso assembly which has boots attached. The lower torso consists of the pants, boots and the hip, knee and ankle joints. The hard, upper torso assembly includes the life support backpack and provides the structural mounting interface for most of the EMU including helmet, arms, lower torso, portable life support system, display and control module and electrical harness. The arm assembly contains the shoulder joint and upper arm bearings that permit shoulder mobility as well as the elbow joint and wrist bearing. The gloves contain the wrist

disconnect, wrist joint and insulation padding for palms and fingers. The helmet consists of a clear polycarbonate bubble neck disconnect and ventilation pad. An EVA visor assembly is attached externally to the helmet which contains visors which are manually adjusted to shield the crew member's eyes. The upper and lower torsos are connected with a waist ring.

In addition, the portable life support system consists of an EMU electrical harness that provides bioinstrumentation and communications connections; a display and control module that is chest mounted which contains all external fluid and electrical interfaces and controls and displays; the portable life support subsystem referred to as the "backpack" which contains the life support subsystem expendables and machinery; a secondary oxygen pack mounted on the base of the portable life support subsystem which contains a 30 minute emergency oxygen supply and a valve and a regulator assembly, and an in-suit drink bag

Extravehicular Mobility Unit (EMU)

that stores liquid in the hard upper torso which has a tube projecting up into the helmet to permit the crew member to drink while suited.

The orbiter provides electrical power, oxygen, liquid cooled ventilation garment cooling and water to the EMU's in the airlock via the SCU for EVA prep and post-EVA operations.

The service and cooling umbilical (SCU) is launched with the orbiter end fittings permanently connected to the appropriate ECLSS panels and the EMU connected to the airlock adapter plate stowage connector. The SCU contains communication lines, electrical power, water and oxygen, recharge lines and drain lines. It allows all supplies (oxygen, water, electrical, and communication) to be transported from the airlock control panels to the EMU before and after EVA without using the EMU expendable supplies of water, oxygen and battery power that are scheduled for use in the EVA. The SCU also provides EMU recharge. The SCU umbilical is disconnected just before the crew member leaves the airlock on an EVA and upon return to the airlock after an EVA. Each SCU is 3,657 millimeters (144 inches) long and 88 millimeters (3.5 inches) in diameter and weighs 9.1 kilograms (20 pounds). Actual usable length after attachment to the control panel is approximately 2 meters (7 feet).

The airlock has two display and control panels. The airlock control panels are basically split to provide either ECLSS or avionics operations. The ECLSS panel provides the interface for the SCU waste and potable water, liquid cooled ventilation garment cooling water, EMU hardline communication, EMU power and oxygen supply. The avionics panel includes the airlock lighting, the airlock audio system, and the EMU power and battery recharge controls. The avionics panel is located on the starboard (right) side of the cabin airlock hatch and the ECLSS panel on the port (left) side. The airlock panels are designated AW18H, AW18D, and AW18A on the port side and AW82H, AW82D, and AW82B on the starboard side. The ECLSS panel is divided into EMU1 functions on the starboard side and EMU2 functions on the port side.

Airlock communications are provided with the orbiter audio system at airlock panel AW82D where connectors for the headset interface units (HIU's) and the EMU's are located at airlock panel AW18D which is the airlock audio terminal (ATU). The HIU's are inserted in the crew-member communications carrier unit (CCU1 and CCU2) connectors on airlock panel AW82D. The CCU's are also known as the "Snoopy Cap" which fits over the crew member's head and snaps into place with a chin guard. It contains a microphone and headphones for two-way communications and receiving caution and warning tone. The adjacent two-position switches labeled CCU1 and CCU2 POWER enable transmit functions only, as reception is normal as soon as the HIU's are plugged in. The EMU1 and EMU2 connectors on the same panel to which the service and cooling umbilical (SCU) is connected include contacts for EMU hard-line communications with the orbiter prior to EVA. Panel AW18D contains displays and controls used to select access to and control volume of various audio signals. Control of the airlock audio functions can be transferred to the mid-deck ATU's panel M042F, by placing the CONTROL knob to MIDDECK position.

During EVA, the Extravehicular Communicator (EVC) is part of the same UHF system which is used for air-to-air and air-to-ground voice communications between the orbiter and landing site control tower and the orbiter and chase aircraft. The EVC provides full duplex (simultaneous transmission and reception) communications between the orbiter and the two EVA crew members and continuous data reception of electrocardiogram signals from each crew member by the orbiter and orbiter processing and relay of electrocardiogram signals to the ground. The UHF airlock antenna in the forward portion of the payload bay provides the UHF-EVA capability.

Panel AW18H in the airlock provides 17 plus or minus 0.5 Vdc at five amperes at both EMU electrical connector panels, panel AW82D, in EVA prep. Bus MNA or B can be selected on the BUS SELECT switch and then the MODE switch is positioned to POWER. The BUS SELECT switch provides a signal to a remote power controller (RPC) which applies 28 Vdc from the selected bus to the power/battery recharger. The MODE switch in the POWER psoition makes the power available at the SCU connector and also closes a circuit that provides a battery feedback voltage charger control which inhibits EMU power when any discontinuity is sensed in the SCU/EMU circuitry. The MODE switch in the POWER position also applies power through the SCU for the EMU microphone amplifiers for hardline communication. When the SCU umbilical is disconnected for EVA, the EMU operates on its self contained battery power. For post-EVA, when the SCU is reconnected to the EMU, selecting a bus and the CHARGE position on the MODE switch charges the portable life support system battery at 1.55 plus or minus 0.05 amps. When the battery reaches 21.8 plus or minus 0.1 Vdc and/or the charging circuit exceeds 1.55 plus or minus 0.05 amps, a solenoid controlled switch internal to the battery charger removes power to the charging circuitry. The EMU silver zinc battery provides all electrical power used by the portable life support system during EVA and is filled with electrolyte and charged prior to flight.

Cooling for the flight crew members before and after the EVA is provided by the liquid cooled garment circulation system via the SCU and LCG (liquid cooled garment) SUPPLY AND RETURN connections on panel AW82B. These connections are routed to the orbiter liquid cooled garment heat exchanger which transfers the collected heat to the orbiter Freon-21 coolant loops. The nominal loop flow of 113 kilograms per hour (250 pounds per hour) is provided by the EMU/portable life support system water loop pump. The system circulates chilled water at 10 degrees Celsius (50 °F) maximum to the liquid cooled ventilation garment inlet and provides a heat removal capability of 2,000 Btu (British Thermal Units) per hour per crew member. When the SCU is disconnected the portable life support system provides the cooling. Upon return from the EVA, the portable life support system is reconnected to the SCU and the crew member cooling is provided as it was in the EVA prep.

With the suit connected to the SCU, oxygen at 46,575 mmhg (900 psia) plus or minus 2,587 mmhg (500 psia) is sup-

plied through airlock panel AW82B from the orbiter oxygen system when the OXYGEN valve is in the OPEN position on the airlock panel. This provides the suited crew member with breathing oxygen, preventing depletion of the portable life support system oxygen tanks prior to the EVA. Prior to the crew member sealing the helmet, an oxygen purge adapter hose is connected to the airlock panel to flush nitrogen out of the suit.

The crew member will prebreathe pure oxygen in the EMU for approximately 3 and one-half hours prior to the EVA. This is necessary to remove nitrogen from their blood before working in the pure oxygen environment of the EMU due to the orbiter pressurized crew cabin mixed gas atmosphere of 20 percent oxygen and 80 percent nitrogen at a pressure of 750 plus or minus 10 mmhg (14.5 plus or minus 0.2 psia). Without prebreathing, bends occur when an individual fails to reduce nitrogen levels in the blood prior to working in a pressure condition that can result in nitrogen coming out of solution in the form of bubbles in the bloodstream. This condition results in pain in the body joints, possibly because of restricted blood flow to connective tissues or the extra pressure caused by bubbles in the blood at joint area. During prebreathe, the suit is at 2.5 mmhg (1/2 psia).

When the SCU is disconnected, the portable life support system provides oxygen for the suit. When the EVA is completed and the SCU is reconnected, the orbiter oxygen supply begins recharging the portable life support system, providing the OXYGEN valve on panel AW82B is OPEN. Full oxygen recharge takes approximately one hour (allowing for thermal expansion during recharge) and the tank pressure is monitored on the EMU display and control panel as well as on the airlock oxygen pressure readout.

Each EMU is pressurized to 207 mmhg (4.0 psid) differential. They are designed for a 15 year life with cleaning and drying between flights.

The EMU WATER SUPPLY and WASTE valves are opened during the EVA prep by switches on panel AW82D. This provides the EMU, via the SCU, access to both the orbiter potable water and waste water systems. The support provided to the EMU portable life support system is further controlled by the EMU display and control panel. Potable water — supplied from the orbiter at 828 plus or minus 25 mmhg (16 plus or minus 0.5 psi), 45 to 58 kilograms per hour (100 to 300 pounds per hour), and 4 to 37 degrees C (40 to 100 °F) — allowed to flow to the feedwater reservoir in the EMU which provides pressure which would "top-off" any tank not completely filled. Waste water, condensate, developed in the portable life support system is allowed to flow to the orbiter waste water system via the SCU whenever the regulator connected at the bacteria filters (airlock end of the SCU) detects upstream pressure in excess of 828 plus or minus 25 mmhg (16 plus or minus 0.5 psi).

When the SCU is disconnected from the EMU, the portable life support system assumes this function. When the SCU is reconnected to the EMU upon completion of the EVA, the same functions as in pre-EVA are performed except that the water supply is allowed to continue until the portable life support system water tanks are filled, which takes approximately 30 minutes.

In preparation for the EVA from the airlock, the airlock hatch to the orbiter crew cabin is closed and depressurization of the airlock begins.

Airlock depressurization is accomplished by a three position valve located on the ECLSS (Environmental Contol Life Support System) panel AW82A in the airlock. The airlock depressurization valve is covered with a pressure/dust cap. Prior to removing the cap from the valve, it is necessary to vent the area between the cap and valve by pushing the vent valve on the cap. In-flight storage of the pressure/dust cap is adjacent to the valve. The airlock depressurization valve is connected to a 50 millimeter (2 inch) inside diameter stainless steel overboard vacuum line. The AIRLOCK DEPRESS valve controls the rate of depressurization by varying the valve diameter size. Depressurization is accomplished in two stages. The CLOSED position prevents any airflow from escaping to the overboard vent system.

When the crew members have completed the prebreathe in the EMU's for 3.5 hours, the airlock is depressurized from 750 mmhg (14.5 psia) to 258 mmhg (5 psia) by position labeled "5" on the AIRLOCK DEPRESS valve which opens the depressurization valve and allows the pressure in the airlock to decrease. Pressure during depressurization can be monitored by the delta pressure gage on either airlock hatch. A delta pressure gage is installed on each side of both airlock hatches. The depressurization from 750 mmhg (14.5 psia) to 258 mmhg (5 psia) takes approximately 200 seconds.

At this time the flight crew performs an EMU suit leak check, electrical power is transferred from the umbilicals to the EMU batteries, the umbilicals are disconnected and the suit oxygen packs are brought on line.

The second stage of airlock depressurization is accomplished by positioning the AIRLOCK DEPRESS valve to "0" which increases the valve diameter and allows the pressure in the airlock to decrease from 258 mmhg (5 psia) to 0 mmhg (0 psia) in approximately 13 seconds. The suit sublimators are activated for cooling, EMU system checks are performed and the airlock/payload bay hatch can be opened. The hatch is capable of opening against a 10 mmhg (0.2 psia) differential maximum.

Hardware provisions are installed in the orbiter payload bay for use by the crew member during the EVA.

Handrails and tether points are located on the payload bulkheads, forward bulkhead station X_O 576 and aft bulkhead station X_O 1307, and along the sill longeron on both sides of the bay to provide translation and stabilization capability for the EVA crew member. The handrails are designed to withstand a load of 90.72 kilograms (200 pounds), 127.01 kilograms (280 pounds) maximum in any direction. Tether attach points are designed to sustain a load of 260.37 kilograms (574 pounds), 364.69 kilograms (804 pounds) maximum, in any direction.

The handrails have a cross section of 33 by 19 millimeters (1.32 by 0.75 inches). They are made of aluminum alloy tubing and are painted yellow. The end braces and side struts of the handrails are constructed of titanium. An aluminum alloy end support standoff functions as the terminal of the handrail. Each end support standoff incorporates a 25.4 millimeter (one inch) diameter tether point.

A 7.62 meter (25 foot) crew member safety tether is attached to each crew member at all times during an EVA.

The tether consists of a reel case with an integral "D" ring, a reel with a light takeup spring, a cable and a locking hook. The safety tether hook is locked onto the slidewire before launch and the cable is routed and clipped along the port (left) and starboard (right) handrails to a position just above the airlock/payload bay hatch. After opening the airlock hatch and before egress, the crew member attaches a waist tether to the "D" ring of the safety tether to be used. The other end of the waist tether is hooked to a ring on the EMU waist bearing. The crew member may select either the port or the starboard safety tether. With the selector on the tether in the locked position, the cable will not retract or reel out. Moving the selector to the unlocked position allows the cable to reel out and the retract feature to take up slack. The cable is designed for a maximum load of 398 kilograms (878 pounds). The routing of the tethers follows the handrails, allowing the crew member to deploy and restow his tether during translation.

The two slidewires, approximately 14.11 meters (46.3 feet) long, are located in the longeron sill area on each side of the payload bay. They start approximately 2.83 meters (9.3 feet) aft of the forward bulkhead and extend approximately 14.11 meters (46.3 feet) down the payload bay. The slidewires withstand a tether load of 260.37 kilograms (574 pounds) with a safety factor of 1.4 or 364.49 kilograms (804 pounds) maximum.

The airlock/cabin hatch has two pressure equalization valves which can be operated from both sides of the hatch for repressurizing the airlock volume. Each valve has three positions, CLOSED, NORM (Normal), and EMERG (Emergency) and is protected by a debris pressure cap on the intake (high-

pressure) side of the valve, which on the outer hatch must be vented for removal. The caps are tethered to the valves and also have small Velcro spots which allow temporary stowage on the hatch. The exit side of the valve contains an air diffuser to provide uniform flow out of the valve.

Through the use of the equalization valve/valves in the various positions, the airlock can be repressurized in a normal mode to 745 mmhg (14.4 psia) in 325 seconds, then equalized to the crew cabin pressure of 750 mmhg (14.5 psia) in 110 seconds. If both equalization valves are positioned to EMERG, the airlock can be repressurized to 754 mmhg (14.4 psia) in 28 seconds, then equalized to the crew cabin pressure of 750 mmhg (14.5 psia) in 200 seconds. The hatch is capable of opening against a 10 mmhg (0.2 psia) differential maximum.

The airlock is initially pressurized to 258 mmhg (5 psia) and the umbilicals are connected and electrical power is transferred back to umbilical power. The airlock is then pressurized to equalize with the cabin pressure, followed by EMU doffing and the crew members' recharge of the EMU's.

The orbiter provides accommodations for three two-flight-crew member EVA's of six-hour duration per flight at no weight or volume cost to the payload. Two of the EVA's are for payload support and the third is reserved for orbiter contingency. Additional EVA's can be considered with consumables charged to payloads.

CARGO BAY STOWAGE ASSEMBLY (CBSA)

The Cargo Bay Stowage Assembly contains miscellaneous tools for use in the payload bay. It is located on the starboard (right) side of the payload bay forward, between Orbiter Station $X_O = 589$ and $X_O = 636$.

The CBSA is approximately 1,066 millimeters (42 inches) wide, 609 millimeters (24 inches) in depth and 914 millimeters (36 inches) in height. The CBSA weight is approximately 259 kilograms (573 pounds).

MODULAR AUXILIARY DATA SYSTEM (MADS)

The Modular Auxiliary Data System (MADS) for OV-099, the *Challenger* is an onboard instrumentation system that measures and records selected pressure, temperature, strain, vibration, and event data to support payloads and experiments and to determine orbiter environments during the flights of the *Challenger*. MADS supplements the operational instrumentation (OI) that exists in the *Challenger*. The MADS equipment conditions, digitizes, and stores data from selected sensors and experiments.

MADS collects detailed data during ascent, orbit, and entry to define the vehicle response to the flight environment, permit correlation of data from one flight to another, and enable comparison of the *Challenger* flight data to the flight data of the *Columbia*.

All of the MADS equipment installed on the *Challenger* are structurally mounted and environmentally compatible with the orbiter and mission requirements. Due to its location, the MADS will not intrude into the payload envelope.

The MADS for *Challenger* consists of a pulse code modulation (PCM) multiplexer, a frequency division multiplexer (FDM), a power distribution assembly (PDA), and appropriate signal conditioners mounted on shelf 8 beneath the payload bay liner of the mid-fuselage. The MADS also consists of a MADS control module (MCM) and a MADS recorder that are mounted below the mid deck floor.

MADS will record approximately 246 measurements throughout the orbiter. These measurements are from the orbiter airframe and skin and the orbital maneuvering system/reaction control system (OMS/RCS) left hand pod only. Measurements of MADS components are connected to existing operational instrumentation for real time monitoring of MADS status.

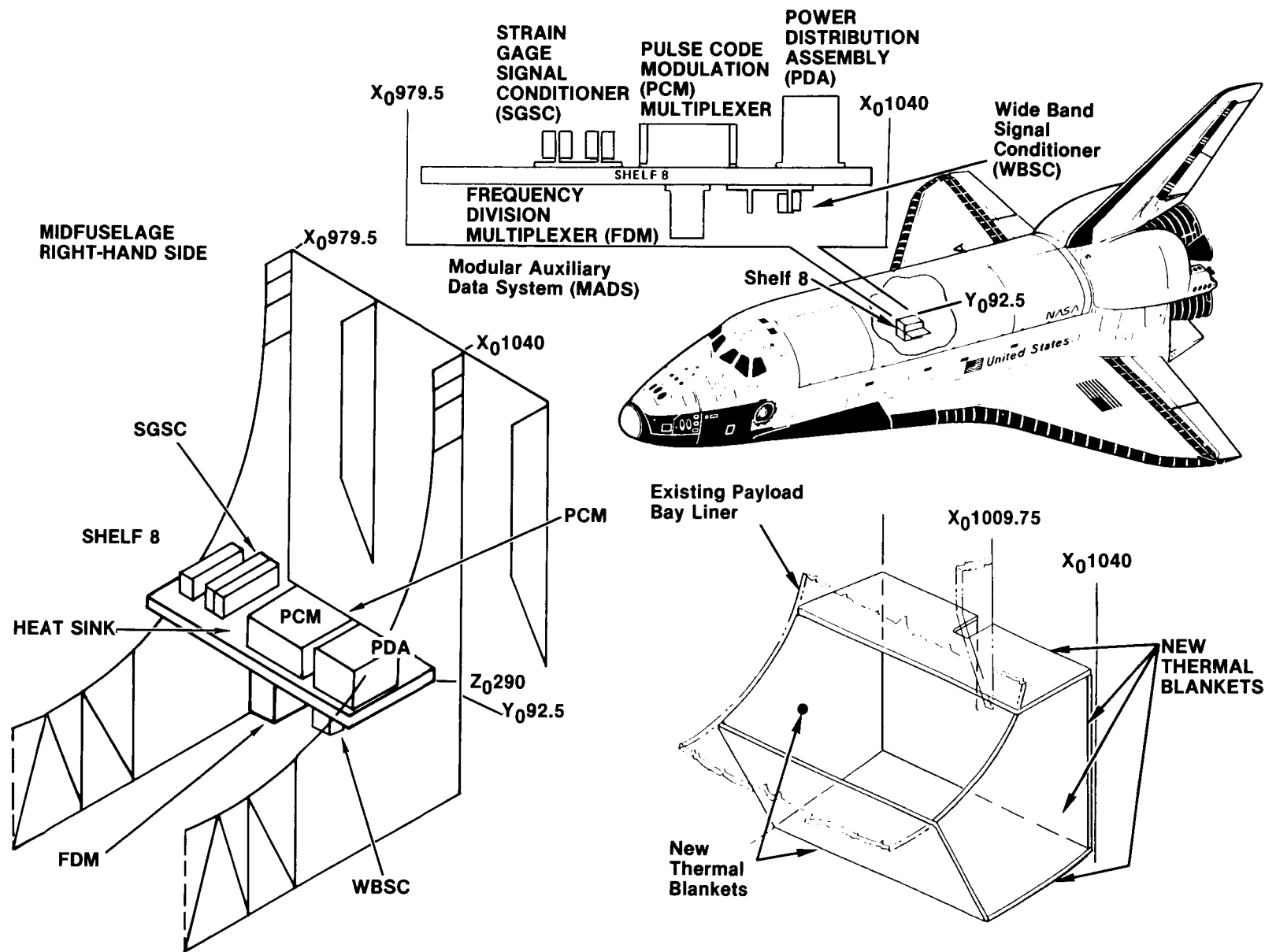The MADS interfaces with the orbiter through the orbiter

electrical distribution system and the inputs to the operational instrumentation for MADS status monitoring. Coaxial cables and wire harnesses from the sensors are routed through the orbiter payload bay harness bundles to the signal conditioners, PCM, and FDM, attached to mid-fuselage shelf 8. After the signal conditioners and the multiplexers have processed the data, four outputs of the FDM and one output of the PCM is routed forward to the MCM, which will then record them on five tracks of the MADS recorder. The same five channels will be routed back through the X-1307 bulkhead to the T-0 umbilical.

Eight tracks of the MADS recorder will be used during ascent to record additional Space Shuttle data. Two tracks will be used to record solid rocket booster (SRB) wideband (WB) data, five tracks to record heavyweight external tank (ET) data, and one track to record aerodynamic coefficient package (ACIP) data.

The MADS is not considered mandatory for launch nor will the loss of MADS during flight be a cause for a mission abort.

MADS will measure and record data for predetermined events. These events are determined by test and mission requirements.

During a typical mission at approximately five hours prior to launch, the MADS will be powered on from the preset switch configuration to supply a prelaunch manual calibration. After completion of the calibration, all switches will be returned to the preset configuration. This leaves the MADS in the standby position, with only the MCM receiving power. This mode will continue until five minutes 30 seconds prior to launch, at which time the MADS will be put into the full system mode through uplink commands and all the MADS components are powered on. In this mode, the MADS will be recording at a continuous (CONT) tape speed of 381 millimeters (15 inches) per second. It

STRAIN
GAGE
SIGNAL
CONDITIONER
(SGSC)

PULSE CODE
MODULATION
(PCM)
MULTIPLEXER

POWER
DISTRIBUTION
ASSEMBLY
(PDA)

$X_0 979.5$

$X_0 1040$

Wide Band
Signal
Conditioner
(WBSC)

SHELF 8

FREQUENCY
DIVISION
MULTIPLEXER (FDM)

Modular Auxiliary
Data System (MADS)

Shelf 8

$Y_0 92.5$

MIDFUSELAGE
RIGHT-HAND SIDE

$X_0 979.5$

$X_0 1040$

SGSC

SHELF 8

PCM

HEAT SINK

PCM

PDA

$Z_0 290$

$Y_0 92.5$

FDM

WBSC

Existing Payload
Bay Liner

$X_0 1009.75$

$X_0 1040$

NEW
THERMAL
BLANKETS

New
Thermal
Blankets

74

Modular Auxiliary Data System (MADS) Mid-Fuselage

will be recording ACIP flight acceleration safety cutoff (FASCO), ET, SRB, WB, and PCM data. The MADS PCM will have a bit rate of 64 kilo-bits-per second (kbps).
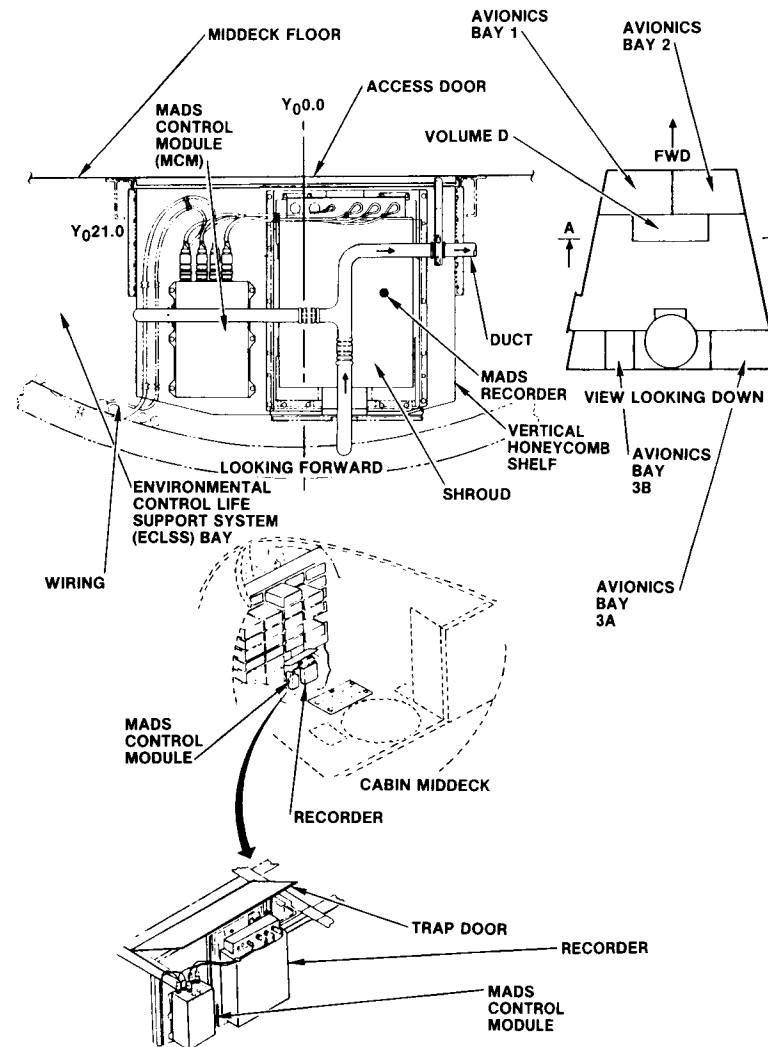
The wideband (WB) only mode will be used only during the prelaunch automatic (AUTO) and manual (MAN) calibrations. In this mode, the recorder will be recording the AC and DC current calibration levels provided by the FDM. Each manual calibration level will be recorded for 10 seconds at a tape speed of 381 millimeters (15 inches) per second in the continuous mode.

At 12 minutes after launch MADS will be commanded into the PCM snapshot (S/S) with strain gage signal conditioner (SGSC) mode. In this mode, the recorder will be in the sample mode and conserves power and recorder tape. In this S/S mode, data will be recorded every 10 seconds every 10 minutes at a PCM bit rate of 32 kbps and a tape speed of 95 millimeters (3-3/4 inches) per second.
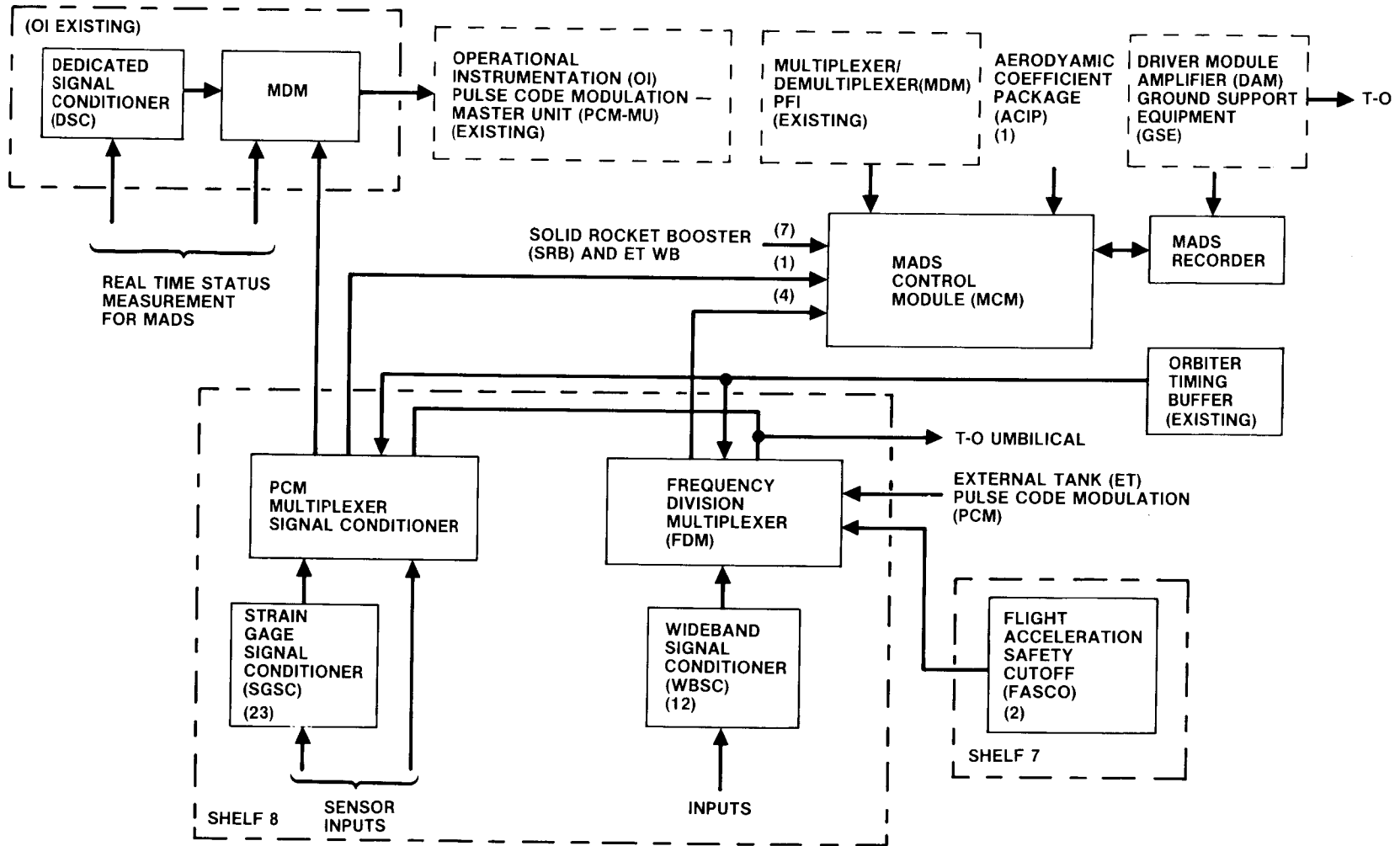
At two minutes prior to the OMS-2 thrusting period, commands will be given to put the MADS back into the full system mode until the thrusting period is completed. At this time, commands will be given to put the MADS into the PCM only mode, which will continue during the orbit until a quiescent period is achieved. During the quiescent period, one minute of ACIP calibration will be required, after which the MADS will continue in the PCM only mode. The system will be switched to the full system mode for the OMS separation thrusting periods and then be returned to the PCM only mode for the majority of the on-orbit mission.

The PCM with strain gage signal conditioners (SGSC) mode is similar to the PCM only mode, but strain measurements will also be recorded during this period. The SGSC's will be cycled along with the other MADS components to signal conditioners to warm up. This mode will occur between two full system modes to minimize flight crew participation and conserve power and recorder tape. This mode can be initiated from the full system mode or returned to the full system mode by one

uplink command. This mode can be put into the PCM only mode by commanding the SGSC off, which is done manually by positioning switch 4 on panel A7A2 in the OFF position. This mode is used on orbit.

Modular Auxiliary Data System (MADS) Crew Compartment

75

(OI EXISTING)

DEDICATED
SIGNAL
CONDITIONER
(DSC)

MDM

OPERATIONAL
INSTRUMENTATION (OI)
PULSE CODE MODULATION —
MASTER UNIT (PCM-MU)
(EXISTING)

MULTIPLEXER/
DEMULTIPLEXER(MDM)
PFI
(EXISTING)

AERODYAMIC
COEFFICIENT
PACKAGE
(ACIP)
(1)

DRIVER MODULE
AMPLIFIER (DAM)
GROUND SUPPORT
EQUIPMENT
(GSE)

T-O

REAL TIME STATUS
MEASUREMENT
FOR MADS

SOLID ROCKET BOOSTER
(SRB) AND ET WB

(7)

(1)

(4)

MADS
CONTROL
MODULE (MCM)

MADS
RECORDER

ORBITER
TIMING
BUFFER
(EXISTING)

T-O UMBILICAL

PCM
MULTIPLEXER
SIGNAL CONDITIONER

FREQUENCY
DIVISION
MULTIPLEXER
(FDM)

EXTERNAL TANK (ET)
PULSE CODE MODULATION
(PCM)

STRAIN
GAGE
SIGNAL
CONDITIONER
(SGSC)
(23)

WIDEBAND
SIGNAL
CONDITIONER
(WBSC)
(12)

FLIGHT
ACCELERATION
SAFETY
CUTOFF
(FASCO)
(2)

SHELF 7

SHELF 8

SENSOR
INPUTS

INPUTS

Modular Auxiliary Data System (MADS) Block Diagram

At two minutes before the deorbit thrusting period, the MADS will be put into the full system mode for one hour to record descent (entry) data. At the conclusion of the one hour period, the MADS will be powered down for the entire post-landing period.

With the use of the MADS switches located in the flight crew compartment, commands can be initiated by the flight crew. These switches are located on two panels, C3A5 and A7A2. Panel C3A5 is located on the forward flight deck center console and contains the MADS master power switch (S14). This switch will be used to turn power on or off during prelaunch, postlanding and emergencies. Panel A7A2 is located on the aft flight station and contains the component power and functional switches for MADS. From this panel, various control functions can be accomplished. To reduce flight crew participation, all commands should be uplink if possible from Mission Control Center (MCC) Houston (H) and transmitted to the onboard multiplexer/demultiplexer (MDM), Payload Forward (PF)-1. The MDM will then route the commands to the MCM for processing.

Power for the MADS will be supplied from the orbiter's 28 vdc main buses A and B. The ACIP experiment is a separate identity, but its power will be distributed by the MADS power distribution assembly (PDA). The ACIP experiment will consume power when the WB is powered on, using switch 5 on panel A7A5. The 64 kbps of PCM data from the ACIP experiment will be recorded on the MADS recorder during the ascent and entry phases.

The flight acceleration safety cutoff located on shelf 7 in the mid fuselage, directly above the MADS shelf 8, interfaces 12 vibration measurements with the MADS.

The MADS shelf 8 components will be protected from overheating by a passive thermal control system that will be used to constrain maximum temperatures. The MADS installation is thermally isolated from the orbiter structure by 1.2 millimeter (0.049 inches), thin wall titanium struts. The installa-

tion is also enclosed from the orbiter environment by a 38 millimeter (1.5 inch) bulk insulation enclosure.

Each measurement uses either a thermocouple, resistance thermometer, radiometers, vibration sensor, strain gage, or pressure transducer.

The MADS recorder is a Bell and Howell 28-track wideband modular airborne recording system (MARS) similar to the *Columbia* development flight instrumentation (DFI) missions and orbiter experiments (OEX recorders). The recorder is capable of simultaneously recording, and subsequently reproducing, 28 tracks of digital biphase L data or any combination of wideband analog and digital biphase L data equal to 28 tracks.

All 28 tracks can be output simultaneously with adequate levels to drive the input circuitry of the driver amplifier module (DAM) which is part of the MADS equipment that is not installed in the orbiter. It is support equipment that will be carried on and used for dumping the data recorder during the checkout or postlanding.

The total weight of the MADS is 290 kilograms (641 pounds).

The ACIP incorporates three triaxial instruments: one of dual-range linear accelerometers, one of angular accelerometers, and one of rate gyros. Also included are the power conditioner for the gyros, the power control system, and the housekeeping components for the instruments. The ACIP is aligned to the orbiter axes to a very high order of accuracy. Mounted on the ACIP base is a triaxial vibrometer which will provide the structural vibration characteristics of the orbiter affecting the ACIP experiment necessary for baseline filtration of accelerometer data. The output signals of the instruments are recorded on the Modular Auxiliary Data System (MADS) recorder. The ACIP operates through launch and through the entry and descent phases. The internal instruments continuously sense the dynamic and performance characteristics of the or-

biter through these critical flight phases. In addition, the ACIP receives indications of position of the control surfaces and converts them into higher orders of precision before recording them with the attitude data. Power is supplied from the mid-power control assembly 3 main bus C. Heaters are employed on the package and controlled by a switch on panel R11.

Weight of the ACIP is 119 kilograms (262 pounds). The principal technologist for the experiment is David Howes of NASA's Johnson Space Center.

AERODYNAMIC COEFFICIENT IDENTIFICATION PACKAGE (ACIP)

The ACIP is a sensor package installed below the payload bay area in the aft area of the mid-fuselage at station X_O 1069. It contains a rate gyro package, a linear accelerometer package, an angular accelerometer package, and associated electronics.
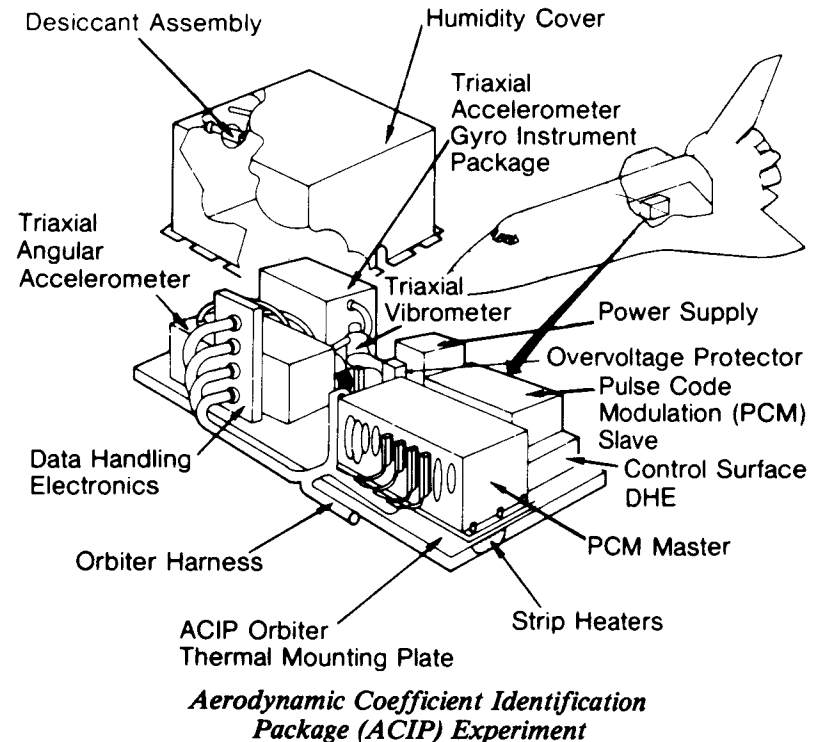
The ACIP will collect aerodynamic data in the hypersonic, supersonic, and transonic flight regimes, regions in which there has been little opportunity for gathering and accumulating practical data, to establish an extensive aerodynamic data base for verification of and correlation with ground-based test data including assessments of the uncertainties in such data. In addition, it will provide flight dynamics state and variable data in support of other technology areas, such as aerothermal and structural dynamics.

The implementation of the ACIP will benefit the Space Shuttle because the more precise data obtainable through the ACIP will enable earlier attainment of the full operational capability of the Space Shuttle. Currently installed instrumentation provides data that is sufficiently precise for spacecraft operations but not for research. The result is that constraint removal would either be based on less substantive data or would require a long-term program of gathering less accurate data.

Although all of the generic types of data required for aerodynamic parameter identification are available from the baseline spacecraft systems, the data is not suitable for experimentation due to such factors as sample rate deficiencies, sensor ranges too large for bit resolutions, or computer cycle time/core size interactions. In addition, the baseline data compromises operational measurements and is not subject to the desired changes required for experiments. The ACIP places a sensor package on the spacecraft to obtain experiment measurements that are not available through the baseline system.

The ACIP incorporates three triaxial instruments: one of dual-range linear accelerometers, one of angular accelerometers, and one of rate gyros. Also included are the power conditioner for the gyros, the power control system, and the housekeeping components for the instruments. The ACIP is aligned to the orbiter axes to a very high order of accuracy. Mounted on the ACIP base is a triaxial vibrometer which will provide the structural vibration characteristics of the orbiter affecting the ACIP experiment necessary for baseline filtration of accelerometer data. The output signals of the instruments are recorded on the modular auxiliary-data system (MADS) recorder. The ACIP operates through launch and through the entry and descent phases. The internal instruments continuously sense the dynamic and performance characteristics of the orbiter through these critical flight phases. In addition, the ACIP receives indications of position of the control surfaces and converts them into higher orders of precision before recording them with the attitude data. Power is supplied from the mid-

Aerodynamic Coefficient Identification Package (ACIP) Experiment

power control assembly 3 main bus C. Heaters are employed on the package and controlled by a switch on panel R11.

Weight of the ACIP is 119 kilograms (262 pounds). The principle technologist for the experiment is David Howes of NASA's Johnson Space Center.

MODIFICATIONS TO *COLUMBIA* FOR STS-9 SPACELAB MISSION

1982

Dec. 20   Start Spacelab-1 modifications

1983

May 13   Install Forward Reaction Control System
May 16   Install Right Hand Orbital Maneuvering System/Reaction Control System pod
May 23   Post modification power up
June 8   Install Left Hand Orbital Maneuvering System/Reaction Control System pod
June 25   Install Space Shuttle Main Engine (SSME) No. 1
July 18   Install SSME No. 2
July 19   Install SSME No. 3
Aug. 16   Install Spacelab-1
Sept. 22 Transfer *Columbia* from Orbiter Processing Facility to Vehicle Assembly Building for mating with External Tank and Solid Rocket Boosters
Sept. 29 Transfer Space Shuttle *(Columbia)* from Vehicle Assembly Building to Launch Complex 39A
Oct. 28   Launch STS-9 Spacelab-1

MODIFICATIONS COMPLETED

NOTE: Ejection seats remain for commander and pilot. Ejection seats however are safed.

Thermal Protection System

Densification of remaining high temperature reusable surface insulation (HRSI) tiles, bottom of mid-fuselage and wings.
    Approximately 314 tiles wing
    Approximately 2,156 tiles mid-fuselage
Elevon ablators replaced with HRSI tiles

Seat floor beefup at attach point of mission specialist and scientist operational seats on crew compartment flight-deck and mid-deck floor to support 20 "g" crash load requirements

Complete catalytic surface coating experiment removal

Aerosurface servo amplifier removal and replacement update to operational configuration

Complete aft flight deck distribution panel redesign to relocate existing wiring and connectors to be compatible with Standard Mixed Cargo Harness (SMCH). Added 36 holes to support wire harness.

Removed one payload timing buffer in aft flight deck and replaced with modified timing buffer and installed one modified operational configuration orbiter timing buffer at aft flight deck.

Added attachments in secondary aft flight station for SMCH and added payload console access panel.

Removed, reworked and installed two orbital Maneuvering System Engines for replacement of bi-propellant valve due to shaft seal leaks.

Provided various supports for Ku-band antenna installation in mid-fuselage structure.

Removed and replaced six forward radiators and two aft mission set radiators with diffusion coated radiators for extra-vehicular activities and Ku-band reflection.

Removed and replaced ammonia boiler.

Relocated wiring at SSME engine interface (30 wires) to be compatible with SSME's for skin temperature measurement of SSME's in prelaunch.

Water dump valve replaced with updated configuration.

Removed and replaced two retention bolts at main hydraulic pump solenoid isolation valve with high strength bolts on valve mounting flange.

Ground support equipment addition for active keel latch wiring with Spacelab-1 installed.

Replaced three signal conditioners for lightweight external tank, heavyweight external tank required 33 to 35 psia, lightweight external tank required 32 to 34 psia.

Two sky genies installed aft of overhead ejection panels for emergency egress provision in horizontal position at panels R7 and R15.

Removed and replaced accelerometer assemblies.

Provided four payload feeders from orbiter power supply. Added four fuse/fuse holders, one connector and two new harnesses.

Removed and replaced Orbital Maneuvering System high pressure helium isolation valves.

Stowed 16 wire segments, added 16 wire segments, avionics bay 3 to Panel R12A2 for communications modifications.

Added 20 wires in avionics bay 3A and 3B, relocated 16 wires for communications modifications.

Relocated Ku-band rigid coax to facilitate Ku-band antenna installation.

Removed and replaced expansion hinges at No. 1 left hand (port) and right hand (starboard) radiator panels and removed and replaced silver plated nuts at mid-aft and aft radiator panels.

Removed and replaced four structural retract box assemblies and hose line clamp at interface of radiators to eliminate torsion load with redesigned clamp.

Orbital Maneuvering System Engine gimbal actuator replacement.

Added Flight Acceleration Monitoring System (FAMOS) to the Operational Instrumentation (OI) multiplexer/demultiplexers (MDM's). Install 12 accelerometers on SSME's (four per engine) and coax cables routed through engine interface to 12 signal conditioners mounted in aft avionics bays 4 and 5.

Added eight wires from T-O umbilical to external tank umbilical to be compatible with lightweight external tank.

Removed and replaced forward Orbital Maneuvering System propellant (fuel and oxidizer) gauging probe, also added brackets for helium line support at helium line/probe flange weld point.

Installed new panel in aft face of flight deck center console for providing reduced oxygen breathing supply to 100 psi regulator for Launch/Entry Helmets (LEH), Personal Egress Air Packs (PEAP).

Modified left hand Orbital Maneuvering System fuel pressure transducer fitting.

Replaced aft Orbital Maneuvering System aft fuel probe in fuel tanks.

Modification of timing buffer power supply.

Incorporation of payload timing signal distribution.

Relocation of treadmill in crew compartment mid-deck.

SSME electrical panel FASCO rework at aft thrust structure for SSME changeout from 100% to 104%.

Microwave Scan Beam Landing System (MSBLS) decoder update.

Removal and replacement of main hydraulic pump bolt/washer.

Removed Development Flight Instrumentation (DFI) container in mid-deck, relocated panels MO42F and MO58F, interchanged panels R11 and R12. Removed DFI pallet in payload bay and DFI wiring and wire trays in mid-fuselage. The instruments were not removed but sensor pigtails were stowed. All unused connectors have protective caps. Wiring and sensors on payload bay doors remain.

Main propulsion system 17 inch external tank disconnect flow liner modification.

Orbital Maneuvering System helium pressure regulators changed out.

Modification of screw in Star Tracker Light shade.

Change of location of two payload and payload interrogator data buses and wires from orbiter station X_O 693 to X_O 603 for new SMCH cable trays near forward end of cable trays, left hand (port) and right hand (starboard) sides.

Add cabin oxygen flow restrictors to provide oxygen flow capability for crew size of two to seven.

Multiplexer/demultiplexer (MDM) rechannelization of payload data interleaver and pulse code modulation master unit (PCMMU) programmable read only memory (PROM) requirements and OI MDM rewire to insure compatibility with onboard flight software.

Addition of switched beam S-band antenna system. Adds switch beam control assembly in avionics bay 3B, adds rotary antenna select switch on panel C3A7, adds 250 wire segments.

Removal and installation of updated operational configuration flash evaporator system.

Installation of galley in crew compartment of mid-deck and water dispenser provisions.

Removal of 20 payload "U" channel wire trays (10 each side of mid-fuselage) along with tray covers to allow replacement of approximately 500 nut plates with DZUS fasteners. Wire tray dividers will have cutouts added for wire egress. Provide six thermal control system blankets on lower side of mid-fuselage wire trays.

Inlet fittings of Freon coolant loop flow proportional valve change.

Removal of atmospheric revitalization system diffusers.

Removal of two substack fuel cells (three fuel cell powerplants) and replace with three substack fuel cells (three fuel cell powerplants). To provide increased voltage margins and incorporates changes to fuel cell powerplants hydrogen pump/separator, thermal control valve and flowmeter. Also requires beef-up mounting of mounting shelves and wire harness modifications.

Removal and replacement of four quad and two hemi S-band antennas to provide higher gain, narrow beam, switchable fore and aft (nose to tail) for tracking data relay satellite S-band.

Partial incorporation of 100 Development Flight Instrumentation (DFI) measurements to Operational Instrumentation (OI).

Modification of main landing gear door thermal barrier.

Removal of ablators on inboard edge of right outboard elevon and outboard edge of inboard elevon and replace with High Temperature Reusable Surface Insulation (HRSI) tiles. Left hand elevons ablators were removed and replaced with HRSI tiles in turnaround from STS-4 to STS-5.

Redesign of Orbital Maneuvering System/Reaction Control System pods forward facing tile.

Removal secondary structure from X_O 1307 and add new thermal control system configuration and add bulkhead to wire tray transition structure to accommodate SMCH cable.

Airlock in mid-deck tunnel adapter in payload bay, hatch on payload bay side of airlock moved to Spacelab side of tunnel adapter, new hatch at top of tunnel adapter. For extravehicular activity (EVA) depressurizes airlock and tunnel adapter, repressurize same on ingress from EVA. EVA from hatch in top of tunnel adapter. New ducting ventilation. Add antenna to tunnel adapter.

Addition of strut pad for Spacelab unique crew stations.

Avionics bay 6 strut rework.

Installation of three bunk type sleep stations in mid deck of crew compartment with sleeping bag in bunk for restraint and three hammock type sleeping bags in mid-deck of crew compartment (includes eyes and ear covers).

Addition of permanent stowage compartments under mid-deck crew compartment floor, hygiene kit in waste management system area, also lockers above avionics bays 1 and 2 and adds locker outboard of avionics bay 3A.

Changing of materials used for manufacture of solar shields from Tedlar to Goldize Kapton to prevent overheating of payload bay multilayer insulation material.

Addition of power reactant storage distribution (PRSD) cryogenic oxygen and hydrogen tank set No. 5 in mid-fuselage.

Add text and graphics for government furnished equipment (GFE) supplied units. This is basically a hard copy machine that operates via telemetry. The system provides the capability to transmit text material, maps, schematics, and photographs to the orbiter through a two-way Ku-band link using the Tracking and Data Relay Satellite (TDRS). The hard copier is installed on a dual coldplate in avionics bay 3 of the Orbiter. Consists of secon-

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dary shelf supports in avionics bay 3B, installation of 94 wire segments on closeout doors and installation of 94 wire segments between unit on avionics bay 3B shelf 3 and closed circuit television and MDM OF4 on the flight deck.

Replacement of one S-band network signal processor, one switch, add on switch on panel A1A2 panel and add 26 wires external to panel for NASA communications security.

Provide stabilizing links between longeron bridges and sill longeron at points having "Y" deflection from maximum loads to meet Spacelab load requirements. Install in payload bays 3, 5, 7, 10, 12 and 13.

Partial pressure oxygen sensor and amplifier removal and replacement.

Removal and replacement of gaseous oxygen flow control valve.

Main landing gear brake line bracket installation.

Aerodynamic coefficient package (ACIP) recording capability to operational recorders in orbiter.

Addition of fuel cell instrumentation.

Relocation of crew compartment mid-deck fire extinguisher from avionics bay 3A to on the airlock and installation of multiple headset adapter to crew compartment mid-deck ceiling.

Air data transducer assembly removal and replacement.

UHF transceiver removal and replacement.
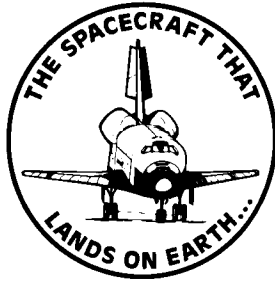
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STS-1 MISSION FACTS
(COLUMBIA)
APRIL 12-14, 1981

Commander: John W. Young

Pilot: Robert L. Crippen

Mission Duration—54 hours, 21 minutes, 57 seconds

Miles Traveled—Approximately 933,757 nautical miles (1,074,567 statute miles)

Orbits of Earth—36

Orbital Attitude—145 nautical miles (166 statute miles)

Landing Touchdown—853 meters (2,800 feet) beyond planned touchdown point

Landing Rollout—274 meters (8,993 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 89,014 kilograms (196,500 pounds)

Landing Speed at Main Gear Touchdown—180 to 185 knots (207 to 212 mph)

STS-1 Liftoff Weight—Approximately 2,020,052 kilograms (4,453,379 pounds)

Landed—Runway 23 dry lake bed at Edwards Air Force Base, Calif.

STS-2 MISSION FACTS
(COLUMBIA)
NOV. 12-14, 1981

Commander: Joe Engle

Pilot: Richard Truly

Mission Duration—54 hour, 24 minutes, 4 seconds

Miles Traveled—Approximately 933,757 nautical miles (1,074,567 statute miles)

Orbits of Earth—36

Orbital Altitude—137 nautical miles (157 statute miles)

Landing Touchdown—Approximately 304 meters (1,000 feet) earlier than planned touchdown point

Landing Rollout—Approximately 2,133 meters (7,000 feet)

from main gear touchdown

Orbiter Weight at Landing—Approximately 92,534 kilograms (204,000 pounds)

Landing Speed at Main Gear Touchdown—Approximately 195 knots (224 miles per hour)

STS-2 Liftoff Weight—Approximately 2,030,287 kilograms (4,475,943 pounds)

STS-2 Cargo Weight—Approximately 8,771 kilograms (19,388 pounds)

Landed—Runway 23 dry lake bed at Edwards Air Force Base, Calif.

STS-3 MISSION FACTS
(COLUMBIA)
MARCH 22-30, 1982

Commander: Jack Lousma

Pilot: Gordon Fullerton

Mission Duration—192 hours (8 days), 6 minutes, 9 seconds

Miles Traveled—Approximately 3.9 million nautical miles (4.4 million miles)

Orbits of Earth—130

Orbital Altitude—128 nautical miles (147 statute miles)

Landing Touchdown—Approximately 359 meters (1,180 feet) from threshold

Landing Rollout—Approximately 4,185 meters (13,732 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 94,122 kilograms (207,500 pounds)

Landing Speed at Main Gear Touchdown—Approximately 220 knots (253 miles per hour)

STS-3 Liftoff Weight—Approximately 2,031,653 kilograms (4,478,954 pounds)

STS-3 Cargo Weight—Approximately 9,658 kilograms (21,293 pounds)

Landed—Runway 17 lake bed at White Sands Missile Range, New Mexico

STS-4 MISSION FACTS
(COLUMBIA)
JUNE 27, JULY 4, 1982

Commander: Ken Mattingly

Pilot: Henry Hartsfield

Mission Duration—168 hours (7 days), 1 hour, 10 minutes, seconds

Miles Traveled—Approximately 2.9 million nautical miles (3.3 million statute miles)

Orbits of Earth—112 orbits

Orbital Altitude—160 nautical miles (184 statute miles), then to 172 nautical miles (197 statute miles)

Landing Touchdown—Approximately 288 meters (948 feet) from threshold

Landing Rollout—Approximately 2,924 meters (9,595 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 95,029 kilograms (209,500 pounds)

Landing Speed at Main Gear Touchdown—Approximately 195 knots (224 miles per hour)

STS-4 Liftoff Weight—Approximately 2,033,437 kilograms (4,482,888 pounds)

Landed—Runway 22 concrete at Edwards Air Force Base, Calif.

STS-5 MISSION FACTS
(COLUMBIA)
NOV. 11-16, 1982

Commander: Vance D. Brand

Pilot: Robert F. Overmyer

Mission Specialist: Joseph P. Allen

Mission Specialist: William B. Lenoir

Mission Duration—120 hours (5 days), 2 hours, 15 minutes, 29 seconds

Miles Traveled—1.5 million nautical miles (1.8 million statute miles)

Orbits of Earth—81

Orbital Altitude—160 nautical miles (184 statute miles)

Landing Touchdown—Approximately 498 meters (1,637 feet) from threshold

Landing Rollout—Approximately 2,911 meters (9,553 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 92,581 kilograms (204,103 pounds)

Landing Speed at Main Gear Touchdown—Approximately 198 knots (227 miles per hour)

STS-5 Liftoff Weight—Approximately 2,036,010 kilograms (4,488,559 pounds)

STS-5 Cargo Weight Up—Approximately 14,974 kilograms (33,013 pounds)

Landed—Runway 22 concrete at Edwards Air Force Base, Calif.

STS-6 MISSION FACTS
(CHALLENGER)
APRIL 4-9, 1983

Commander: Paul Weitz

Pilot: Karol Bobko

Mission Specialist: Donald Peterson

Mission Specialist: Story Musgrave

Mission Duration—120 hours (5 days), 24 minutes, 31 seconds

Miles Traveled—1,819,859 nautical miles (2,092,838 statute miles)

Orbits of Earth—80

Orbital Altitude—153.5 nautical miles (176.6 statute miles)

Landing Touchdown—Approximately 548 meters (1,800 feet) beyond threshold

Landing Rollout—Approximately 2,225 meters (7,300 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 89,177 kilograms (196,600 pounds)

Landing Speed at Main Gear Touchdown—Approximately 195 knots (224 miles per hour)

STS-6 Liftoff Weight—Approximately 2,036,889 kilograms (4,490,498 pounds)

Cargo Weight Up—Approximately 20,658 kilograms (45,544 pounds)

Landed—Runway 22 concrete at Edwards Air Force Base, Calif.

STS-7 MISSION FACTS
(CHALLENGER)
JUNE 18-24, 1983

Commander: Robert L. Crippen

Pilot: Frederick H. Hauck

Mission Specialist: Sally K. Ride

Mission Specialist: John M. Fabian

Mission Specialist: Norman E. Thagard

Mission Duration—144 hours (6 days), 2 hours, 25 minutes, 41 seconds

Miles Traveled—2,198,964 nautical miles (2,530,567 statute miles)

Orbits of Earth—97

Orbital Altitude—160 nautical miles (184 statute miles) to 160 x 165 nautical miles (184 x 189 statute miles) to 160 x 170 nautical miles (184 x 195 statute miles) to 157 x 170 nautical miles (180 x 195 statute miles) to 157 nautical miles (180 statute miles)

Landing Touchdown—Approximately 831 meters (2,727 feet) beyond threshold

Landing Rollout—Approximately 3,185 meters (10,450 feet) from main gear touchdown

Orbiter Weight at Landing—Approximately 92,069 kilograms (202,976 pounds)

Landing Speed at Main Gear Touchdown—Approximately 205 knots (235 miles per hour)

STS-7 Liftoff Weight—Approximately 2,034,666 kilograms (4,485,579 pounds)

Cargo Weight Up—Approximately 14,553 kilograms (32,085 pounds)

Landed—Runway 15 lake bed at Edwards Air Force Base, Calif.

STS-7 SUMMARY

The STS-7 flight crew had high praise for the performance of *Challenger* in its second flight into Earth orbit. Commander Robert Crippen stated that *Challenger* worked like a champ. *Challenger* with its 2,325 cubic feet of habitable volume in the crew compartment drew raves from all five crew members who spent those five days together.

Scrubbing of the planned Kennedy Space Center, Florida landing, however, did little to dampen the spirits of the STS-7 flight crew who came away saying "we not only deliver . . . we now pick up and deliver." This was in reference to the deployment, station keeping and retrieval of the West German SPAS (Shuttle Pallet Satellite) -01. During the proximity operations of *Challenger* and SPAS-01, the amount of propellants consumed by the Reaction Control System (RCS) was less than predicted.

The Canadian remote manipulator system used in the deployment and retrieval was a very manageable task from inside *Challenger* as well as the operations with SPAS-01 which was described as "a piece of cake, no problem at all."

The Canadian TELESAT communications satellite deployment and the Indonesian communications satellite PALAPA were deployed on time and within the accuracies required.

Operation of the OSTA (Office of Space and Terrestrial Applications) -2 pallet, the CFES (Continuous Flow Electrophoresis System) experiment and the MLR (Monodisperse Latex Reactor) experiment were performed as scheduled.

Fifty-six out of fifty-eight test objectives were accomplished. Twenty-seven anomolies were tracked and upon completion of the post-landing inspection, the number grew to forty-two and that was reduced to twenty-one with only five significant.

The STS-7 flight was launched on June 18, 1983, at 11:33:00.033 G.m.t. (7:33:00.033 a.m. E.O.T.) from Kennedy Space Center, Florida, and landed at Edwards AFB, CA. The crew for this flight, the largest number ever flown, were Captain R.L. Crippen, Commander; Captain F.H. Hauck, Pilot; and Colonel J.M. Fabian and S.K. Ride, Phd., Mission Specialists; and N.E. Thagard, M.D., Medical Specialist. Fifty-six of the planned 58 detailed test objectives (DTO's) were accomplished. The two objectives not accomplished were four of the nine programmed test inputs (aerodynamic maneuvers) and the planned y c.g. (center of gravity) offset of 38.1 millimeters (1.5 inches).

The ascent phase was normal with all systems operating near predicted levels. All SRB (solid rocket booster), ET (external tank) SSME (Space Shuttle Main Engine) and MPS (main propulsion system) performed as designed. The SRB's separated

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within two seconds of the planned time and all recovery systems operated satisfactorily, resulting in the recovery of both SRB's and all parachutes.

All ET systems operated properly and the ET impact point was within 12 nautical miles (13 statute miles) downrange of the predicted point.

The main propulsion system operated normally. The main engine cutoff occurred after eight minutes 20.24 seconds of powered flight, followed by ET separation 18 seconds later. Approximately two minutes after MECO, the first of two OMS (orbital maneuvering system) maneuvers that occurred during the first revolution was initiated. Following the completion of the second OMS maneuver at 169:12:19:28.05 G.m.t (38 minutes after MECO), the vehicle was in essentially a 160 nautical mile (184 statute mile) circular orbit.

The first day's activities were all conducted in accordance with the flight plan including the on-time deployment of the ANIK-C (Telesat) satellite at 169:21:02:00 G.m.t. The OMS-3 separation maneuver followed the deployment by about 14.5 minutes. The ANIK-C satellite later performed the necessary maneuvers to achieve the desired geosynchronous orbit. No significant anomalies occurred during day one activities.

The major activity of the second day was the successful deployment of the PALAPA satellite followed by the OMS-4 separation maneuver. The satellite later performed the required maneuvers to place it in a geosynchronous orbit. The RMS (remote manipulator system) and SPAS (Shuttle Pallet Satellite) payload were checked out, and all systems were operating properly. OSTA-2 experiment activities were also initiated during day two.

Early on day three, two detailed test objectives were successfully performed. They were the KU-band communications link performance test and S-band/TDRS communications link performance test. The OMS-5 and OMS-6 orbit adjust maneuvers were also performed. Major events for the re-

mainder of the day included the SPAS attached operations, OSTA-2 activities, and experiment (GAS and MLR) activities. The 30-hour 10.2-psia cabin pressurization test was initiated the third day. All systems operated satisfactorily during this 30-hour period.

The significant events of the fourth day were the completion of the first three runs of the CFES (continuous flow electrophoresis system) experiment and the SPAS attached activities during which the SPAS was released from its latches and moved outside the payload bay by the RMS (remote manipulator system) arm.

A highly active fifth day began with the unberthing and release of the SPAS-01 payload using the RMS. The SPAS-01 experiments were conducted during the long range 304 meters (1000 ft) station keeping activity. The SPAS-mounted cameras (16-mm, 70-mm, and TV) were used to photograph the Orbiter during detached operations. A V-bar approach (rendezvous) was performed and SPAS-01 grapple and release operations were again performed. Short range (up to 60 meters—200 ft) station keeping operations then followed, after which an inertial approach was made by the Orbiter to the SPAS-01. Grapple operations were again performed by the RMS with the SPAS-01, followed by berthing the SPAS-01 in the Orbiter cargo bay.

During the sixth day, the final RMS tests were performed, the KU-band antenna was stowed, and cabin stowage was begun in preparation for entry the following day. The flight control system checkout was also performed. One of the most significant anomalies of the flight occurred during this checkout when APU (auxiliary power unit) 3 shut down because of a turbine underspeed condition during the start operations of the APU. The data from this failure were analyzed and seven hours later a successful second attempt was made of the flight control system checkout using APU 3.

On day seven, the OSTA-2 experiments were powered down and the payload bay doors were closed in anticipation of

entry on revolution 96 with a landing at KSC (Kennedy Space Center). Poor weather conditions at KSC resulted in a decision to delay entry until revolution 97, and still land at KSC. However, weather conditions did not improve adequately to allow a landing at KSC; consequently, the entry was delayed until revolution 98 with landing at Edwards AFB, CA. The de-orbit maneuver was performed at 175:12:56 G.m.t., and after a satisfactory entry and blackout phase, the Orbiter was landed at Edwards AFB at 175:13:56:59 G.m.t. on the lake bed runway.

All systems operated satisfactorily throughout entry and landing, however, during towing operations, noises and chattering came from the right wheel. It was necessary to jack up the Orbiter and remove the wheel, take out the brake assembly, and remount the wheel before towing could be completed.

SOLID ROCKET BOOSTERS

The thrust time history for the SRMs (solid rocket motors) was well within the specification limits. The evaluation shows that head pressures were higher than predicted by approximately 0.7 percent for the left-hand and 1.2 percent for the right-hand motor between five and 20 seconds. The propellant burn rate on both SRMs was approximately 1.0-percent higher than predicted. The action time was short by approximately 2.35 seconds for the right-hand motor and 2.03 seconds for the left-hand motor resulting in a earlier than predicted separation by approximately two seconds.

The deceleration subsystems on both SRBs performed normally and all parachutes were recovered. As on previous flights, the parachutes suffered burn damage. Performance of all location aids was good, and recovery operations went smoothly.

EXTERNAL TANK

During prelaunch, the ET LH_2 loading operation was halted momentarily due to a leak in the T-zero umbilical that exceeded the 3.6 percent red line value. The leak was isolated to the 1.5-inch MPS high-point bleed disconnect. As LH_2 loading continued, the leak was kept below the red line value and there were no problems during launch.

All ET (external tank) systems met all launch requirements. During flight, the liquid hydrogen ullage pressure transducer no. 2 apparently failed to function properly from 120 seconds and 390 seconds after lift-off. This resulted in the LH_2 flow control valve not opening which allowed the liquid hydrogen ullage pressure to drop below 32 psia. There was no impact to the flight.

The prelaunch thermal environment was as expected with no launch commit criteria violations. The TPS (thermal protection system) acreage experienced only minor ice/frost buildup in waived areas. During loading, one of two inboard LH_2 feedline bracket heater circuits failed. For STS-7, one heater failure was allowable at T-2 hours. The heater circuit was deenergized and loading proceeded with no impact. The failure has been attributed to a short in a facility junction box.

The ET separation, entry and disposal were as predicted. The ET impact point was within approximately 12 nautical miles (13 statute miles) (downrange) of the predicted point.

MAIN PROPULSION SYSTEM

The liquid oxygen and liquid hydrogen propellant loading was completed satisfactorily. Flight mass was maintained for both fluids during the terminal count. ET ullage pressures during loading met requirements for both fluids.

The engine start buildups and transitions to mainstage were normal. Engine operation and performance during mainstage appeared satisfactory. Mixture ratio and thrust values from the flight indicate repeatable engine performance. Power level throttling operation appeared normal. The system specific impulse was 452.97 seconds or 0.43 seconds above the assessment tag values. Engine shutdown was satisfactory. Actual MECO occurred approximately 0.5 second later than predicted. During

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ascent, the Orbiter GH2 pressurant pressure sensors for engine two and engine three failed. Neither of these failures impaired the successful performance of the pressurization system.

Initiation of LO2 and LH2 propellant dump performance appeared to be normal. MPS helium storage bottle pressures and temperatures were within limits during prelaunch and boost as were orbiter/SSME helium interface pressures and temperatures.

STS-7 TIMELINE

Day of Year	GMT* Hr:Min:Sec	Event
169	11:28:08	APU activation (1)
	11:28:09	(2)
	11:28:10	(3)
	11:32:32.23	SRB HPU activation command (4)
	11:32:53.43	MPS start command (Engine 3)
	11:33:00.03	SRB ignition command from GPC (lift-off)
	11:33:27.92	Main engine throttledown to 81-percent thrust
	11:34:01.40	MPS throttleup to 104-percent thrust
	11:34:03	Maximum dynamic pressure
	11:35:06.12	SRB separation command
	11:40:23	MPS throttledown for 3g acceleration
	11:40:23.60	3g acceleration
	11:41:20.24	Main engine cutoff (MECO) command
	11:41:38.24	External tank separation
	11:43:20.36	OMS-1 ignition
	11:45:39.81	OMS-1 cutoff
	11:46:13	APU deactivation
	12:17:30.53	OMS-2 ignition
	12:19:28.05	OMS-2 cutoff
	21:02:00	Telesat (ANIK-C) deployment
	21:16:29.41	OMS-3 ignition
	21:16:34.41	OMS-3 cutoff
170	13:33:00	PALAPA deployment
	13:51:10.45	OMS-4 ignition

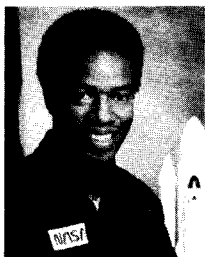| Day of Year	GMT* Hr:Min:Sec	Event
	13:51:15.37	OMS-4 cutoff
171	14:50:10.97	OMS-5 ignition
	14:50:14.09	OMS-5 cutoff
	15:35:33.41	OMS-6 ignition
	15:35:46.37	OMS-6 cutoff
174	07:23:52	OPS-8 checkout attempt
	14:51:03	OPS-8 checkout accomplished
175	12:56:00.21	Deorbit maneuver ignition
	12:58:46.21	Deorbit maneuver cutoff
	12:51:01	APU 1 activation
	13:13:04	APU 2 and 3 activation
	13:25:58	Entry interface (400,000 ft)
	13:42:59	End blackout
	13:50:31	Terminal area energy management
	13:56:59	Main landing gear contact
	13:57:19	Nose landing gear contact
	13:58:14	Wheels stop
	14:08:17	APU deactivation completion

*GMT—Subtract 4 hours for EDT
5 hours for CDT
6 hours for MDT
7 hours for PDT

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STS-8 FLIGHT CREW

RICHARD H. TRULY, is the commander for the STS-8 flight. He was the spacecraft pilot for the 54 hour, 24 minute STS-2 flight. He was an orbiter pilot during the successful Approach and Landing Test program, and as a naval pilot and astronaut has logged nearly 6,000 hours in jet aircraft. He graduated from the Georgia Institute of Technology in aeronautical engineering and entered naval flight training. Following service as a carrier pilot, Truly completed the USAF Aerospace Research Pilot School at Edwards and was subsequently assigned there as an instructor. In 1965 he was assigned to the Manned Orbiting Laboratory program and in 1969 was assigned to the NASA Astronaut Office. Truly was a member of the Skylab support crew and served in a similar capacity for the ASTP flight. He has been awarded two NASA Exceptional Service Medals, the JSC Superior Achievement Award and Special Achievement Award, the SETP Iven C. Kincheloe Award, the AFA's David C. Schilling Award, the American Astronomical Society's Flight Achievement Award, the Navy Distinguished Flying Cross, and the AIAA's Haley Space Flight Award. Truly was born in Fayette, Miss., Nov. 12, 1937, is married and has three children. He is 5'8" in height, weighs 150 pounds, and has brown hair and eyes.
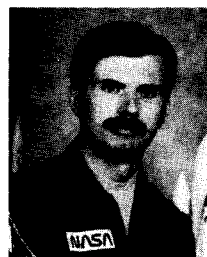
DANIEL C. BRANDENSTEIN, is the pilot for the STS-8 flight. Brandenstein was selected as an astronaut candidate in 1978. He was a member of the STS-1 and STS-2 astronaut support crew and served as ascent capcom. He received a bachelor of science degree in Mathematics and Physics from the University of Wisconsin in 1965. He entered the Navy in 1965 and was designated a naval aviator in 1967. He flew 192 combat missions in Southeast Asia from the USS Constellation and Ranger. He graduated from the U.S. Naval Test Pilot School. He then served aboard the USS Ranger in the Western Pacific and Indian Ocean flying A-6 aircraft. He has logged 3,600 hours flying time in 19 different types of aircraft and has 400 carrier landings. Brandenstein is married and has one child. He was born in Watertown, Wisc., January 17, 1943. He is 5'11" in height and weighs 185 pounds. He has brown hair and blue eyes.

GUION S. BLUFORD JR., is a mission specialist for the STS-8 flight. He was selected as an astronaut candidate in 1978. He received a bachelor of science degree in Aerospace Engineering from Pennsylvania State University in 1964, a master of science degree with distinction in Aerospace Engineering from the Air Force Institute of Technology in 1974, and a doctor of philosophy in Aerospace Engineering with a minor in Laser Physics from the Air Force Institute in 1978. Bluford was an Air Force ROTC graduate at Penn State University and attended pilot training at Williams AFB, Ariz., and received his wings in 1965. He was assigned to F-4C combat crew training and subsequently flew 144 combat missions. He was assigned then as a T-38A instructor pilot at Sheppard AFB, Tx., and served as a standardization/evaluation officer and as an assistant flight commander. In 1972 he entered the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, and upon graduating in 1974, he was assigned to the Air Force Flight Dynamics Laboratory at Wright-Patterson AFB as a staff development engineer. He then served as Deputy for Advanced Concepts for the Aeromechanics Division and as Branch Chief of the Aerodynamics and Airframe Branch in the Laboratory. He has logged over 3,000 hours jet flight time in the T-33, T-37, T-38, F-4C, C-135, and F-5A/B, including 1,300 hours as a T-38 instructor pilot. Bluford also has an FAA commercial license. He is married and has two children. He was born in Philadelphia, Pa., November 22, 1942. He is 6' in height and weighs 180 pounds. He has black hair and brown eyes.

DALE A. GARDNER, is a mission specialist for the STS-8 flight. He was selected as an astronaut candidate in 1978. He received a bachelor of science degree in Engineering Physics from the University of Illinois in 1970. Gardner entered the U.S. Navy in 1970 upon graduation from college and was assigned to Aviation Officer Candidate School. In 1970 he attended basic naval officer training and was graduated with the highest academic average ever achieved in the 10-year history of the squadron. He proceeded to the Naval Aviation Technical Training Center for advanced naval flight officer training and received his wings in 1971. From 1971 to 1973 he was assigned to weapons system test division at the Naval Test Center in F-14A development test and evaluation as project officer for testing inertial navigation system. He then flew F-14A aircraft and participated in two WESTEC cruises while deployed aboard the USS Enterprise. From 1976 until reporting to NASA, Gardner was with the Air Test and Evaluation Squadron in the operational test and evaluation of fighter aircraft. Gardner is married and has one child. He was born in Fairmont, Minn., November 8, 1948, but considers Clinton, Iowa, his hometown. He is 6' in height and weighs 160 pounds. He has brown hair and eyes.

STS-8 FLIGHT CREW

WILLIAM E. THORNTON, is a mission specialist on the STS-8 mission. He will conduct medical tests to collect additional data on several physiological changes that are associated with the space adaptation syndrome. These tests will focus on the neurological system and are a continuation of the new approach to making inflight measurements which began on STS-4. These efforts are directed toward initiation of an inflight search for countermeasures and to provide a more complete understanding of the space adaptation syndrome. He received a bachelor of science degree in Physics and a doctorate in Medicine from the University of North Carolina in 1952 and 1963. Following graduation from the University of North Carolina and having completed Air Force ROTC training, Thornton served as officer-in-charge of the Instrumentation Lab at the Flight Test Air Proving Ground. From 1955 to 1959 he was chief engineer of the electronics division of the Del Mar Engineering labs in Los Angeles, Calif. and directed its Avionics Division. He returned to the University of North Carolina Medical School in 1959 and graduated in 1963. Thornton completed his internship training in 1964 at the Wilford Hall USAF Hospital at Lackland AFB, San Antonio, Texas. He returned to active duty with the USAF and was assigned to the USAF Aerospace Medical Division at Brooks AFB in San Antonio, Texas and became involved in space medicine research during his two year duty. Dr. Thornton was selected as a scientist astronaut in August 1967. He completed flight training at Reese AFB, Texas. He was physician crew member on the 56 day simulation of Skylab Medical Experiments Altitude Test (SMEAT). He was a member of the astronaut support crew for Skylab 2, 3, and 4 missions and principle investigator of Skylab experiments on mass measurement, anthropometric measurements, hemodynamics, and human fluid shifts and physical conditioning. Dr. Thornton holds more than 15 issued patents. He is recipient of the Air Force Legion of Merit, the NASA Exceptional Service Medal in 1972, NASA Exceptional Scientific Achievement Medal in 1974, and presented the American Astronautical Society's Melbourne W. Boynton Award for 1975 and 1977. He has logged over 2,375 hours in jet aircraft. Dr. Thornton was born in Faison, North Carolina, April 14, 1929. He is married and has two children. He has blond hair and blue eyes. He is 6' in height and weighs 200 pounds.

STS-9 FLIGHT CREW
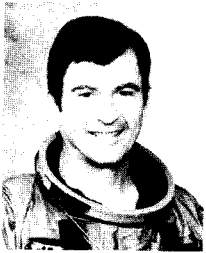
JOHN W. YOUNG, veteran of five space flights, is the commander of the STS-9 flight and was commander for the 54-1/2 hour STS-1 flight. He has logged 642 hours, 30 minutes in space flight on the Gemini 3 and 10 missions, the Apollo 10 and 16 flights to the moon, and the STS-1 flight. A graduate of Georgia Institute of Technology in aeronautical engineering, Young entered U.S. Naval service and after a year of destroyer duty he was accepted and completed flight training. He is a graduate of the Navy's Test Pilot School and was stationed at the Naval Air Test Center for three years prior to entering the Astronaut Corps in 1962. He retired from the Navy in 1976. Young was assigned responsibility for the Space Shuttle Branch of the Astronaut Office in 1973, and in 1975 was named as chief of the Astronaut Office. Young is a Fellow of the American Astronautical Society (AAS), and the Society of Experimental Test Pilots (SETP) and associate fellow of the American Institute of Aeronautics and Astronautics (AIAA). He was awarded the Congressional Medal of Honor, the Department of Defense Distinguished Service Medal, three NASA Distinguished Service Medals, two NASA Exceptional Service Medals, the JSC Certificate of Commendation, two Special Achievement Awards, the Navy Astronaut Wings, two Navy Distinguished Service Medals, three Navy Distinguished Flying Crosses, the Georgia Tech Distinguished Alumni Award (1965) and the Distinguished Service Alumni Award (1972), the SETP Iven C. Kincheloe Award, the AAS Flight Achievement Award, the FAI Yuri Gagarin Gold Medal, and the AIAA Haley Astronautics Award. Young was born in San Francisco, Calif., Sept. 24, 1930, is married and has two children. He is 5'9" in height, weighs 165 pounds, and has green eyes and brown hair.

BREWSTER A. SHAW, is the pilot for the STS-9 flight. Shaw was selected as an astronaut candidate in 1978. He received a bachelor and master of science degrees in Engineering Mechanics from the University of Wisconsin in 1968 and 1969 respectively. Shaw entered the Air Force in 1968 and after completing Officer Training School, attended undergraduate pilot training, receiving his wings in 1970 and was assigned to the F-100 at Luke AFB, Ariz., and was subsequently assigned to the Republic of Vietnam. He returned to the U.S. in 1971 and was assigned to the F-4 and subsequently reported to Thailand, where he flew the F-4. In 1973 he returned to George AFB, Calif., for F-4 instructor duties. In 1976, he attended the USAF Test Pilot School and remained at Edwards AFB, Calif., as an operational test pilot. He then served as an instructor at the USAF Test Pilot School from 1977 until selected as an astronaut candidate. Shaw is married and has three children. He was born in Cass City, Mich., May 16, 1945. He is 5'8" in height and weighs 135 pounds. He has brown hair and blue eyes.

ROBERT ALLAN RIDLEY PARKER, is a mission specialist for the STS-9 flight. Parker was a member of the astronaut support crews for the Apollo 15 and 17 missions and served as program scientist for the Skylab Program Director's Office during the three manned Skylab flights. He received a bachelor of arts degree in Astronomy and Physics from Amherst College in 1958 and a doctorate in Astronomy from the California Institute of Technology in 1962. Parker was an associate professor of astronomy at the University of Wisconsin prior to his selection as an astronaut. Dr. Parker was selected as a scientist-astronaut in 1967. He has logged over 2,225 hours flying time in jet aircraft. He was awarded the NASA Exceptional Scientific Achievement Medal and the NASA Outstanding Leadership Medal. He is married and has two children. He was born in New York City, December 14, 1936, but grew up in Shrewsburg, Mass. Parker is 5'10" in height and weighs 160 pounds. He has brown hair and blue eyes.

OWEN K. GARRIOTT, is a mission specialist for the STS-9 flight. Dr. Garriott was the science pilot for the Skylab 3, 59-1/2 day mission. He logged 1,427 hours and 9 minutes in space in the Skylab 3 mission and also spent 13 hours and 43 minutes in three separate extravehicular activities outside the Skylab workshop. Since the Skylab 3 flight, Garriott has served as Deputy and then Director of Science and Applications and as the Assistant Director for Space Science at JSC. Dr. Garriott was selected as a scientist astronaut in 1965. Prior to his selection as an astronaut, he taught electronics, electromagnetic theory, and ionospheric physics as an associate professor in the Department of Electrical Engineering at Stanford University. He has performed research in ionospheric physics since obtaining his doctorate. Garriott remains a consulting professor at Stanford University. He has logged over 3,900 flying hours—including over 2,100 hours in jet aircraft and the remainder in spacecraft, light aircraft, and helicopters. In addition he holds FAA commercial pilot and flight instructor certification for instrument and multi-engine aircraft. He has received the NASA Distinguished Service Medal, the City of Chicago Gold Medal, the Robert J. Collier Trophy, the FAI V. M. Komarov Diploma, and was elected to the International Academy of Astronautics. He is a Fellow of the AAS and a member of the IEEE. He is married and has four children. Garriott was born in Enid, Okla., November 22, 1930. He is 5'9 in height and weighs 140 pounds. He has brown hair and blue eyes.

STS-9 FLIGHT CREW

BYRON K. LICHTENBERG, is one of the payload specialists in the STS-9 flight. Payload specialists are normally career scientists selected to go into space aboard a particular Spacelab mission, in this case, Spacelab 1. His profession is biomedical engineer/pilot. Lichtenberg received his science degree in electrical engineering from Brown University, Providence, R.I., in 1969. He did graduate work at the Massachusetts Institute of Technology, Cambridge, Mass., receiving his master's degree in mechanical engineering in 1975 and his SC.D in biomedical engineering in 1979. Dr. Lichtenberg is a member of the research staff at the Massachusetts Institute of Technology. His primary area of research is biomedical engineering. Lichtenberg was selected to train for the Spacelab mission as one of two U.S. payload specialists. Payload specialists training is coordinated by the Marshall Space Flight Center at Huntsville, Ala. Between 1969 and 1973 he served in the U.S. Air Force. He received two Distinguished Flying Crosses during his tour of duty in Vietnam. At present he is a fighter pilot in the Massachusetts Air National Guard, flying the A-10 close air support aircraft. Lichtenberg is a member of the Aerospace Medical Association. He was born in Stroudsburg, Pa., in 1948. He is married and has two children.

ULF MERBOLD, is one of the payload specialists in the STS-9 flight. His profession is physicist. Merbold received a diploma in physics in 1968 and a doctorate in science from Stuttgart University in 1976. He joined the Max-Planck Gesellschaft at Stuttgart, Germany, first on a scholarship in 1968, and later as a staff member. He worked as a solid-state physicist on a research team of the Max-Planck Institute for metals research. His main fields of research were crystal lattice defects and low-temperature physics. He was involved in the investigation of the irradiation damage on iron and vanadium produced by fast neutrons. In 1978 he was selected by the European Space Agency (ESA) as one of two European payload specialists to train for the Spacelab 1 mission. Dr. Merbold is a member of the German Society for physics. He holds a private pilots license. He is a German citizen and was born in Greiz, Germany in 1941. He is married and has two children. Merbold is presently based at the Marshall Space Flight Center, Huntsville, Ala.

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STS-10 FLIGHT CREW
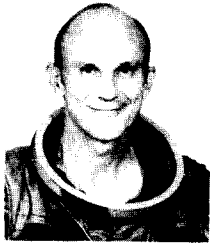
THOMAS K. MATTINGLY, II, is the commander for the STS-10 mission. He was also the commander in the STS-4 flight. He was the backup commander for the STS-3 flight and STS-2 flight. From 1979 to 1981 he headed the astronaut ascent/entry group. Mattingly was previously assigned as technical assistant for flight test to the manager of the Development Flight Test program. He was the head of the astronaut office support to the STS program from 1973 to 1978. Mattingly was the designated command module pilot for the Apollo 13 flight, but was removed from flight status 72 hours prior to the scheduled launch due to exposure to the German measles. He subsequently served as command module pilot of Apollo 16, April 16 through April 27, 1972. With the completion of his first space flight Mattingly has logged 435 hours and 1 minute in space—1 hour and 13 minutes of which were spent in extravehicular activity (EVA). He has logged 6,300 hours of flight time—4,130 hours in jet aircraft. Mattingly is one of the 19 astronauts selected by NASA in April 1966. Prior to reporting for duty as an astronaut, he was a student at the Air Force Aerospace Research Pilot school. Mattingly began his naval career as an ensign in 1958 and received his wings in 1960. He was then assigned to the USS Saratoga from 1960 to 1963 flying AIH aircraft and then served aboard the USS Franklin D. Roosevelt where he flew A3B aircraft for two years. He served as a member of the astronaut support crews for the Apollo 8 and 11 missions. Mattingly is an Associate Fellow, American Institute of Aeronautics and Astronautics; Fellow, American Astronautical Society; and Member, Society of Experimental Test Pilots, and the U.S. Naval Institute. He has the NASA Distinguished Service Medal, the JSC Group Achievement Award, the Navy Distinguished Service Medal and Navy Astronauts Wings, the SETP Ivan C. Kincheloe Award, the Delta Tau Delta Achievement Award, the Auburn Alumni Engineers Council Outstanding Achievement Award, the AAS Flight Achievement Award, the AIAA Haley Astronautics Award, and the Federation Aeronautique Internationale V. M. Komarov Diploma. Mattingly was born in Chicago, Illinois, March 17, 1936, and has one child. He is 5'10" and weights 140 pounds. He has brown hair and blue eyes.

ELLISON S. ONIZUKA, is a mission specialist on the STS-10 mission. He received bachelor and master of science degrees in Aerospace Engineering in June and December 1969, respectively, from the University of Colorado. Onizuka entered active duty with the United States Air Force in January 1970 after receiving his commission at the University of Colorado through the four year ROTC program as a distinguished military graduate. As an aerospace flight test engineer with the Sacramento Air Logistics Center at McClellan Air Force Base, California, he participated in flight test programs and systems safety engineering for the F-84, F-100, F-105, F-111, EC-121T, T-33, T-39, T-28 and A-1 aircraft. He attended the USAF Test Pilot School and in July 1975 he was assigned to the Air Force Flight Test Center at Edwards Air Force Base, California, serving on the USAF Test Pilot School staff initially as squadron flight test engineer and later as chief of the engineering support section in the training resources branch. He has logged more than 900 hours flying time. Onizuka was selected as an astronaut candidate in January 1978 and in August 1979, he completed a one year training and evaluation period making him eligible for assignment as a mission specialist. He is a recipient of the Air Force Commendation Medal, Air Force Meritorious Service Medal, Air Force Outstanding Unit Award, Air Force Organizanizational Excellence Award, and National Defense Service Medal. He is a member of the Society of Flight Test Engineers, the Air Force Association and AIAA. He was born in Kealakekua, Kona, Hawaii, June 24, 1946. He is married and has two children. He is 5'9" in height and wei   162 pounds. He has black hair and brown eyes.
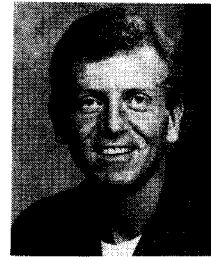
LOREN J. SHRIVER, is the pilot for the STS-10 mission. He received a bachelor of science in Aeronautical Engineering from the United States Air Force Academy in 1967 and a master of science degree in Astronautical Engineering from Purdue University in 1968. Shriver was commissioned in 1967 upon graduation from the USAF Academy and from 1969 to 1973 he served as a T-38 academic instructor pilot at Vance Air Force Base, Oklahoma. He completed F-4 combat crew training at Homestead Air Force Base, Florida, in 1973, and was assigned to Thailand until 1974. He attended the USAF Test Pilot School in 1975 and was assigned to the 6512th Test Squadron at Edwards Air Force Base. In 1976, Shriver served as a test pilot for the F-15 joint Test Force at Edwards. He was selected as an astronaut candidate in January 1978, and in August 1979, he completed a one year training and evaluation period making him eligible for assignment as a pilot. He has flown in 30 different types of single and multi-engine civilian and military fixed wing and helicopter aircraft and has logged over 2,950 hours in jet aircraft, and holds commercial pilot and glider ratings. He has received the Air Force Meritorious Service Medal, Air Force Commendation Medal, two Air Force Outstanding Unit Awards, and the National Defense Service Medal, Shriver is a member of SETP, Air Force Association and AIAA. He was born in Jefferson, Iowa but considers Paton, Iowa his hometown. He is married and has four children. He is 5'10" in height and weighs 160 pounds. He has blond hair and blue eyes.
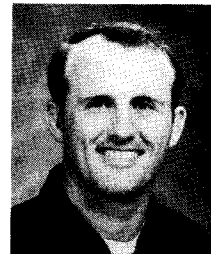
JAMES F. BUCHLI, is a mission specialist on the STS-10 mission. He received a bachelor of science degree in Aeronautical Engineering from the United States Naval Academy in 1967 and a master of science degree in Aeronautical Engineering Systems from the University of West Florida in 1975. He received his commission in the United States Marine Corps following graduation from the United States Naval Academy at Annapolis in 1967. He served a one year tour of duty in the Republic of Vietnam and upon his return to the United States in 1969, he reported to naval flight officer training at Pensacola, Florida. Buchli spent the next three years assigned to the Marine Fighter/Attack Squadron at Kaneohe Bay, Hawaii and Iwakuni, Japan and in 1973 he proceeded to duty with Marine Fighter/Attack Squadron at Namphong, Thailand, and Iwakuni, Japan. At completion of this tour of duty he returned to the United States and participated in the Marine Advanced Degree Program at the University of West Florida. He was assigned subsequently to Marine Fighter/Attack Squadron at the Marine Corps Air Station, Beaufort, S.C., and in 1977, to the U.S. Test Pilot School, Patuxent River, Maryland. He was selected as an astronaut candidate by NASA in January 1978 and in August 1979, he completed a one-year training and evaluation period making him eligible for assignment as a mission specialist. He has logged 1,900 hours flying time, 1,780 hours in jet aircraft. Buchli is the recipient of an Air Medal, Navy Commendation Medal, Purple Heart, Combat Action Ribbon, Presidential Unit Citation, Navy Unit Citation, a Meritorious Unit Citation, and a Vietnamese Cross of Gallantry with the Silver Star. He was born in New Rockford, North Dakota, June 20, 1945, but considers Fargo, North Dakota his hometown. He is married and has two children. He has brown hair and hazel eyes. He is 5'7" in height and weighs 160 pounds.

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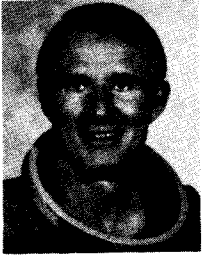
STS-11 FLIGHT CREW

VANCE D. BRAND, is the spacecraft commander for the STS-11 flight. Brand was also the commander on the STS-5 flight. He has logged 339 hours and 43 minutes in space flight as command module pilot of the Apollo-Soyuz Test Project and commander of the STS-5 flight. A graduate of the University of Colorado with a bachelor of science degree in business (1953) and a bachelor of science degree in aeronautical engineering (1960), and a masters degree in business administration from UCLA in 1964, Brand was commissioned a naval aviator and served as a Marine Corps fighter pilot until 1957. He was with the Marine Reserve and Air National Guard until 1964. He joined Lockheed Aircraft as a flight test engineer in 1960, and following completion of the Navy's Test Pilot School was assigned to Palmdale, Calif., as an experimental test pilot on the F-104. He was selected as an astronaut in 1966, and was a crew member of the prototype command module in thermal-vacuum chamber program. He was a support crewman on Apollo 8 and 13, and was backup pilot for Apollo 15 and the Skylab 3 and 4 missions. Brand is a Fellow, American Astronautical Society, Associate Fellow of AIAA, and a member of SETP. He has the NASA Distinguished and Exceptional Service Medals, the JSC Certificate of Commendation, the Richard Gottheil Medal, the Wright Brothers International Manned Space Flight Award, the VFW National Sapce Award, the FAI Yuri Gagarin Gold Medal, the AIAA Special Presidential Citation and the Hanley Astronautics Award, the AAS's Flight Achievement Award, and the University of Colorado's Alumnus of the Century award. Brand was born in Longmont, Colo, May 9, 1931, is married and has five children. He is 5'11" in height, and weighs 175 pounds. He has blond hair and gray eyes.

BRUCE McCANDLESS, is a mission specialist for the STS-11 mission. He received a bachelor of science degree in Naval Sciences from the United States Naval Academy in 1958 and a master of science degree in electrical engineering from Stanford University in 1965. McCandless received flight training at Navy bases in Florida and Texas and was designated a naval aviator in March of 1960 and proceeded to Key West, Florida for weapons system and carrier landing training in the F-6A. From December, 1960 to February 1964 he flew the Skyray and F-4B from the USS Forrestal and USS Enterprise. In early 1964, he was an instrument flight instructor at the Naval Air Station, Apollo Soucek Field, Oceana, Virginia and then reported to the Naval Reserve Officer's Training Corps Unit at Stanford University for graduate studies in electrical engineering. McCandless has logged more than 3,650 flying hours, 3,300 hours in jet aircraft. He was selected as an astronaut by NASA in April 1966. He was a member of the astronaut support crew for the Apollo 14 mission and was backup pilot for the Skylab 2 mission. His awards include the National Defense Service Medal, American Expeditionary Service Medal, NASA Exceptional Service Medal (1974) and the American Astronautical Society Victor A. Prather Award (1975). He is a member of the U.S. Naval Institute and Institute of Electrical and Electronic Engineers. McCandless was born in Boston, Massachusetts, June 8, 1937, is married and has two children. He is 5'10" and weighs 155 pounds. He has brown hair and blue eyes.
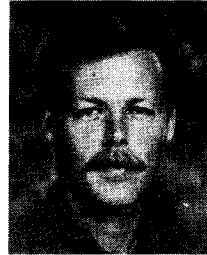
ROBERT L. GIBSON, is the pilot for the STS-11 flight. He received a bachelor of science degree in aeronautical engineering from California Polytechnic State University in 1969. Gibson entered active duty with the Navy in 1969. He received primary and basic flight training at Naval Air Stations in Florida and Mississippi and completed advanced flight training at the Naval Air Station Kingsville, Texas. From April 1970 to September 1975 he saw duty aboard the USS Coral Sea and the USS Enterprise, flying 56 combat missions in Southeast Asia. He returned to the United States and was assigned as an F-14A instructor pilot with Fighter Squadron 124. He graduated from the U.S. Naval Test Pilot School, Patuxent River, Maryland in June 1977 and later became involved in the test and evaluation of F-14A aircraft while assigned to the Naval Air Test Center's Strike Aircraft Test Directorate. His flight experience includes over 2,500 hours in over 35 types of civil and military aircraft. He holds commercial pilot, multi-engine, and instrument ratings, and has held private pilot rating since age 17. He was selected as an astronaut candidate in January 1978 and completed his one year training and evaluation in August, 1979 making him eligible for assignment as a pilot. Gibson was awarded three Air Medals, the Navy Commendation Medal with Combat V, a Navy Unit Commendation, Meritorious Unit Commendation, Armed Forces Expeditionary Medal, Humanitarium Service Medal, an RVN Cross of Gallantry, RVN Meritorious Unit Commendation, and Vietnam Service Medal. Gibson was born in Cooperstown, New York, October 30, 1946 but considers Lakewood, California his hometown. He married Astronaut Margaret Seddon and has two children. Gibson is 5'11" and weighs 165 pounds. He has blond hair and blue eyes.
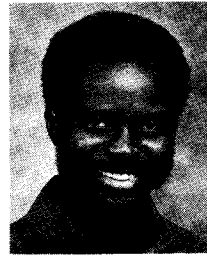
RONALD E. McNAIR, is a mission specialist on the STS-11 flight. He received a bachelor of science degree in physics from North Carolina A&T State University in 1971 and a doctor of philosophy in physics from Massachusetts Institute of Technology in 1976 and presented an honorary doctorate of Laws from North Carolina A&T State University in 1978. Dr. McNair performed some of the earliest development of chemical HF/DF and high pressure CO lasers while at Massachusetts Institute of Technology. In 1975 Dr. McNair studied laser physics at E'cole D'ete Theorique de Physique, Les Houches, France with many authorities in the field. Following graduation from MIT in 1976, McNair became a staff physicist with Hughes Research Laboratories in Malibu, California. Dr. McNair was selected as an astronaut candidate by NASA in January 1978 and completed a one year training and evaluation period in August 1979, making him eligible for assignment as a mission specialist. He was named a Presidential Scholar (1967-1971), a Ford Foundation Fellow (1971-1974), a National Fellowship Fund Fellow (1974-1975), a NATO Fellow (1975) and a recipient of the National Society of Black Engineers Distinguished National Scientist Award (1979). He was born in Lake City, South Carolina, October 21, 1950, is married. He is 5'8" and weighs 158 pounds. He has black hair and brown eyes.

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STS-11 FLIGHT CREW

ROBERT L. STEWART, is a mission specialist for the STS-11 mission. He received a bachelor of science degree in mathematics from the University of Southern Mississippi in 1964 and a master of science in Aerospace Engineering from the University of Texas in 1972. Stewart entered active duty with the United States Army in May 1964 and was designated an Army aviator in July 1966 upon completion of rotary wing training. He flew 1,035 hours combat time from August 1966 to 1967. He was an instructor pilot at the U.S. Army Primary Helicopter school. Stewart is a graduate of the U.S. Army's Air Defense School's Air Defense Officers Advanced Course and Guided Missile System Officers Course. From 1972 to 1973 he served in Seoul, Korea. He next attended the U.S. Naval Test Pilot School at Patuxent River, Maryland, completing rotary wing Test Pilot Course in 1974 and then assigned as an experimental test pilot to the U.S. Army Aviation Engineering Flight Activity at Edwards Air Force Base, California. He has military and civilian experience in 38 types of airplanes and helicopters and has logged approximately 4,600 hours of flying time. Stewart was selected as an astronaut candidate by NASA in January 1978 and completed a one year training and evaluation period in August, 1979, making him eligible for assignment as a mission specialist. He was awarded three Distinguished Flying Crosses, a Bronze Star, Meritorious Service Medal, 33 Air Medals, Army Commendation Medal with Oak Leaf Cluster and "V" Device, two Purple Hearts, the National Defense Service Medal, the Armed Forces Expeditionary Medal, and the U.S. and Vietnamese Vietnam Service Medals. He is a member of the Society of Experimental Test Pilots, the National Geographic Society and the Scabbard and Blade (military honor society). He was born August 13, 1942 in Washington, D.C., but considers Arlington, Texas his hometown. He is married and has two children. Stewart is 5'6" and weighs 138 pounds. He has brown hair and brown eyes.
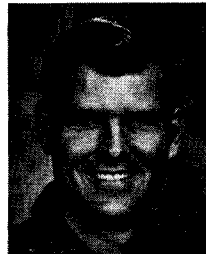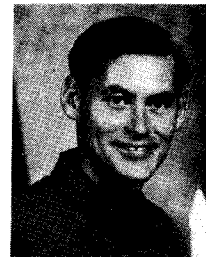
STS-12 FLIGHT CREW

HENRY W. HARTSFIELD, JR., is the commander for the STS-12 flight. He was the pilot on the STS-4 flight. He has logged 169 hours and 10 minutes in space. Hartsfield was a member of the Development Flight Test missions group of the astronaut office and was responsible for supporting the development of the Space Sbuttle entry flight control system and its associated interface. In 1977, he retired from the U.S. Air Force with more than 22 years of service, but continues his assignment as a NASA astronaut in a civilian capacity. Hartsfield became a NASA astronaut in 1969. He was a member of the astronaut support crew for Apollo 16 and Skylab 2, 3, and 4 missions. Hartsfield was assigned in 1966 to the USAF Manned Orbiting Laboratory program as an astronaut until the program was canceled in 1969, when he was reassigned to NASA. He has logged over 5,270 flying hours—of which over 4,700 hours are in the F-86, F-100, F-104, F-105, F-106, T-33 and T-38A. Hartsfield received his commission through the Reserve Officers Training program at Auburn University. He entered the Air Force in 1955, and his assignments included a tour with the 53rd Tactical Fighter Squadron in Germany. He is also a graduate of the USAF Test Pilot school at Edwards Air Force Base, California and was an instructor there prior to his assignment as an astronaut in the USAF Manned Orbiting Laboratory program. He was awarded the Air Force Meritorious Service Medal and the General Thomas D. White Space Trophy. Hartsfield was born in Birmingham, Alabama, November 21, 1933, is married and has two children. He is 5'10" in height, weighs 165 pounds, and has green eyes and brown hair.

MICHAEL L. COATS, is the pilot for the STS-12 flight. He received a bachelor of science degree from the United States Naval Academy in 1968, a master of science in administration of science and technology from George Washington University in 1977, and master of science in aeronautical engineering from the U.S. Naval Postgraduate School in 1979. Coats was designated a naval aviator in September 1969. After training as an A-7E pilot, he was assigned from August 1970 to September 1972 aboard the USS Kitty Hawk and flew 315 combat missions in Southeast Asia. He served as a flight instructor with A-71 at Naval Air Station, Lemoore, California from September 1972 to December, 1973, and was then selected to attend the U.S. Naval Test Pilot School, Patuxent River, Maryland. Following test pilot training in 1974, he was project officer and test pilot for A-7 and A-4 aircraft at Strike Aircraft Test Directorate. Coats served as a flight instructor at the U.S. Naval Postgraduate School from April 1976 until May 1977 and then attended U.S. Naval Postgraduate School at Monterey, California. He has logged 2,600 hours of flying time and 400 carrier landings in 22 different types of aircraft. Coats was selected as an astronaut candidate by NASA in January 1978 and completed a one year training and evaluation in August, 1979, making him eligible for assignment as a pilot. Coats was awarded two Navy Distinguished Flying Crosses, 32 Strike Flight Air Medals, three Individual Action Air Medals, and nine Navy Commendation Medals with Combat V. Coats was born in Sacramento, California, January 16, 1946, but considers Riverside, California his hometown. He is married and has two children. He is 6' and weighs 185 pounds. He has brown hair and blue eyes.

JUDITH A. RESNICK, is a mission specialist for the STS-12 flight. She received a bachelor of science degree in electrical engineering from Carnegie-Mellon University in 1970 and a doctorate in electrical engineering from the University of Maryland in 1977. Upon graduating from Carnegie-Mellon in 1970, Dr. Resnick was employed by RCA Missile and Surface Radar in Morristown, New Jersey and in 1971, she transferred to the RCA Service Company in Springfield, Virginia. While with RCA, her projects as a design engineer included circuit design and development of custom integrated circuitry for phased array radar control systems. From 1974 to 1977 Dr. Resnick was a biomedical engineer and staff fellow in the Laboratory Neurophysiology at the National Institute of Health in Bethesda, Maryland, where she performed biological research experiments concerning the physiology of visual systems. Immediately preceding her selection by NASA in 1978, she was a senior systems engineer in product development with Xerox Corporation at El Segundo, California. Dr. Resnick was selected as an astronaut candidate by NASA in January 1978 and completed one year training and evaluation period in August 1979, making her eligible for assignment as a mission specialist. She is a member of the Institute of Electrical and Electronic Engineers, American Association for the Advancement of Science, American Institute of Aeronautics and Astronautics and Senior Member of the Society of Women Engineers. Dr. Resnick's special honors include the American Association of University Women Fellow, 1975-1976. Dr. Resnick was born April 5, 1949 in Akron, Ohio. She is single and is 5'4" and weighs 115 pounds. She has black hair and brown eyes.

RICHARD M. MULLANE, is a mission specialist for the STS-12 flight. He received a bachelor of science degree in military engineering from the United States Military Academy in 1967 and awarded a master of science degree in aeronautical engineering from the Air Force Institute of Technology in 1975. Mullane, an Air Force Major completed 150 combat missions as an RF-4C weapon system operator in Vietnam from January to November 1969 and a subsequent four tour of duty in England. In July 1976, he completed the USAF Test Pilot School's Flight Test Engineer Course at Edwards Air Force Base, California and assigned as a flight test weapon system operator at Eglin Air Force Base, Florida. He was selected as an astronaut by NASA in January 1979, and completed a one year training and evaluation in August 1979 making him eligible for assignment as a mission specialist. Mullane was awarded six Air Medals, the Air Force Distinguished Flying Cross, Meritorious Service Medal, Vietnam Campaign Medal, National Defense Service Medal, Vietnam Service Medal and Air Force Commendation Medal. He is a member of the Air Force Association. He was born September 10, 1945 in Wichita Falls, Texas, but considers Albuquerque, New Mexico his hometown. He is married and has three children and is 5'10" and weighs 146 pounds. He has brown hair and brown eyes.

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STS-12 FLIGHT CREW

STEVEN A. HAWLEY, is a mission specialist on the STS-12 flight. He received a bachelor of arts degree in physics and astronomy from the University of Kansas in 1973 and a doctor of philosophy in astronomy and astrophysics from the University of California in 1977. During his tenure as an undergraduate at the University of Kansas he was employed by the Department of Physics and Astronomy as a teaching assistant. In 1971, he was awarded an undergraduate research grant from the College of Liberal Arts and Sciences for an independent studies project on stellar spectroscopy. He spent the summers of 1972, 1973 and 1974 as a research assistant at the U.S. Naval Observatory in Washington, D.C., National Radio Astronomy Observatory in Green Bank, West Virginia. He attended graduate school at Lick Observatory, University of California, Santa Cruz and while there held a research assistantship for three years. Prior to his selection as an astronaut, Dr. Hawley was a postdoctoral research associate at Cerro Tolola Inter-American Observatory in La Serena, Chile. Dr. Hawley was selected by NASA as an astronaut candidate in January 1978 and completed a one year training and evaluation period in August 1979, making him eligible for assignment as a mission specialist. He has received the Evans Foundation Scholarship (1970), Veta B. Lear Award (1970), University of California Regents Fellowship (1974) and is a member of the American Astronomical Society and Astronomical Society of the Pacific. He was born December 12, 1951 in Ottawa, Kansas, but considers Salina, Kansas his hometown. He married Astronaut Sally Ride on July 24, 1982. He is 6' and weighs 150 pounds. He has blond hair and blue eyes.
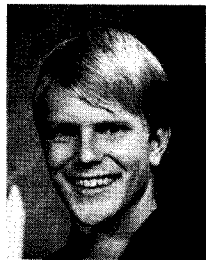
STS-13 FLIGHT CREW
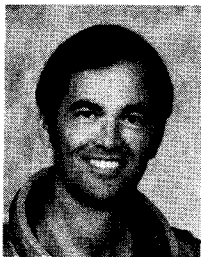
ROBERT L. CRIPPEN, is the commander for the STS-13 flight. He was the pilot in the 54-1/2 hour STS-1 flight and the commander in the 146 hour 25 minute STS-7 flight. He has logged more than 4,980 hours of flying time-most of it in jet-powered aircraft—as a U.S. Navy pilot and astronaut. A graduate of the University of Texas in aerospace engineering, Crippen entered naval service and was a carrier pilot. He completed the U.S. Air Force's Aerospace Research Pilot School at Edwards AFB and remained as an instructor until he was selected for the Manned Orbiting Laboratory program in 1966. He transferred to the NASA Astronaut Office in 1969 and was a crew member of the Skylab Medical Experiments Altitude Test—a 56-day simulation of the Skylab mission. He was a member of the support crew for Skylab 2, 3, and 4, and the ASTP mission. He has been awarded the NASA Distinguished Service Medal and Exceptional Service Medal and the JSC Group Achievement Award. Crippen was born in Beaumont, Tex., September 11, 1937, is married and has three children. He is 5'10" in height, weighs 160 pounds, and has brown hair and eyes.
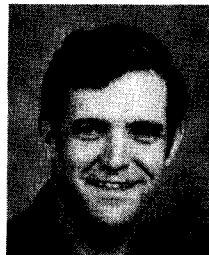
FRANCIS R. (DICK) SCOBEE, is the pilot for the STS-13 flight. Scobee received a bachelor of science degree in aerospace engineering from the University of Arizona in 1965. Scobee enlisted in the United States Air Force in October 1957, trained as an reciprocating engine mechanic and stationed at Kelly AFB, Texas. While there, he attended night school and acquired two years of college credit which led to his selection for the airman's education and commissioning program. Upon graduation from the University of Arizona, he was assigned to officer's training school and pilot training. He received his commission in 1965 and received his wings in 1966. He completed a number of assignments including a combat tour in Vietnam. Scobee returned to the United States and attended the USAF Aerospace Research Pilot School at Edwards Air Force Base, California, graduating in 1972. He has participated in test programs on the C-5, 747, X-24B and F-111. He has logged more than 5,300 hours flying time in 40 types of aircraft. Scobee was selected as an astronaut candidate by NASA in January, 1978 and completed a one year training and evaluation period in August, 1979 making him eligible for assignment as a pilot. He retired from the United States Air Force in January, 1980 after more than 22 years of active service but continues his assignment as a NASA astronaut in a civilian capacity. He has received the Air Force Distinguished Flying Cross and Air Medal. He is a member of the Society of Experimental Test Pilots, the Experimental Aircraft Association, and the Air Force Association. Scobee was born May 19, 1939, in Cle Elum, Washington. Scobee is married and has two children. He is 6'1" and weighs 175 pounds. He has brown hair and blue eyes.

GEORGE D. NELSON, is a mission specialist for the STS-13 flight. Nelson received a bachelor of science degree in physics from Harvey Mudd College in 1972 and a master of science and a doctorate in astronomy from the University of Washington in 1974 and 1978, respectively. Dr. Nelson has performed various astronomical research at the Sacrements Peak Solar Observatory, Sunspot, New Mexico; the Astronomical Institute of Utrecht, the Netherlands; and the University of Gottingen Observatory, Gottingen, West Germany. Prior to reporting for training as an astronaut candidate, he was a postdoctoral research associate at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado. Dr. Nelson was selected as an astronaut candidate in January, 1978 and completed a one year training and evaluation period in August, 1979, making him eligible for assignment as a mission specialist. Dr. Nelson is a member of the American Association for Advancement of Science and the American Astronomical Society. Dr. Nelson was born July 13, 1950, in Charles City, Iowa but considers Willmar, Minnesota to be his hometown. Dr. Nelson is married and has two children. He has blond hair and blue eyes. He is 5'9" and weighs 160 pounds.
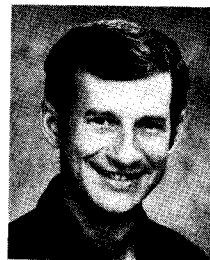
TERRY J. HART, is a mission specialist for the STS-13 flight. Hart received a bachelor of science degree in mechanical engineering from Lehigh University in 1968, a master of science in mechanical engineering from the Massachusetts Institute of Technology in 1969, and a master of science in electrical engineering from Rutgers University in 1978. Hart entered active duty with the Air Force Reserve in June, 1969. He completed undergraduate pilot training in Georgia and in December 1970 to 1973, he flew F-106 aircraft at Tyndall Air Force Base, Florida, Loring Air Force Base, Maine, and at Dover Air Force Base, Delaware. He joined the New Jersey Air National Guard and continued flying the F-106 until 1978. From 1968 to 1978, Hart was employed as a member of the technical staff of Bell Telephone Laboratories. He has logged 2,000 hours flying time, 1,400 hours in jets. Mr. Hart was selected as an astronaut candidate by NASA in January, 1978 and completed a one year training and evaluation period in August 1979, making him eligible for assignment as a mission specialist. Hart has received the National Defense Medal. He was born October 27, 1946 in Pittsburg, Pennsylvania. Hart is married and has two children. He has brown hair and brown eyes. He is 5'8" and weighs 145 pounds.

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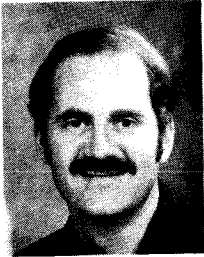
STS-13 FLIGHT CREW

JAMES D. van HOFTEN, is a mission specialist for the STS-13 flight. He received a bachelor of science degree in civil engineering from the University of California, Berkeley, in 1966; and a master of science degree in hydraulic engineering and a doctor of philosophy in fluid mechanics from Colorado State University in 1968 and 1976, respectively. From 1969 to 1974 van Hoften was a pilot in the United States Navy. He received flight training at Pensacola, Florida, and completed jet pilot training at Beeville, Texas, in November 1970. He was assigned to the Naval Air Station, Miramar, California to fly F-4's and subsequently assigned to the carrier USS Ranger in 1972 and participated in two cruises to Southeast Asia where he flew 60 combat missions. He has logged 1,850 hours flying time, 1.750 hours in jet aircraft. He resumed his academic studies in 1974 and in September 1976, he accepted an assistant professorship of civil engineering at the University of Houston teaching fluid mechanics and conducted research on biomedical fluid flows concerning flows in artificial internal organs and valves until his selection as an astronaut candidate. Dr. van Hoften was selected by NASA as an astronaut candidate in January, 1978, and completed a one year training and evaluation period in August, 1979, making him eligible for assignment as a mission specialist. Dr. van Hoften has received two Navy Air Medals, the Vietnam Service Medal, and the National Defense Service Medal. He is a member of the American Society of civil engineers. He was born on June 11, 1944, in Fresno, California, but considers Burlingame, California his hometown. He is married and has two children. He has brown hair and hazel eyes. He is 6'4" and weighs 208 pounds.

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STS-18 FLIGHT CREW

ROBERT F. OVERMYER, is the commander for the STS-18 flight. He was a pilot on the STS-5 flight, logging 122 hours in space. He was previously assigned engineering development duties on the Space Shuttle program and the Development Flight Test missions group of the astronaut office. His first assignment with NASA was engineering development duties on Skylab. Overmyer then served on the support crews for the Apollo 17 and Apollo-Soyuz Test Project. In 1976 he was the prime T-38 chase pilot for the Approach and Landing Test program on orbiter free flights 1 and 3. Overmyer was selected as a NASA astronaut when the U.S. Air Force Manned Orbiting Laboratory program was canceled in 1969. Colonel Overmyer entered active duty with the Marine Corps in January 1958. After flight training, several squadron tours, and graduate school, he attended the Air Force Test Pilots school in 1965. He was selected as an astronaut for the U.S. Air Force Manned Orbiting Laboratory program in 1966. He is a member of the Society of Experimental Test Pilots. He has the USAF Meritorious Service Medal and the USMC Meritorious Award. Overmyer was born in Lorain, Ohio, July 14, 1936, but considers Westlake, Ohio his hometown. He is married and has three children. He is 5'11-3/4" and weighs 180 pounds. He has brown hair and blue eyes.

NORMAN E. THAGARD, is a mission specialist on the STS-18 mission. He is a mission specialist on the STS-7 flight and will conduct medical tests to collect additional data on several physiological changes that are associated with space adaptation syndrome. These tests will focus on the neurological system and are a continuation of the new approach to making inflight measurements which began on STS-4. These efforts are directed toward initiation of an inflight search for countermeasures and to provide a more complete understanding of the space adaptation syndrome. He received a bachelor and master of science degrees in Engineering Science in 1965 and 1966 and subsequently performed pre-med coursework and received a doctor of Medicine from the University of Texas Southwestern Medical School in 1977. September 1966, he entered on active duty with the United States Marine Corps Reserve. In 1967, he achieved the rank of Captain and was designated a naval aviator in 1968 and was assigned to duty flying F-4s at Marine Corps Air Station, Beaufort, South Carolina. He flew 163 combat missions in Vietnam from January 1969 to 1970. He returned to the United States and was assigned aviation weapons division officer at the Marine Corps Air Station, Beaufort, South Carolina. Thagard resumed his academic studies in 1971, pursuing a degree in medicine. His interning was in the Department of Internal Medicine at the Medical University of South Carolina. Thagard was selected as an astronaut candidate in January 1978 and in August 1979, he completed a one-year training and evaluation period making him eligible for assignment as a mission specialist. He has logged 1,100 hours flying time, 1,000 hours in jet aircraft. He was awarded 11 Air Medals, the Navy Commendation Medal with Combat V, the Marine Corps "E" Award, the Vietnam Service Medal and the Vietnamese Cross of Gallantry with Palm. Thagard is a member of AIAA. He was born in Marianna, Florida, July 3, 1943, but considers Jacksonville, Florida his hometown. He is married and has three children. He has brown hair, blue eyes. He is 5'9" in height and weighs 164 pounds.
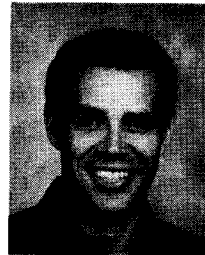
FREDERICK D. GREGORY, is the pilot for the STS-18 flight. He received a bachelor of science degree from the United States Air Force Academy in 1964, and a masters degree in information systems from George Washington University in 1977. Gregory entered pilot training after graduation from the United States Air Force Academy in 1964 and received his wings from undergraduate training in 1965. After three years of helicopter flying, including a Vietnam tour, he was re-trained as a fighter pilot and flew the F-4. He attended the U.S. Naval Test Pilot School in 1970 and was subsequently assigned as a research/engineering test pilot for the Air Force and for NASA from 1971 until 1977. Gregory has flown more than 40 different types of single and multi-engine fixed and rotary wing aircraft including gliders. He has logged over 4,100 hours of flight time and holds an FAA commercial and instrument certificate for single, multi-engine and rotary aircraft. Gregory was selected as an astronaut candidate by NASA in January 1978, and completed a one year training and evaluation period in August 1979, making him eligible for assignment as a pilot. Gregory was awarded the Air Force Distinguished Flying Cross, the Meritorious Service Medal, the Air Medal with 15 Oak Leaf Clusters, the Air Force Commendation Medal and recipient of the National Society of Black Engineers Distinguished National Scientist Award (1979). He is a member of the Society of Experimental Test Pilots, the American Helicopter Society, the Air Force Association and the National Technical Association. He was born January 7, 1941, in Washington, D.C. He is married and has two children. He has brown hair and blue eyes. He is 5'11" and weighs 175 pounds.

DON LESLIE LIND, is a mission specialist for the STS-18 flight. Lind received a bachelor of science with high honors in physics from the University of Utah in 1953 and a doctor of philosophy degree in high energy nuclear physics in 1964 from the University of California, Berkeley and performed post-doctoral study at the Geophysical Institute, University of Alaska, in 1975-1976. Lind served four years on active duty with the Navy at San Diego and later aboard the carrier USS Hancock. He received his wings in 1957. Lind has logged more than 3,800 hours flying time, 3,300 hours in jet aircraft. Before his selection as an astronaut, he worked at the NASA Goddard Space Flight Center as a space physicist. He had been at Goddard since 1964 and was involved in experiments to determine the nature and properties of low energy particles within the earth's magnetosphere and interplanetary space. Previous to this, he worked at the Lawrence Radiation Laboratory, Berkeley, California, doing research in basic high energy particle interaction. Dr. Lind was selected as a NASA astronaut in April 1966. He served as a backup science pilot for Skylab 3 and 4 and as a member of the rescue crew for the Skylab missions. Lind has received the NASA Exceptional Service Medal (1974). Lind is a member of the American Geophysical Union, and the American Association for Advancement of Science. He is married and has seven children. Lind was born May 18, 1930, in Midvale, Utah. He has brown hair and hazel eyes. He is 5'11-3/4" and weighs 180 pounds.

STS-18 FLIGHT CREW
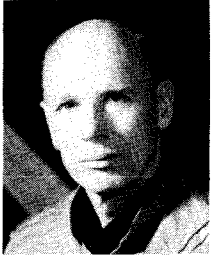
WILLIAM E. THORNTON, is a mission specialist on the STS-18 mission. He is a mission specialist on the STS-8 flight and will conduct medical tests to collect additional data on several physiological changes that are associated with the space adaptation syndrome. These tests will focus on the neurological system and are a continuation of the new approach to making in-flight measurements which began on STS-4. These efforts are directed toward initiation of an inflight search for countermeasures and to provide a more complete understanding of the space adaptation syndrome. He received a bachelor of science degree in Physics and a doctorate in Medicine from the University of North Carolina in 1952 and 1963. Following graduation from the University of North Carolina and having completed Air Force ROTC training, Thornton served as officer-in-charge of the Instrumentation Lab at the Flight Test Air Proving Ground. From 1955 to 1959 he was chief engineer of the electronics division of the Del Mar Engineering labs in Los Angeles, Calif. and directed its Avionics Division. He returned to the University of North Carolina Medical School in 1959 and graduated in 1963. Thornton completed his internship training in 1964 at the Wilford Hall USAF Hospital at Lackland AFB, San Antonio, Texas. He returned to active duty with the USAF and was assigned to the USAF Aerospace Medical Division at Brooks AFB in San Antonio, Texas and became involved in space medicine research during his two year duty. Dr. Thornton was selected as a scientist astronaut in August 1967. He completed flight training at Reese AFB, Texas. He was physician crew member on the 56 day simulation of Skylab Medical Experiments Altitude Test (SMEAT). He was a member of the astronaut support crew for Skylab 2, 3, and 4 missions and principle investigator of Skylab experiments on mass measurement, anthropometric measurements, hemodynamics, and human fluid shifts and physical conditioning. Dr. Thornton holds more than 15 issued patents. He is recipient of the Air Force Legion of Merit, the NASA Exceptional Service Medal in 1972, NASA Exceptional Scientific Achievement Medal in 1974, and presented the American Astronautical Society's Melbourne W. Boynton Award for 1975 and 1977. He has logged over 2,375 hours in jet aircraft. Dr. Thornton was born in Faison, North Carolina, April 14, 1929. He is married and has two children. He has blond hair and blue eyes. He is 6' in height and weighs 200 pounds.

STS-24 FLIGHT CREW

KARL C. HENIZE, is a mission specialist for the STS-24 flight. He received a bachelor of arts degree in Mathematics in 1947 and a master of arts degree in Astronomy in 1948 from the University of Virginia; and awarded a doctor of Philosophy in Astronomy in 1954 by the University of Michigan. Henize was an observer for the University of Michigan Observatory from 1948 to 1951, stationed at the Lamont Hussey Observatory in Bloemfontein, Union of South Africa. In 1954, he became a Carnegie post-doctoral fellow at the Mount Wilson Observatory in Pasadena, California. From 1956 to 1959 he served as a senior astronomer at the Smithsonian Astrophysical Observatory. Dr. Henize was appointed associate professor in Northwestern University's Department of Astronomy in 1959 and was awarded a professorship in 1964. In addition to teaching he conducted research on planetary nebulae, peculiar emission-line stars, S-stars, and T-associations. During 1961 and 1962, he was guest observer at Mt. Stromoto Observatory in Canberra, Australia. He became principal investigator of experiment S-013 which obtained ultraviolet stellar spectra during the Gemini 10, 11, and 12 flights. He also became principal investigator of experiment S-019 used on Skylab to obtain ultraviolet spectra of faint stars. Spectra were obtained of hundreds of stars and these are being studied at the Unversity of Texas where Dr. Henize now holds an adjunct professorship. He is the author and/or co-author of 56 scientific publications dealing with astronomy research. Dr. Henize was selected as a scientist-astronaut by NASA in August 1967. He completed the academic training and the 53-week jet pilot training program at Vance Air Force Base, Oklahoma. He has logged 1,900 hours of flying time in jet aircraft. He was a member of the astronaut support crew for the Apollo 15 mission and for the Skylab 2, 3, and 4 missions. He was presented the Robert Gordon Memorial Award for 1968; recipient of the NASA Group Achievement Award (1971, 1974, 1975, 1978); awarded the NASA Exceptional Scientific Achievement Medal (1974). He is a member of the American Astronomical Society; the Royal Astronomical Society; the Astronomical Society of the Pacific; and the Astronomical Union. He was born October 17, 1926, in Cincinnati, Ohio. He is married and has four children. He has brown hair and brown eyes. He is 5'7" and weighs 170 pounds.
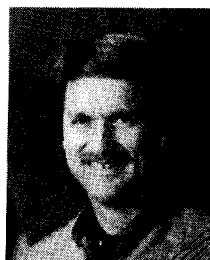
ANTHONY W. ENGLAND, is a mission specialist on the STS-24 flight. He received bachelor and master of science degrees in Geology and Physics from Massachusetts Institute of Technology in 1965 and a doctor of philosophy from the Department of Earth and Planetary Sciences at MIT in 1970. He was a graduate fellow at MIT for three years immediately preceding his assignment to NASA. He has performed heat flow measurements throughout the southwest, has taken part in a magnetic study in Montana, has performed radar sounding studies of glaciers in Washington state and Alaska, has performed microwave airborne surveys throughout the western United States, and has participated in and led field parties during two seasons in Antarctica. Dr. England was selected as a scientist-astronaut by NASA in August 1967. He completed academic training and a 53 week course in flight training at Laughlin Air Force Base, Texas. He has logged over 2,000 hours in flying time. He served as a support crewman for the Apollo 13 and 16 flights. From August 1972 to June 1979, England was a research geophysicist with the U.S. Geological Survey. He returned to the Johnson Space Center in 1979 as a senior scientist astronaut. England was presented the Johnson Space Center Superior Achievement Award (1970); the NASA Outstanding Achievement Medal (1973); and the U.S. Antarctic Medal (1979). He is a member of the American Geophysical Union, the American Geological Institute, the Society of Exploration Geophysicists, the American Association for the Advancement of Science, and the International Glaciological Society. England was born May 15, 1942 in Indianapolis, Indiana, but considers Fargo, North Dakota his hometown. England is married and has two children. He has brown hair and blue eyes. He is 5'10" and weighs 165 pounds.

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