STS-6
PRESS INFORMATION

March 1983

Rockwell International
Space Transportation &
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Office of Public Relations

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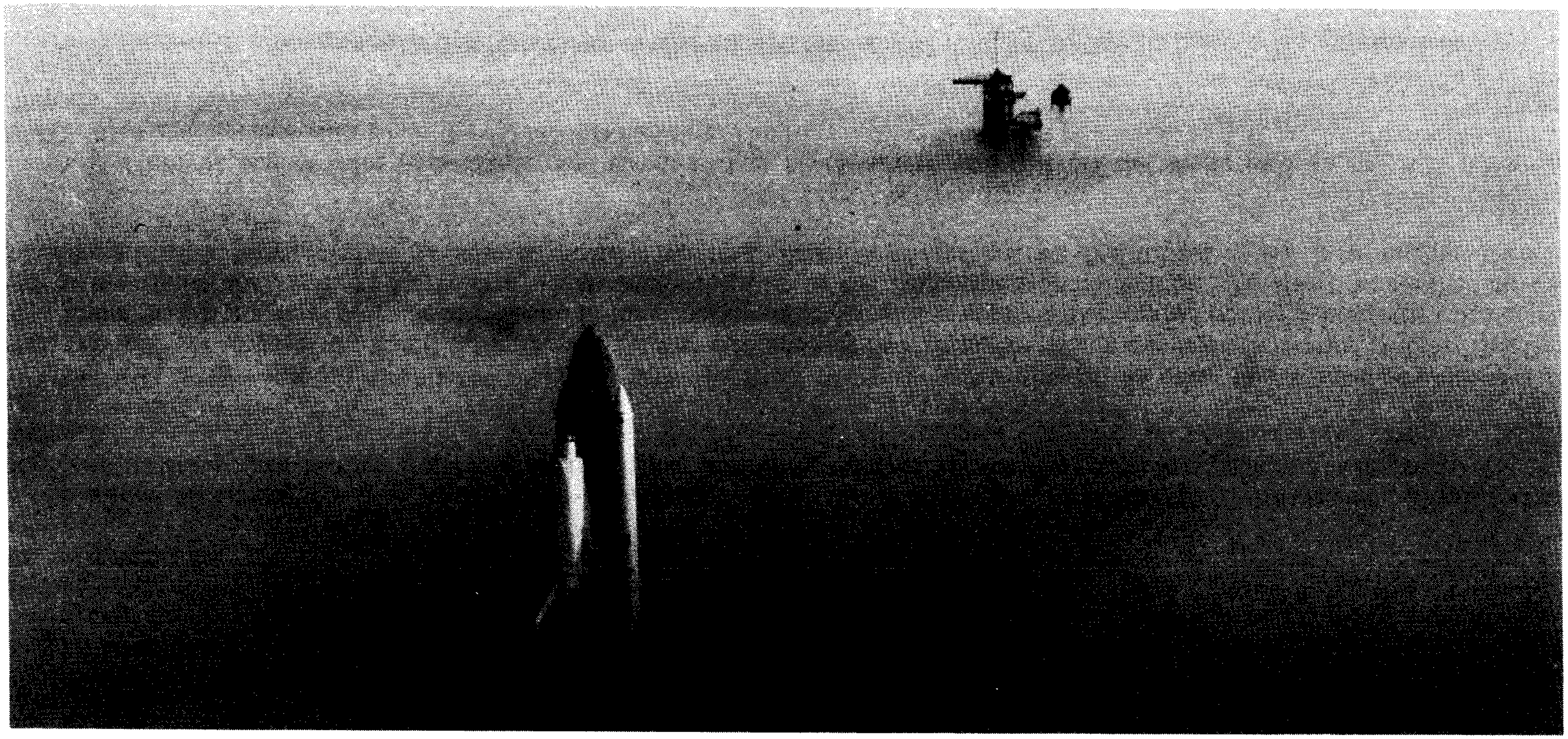


CHALLENGER, THE “EARLY BIRD” JOINS THE SHUTTLE SPACECRAFT FLEET

In actuality, the spacecraft *Challenger* is the “early bird” of America’s Space Transportation System’s (STS) Earth-orbiting fleet. Structural fabrication of *Challenger* was underway in 1975 . . . about a year earlier than the origin of *Columbia,* the Rockwell International-built spacecraft which has flown the first five STS missions. In several transitional periods the *Challenger* went from structural assembly to becoming the Structural Test Article (STA) . . . then back into a manufacturing modification period for renovation and uprating to “flight worthy” status . . . to final assembly and checkout . . . rollout . . . then ferry flight to KSC and prelaunch testing.

Literally millions first saw *Challenger* last July 4th when, aboard the 747 Shuttle Carrier Aircraft, the spacecraft’s right wing was dipped during a nationally televised low-pass salute to President and Mrs. Reagan attending the landing of *Columbia* (STS-4) at Edwards Air Force Base, Calif. on its way to Florida and the Kennedy Space Center.

After launch acceptance testing and preparation, two flight readiness firing tests of the spacecraft's main propulsion system and engines were conducted in December and January. In both instances, the test of the firing procedures, avionics and main propulsion system were excellent. One anomoly was noted in both tests – a higher than desired amount of hydrogen gas was detected in the "closed out" aft section. Following the first test, it was generally thought that the hydrogen gas was from an external source which because of vibration and current conditions during the twenty seconds of firing had found its way back into the aft area behind the engine's dome heat shields. There was a leak near the rim of an engine nozzle (the right hand side) of the three engine cluster. Extra sensors and a higher than ambient pressurization was "installed" in the aft section for the second test. This was to prohibit any outside hydrogen to penetrate the aft section. Following the second test, again a higher than desired hydrogen gas content was detected in the aft section.

During extensive and revised type of leak checks on the *Challenger's* engines, it was discovered that there was a leak from a weld on tubing leading to the engine position No. 1's combustion chamber. Engine position one is the top of the cluster with position two on the left and position three on the right.

Rocketdyne, a division of Rockwell International is the designer and builder of the high pressure, cryogenic fueled engines. The Rocketdyne number for the number one engine is SSME 2011. The number two is SSME 2015 and the number three is SSME 2012.

That number one engine was removed from *Challenger* and a replacement engine, which had just completed its acceptance firing tests, was sent to KSC from the National Space Technologies Laboratories, Miss. That engine is numbered SSME 2016. Before it could even be installed in *Challenger* during its post delivery acceptance checks at KSC, a leak was found in the engine's heat exchanger used to warm a small portion of the liquid oxygen into gas then directing it back to the External Tank where it was used for pressurization.

A second replacement engine was required. This engine, SSME 2017, required a "full duration"–500 seconds–firing test to complete its acceptance testing. Following the successful test firing and leak checks the engine was packaged and sent to KSC on March 3.

But, with revised and improved leak checks put into operation during on-pad testing of the other two Challenger engines . . . a "generic leak" or seepage was noted in an 18 inch inconel 625 one-half inch diameter tube in the engine's ignition system. This leak was found in one engine and cracks were found in the other up-rated generation engines. The leakage occurs underneath a protective sleeve brazed on the small hydrogen line which sends the fuel to the Augmented Spark Igniter. The sleeve was added to the *Challenger* higher thrust engines because of possible chafing. This sleeve was not on the tubing of the three engines used in *Columbia's* five flights.

A Rocketdyne engine team immediately was dispatched to NSTL where they cut off the sleeve area on the ASI tubing of SSME 2014 and replaced with a non-sleeved inconel 625 line. The Rocketdyne team then proceeded to KSC where they made similar "repairs" to all three *Challenger* engines.

Now, *Challenger* is poised for its first launch and orbital mission into space . . . ready to take its place in the Shuttle fleet.

Challenger is the first "operational" Shuttle spacecraft. All of its on-board systems have qualified to operate for a minimum of 100 missions without major overhaul. Although *Columbia,* on its STS-5 flight, was "billed" as the first operational mission, the on-board spacecraft systems do not have "operational certification." Following the STS-9 mission later this year, *Columbia* will be scheduled to return to Rockwell's Palmdale, Calif., plant for a major modification which includes installation of "operational" systems.

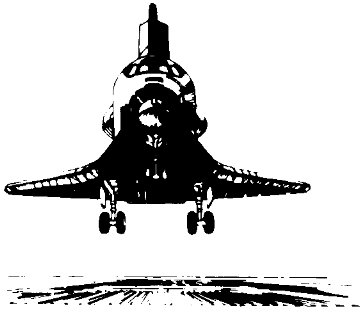
This first flight of *Challenger* will have a mission duration of about five days . . . requiring only three sets of liquid hydrogen and liquid oxygen tanks in the cargo bay which forms the storage portion of the Power Reactant Storage and Distribution system (PRSD) and the liquids used to activate the spacecraft's fuel cells and provide necessary oxygen for the Environmental Control and Life Support Systems (ECLSS).

Challenger, because of the extensive weight reduction program, is a net 2,000 pounds lighter than *Columbia,* and that includes provisions for a galley and sleep stations in the Crew Compartment mid-deck. (Note: The External Tank and both Solid Rocket Boosters are also considerably lighter in weight than the previous five STS stacks.)

The Remote Manipulator System (RMS) . . . the 50-foot-long arm for handling payloads which can be attached and operated from the left side of the open cargo bay . . . is not on this flight of *Challenger.* It will be used in later flights. *Challenger* also will use a KU band antenna for later flights.

Challenger is joining the Shuttle spacecraft fleet while at Palmdale, the spacecraft *Discovery* is approaching final assembly and will be ready for delivery to the Kennedy Space Center this fall. At Rockwell's Downey facility, the Crew Compartment and Aft Fuselage of the spacecraft *Atlantis* are in structural assembly and that delivery is for late next year.

Challenger has been assigned four flights in 1983 . . . STS-6, 7, 8 and 10. And, the veteran spacecraft *Columbia* is being modified to handle the Spacelab payload in STS-9 this fall.



NEWS ABOUT AMERICA'S SPACE SHUTTLE

...it comes from Rockwell International

STS-6 MISSION STATISTICS

Launch: Monday, April 4, 1983
1:30 P.M. E.S.T.
12:30 P.M. C.S.T.
10:30 A.M. P.S.T.

Mission Duration: 120 hours (5 days) 19 minutes

Landing: Saturday, April 9, 1983
1:48 P.M. E.S.T.
12:48 P.M. C.S.T.
10:48 A.M. P.S.T.

Inclination: 28.5 degrees

SSME throttling: 104 to 81 to 104 to 65 percent

Altitude: 153.5 nautical miles (176.6 statute miles)

Payload weight up: Approximately 20,798 kilograms (45,853 pounds)

Payload weight down: Approximately 3,719 kilograms (8,200 pounds)

Payloads: Inertial Upper Stage (IUS-2)/Tracking Data Relay Satellite (TDRS)-A, Getaway Special—Three, Modular Auxiliary Data System (MADS), Aerodynamic Coefficient Package (ACIP), Continuous Flow Electrophoresis System (CFES) Experiment, Monodisperse Latex Reactor (MLR), Night/Day Optical Survey of Lightning (NOSL)

Entry angle of attack: 40 degrees

Maximum Q (Aerodynamic Pressure): 785 pounds per square foot

Crew Members:
- Commander (CDR) Paul Weitz
- Pilot (PLT) Karol Bobko
- Mission Specialist (MS) Donald Peterson
- Mission Specialist (MS) Story Musgrave

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.

Crew stations: Pre- and post-satellite
Deploy
CDR – Left seat
PLT – Right seat
MS1 – Port aft station
MS2 – Starboard aft station

Satellite deploy
CDR – Starboard aft station
PLT – Right seat
MS1 – Port aft station
MS2 – Left seat

Extravehicular activity in payload bay: MS Donald Peterson, MS Story Musgrave

Crossrange: 523.2 nautical miles (602 statute miles)

Runway: Concrete runway 22 at Edwards Air Force Base, Calif.

FLIGHT TEST AND MISSION OBJECTIVES

FLIGHT TEST

- Ascent and entry performance (aerodynamic and heating)
- External tank and solid rocket booster heating during ascent
- Lightweight external tank assessment
- Elevon position observation after auxiliary power unit shutdown during post insertion, also before and after control surface movement during flight control system checkout on orbit
- Primary reaction control system hot fire test
- Payload bay door and radiator operation performance
- Cabin atmosphere verification
- Noise level survey
- S-Band antennas performance
- Automatic speech recognition
- Primary reaction control system plume impingement
- Spacecraft systems vent model determination
- Orbital aero and gravity gradient torque measurements—low gravity
- Payload bay G-level measurements
- Rendezvous phasing
- Extravehicular mobility unit (EMU) and extravehicular activity (EVA) evaluation. No TV camera on EMU helmet. Third EMU upper torso only, without arms and with portable life support system stowed in airlock on one "g" floor.
- Anti-G suit instrumentation
- Braking test on landing has higher priority than cross-wind landing
- Validation of predictive tests and countermeasures for space motion sickness
- Preprogrammed test inputs during entry – total of nine
- Cardiovascular deconditioning countermeasure assessment during reentry

- Aft station crew optical alignment sight calibration
- Head and eye motion monitoring during ascent and entry
- On orbit head and eye tracking tests
- Photographic documentation of body fluid shifts
- Near vision acuity
- Microbiology screening test
- Audiometery
- Improved crew optical sight – lighting device to work under starlight

MISSION OBJECTIVES

- Getaway specials – three
- Continuous flow electrophoresis system experiment
- Monodisperse latex reactor experiment
- Night/day optical survey of lightning experiment
- Deployment of inertial upper stage-2/tracking data relay satellite-A

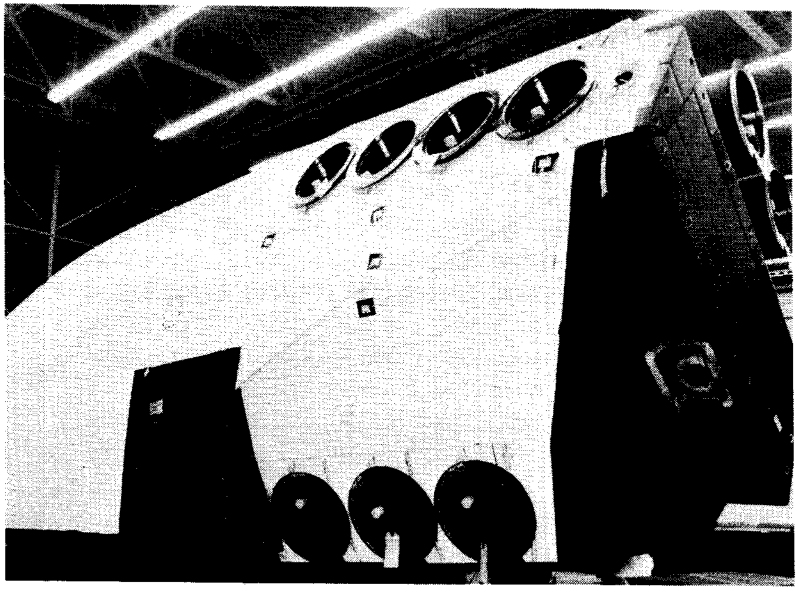
CHALLENGER (OV-099) CONFIGURATION CHANGES FROM *COLUMBIA* (OV-102)

- No ejection seats, rails and overhead ejection panels, operational seats, capable of seating four on flight deck and three crew members in mid-deck. For the STS-6 flight, all four flight astronaut crew members are seated on flight deck

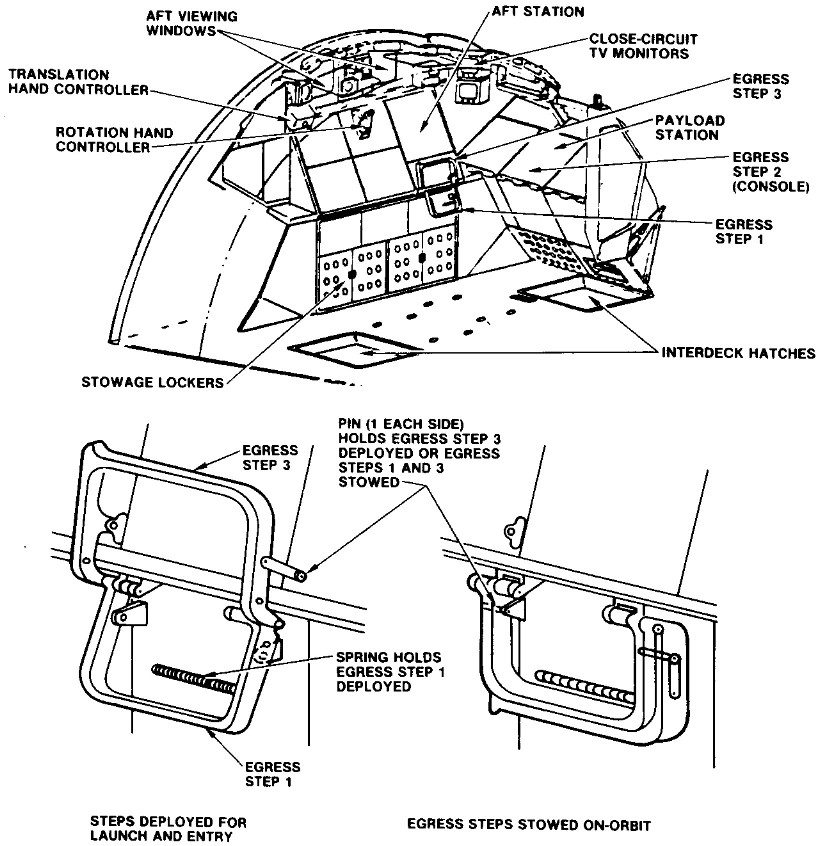
- Left hand (looking forward) – port overhead window can be ejected to provide emergency egress when orbiter is on the ground in a horizontal position. Utilizes same jettison handles as in the *Columbia.* Three egress steps are provided at aft flight station for access to overhead window

- Head-up display at commander and pilot station

- Controls and display panels are uprated to the operational configuration



Challenger OMS/RCS Pod With Advanced Flexible Reusable Surface *Insulation (AFRSI) (Quilted Fabric Blanket)*



Egress steps to left hand (port) overhead window

- Thermal protection system

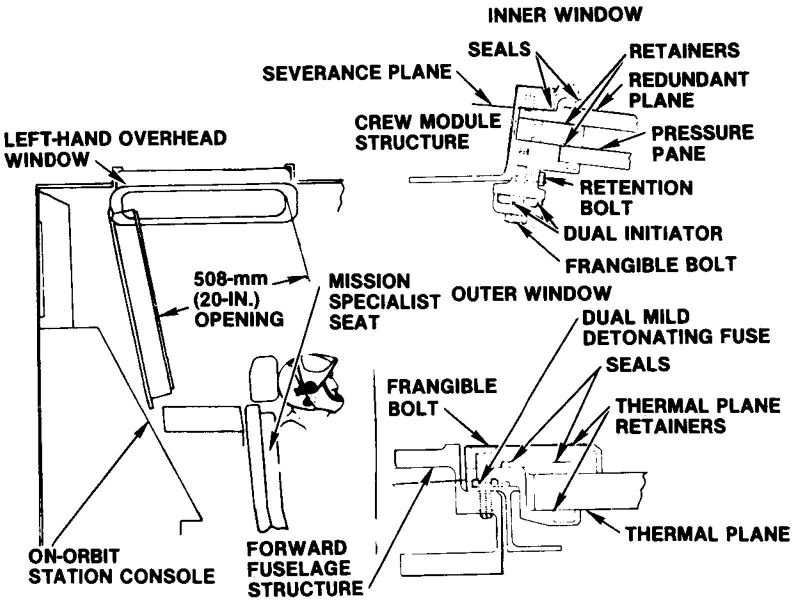
  – All thermal protection system tiles are densified. Orbital maneuvering system/reaction control system low temperature reusable surface insulation tiles (LRSI) replaced with advanced flexible reusable surface insulation (AFRSI) consisting of a sewn composite quilted fabric blanket with same silica tile material sandwiched between outer and inner blanket. AFRSI sheets do not require a strain isolation pad (SIP) and improves producibility, durability, reduces fabrication and installation cost, reduces installation schedule time, and results in weight reduction. AFRSI replaces approximately 606 LRSI tiles.

- Overall weight reduction difference between *Challenger* and *Columbia* is approximately 907 kilograms (2,000 pounds). Weight saving changes includes: removal of number of tube supporting frames and use of honeycomb wire support shelf in forward fuselage; honeycomb landing gear doors; cryogenic tank support boron aluminum tubes; backup structure around Space Shuttle main engine pump fittings; lighter avionics bay structures, rerouting of electrical wiring on floor to avoid handling damage; lighter Space Shuttle main engine heat shields; honeycomb structure in vertical stabilizer; passive thermal control insulation on crew module rather than forward fuselage.

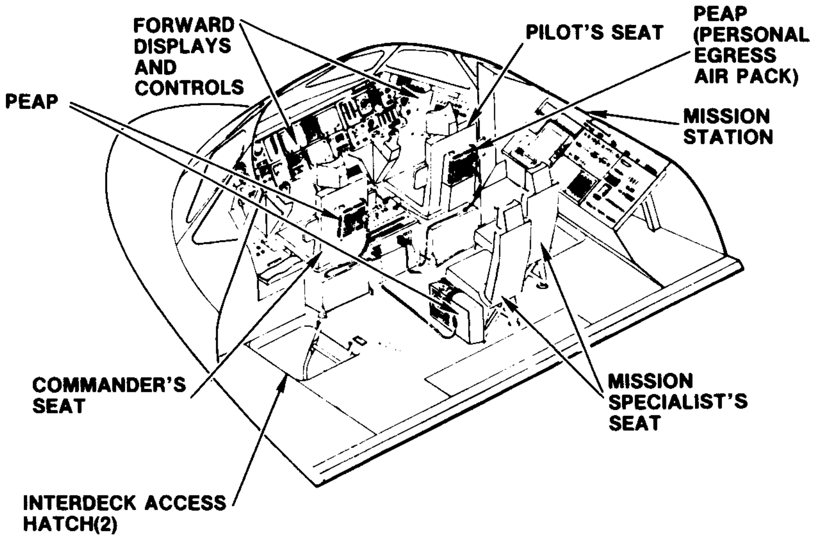
- S-Band switched beam antenna system, provides higher gain, narrow beam, switchable fore and aft (nose to tail) with four upgraded spacecraft S-Band antennas for TDRSS (tracking and data relay satellite system).

- No development flight instrumentation (DFI)

- Modular auxiliary data system (MADS)



Emergency Exit–Left Hand (Port) Overhead Window



Operational Flight Configuration

STS-6 ELEMENT WEIGHT AND PERFORMANCE DIFFERENCES

- **Space Shuttle Main Engines (SSME's)**
  Performance uprated to 104 percent for nominal STS-6 mission, 109 percent for abort criteria. Higher thrust level was accomplished by incorporating redesigned engine parts into the original engine design. The changes were necessary because of higher temperatures, pressures and turbo-pump speeds that the engines encounter at the higher thrust level. All the changes were proven out in a very intense engine testing program, which included more than 62,000 seconds of engine firings. Significant examples of changes in the engines included: use of higher strength liquid oxygen posts in the main injector due to higher temperatures and pressures; use of a modified fuel preburner because of previous erosion of turbine blades and thermal shield nut erosion; and using thicker tubes and redesigned coolant supply lines in the nozzle to accommodate high loads at ignition.

- **Lightweight External Tank (ET)**
  Approximately 4,536 kilograms (10,000 pounds) weight savings from STS-1 mission to the STS-6 mission. Although the weight of each future tank may vary slightly, each will weigh approximately 30,391 kilograms (67,000 pounds). For each pound of weight reduced from the ET, the cargo carrying capability of the Space Shuttle spacecraft increases almost 0.4 kilograms (one pound). The weight reduction was accomplished by eliminating portions of stringers (structural stiffeners running the length of the hydrogen tank), using fewer stiffener rings and by modifying major frames in the hydrogen tank. Also, significant portions of the tank are milled differently to reduce thickness, and the weight of the ET's aft solid rocket booster attachments were reduced by using a stronger, yet lighter and less expensive titanium alloy. Earlier several hundred kilograms (pounds) were eliminated by deleting the antigeyser line. The line paralleled the oxygen feedline and provided a circulation path for liquid oxygen to reduce accumulation of gaseous oxygen in the feedline while the oxygen tank was being filled prior to launch. After assessing propellant loading data from ground tests and the first few Space Shuttle missions, the antigeyser line was removed for the STS-5 and subsequent missions. The total length and diameter of the ET remains unchanged due to the weight reduction. The final 34,927 kilogram (77,000 pound) ET which was manufactured earlier than the lightweight tank for STS-6, will be flown on STS-7.

- **Lightweight Solid Rocket Boosters**
  Each solid rocket booster motor case used on STS-6 and subsequent flights will weigh approximately 44,452 kilograms (98,000 pounds) which is approximately 1,814 kilograms (4,000 pounds) less than those flown on previous flights. The weight reduction was achieved by reducing the thickness of the solid rocket motor casings steel skin approximately two to four hundredths of an inch. Areas of the cases that were reduced are the cylindrical, attach and stiffener segments. Also, the solid rocket booster development flight instrumentation (DFI) was reduced.

INERTIAL UPPER STAGE (IUS)

The Inertial Upper Stage (IUS) will be used with the Space Shuttle to transport NASA's Tracking and Data Relay Satellites (TDRS) and other NASA and Department of Defense satellites destined for much higher orbits than that of the Space Shuttle orbiter or for trajectories beyond earth orbit. For instance, many communications satellites are stationed at geosynchronous orbit, some 35,880 kilometers (22,300 statute miles) from earth.

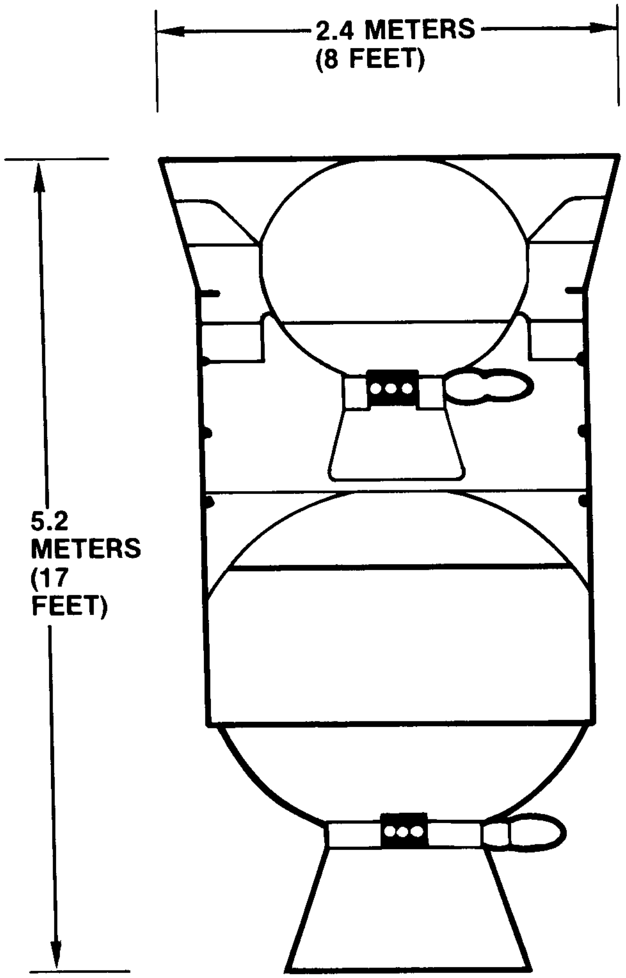
The IUS was originally designed as a temporary stand-in for a reusable space tug and the vehicle was named the Interim Upper Stage. The word "Inertial" (signifying the satellites guidance system) later replaced "Interim" when it was seen that the IUS would be needed through the 1980's.

The IUS is being developed and built under contract to the Air Force Systems Command's Space Division. After two and a half years of competition, Boeing Aerospace Company, Seattle, WA, was selected in August 1976 to begin preliminary design of the IUS.

IUS is a two stage vehicle weighing approximately 14,742 kilograms (32,500 pounds). Each stage is a solid rocket motor and was selected over those of liquid fueled engines due to relative simplicity, high reliability, low cost and safety. Thus, the reference IUS-2 (two stage).

The IUS is 5.18 meters (17 feet) long and 2.8 meters (9.5 feet) in diameter. It consists of an aft skirt; an aft stage solid rocket motor containing 9,707 kilograms (21,400 pounds) of propellant and generating 95,187 Newtons (21,400 pounds) of thrust; an interstage; a forward stage solid rocket motor with 2,721 kilograms (6,000 pounds) of propellant generating 82,288 Newtons (18,500 pounds) of thrust, and an equipment section. The equipment support section contains the avionics which provide guidance, navigation, telemetry, command and data management, reaction control and electrical power. All mission-critical components of the avionics system are redundant, along with thrust vector actuators, reaction control thrusters, motor ignitor and pyrotechnic stage separation equipment to assure reliability of better than 98 percent.

Airborne Support Equipment (ASE). The IUS Airborne Support Equipment (ASE) is the mechanical, avionics, and



Inertial Upper Stage (IUS)-2

structural equipment, located in the orbiter. The ASE supports and provides services to the IUS and the TDRS in the orbiter payload bay and provides positioning of the IUS/TDRS in an elevated position for final checkout prior to deployment from the orbiter.

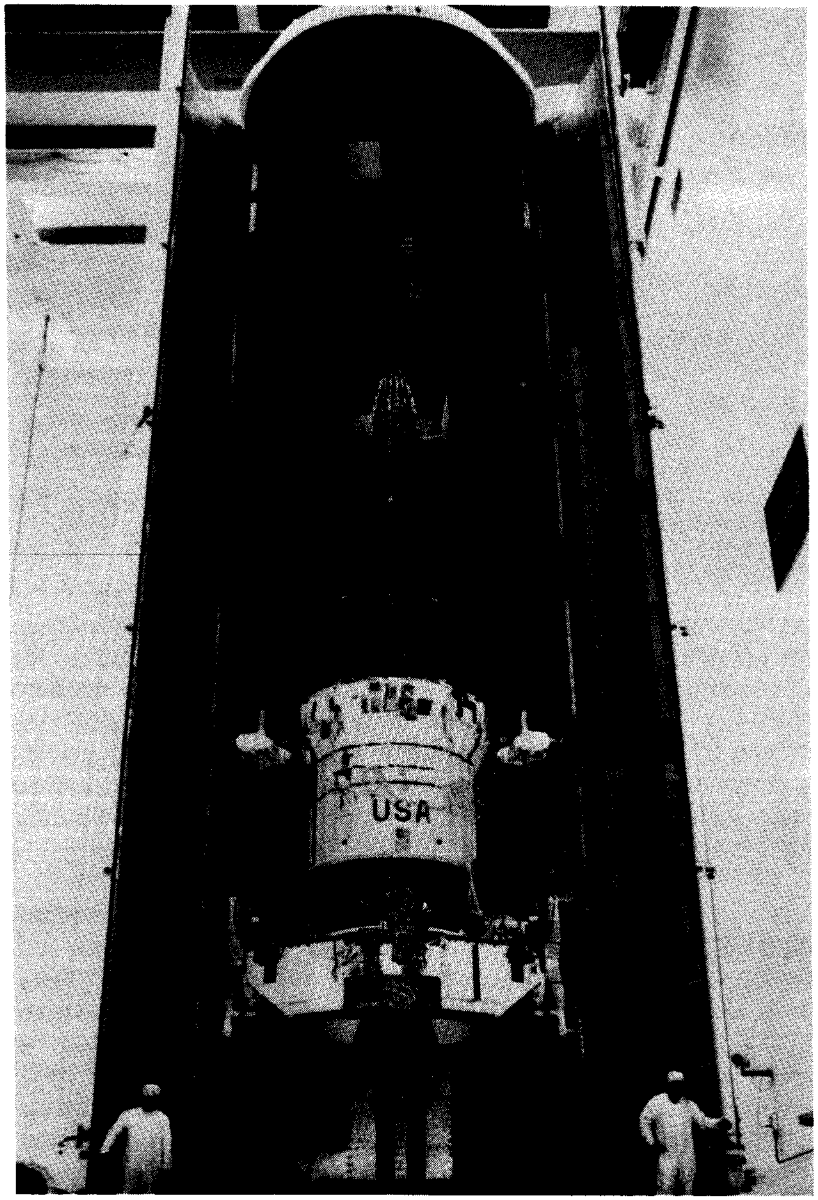
The IUS ASE consists of the structure, batteries, electronics, and cabling to support the IUS vehicle/TDRS combination. These ASE subsystems enable the deployment of the combined vehicle, provide and/or distribute and control electrical power to the IUS and TDRS and communication paths between the IUS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

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

The ASE data subsystem provides for the transfer of data and commands between the IUS/TDRS combination to the appropriate orbiter interface. Telemetry data includes TDRS data received over dedicated circuits via the IUS and TDRS telemetry streams. An interleaved stream is provided to the orbiter for transmission to the ground or transfer to ground support equipment.

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

IUS Structure. The IUS structure is capable of transmitting all the loads generated internally and also by the cantilevered



IUS/TDRS-A with Airborne Support Equipment in payload cannister transporter spacecraft during orbiter operations and the IUS free flight. In addition, the structure supports all the equipment and Solid Rocket Motor's (SRM's) within the IUS, and provides the mechanisms for IUS stage separation. The major structural assemblies of the two-stage IUS are the equipment support section, interstage, and aft skirt. The basic structure is made from aluminum skin-stringer construction with eight longerons and ring frames.

Equipment Support Section (ESS). The Equipment Support Section (ESS) houses the majority of the avionics and control subsystems of the IUS. The top of the ESS contains the 3 meter (10 feet) in diameter interface mounting ring and electrical interface connector segment for mating and integrating the TDRS with the IUS. Thermal isolation is provided by a multilayer insulation blanket across the interface between the IUS and spacecraft. All Line Replaceable Units (LRU's) mounted in the ESS can be removed and replaced via access doors even with the mated TDRS. This includes all equipment except the IUS Reaction Control System (RCS) tankage.

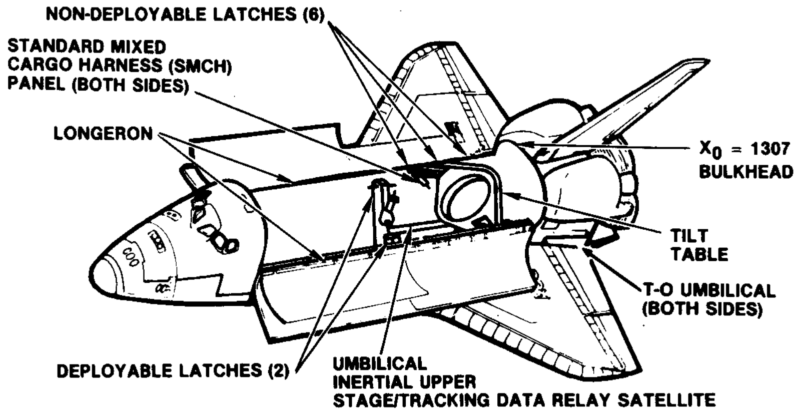
IUS Avionics Subsystem. The avionics subsystem consists of the telemetry, tracking, and command (TT&C) subsystem, guidance and navigation (G&N) subsystem, data management (DM) subsystem, thrust vector control (TVC) subsystem, and electrical power (EP) subsystem. This includes all the electronic and electrical hardware used to perform all computations, signal conditioning, data processing, and software formatting associated with navigation, guidance, control, data management and redundancy management. The IUS avionics subsystem also provides the communications between the orbiter and ground stations, in addition, it also provides for electrical power distribution.

Data management performs the computation, data processing and signal conditioning associated with guidance, navigation and control; safe-arm and ignition of the IUS two stage solid rocket motors (SRM's) and electro-explosive devices (EED's); command decoding and telemetry formatting; redundancy management; and issues spacecraft discretes. The data management subsystem consists of two computers, two signal conditioner units (SCU's) and a signal interface unit (SIU).

Modular, general-purpose computers use operational flight software to perform in-flight calculations and to initiate vehicle thrust and attitude control functions necessary to guide the IUS/TDRS through a predetermined flight path to a final orbit. A stored program including data known as the onboard digital data load, is loaded into the IUS flight computer memory from magnetic tape through the memory load unit (MLU) during pre-launch operations. Memory capacity is 65,536 (64K) 16-bit words.

The signal conditioner unit (SCU) provides the interface for commands and measurements between the IUS avionics computers and the IUS pyrotechnics, power, reaction control system (RCS), thrust vector control (TVC), telemetry, tracking, and command (TT&C), star scanner and the TDRS. The SCU consists of two channels of signal conditioning and distribution for command and measurement functions. The two channels are designated channel A and B. Channel B is redundant to channel A for each measurement and command function.

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



Inertial Upper Stage (IUS) Airborne Support Equipment (ASE)

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

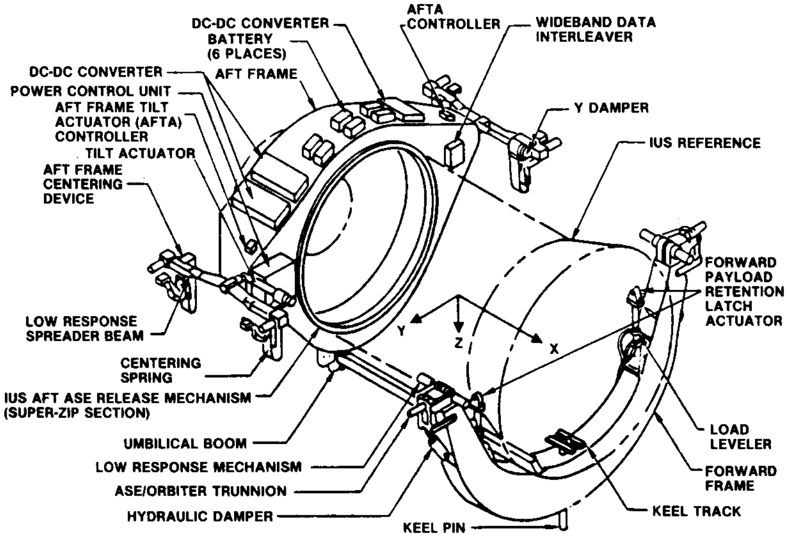
To support TDRS checkout or other IUS initiated functions, the IUS has the capability of issuing a maximum of eight discretes. These discretes may be initiated manually by the orbiter flight crew prior to deployment from the orbiter, or automatically by the IUS mission sequencing flight software after deployment. The discrete commands are generated in the IUS computer either as an event scheduling function (part of normal on-board automatic sequencing) or a command processing function initiated from an uplink command from the orbiter or Air Force Satellite Control Facilities (AFSCF) to alter the onboard event sequencing function and permit the discrete commands to be issued at any time in the mission.

During the ascent phase of the mission, the TDRS telemetry is interleaved with the IUS telemetry and is continually transmitted via the orbiter's S-Band FM downlink communications link. In addition the IUS/TDRS telemetry data is recorded on the orbiter's payload recorder. Telemetry transmission on the IUS rf link begins after the IUS/TDRS is tilted for deployment from the orbiter. TDRS telemetry data may be transmitted by the TDRS directly to the ground when in the orbiter payload bay with the orbiter payload bay doors open or during IUS/TDRS free flight.

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

The guidance and navigation subsystem is calibrated and aligned on the launch pad. The navigation function is initialized at liftoff and data from the IMU is integrated in the navigation software to determine the current state vector. Before vehicle deployment, an attitude update maneuver is performed by the Orbiter, with the IUS star scanner scanning two stars separated by 60 to 120 degrees, to compensate for accumulated drift errors.

If, for any reason, the computer is powered-down prior to



Inertial Upper Stage (IUS) Airborne Support Equipment (ASE) deployment, the navigation function is reinitialized by transferring Orbiter position, velocity, and attitude data to the IUS vehicle. Attitude updates are then performed as described above.

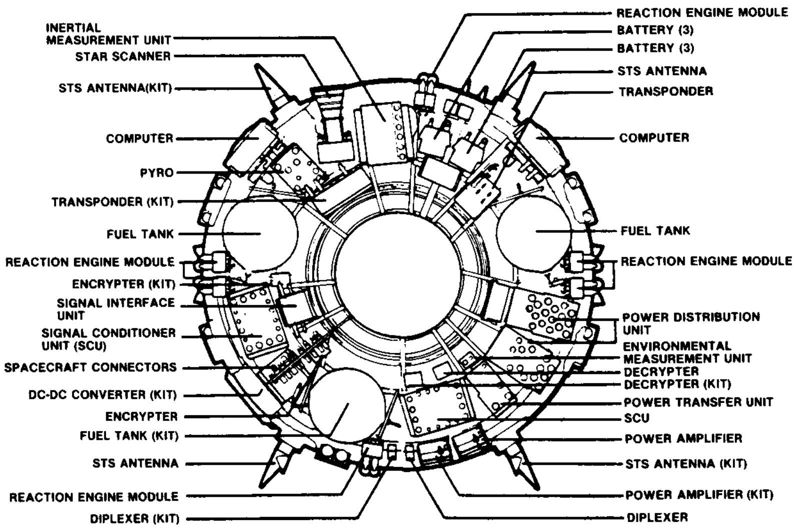
Star scanner attitude updates can also be performed after deployment. For example, an update can be used shortly before SRM-2 ignition to correct for attitude drift accumulated during the transfer orbit coast.

The IUS vehicle uses an explicit guidance algorithm (gamma guidance), to generate thrust steering commands, SRM ignition time and RCS vernier thrust cutoff time. Prior to each SRM ignition and each RCS vernier, the vehicle is oriented to a thrust attitude based on nominal performance of the remaining propulsion stages. During SRM burn, the current state vector determined from the navigation function is compared to the desired state vector, and commanded attitude is adjusted to compensate for the build up of position and velocity errors due to off-nominal SRM performance (thrust, Isp). The primary purpose of the vernier thrust is to compensate for velocity errors resulting from SRM impulse and cutoff time dispersions. However, residual position errors remaining from the SRM thrusting and position errors introduced by impulse and cutoff time dispersions are also removed by the RCS.

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

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

IUS electrical power subsystem consists of avionics batteries, IUS power distribution units, power transfer unit, utility batteries, pyrotechnic switching unit, IUS wiring harness and umbilical, and staging connectors. The IUS avionics system



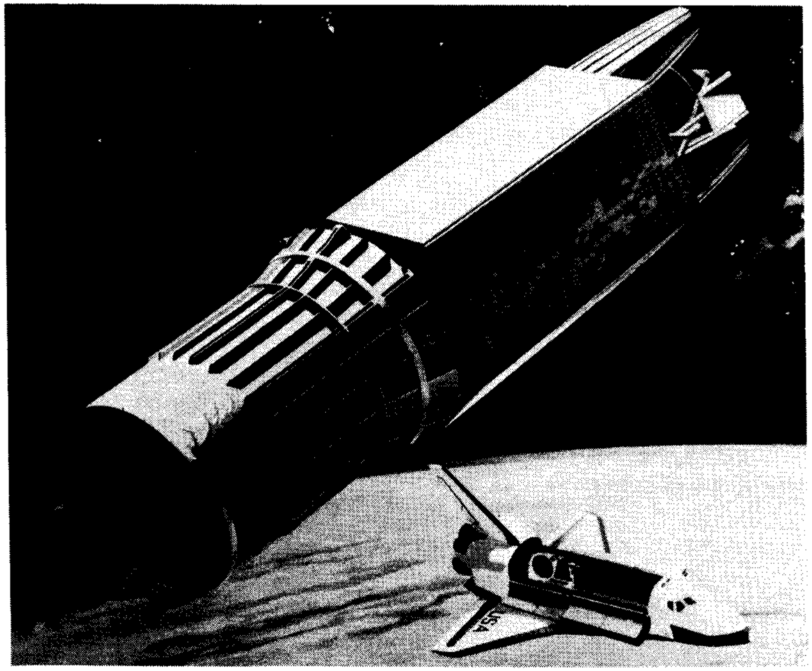
Inertial Upper Stage (IUS) Equipment Support Section distributes electrical power to the IUS/TDRS interface connector for all mission phases from prelaunch to TDRS separation. The IUS system distributes orbiter power to the TDRS during ascent and on-orbit phases. The ASE provides batteries to supply power to the TDRS in the event of orbiter power interruption. A dedicated IUS/TDRS battery ensures uninterrupted power to the TDRS from IUS deployment to TDRS separation. The IUS will also accomplish an IUS automatic power down if high temperature limits are experienced prior to opening of the orbiter payload bay doors. Dual buses ensure that no single power system failure can disable both A and B channels of avionics. For the IUS-two stage vehicle, four batteries (three avionics, one TDRS) are carried in the IUS first stage. Five batteries (two avionics, two utility, one TDRS) are provided to supply power for the IUS second stage, after staging. Redundant IUS switches transfer the power input between TDRS, GSE, ASE, and IUS battery sources.

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

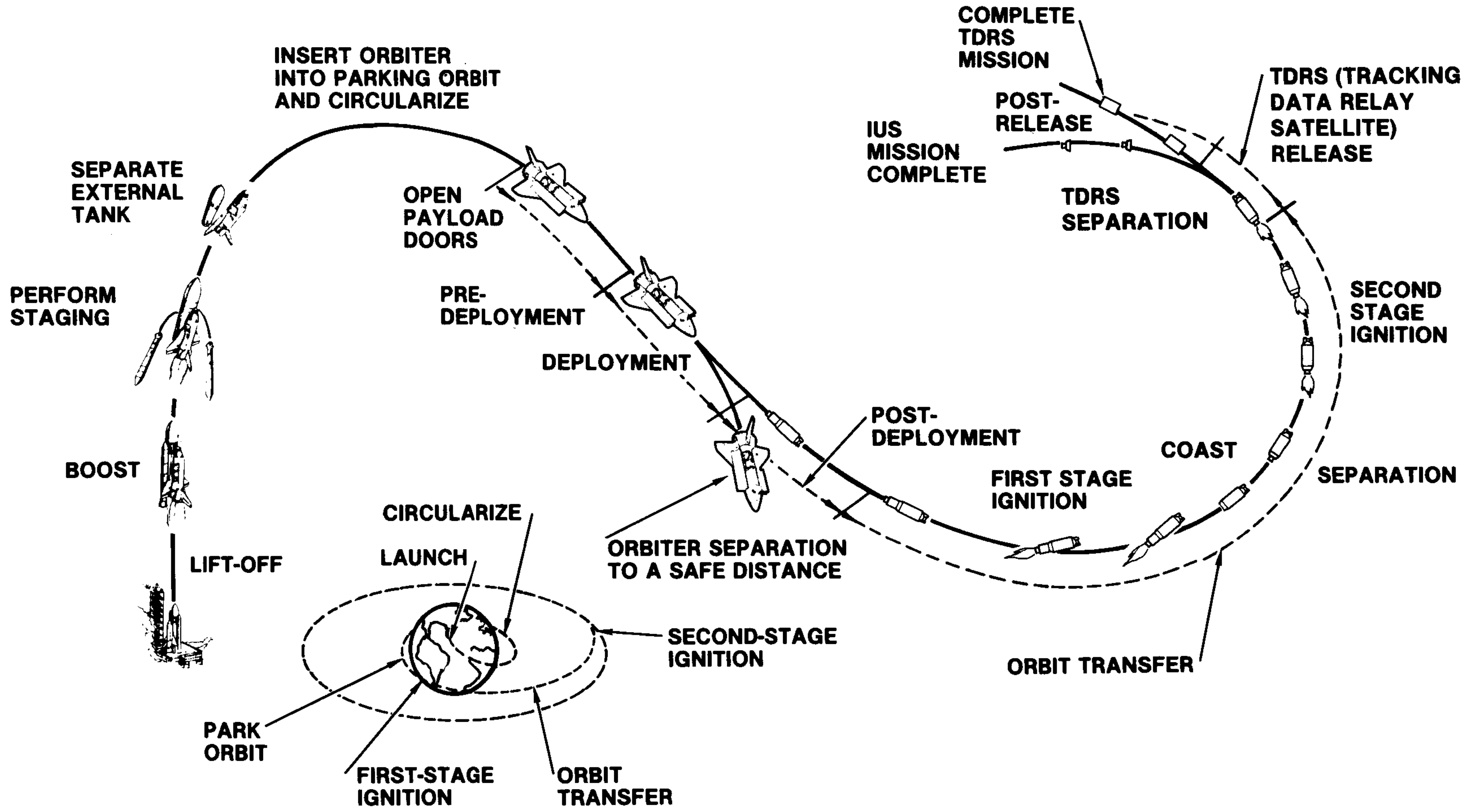
IUS Solid Rocket Motors (SRM's). The IUS two stage vehicle incorporates a large solid rocket motor and a small solid rocket motor. These motors employ movable nozzles for thrust vector control (TVC). The nozzles are positioned by redundant electromechanical actuators permitting up to four degrees of steering on the large motor and seven degrees on the small motor. Kevlar filament wound cases with largely wound in aluminum end rings, provide high strength at minimum weight. The large motor is the longest thrusting duration solid rocket motor ever developed for space, having a thrusting duration of 145 seconds. Variations in user mission requirements are met by tailored propellant offloading. The small motor can be flown either with or without its extendible exit cone (EEC). The EEC provides an increase of 14.5 seconds in the delivered specific impulse (I_{sp}) of the small motor.

IUS Reaction Control System (RCS). The IUS RCS is a hydrazine monopropellant positive expulsion system that controls the IUS/TDRS attitude during IUS coast periods, roll control during SRM thrustings, and the delta velocity impulses for accurate orbit injection. Valves and thrusters are redundant permitting continued operation with a minimum of one failure. The maximum thrusting time during an SRM thrusting period is 14 seconds.

The IUS baseline includes two RCS tanks with a capacity of 54 kilograms (120 pounds) of hydrazine each. A production option is available to add a third tank if required. To avoid TDRS contamination, the IUS has no forward facing thrusters. IUS users with spin stabilized spacecraft can use the RCS to



Inertial Upper Stage Tracking Data Relay Satellite Deployment



Sequence of Events for Typical Geosynchronous Mission provide spinup prior to spacecraft separation. The system is also used to provide the velocities for spacing between multiple spacecraft deployments and for a collision avoidance maneuver after TDRS separation.

The RCS is a sealed system which is serviced prior to TDRS mating. Propellant is isolated in the tanks with pyrotechnic squib operated valves which are not activated until IUS deployment from the orbiter. The tank and manifold safety factors are such that there are no safety constraints imposed on operations in the vicinity of the serviced tanks.

IUS to TDRS Interfaces. Physical attachment of the TDRS to IUS is provided by a maximum of eight attachment points. It provides substantial load carrying capability while minimizing thermal conditions across the interface. Separation between the TDRS and IUS is provided by the TDRS. The separation plane is forward of the IUS/TDRS attachment interface and the TDRS adapter will remain with the IUS after separation occurs.

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

The IUS provides a multilayer insulation blanket made up of aluminized Kapton with polyester net spacers with an aluminized Beta cloth outer layer across the 2,837 millimeter (111.7 inch) diameter IUS/TDRS interface. All IUS thermal blankets are vented toward and into the IUS cavity. All gases within the IUS cavity are vented to the orbiter payload bay. There is no gas flow between the TDRS and the IUS and the thermal blankets are grounded to the IUS structure.

Flight Sequence. After the orbiter payload bay doors are opened in earth orbit, the orbiter maintains a payload bay to earth attitude to fulfill payload thermal requirements and constraints except during those operations that require special attitudes (IUS star scan maneuvers, orbiter IMU alignments, RF communications and deployment operations).

The IUS power is transferred to orbiter power and early predeployment checkout begins, followed by an IUS command link check and TDRS RF command check. The state vector is uplinked to the orbiter for orbiter trim maneuver(s) and the orbiter trim maneuver(s) are performed. The orbiter is oriented for IUS attitude initialization and downlink of the IUS attitude data is verified. The state vector is uplinked to the orbiter and transferred to the IUS and IUS predeployment checkout begins. The orbiter is then maneuvered to the IUS/TDRS deployment attitude.

The forward ASE payload retention latch actuator is released and the aft frame ASE electromechanical tilt actuator tilts the IUS/TDRS combination to 29 degrees. This extends the TDRS into space just outside the orbiter payload bay which allows direct checkout of the TDRS from earth. If a problem has developed within the TDRS, the IUS/TDRS can be restowed.

Prior to deployment, the TDRS electrical power source is switched from orbiter power to IUS internal power by the orbiter flight crew. Verification that the TDRS is on IUS internal power and that all IUS/TDRS predeployment operations have been successfully completed will be evaluated by data contained in the IUS and TDRS telemetry. IUS telemetry data is evaluated by the IUS Mission Control Center at Sunnyvale, CA, and the TDRS data by the TDRS Control Center. Analysis of the telemetry will result in a GO/NO-GO decision for IUS/TDRS deployment from the orbiter.

When the orbiter flight crew is given a GO decision, the orbiter flight crew will activate the ordnance that separates the IUS/TDRS umbilical cables. The flight crew will then command the electromechanical tilt actuator to raise the tilt table to 58 degree deployment position. The Orbiter's RCS thrusters are inhibited and the Super* zip ordnance separation device is initiated which physically separates the IUS/TDRS combination from the tilt table and compressed springs provide the force to jettison the IUS/TDRS from the orbiter payload bay at approximately 0.12 meters per second (0.4 feet per second). The

IUS/TDRS deployment is performed in the shadow of the orbiter or in earth eclipse. Approximately 14 minutes after IUS/TDRS deployment the orbiter Orbital Maneuvering System (OMS) engines are ignited to provide the orbiter with a separation maneuver from the IUS/TDRS.

The IUS/TDRS is now controlled by the IUS onboard computers. Approximately ten minutes after the IUS/TDRS are ejected from the orbiter, the IUS RCS is enabled by the IUS onboard computers and all subsequent operations are similarly sequenced by the IUS computers through TDRS separation and IUS deactivation.

Following RCS activation, the IUS will maneuver the TDRS to its required thermal attitude and perform the required TDRS thermal control maneuver.

At approximately 46 minutes after IUS/TDRS ejection from the orbiter the SRM-1 ordnance inhibits are removed. It is noted that the belly of the orbiter is oriented towards the IUS/TDRS for window protection attitude from the IUS SRM-1 plume. The IUS will then recompute SRM-1 ignition time and maneuver to the proper attitude for the SRM-1 thrusting period. When the transfer orbit injection opportunity is reached, the IUS computer will enable and apply ordnance power, arm and safe arm devices and ignite the first stage SRM. The SRM-1 thrusting period is approximately 145 seconds to provide sufficient thrust for the orbit transfer phase of the geosynchronous mission. The IUS first stage and interstage are separated from the IUS second stage prior to reaching the apogee point of its trajectory.

During the coast phase the IUS is capable of performing the maneuvers required by the TDRS for thermal protection or communication reasons. If the TDRS requires improved accuracy, the IUS can perform a pre SRM-2 star scan attitude update.

At apogee, the second stage motor is ignited and its thrusting period is approximately 104 seconds providing the final injection to geosynchronous orbit. The IUS then supports TDRS separation and performs a final/collision/contamination avoidance maneuver before deactivating its subsystems.

Boeing's propulsion team member Chemical Systems Division of United Technologies, designed and tests the two solid rocket motors. Teamed with Boeing in the avionics area are TRW and Hamilton Standard Division of United Technologies. TRW provides software design and IUS telemetry, tracking and command system hardware. Hamilton Standard provides guidance system hardware support. Delco, under subcontract to Hamilton Standard, provides the avionics computer. Ball Aerospace Systems Division furnishes the star scanner.

In addition to the actual flight vehicles, Boeing is responsible for the development of ground support equipment for the checkout and handling of the IUS vehicles from factory to launch pad. Boeing also develops the airborne support equipment to support the IUS in the Space Shuttle and monitor it while it is in the Space Shuttle payload bay.

Under a separate contract, Boeing integrates the IUS with the various satellites and joins the satellite with the IUS, checks out the configuration and supports launch and mission control operations for both the Air Force and NASA.

The IUS is fabricated, assembled and tested at the Boeing Space Center in Kent, WA, south of Seattle. The first IUS to be used with the Space Shuttle and TDRS-A was shipped in June 1982 to Cape Canaveral, FL. Boeing is building eight IUS vehicles under its full-scale development contract with the Air Force which began in 1978. The Air Force expects to acquire six more IUS vehicles in 1983-1984.

TRACKING AND DATA RELAY SATELLITE SYSTEM (TDRSS)

A new era in space communications opens with the STS-6 mission with the deployment of the first Tracking and Data Relay Satellite (TDRS). This satellite, TDRS-A, is the first of three identical ones which are planned for the TDRS system. The TDRS system was developed following studies in the early 1970's which showed that a system of telecommunication satellites operated from a single ground station could better suport the projected scientific and application mission requirements and also halt the spiralling cost escalation of upgrading and operating a worldwide tracking and communications network of ground stations.

Six TDRS satellites are being built by TRW's Defense and Space Systems Group, Redondo Beach, CA, for Space Communications Company (Spacecom) of Gathersburg, MD. Spacecom is jointly owned by Western Union and American Satellite Company, a partnership between Fairchild Industries and Continental Telephone Company. Spacecom owns and operates the TDRS system, which will consist of three multi-function communication satellites and the White Sands Ground Terminal (WSGT), New Mexico built jointly by the team of TRW, Harris Corporation and Spacecom.

One satellite will be stationed over the Pacific Ocean at the Equator southwest of Hawaii at 171 degrees West longitude and is referred to as TDRSS-West, one satellite will be stationed at the Equator over the northeast corner of Brazil at 41 degrees West longitude and is referred to as TDRSS-East and the remaining satellite is centrally located over the Equator at 79 degrees West which is referred to as in-orbit spare. These three satellites will comprise the space segment of the system. The in-orbit spare would be available for use in the event one of the operational satellite malfunctions, or to augment system capabilities during peak periods. The remaining three satellites will be available as flight ready spares.

NASA will lease TDRSS services from SPACECOM, for a 10 year period, under a contract awarded in December 1976. Funding for the program was arranged by NASA through the Federal Financing Bank, Washington, D.C. Cost to NASA for the 10 year lease period will be approximately $250 million per year.

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 resulting in savings in personnel, operating and maintenance costs. 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.

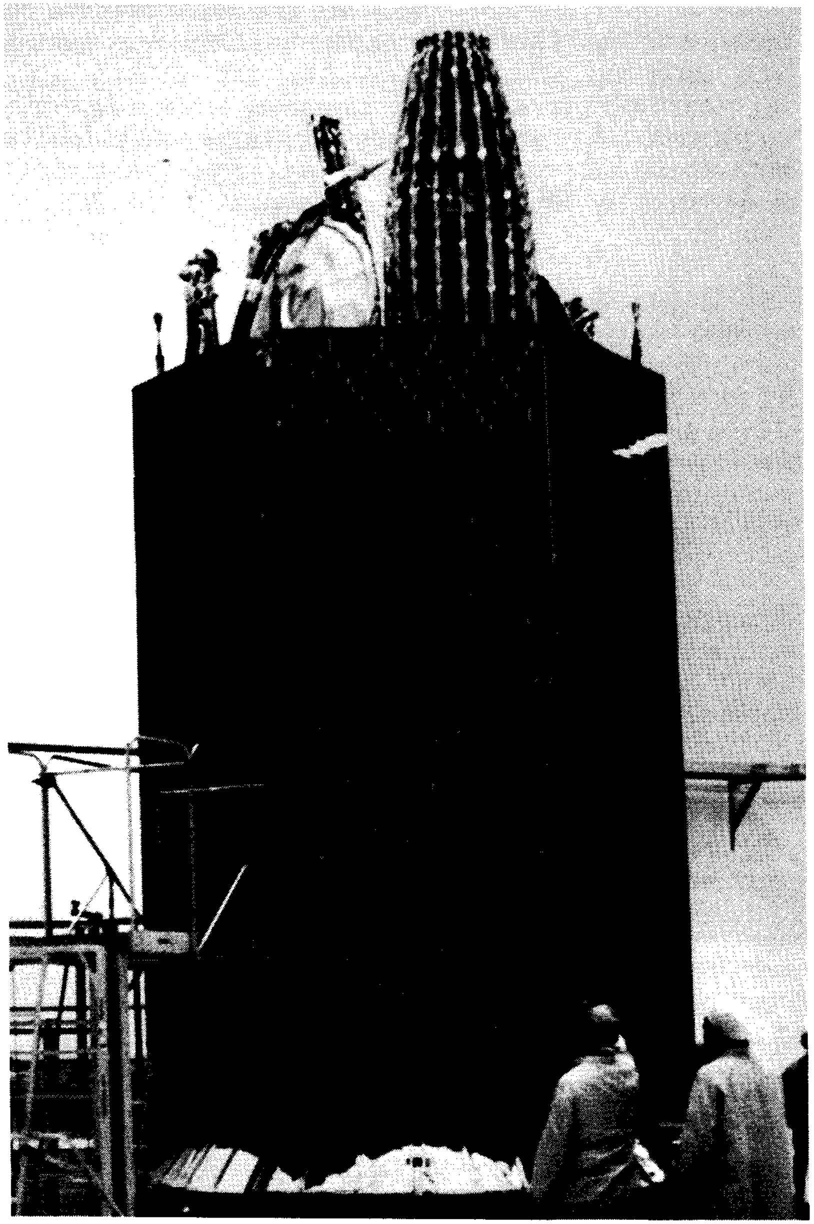
Deep space probes and earth orbiting satellites above approximately 5,000 kilometers (3,100 miles) will use the three ground stations of the Deep Space Network (DSN) operated for NASA by the Jet Propulsion Laboratory, Pasadena, CA. The STDN stations that were co-located with the three DSN stations, Goldstone,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

The TDRSS satellites will be deployed from the Space Shuttle spacecraft at an altitude of 283 kilometers (153 nautical miles) and the Inertial Upper Stage will provide the velocity to place the TDRS satellite 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.

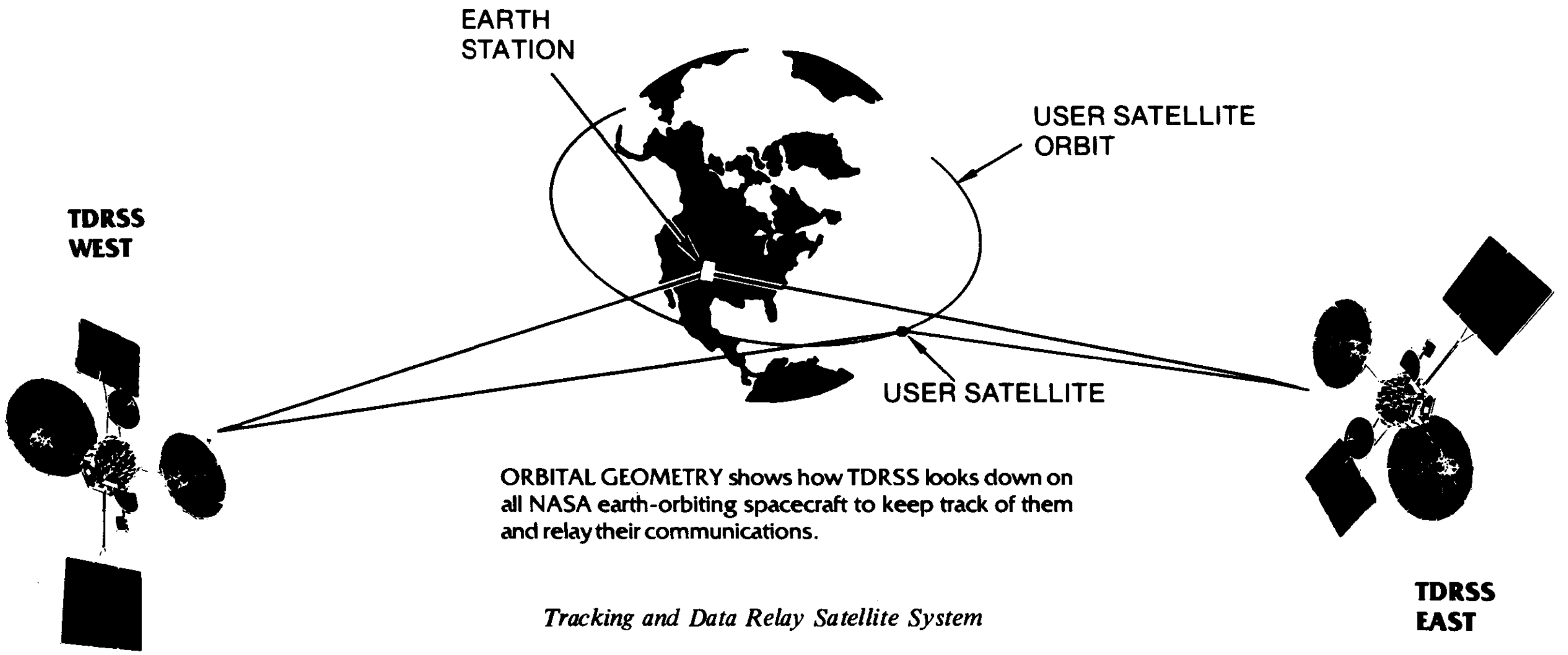
The data acquired by the two TDRS satellites is relayed to a single centrally located ground terminal at NASA's White Sands Test Facility in New Mexico. From New Mexico, the raw data will be sent directly by domestic communications satellite (DOMSAT) to NASA control centers at Johnson Space Center, Houston, 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 communications capability extends across a wide spectrum that includes voice, television, analog and digital signals.

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 complex commumication 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



Tracking Data Relay Satellite



ORBITAL GEOMETRY shows how TDRSS looks down on all NASA earth-orbiting spacecraft to keep track of them and relay their communications.

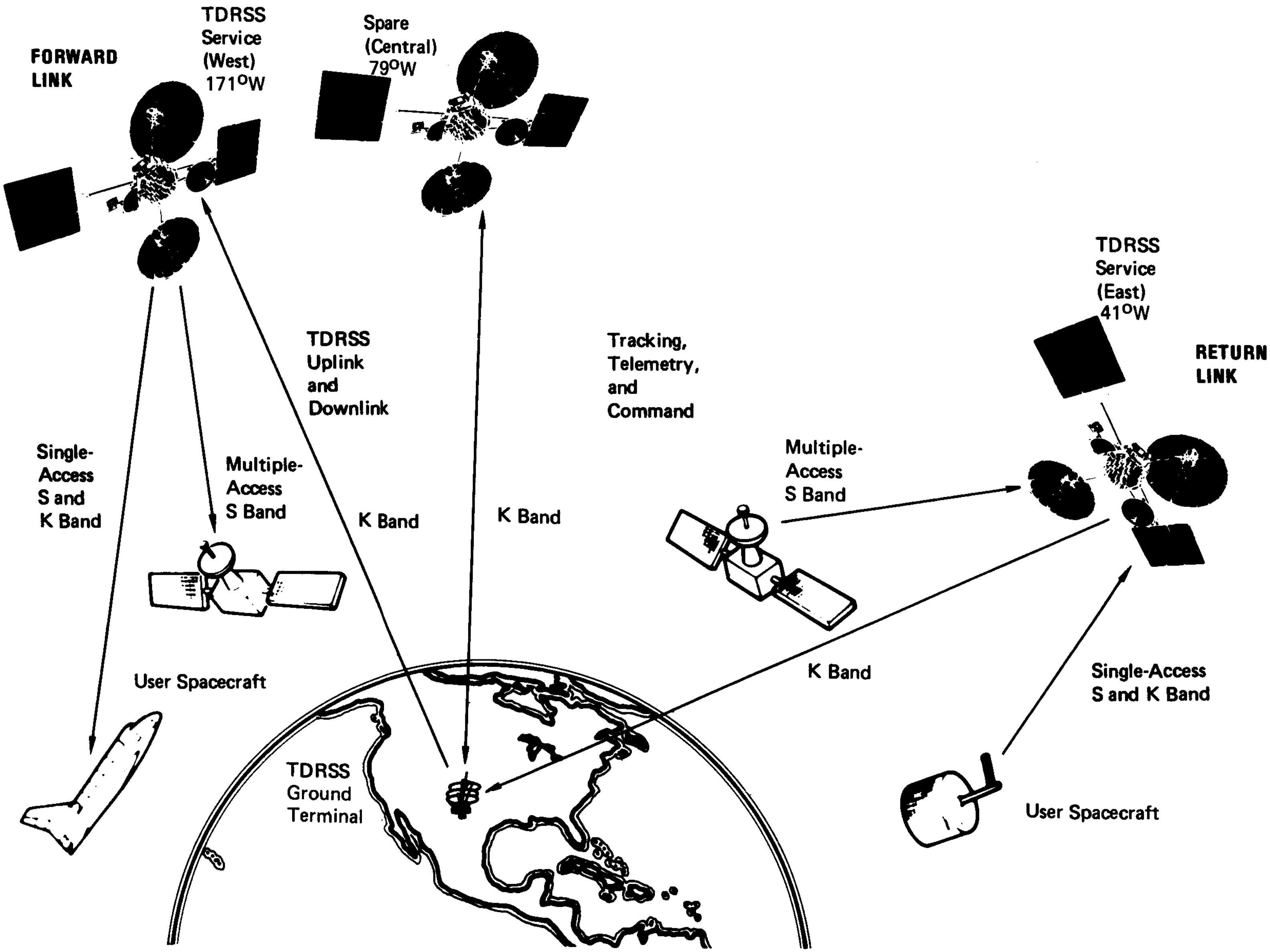
Tracking and Data Relay Satellite System

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.

The two TDRS satellites are positioned 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.

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.

All TDRS satellites will be placed into geosynchronous orbit from the Space Shuttle spacecraft with an Inertial Upper Stage (IUS)-2 (two stage solid rocket motor) developed for the Air Force Space Division by Boeing Aerospace Company. The TDRS satellite attached to its IUS is jettisoned from the payload bay of the Space Shuttle Orbiter. The IUS is then under control of its own onboard computers. The Space Shuttle spacecraft is maneuvered to a safe distance from the IUS/TDRS. The IUS performs a series of preparatory maneuvers, then fires its first stage solid rocket motor which propels it towards its geosynchronous position. The Space Shuttle spacecraft flight

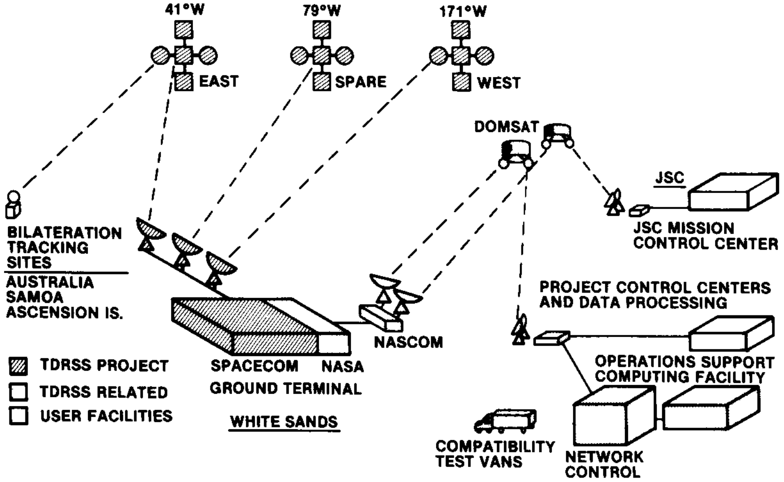


Linking Three Identical and Interchangeable Satellites With Earth Station crew will not see IUS ignition as the Space Shuttle spacecraft is positioned belly towards the IUS for Space Shuttle spacecraft window protection attitude from the IUS solid rocket motor plume. Between the IUS first and second stage firings, repeated earth pointing for TDRS commands and telemetry, plus thermal control maneuvers will take place. Injection into its final geosynchronous orbit is provided by the IUS second stage solid rocket motor.

Deployment of the TDRS satellite solar panels, C-band antenna and space ground link antenna occur prior to the TDRS satellite separation from the IUS. The IUS then separates from the TDRS satellite when the TDRS satellite is in its final orbit and the IUS moves to a non-collision position.

The TDRS single access parabolic antennas deploy after separation from the IUS and subsequent to acquisition of the sun and earth by TDRS satellite sensors utilized for attitude control. Attitude and velocity adjustments place the TDRS satellite into its final geostationary position.

Three-axes stabilization onboard the TDRS satellite maintains attitude control. Body fixed momentum wheels in a vee



TDRSS System Elements

Tracking Data Relay Satellite Mating With Inertial Upper Stage configuration combine with body fixed antennas pointing constantly at earth while the TDRS satellite solar arrays track the sun. Monopropellant hydrazine thrusters are used for TDRS satellite positioning and north-south and east-west station keeping.

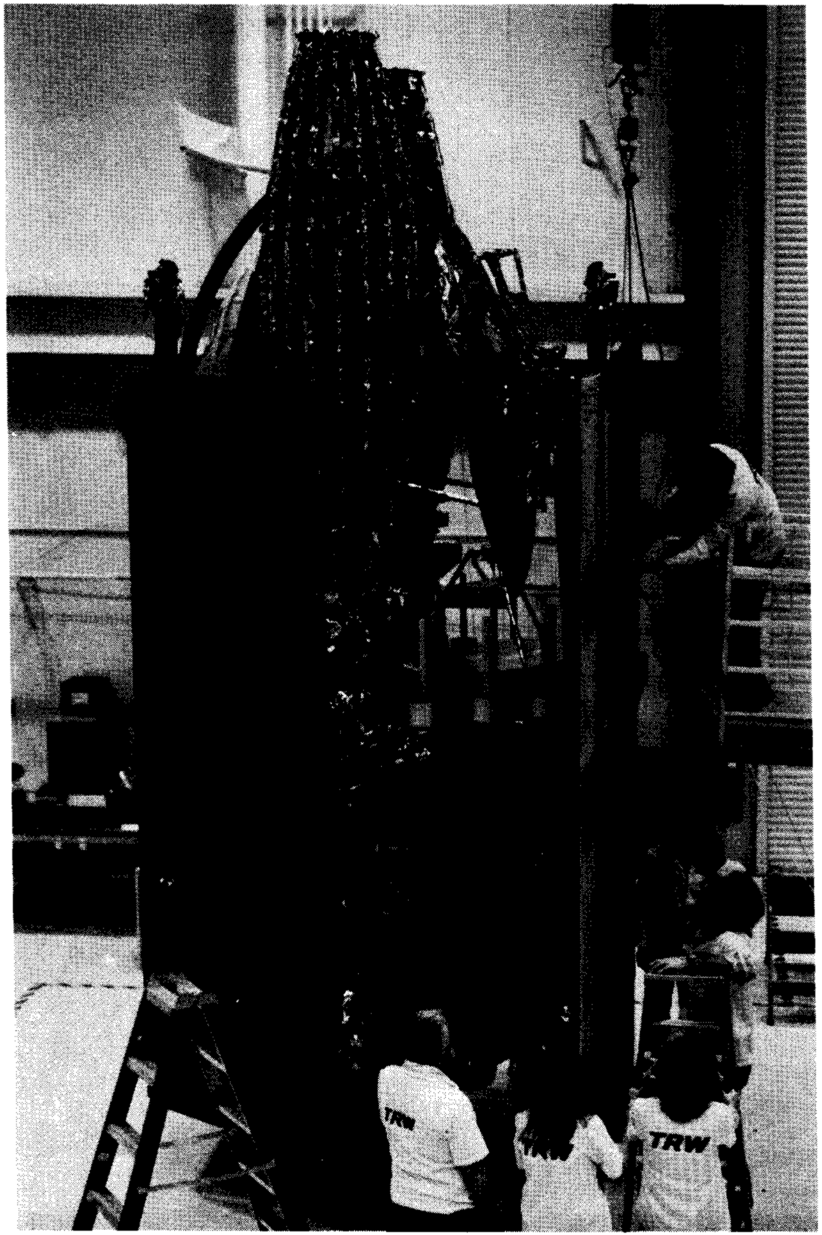
The TDRS satellite to date, are the largest privately owned telecommunications satellites ever built. Each satellite weighs nearly 2,268 kilograms (5,000 pounds) on orbit. The solar arrays on each satellite when deployed span more than 17 meters (57 feet) tip to tip. The two single-access high-gain parabolic antennas when deployed measure 4.9 meters (16 feet) each, in diameter and span 13 meters (42 feet) from tip to tip.

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

The equipment module housing the subsystems that operate the satellite and the communications service is located in the lower hexagon of the satellite. The attitude control subsystem stabilizes the satellite so that the antennas have the proper orientation toward the earth and the solar panels toward the sun. The electrical power subsystem consists of two solar panels that provide a 10 year life span of approximately 1,850 watts of power. Nickel cadmium batteries supply full power when the satellite is in the shadow of earth. The thermal control subsystem consists of surface coatings and controlled electric heaters.

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

The antenna module is composed of four antennas. For single-access services, each TDRS satellite has two dual feed



Tracking Data Relay Satellite Solar Panels and Antenna Stowed

S-band/Ku-band deployable parabolic antennas. These antennae are 4.9 meters (16 feet) in diameter, attached on two axes that can move horizontally or vertically to focus the beam on satellites or spacecraft below. These antennas are used primarily to relay communications to and from user satellites or spacecraft. The high-bit rate service made possible by these antennas is available to users on a time-shared basis. Each antenna simultaneously supports two user satellites or spacecraft (one at S-band and one at Ku-band), if both users are within the antenna bandwidth. The antennas primary reflector surface is a gold clad molybdenum wire mesh woven like cloth on the same type of machine used to make material for women's hosiery. When deployed 18.9 square meters (203 square feet) of mesh are stretched taughtly between 16 supporting tubular ribs by fine threadlike quartz cords like a glittering metallic spider web. The entire antenna structure, including the ribs, reflector surface, a dual frequency antenna feed and the deployment mechanisms needed to fold and unfold the structure like a parasol, weighs aproximately 22 kilograms (50 pounds).

For multiple-access service, the multi-element S-band phased array of 30 helix antennas on each satellite is mounted on the satellite body. The multiple access (MA) forward link (between TDRS and the user satellite or spacecraft) transmits command data to the user satellite or spacecraft and in the return link the signal outputs from the array elements are sent separately to the White Sands Ground Terminal (WSGT) parallel processors. Signals from each helix antenna are received at the same frequency, frequency-division multiplexed into a single composite signal and transmitted to the ground. In the ground equipment, the signal is demultiplexed and distributed to 20 sets of beam forming equipment which allows discrimination of the 30 signals, to select the signals for individual users. The multiple access system uses 12 of the 30 helix antennas on each TDRS satellite to form three transmit beams (one from each TDRS satellite) in the direction of the users.

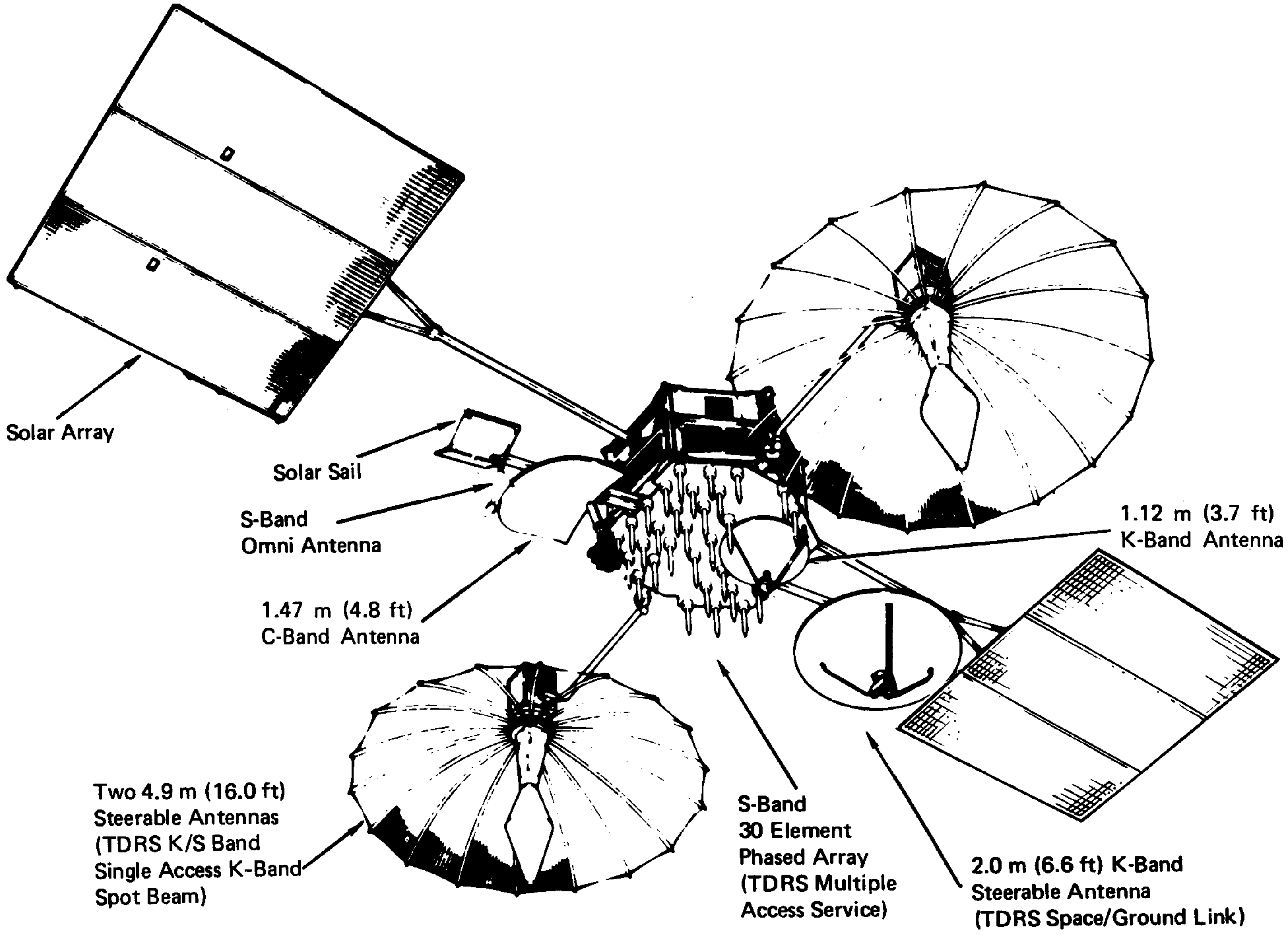
A fourth antenna, a 2 meter (6.5 feet) parabolic reflector, provides the prime link for relaying transmissions to and from the ground terminal at Ku-band.

Each of the six K-band return service channels (two per TDRS satellite) have the capacity to receive up to 300 million bits-per-second of digital information. Receiving equipment at the White Sands Ground Terminal is provided to handle two channels simultaneously.

Thus, 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.

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

Tracking Data Relay Satellite on Station at Geosynchronous Orbit



TDRS Satellite

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

The ground station software and computer component, with more than 900,000 machine language instructions controls the eventual three geosynchronous TDRS satellites and the 300 racks of ground station electronic equipment via a network of 10 computers.

The ground station is located on a nine-acre site at NASA's White Sands, New Mexico, Test Facility. The station includes the electronic equipment, three 18 meter (60 feet) dish antennas for K-band, a number of small antennas, and a multiprocessor computer network.

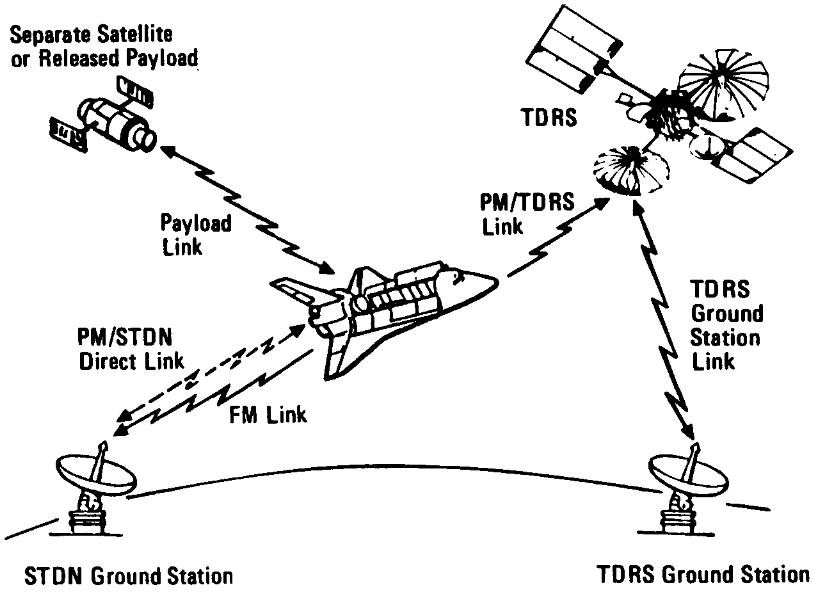
The ground station is owned and managed by Space Communications Company and leased by NASA. Electronic hardware is jointly supplied by TRW and Harris Government Communications Division in Melbourne, FL. TRW performed integration and testing of the ground station and developed software for the TDRS system and integrates the software with the ground station and TDRS satellites, tying together the space and ground segment.

The TDRS-A satellite on STS-6 will be positioned at East station, TDRS-B is scheduled to be carried in the STS-8 flight and will be positioned at West station, and TDRS-C is scheduled for STS-12 and will be positioned at the Central station as backup. A three month checkout is scheduled for each satellite when it is on station and the fully operational three satellites are scheduled for operational status in March 1984.

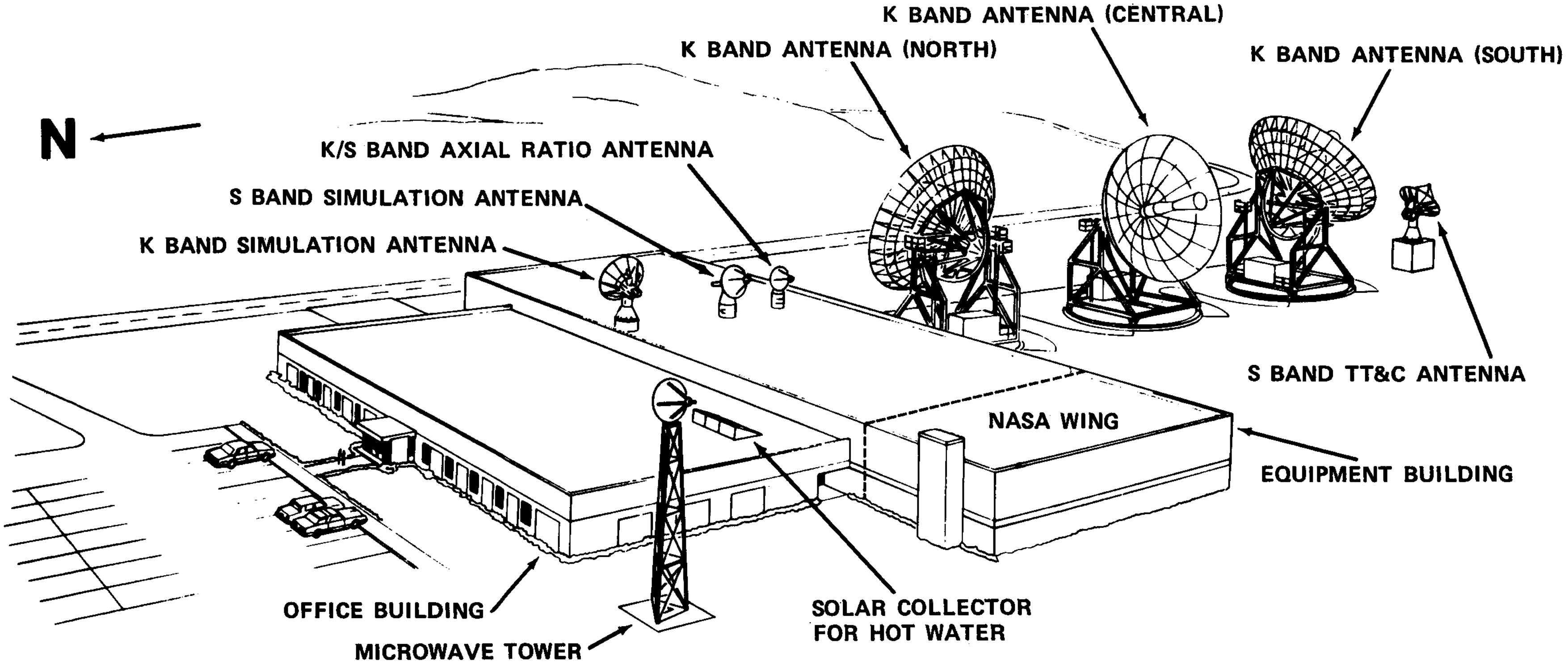
Later flights of the Space Shuttle Orbiter will carry a 914 millimeter (36-inch) diameter orbiter Ku-band antenna stowed in the starboard forward portion of the orbiter payload bay and will be deployed after the orbiter is in orbit and the payload bay doors are open. The capability of installing a Ku-band antenna on the left-hand side is available. If the Ku-band antenna cannot be stowed, provisions are incorporated to jettison it so that the payload bay doors can be closed.

The STS-6 flight of *Challenger* does not have the Ku-band installed due to the TDRS-A not becoming operational during the STS-6 flight of *Challenger*. 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. With Ku-band system, the higher data rates can be used.

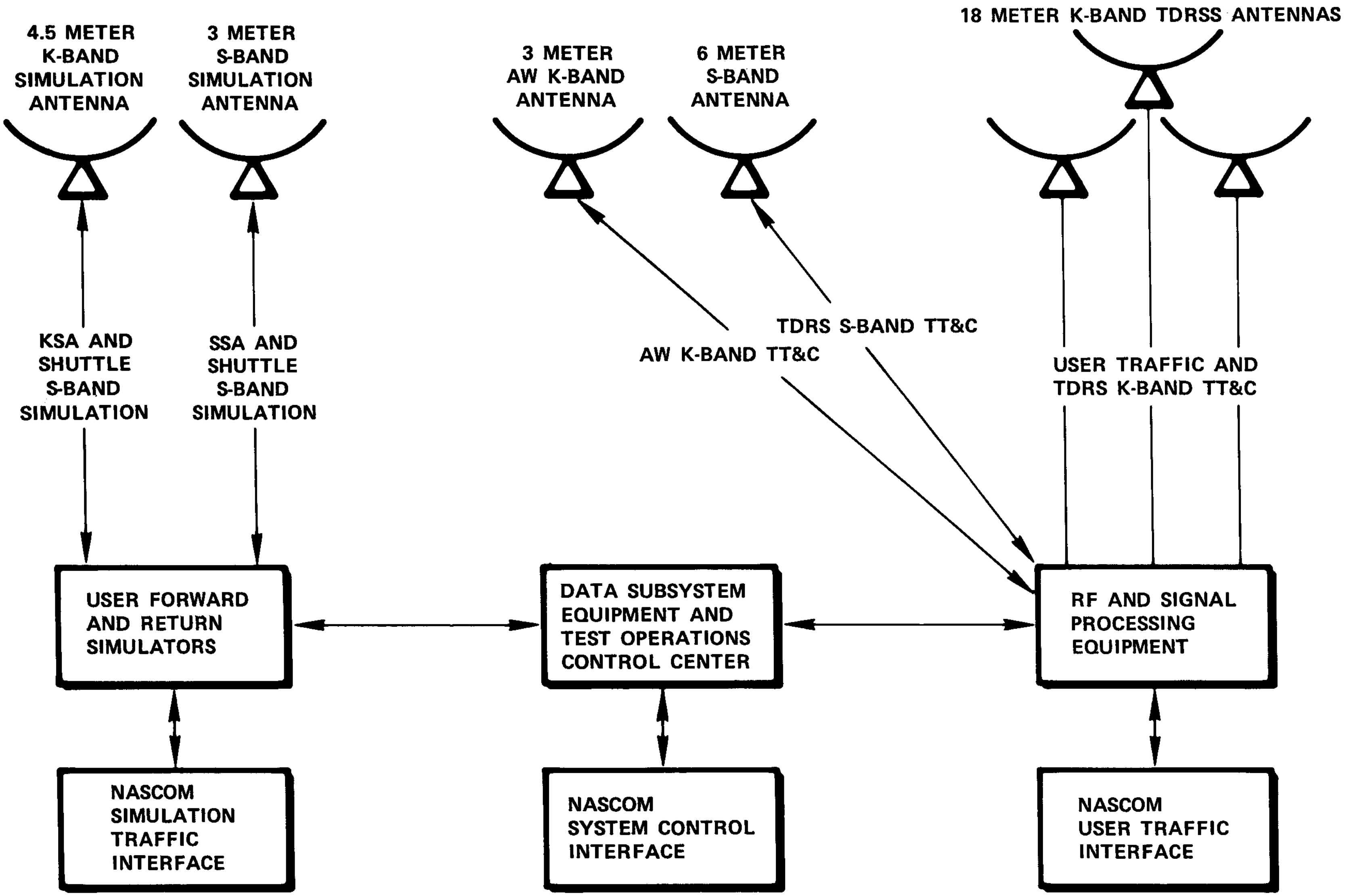
One drawback of the Ku-band system is its narrow pencil beam, which makes it difficult for the antennas on the TDRS to



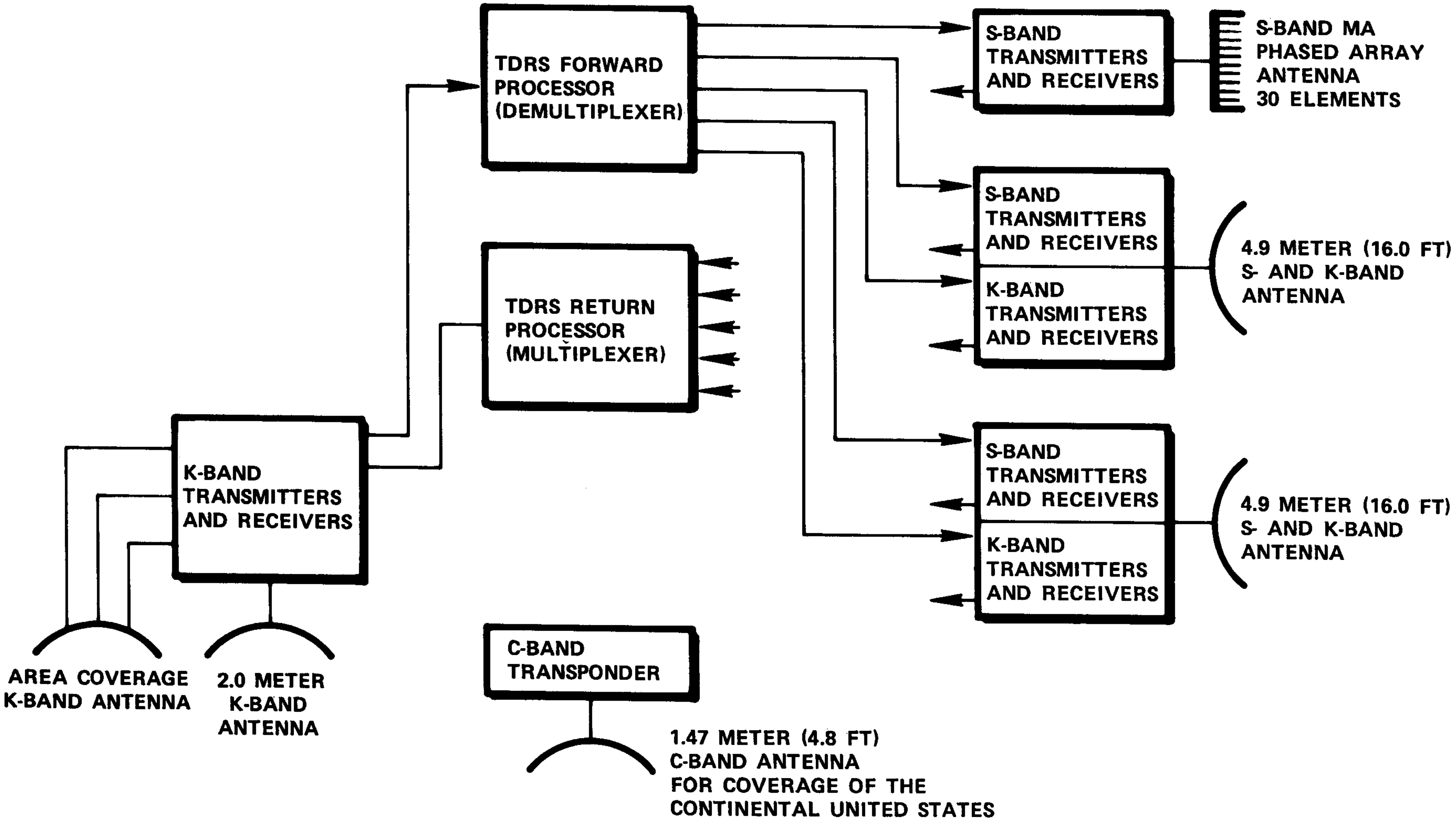
S-Band/TDRS Communications



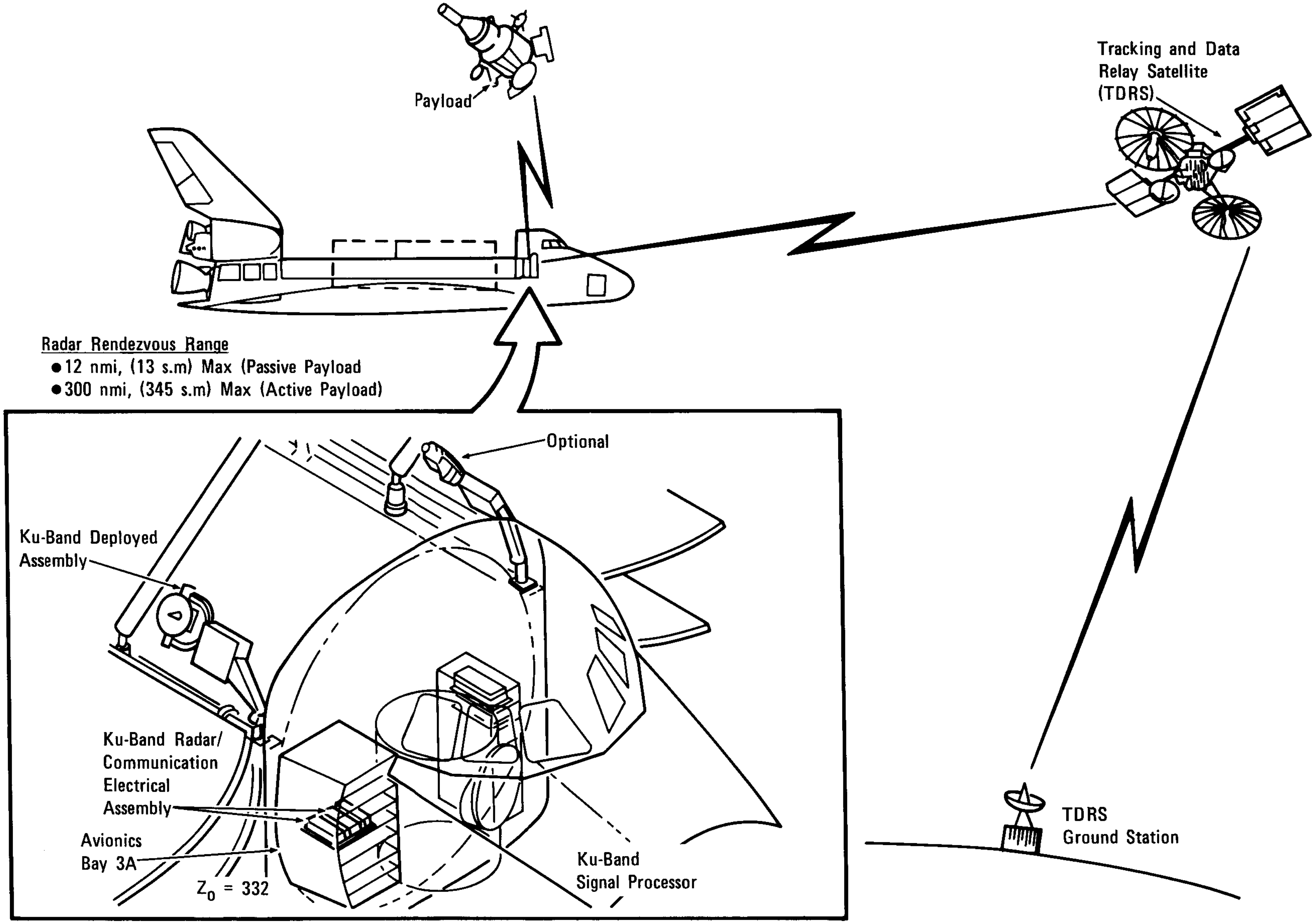
Tracking and Data Relay Satellite System Ground Station, White Sands, New Mexico



Tracking and Data Relay Satellite System Antenna



Tracking and Data Relay Satellite System
Transmission and Receive System



Ku-Band Radar Communication System

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 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 wil rendezvous with the payload that is already in orbit to add on the next section.

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.

Radar search for space hardware may use a wider spiral scan, 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).

EXTRAVEHICULAR ACTIVITY

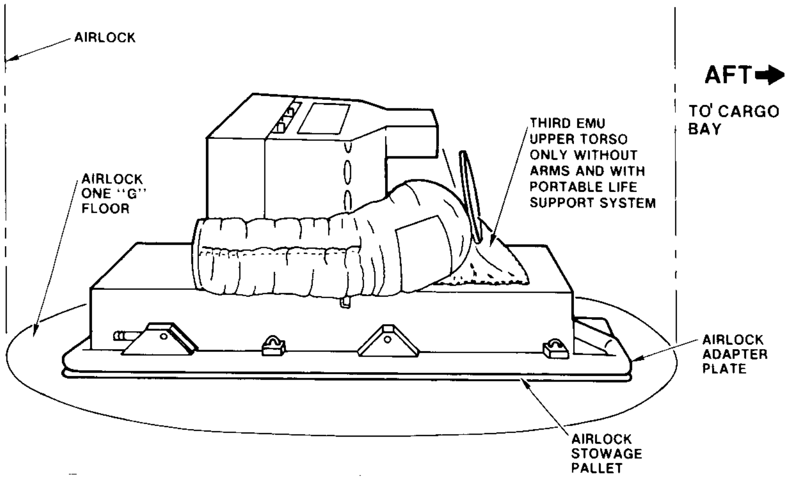
The STS-6 extravehicular activity (EVA) scheduled for both mission specialists requires the use of the airlock in the spacecraft and two extravehicular mobility units (EMU's).

A third EMU upper torso only, without arms and with portable life support system is stowed in the airlock on the one "g" floor.

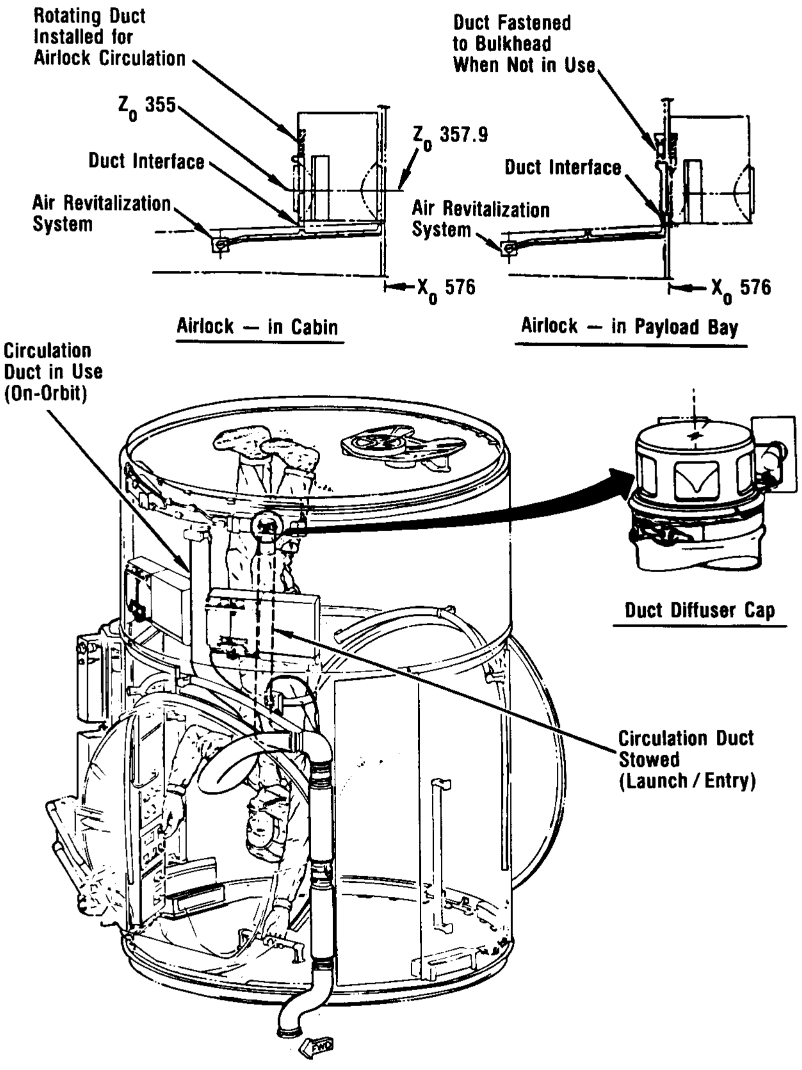
The airlock and airlock hatches permit the EVA flight crew members to transfer from the mid-deck crew compartment into the payload bay without depressurizing the orbiter crew cabin.

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).



Third Extravehicular Mobility Unit (EMU) Stowed in Airlock



Airlock

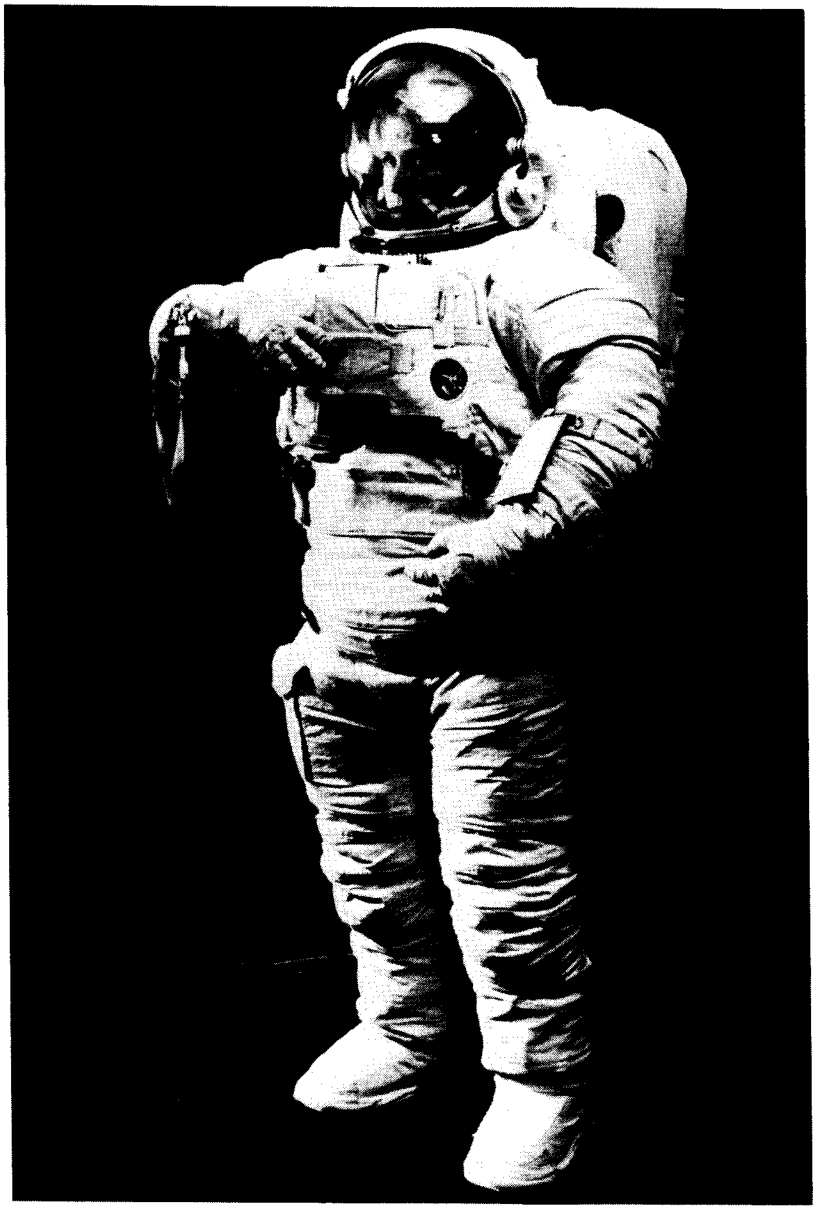
The airlock is sized to accommodate two fully suited flight crew members simultaneously. The airlock support provides airlock depressurization and repressurization, EVA equipment recharge, liquid cooled garment water cooling, EVA equipment checkout, donning and communications. All EVA gear, checkout 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.

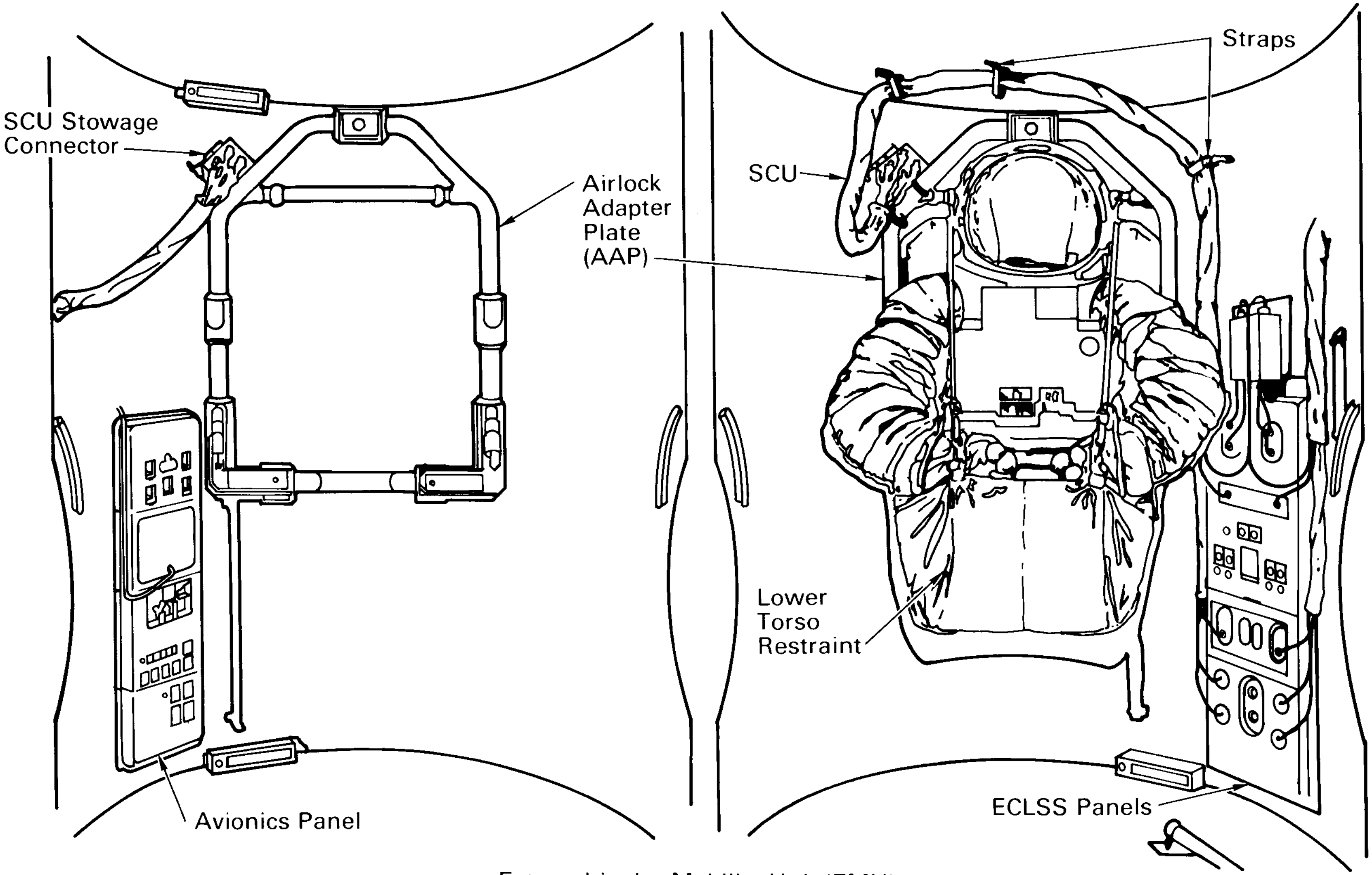
Airlock repressurization is controllable from inside the orbiter crew cabin mid-deck and from inside the airlock. It is performed by equalizing the airlock and cabin pressure with airlock hatch-mounted equalization valves mounted on the inner hatch. Depressurization of the airlock is controlled from 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.

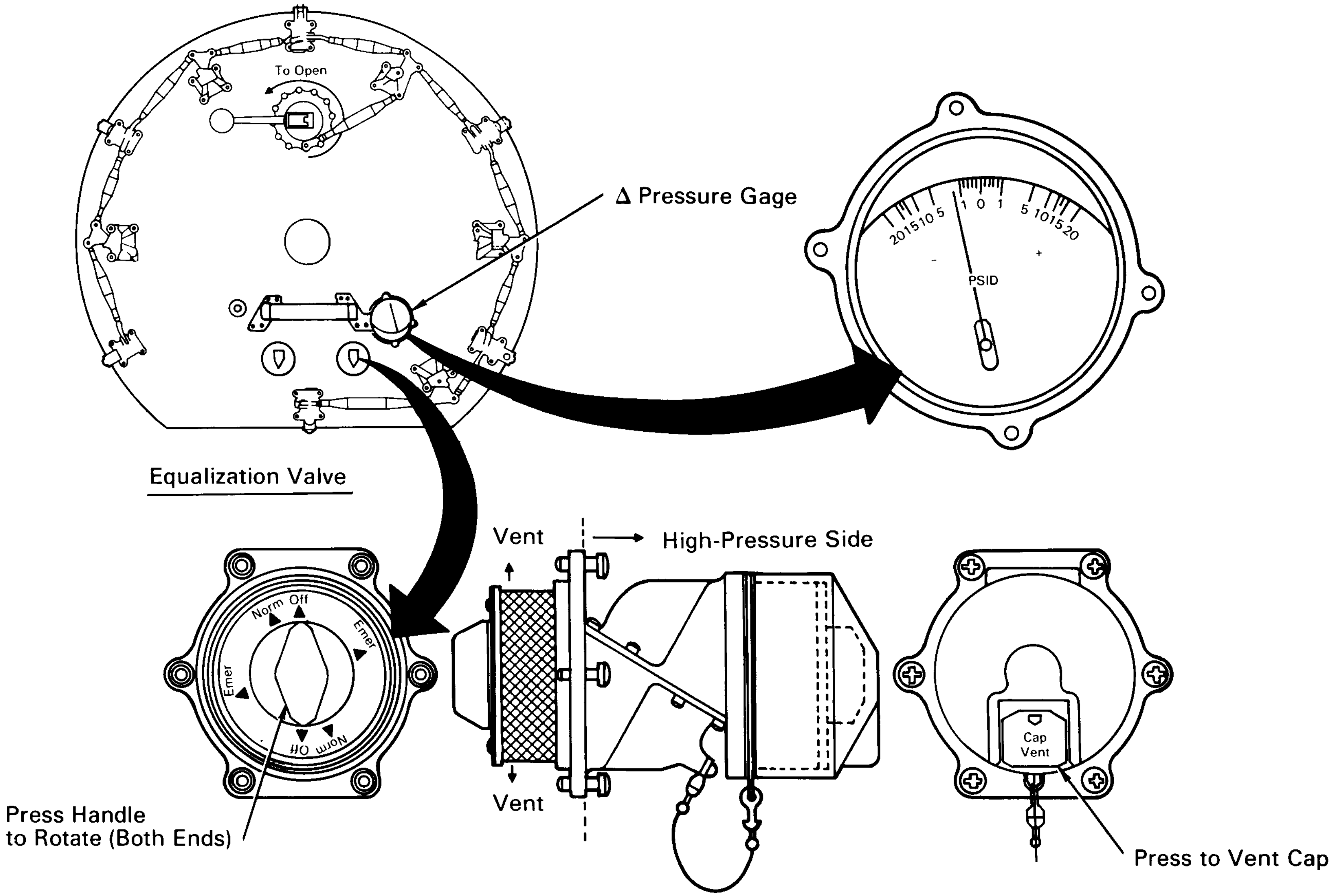


Extravehicular Mobility Unit (EMU)

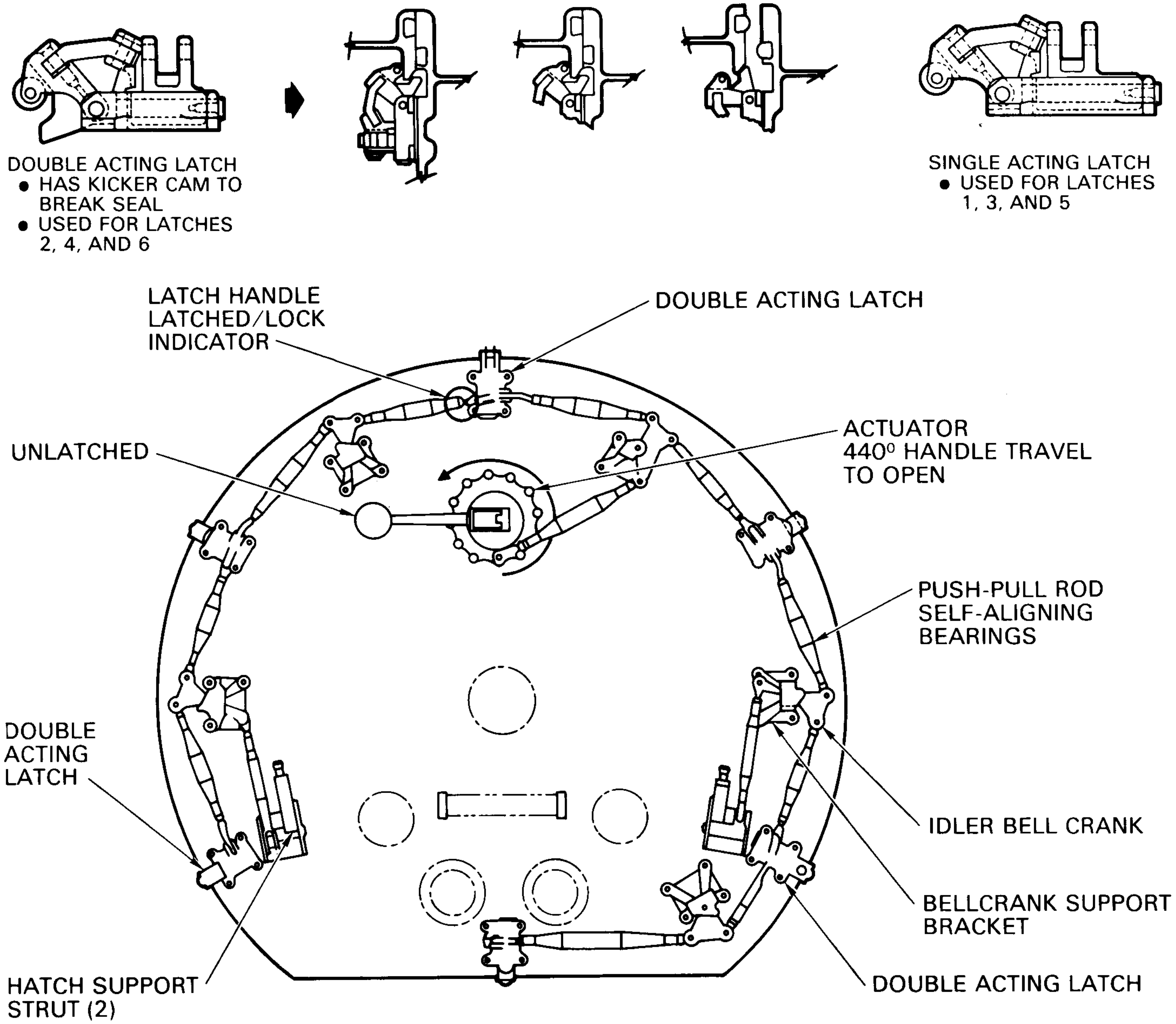


Extravehicular Mobility Unit (EMU)
Service and Cooling Umbilical (SCU)

Airlock Stowage Provisions



Airlock Repressurization



Airlock Hatch Latches

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 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 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 AW18A; 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.

Extravehicular Mobility Unit (EMU)

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 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 position 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 supplied 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).

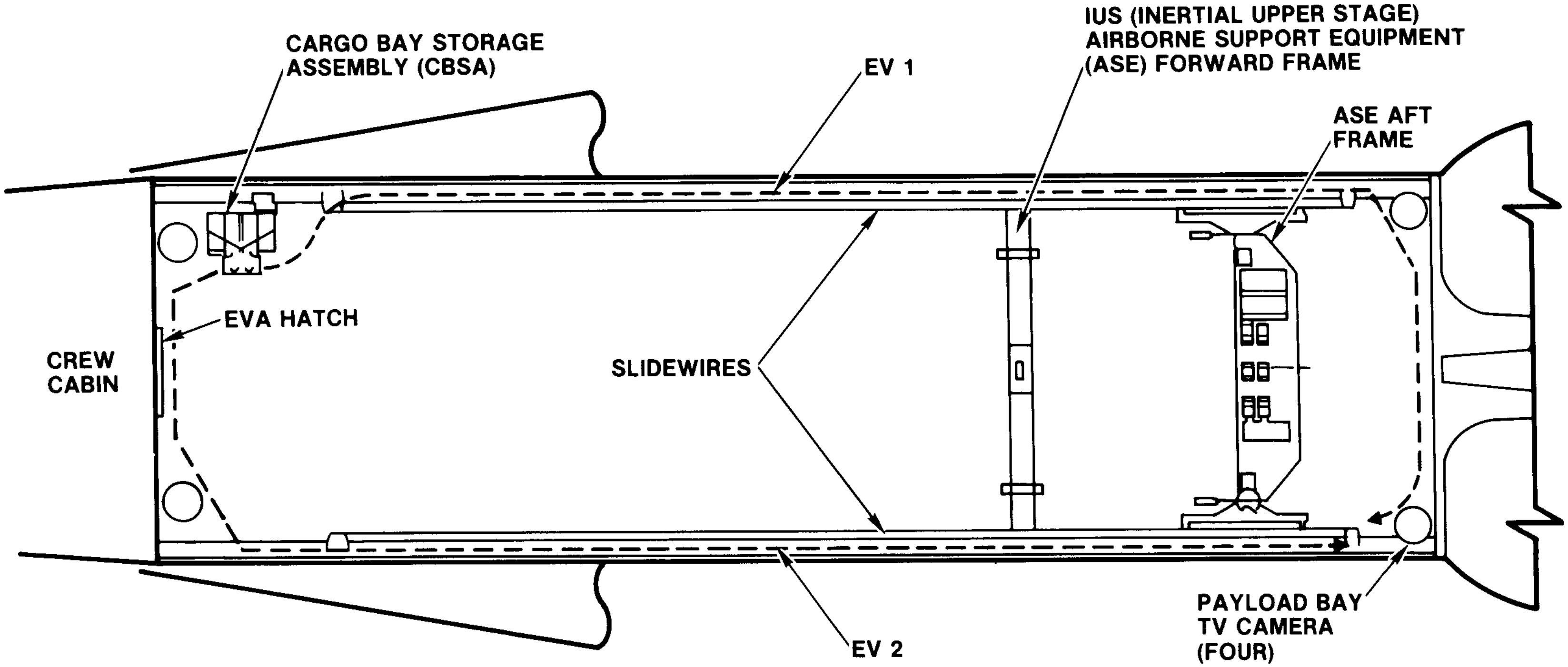
When the SCU is disconnected, the portable life support system provides oxygen for the suit. When the EVA is completed and the SCU is reconnected, the orbiter oxygen supply begins recharging the portable life support system, providing the OXYGEN valve on panel AW82B is OPEN. Full oxygen recharge takes 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.



EVA Translation Paths

Airlock depressurization is accomplished by a three position valve located on the ECLSS (Environmental Control 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.

In this flight the EVA demonstration is to verify the operational adequacy of the end-to-end EVA system, including the EMU, airlock, payload bay provisions, procedures, timelines, and training.

The EVA crew members will be designated EV1 and EV2. Story Musgrave is EV1 and Donald Peterson is EV2. EV1 is attached to the starboard tether and EV2 is attached to the port tether. It is noted that each of the following activities is independent and can be performed in any order without a significant timeline impact. The timeline will be relaxed and will enable the EVA crew members to terminate the EVA at anytime with a minimum of equipment reconfiguration. The duration of the planned EVA is three hours and 30 minutes.

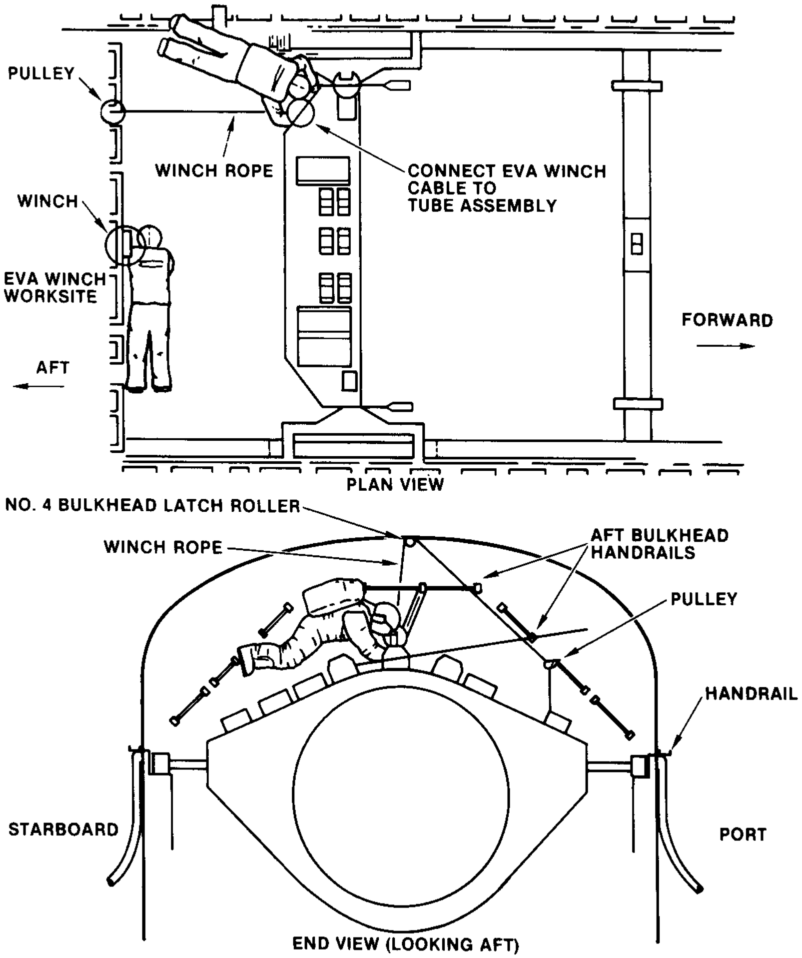
Translation to the Aft Bulkhead. EV1 will translate to the Cargo Bay Stowage Assembly (CBSA) on the starboard forward section of the payload bay. EV1 will open the CBSA and don a restraint device known as a mini-work station. They both will then translate to the aft bulkhead in series so that one can monitor the other during translation. EV1 will translate down the starboard side first, then EV2 will translate down the port side. The translation evaluates translation rates, safety tethers, handholds and miscellaneous restraints/tethers, EMU communications performance from various places in the payload bay, payload bay and EMU lighting provisions, and work sites for possible contingency EVA's. The time for this is approximately 15 minutes.

Safety Tether Dynamics. Both crew members will return to the forward bulkhead on the port side. EV1 will stop at about the mid-point of the port hingeline and evaluate safety tether dynamics. He will attach to the port slidewire with waist tethers and let his safety retractable tether pull him toward the starboard side. When he is pulled to the center of the payload bay, he will evaluate his ability to control rotation of the EMU by varying tension on the tethers. This exercise is to evaluate the reel-in characteristics of the safety tether. The time for this is approximately 45 minutes.

EMU Mobility Evaluation. EV1 will ingress the foot restraints at the CBSA and go through a series of motions in the EMU to evaluate general mobility. He will evaluate the range of motion and stability of each joint (shoulder, elbow, waist, knee, ankle). He will also determine his maximum reach envelope at the work station restrained in the foot restraints. His activities will be documented on the closed circuit television cameras in the payload bay. The time for this is approximately 15 minutes.

Tool Box Operations. Both crew members will evaluate operations at the CBSA. They will evaluate the foot restraints, door (CBSA) operations, removal/restowage of tools, tether management (always keeping tools tethered), and general accessibility and visibility of all areas. The time for this is approximately 15 minutes.

IUS Contingency EVA Operations. An EVA is not required for normal IUS/TDRS deployment, but EVA does provide system redundancy necessary for mission success or flight safety. If the primary and secondary tilt electromechanical actuators should fail leaving the tilt table in a position other than stowed for entry, an EVA will be performed to stow the table. The EVA consists of routing the aft bulkhead winch rope to the tilt table through a pulley and connecting it to a tube assembly at the base. The EVA crew member then disconnects the tilt table drive mechanism (slip ring) and stows the table by cranking on the winch. In the STS-6 mission, this will be



Inertial Upper Stage (IUS) Airborne Support Equipment (ASE) Contingency Extravehicular Activity (EVA) Operations simulated. The winch rope is set-up and the port (left) side tilt table drive mechanism (slip ring) will be disconnected. No loads will be applied to the tilt table which will already be in the stowed position. The time for this is approximately 25 minutes.

Forward Bulkhead Winch Operations. The EVA crew members translate back to the forward end of the payload bay to set up the forward bulkhead winch to demonstrate their ability to apply a load with the winch, both with and without foot restraints. The foot restraint will be installed on the boom which runs across the bulkhead. The winch rope will be routed through pulleys on the bulkhead handrails and then to the tool box where it will be attached to a variable friction device (exergenie). The EVA crew members will apply loads and simulates payload bay door closure. The exergenie provides a resistance of 100 pounds force as the EVA crew members torque the winch in and out of the foot restraints. The time for this is approximately 30 minutes.

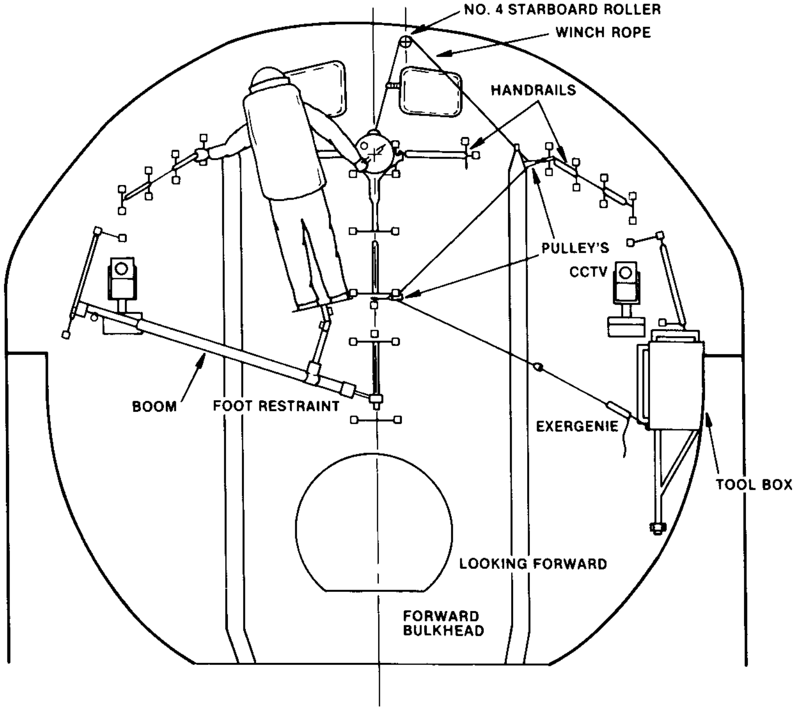
Payload Retention Device (PRD) Operation. The EVA crew members will evaluate the payload retention device (PRD) by installing it between the exergenie at the CBSA and a forward bulkhead handrail. The PRD is similar to a cargo strap and can be used in contigency situations to position a deployable payload for retention latch capture to tiedown the remote manipulator system (RMS), or as a backup to the payload bay bulkhead winches for payload bay door closure. The strap has a unique ratcheting control which enables an EVA crew member to apply loads without body restraints. The time for this is approximately 25 minutes.

Translation With a Large Mass. In this activity, one EVA crew member will translate down the payload bay door hinge line with a bag of latch tools. This evaluates the techniques required to translate with the tools. The time for this is approximately 15 minutes.

The EVA crew members will stow equipment and ingress into the airlock to complete the EVA activity and close the airlock/payload bay hatch. The time for equipment stowage and airlock ingress is approximately 25 minutes.

The EVA in the STS-6 mission will allow for payload bay television coverage and photography coverage. There will not be a television camera mounted on the helmet of the EVA crew member as in the STS-5 flight of *Columbia*, as this modification is not presently installed in the *Challenger* for this capability. This capability will be made for future flights of the *Challenger*.

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)



Forward Bulkhead Winch Operations

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).

MONODISPERSE LATEX REACTOR (MLR) EXPERIMENT

The monodisperse latex reactor experiment flown on *Columbia* in STS-3 produced tiny plastic spheres successfully as planned. The experiment was designed to study the feasibility of making monodisperse (identical size) polystyrene latex microspheres which may have major medical and industrial research applications.

In STS-3, the purpose of the experiment was to see whether near weightlessness in orbit would allow the polymerization reaction to continue without creaming, that is, to produce larger latex spheres without large, irregular masses of latex forming.

The examination of the product from the experiment in the STS-3 flight of *Columbia* showed that the theory was indeed correct and was 95 to 98 percent successful. Latex microspheres were made larger than scientists can produce on earth.

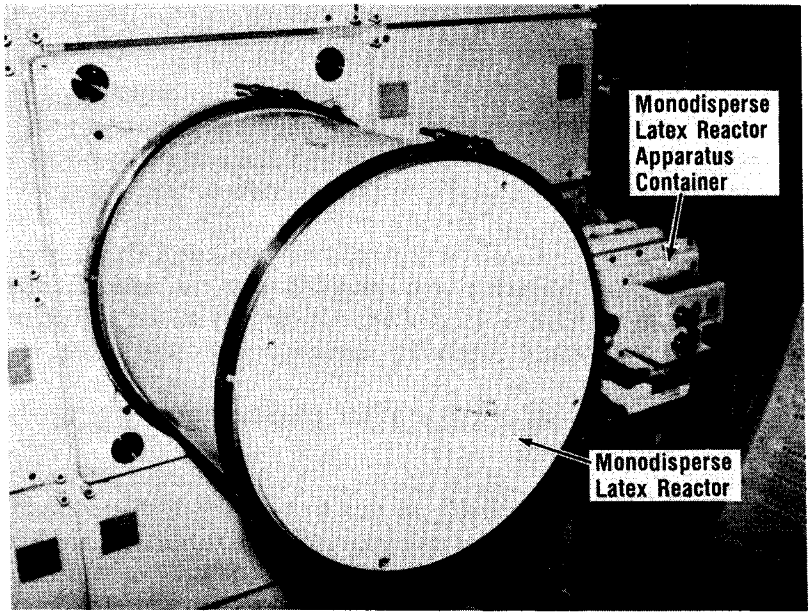
Some of the material produced in the STS-3 flight of *Columbia* were used as a seed in the STS-4 flight of *Columbia* to produce larger spheres.

Each of the four reactor chambers in the STS-3 mission experiment produced about 20 percent useable solids in the 100 cubic centimeters (almost a half-cup) of raw material, each had at the start. One chamber produced spheres that were 0.2 - 0.3 microns wide as a control to be compared with ground-based spheres. The others produced spheres about 3.5 - 4.5 and 5.5 - 6.0 microns wide. Even at the largest size, it would take more than 4,200 spheres to span an inch. The largest that can be produced on the ground are 2-3 microns wide "using nonheroic measures."

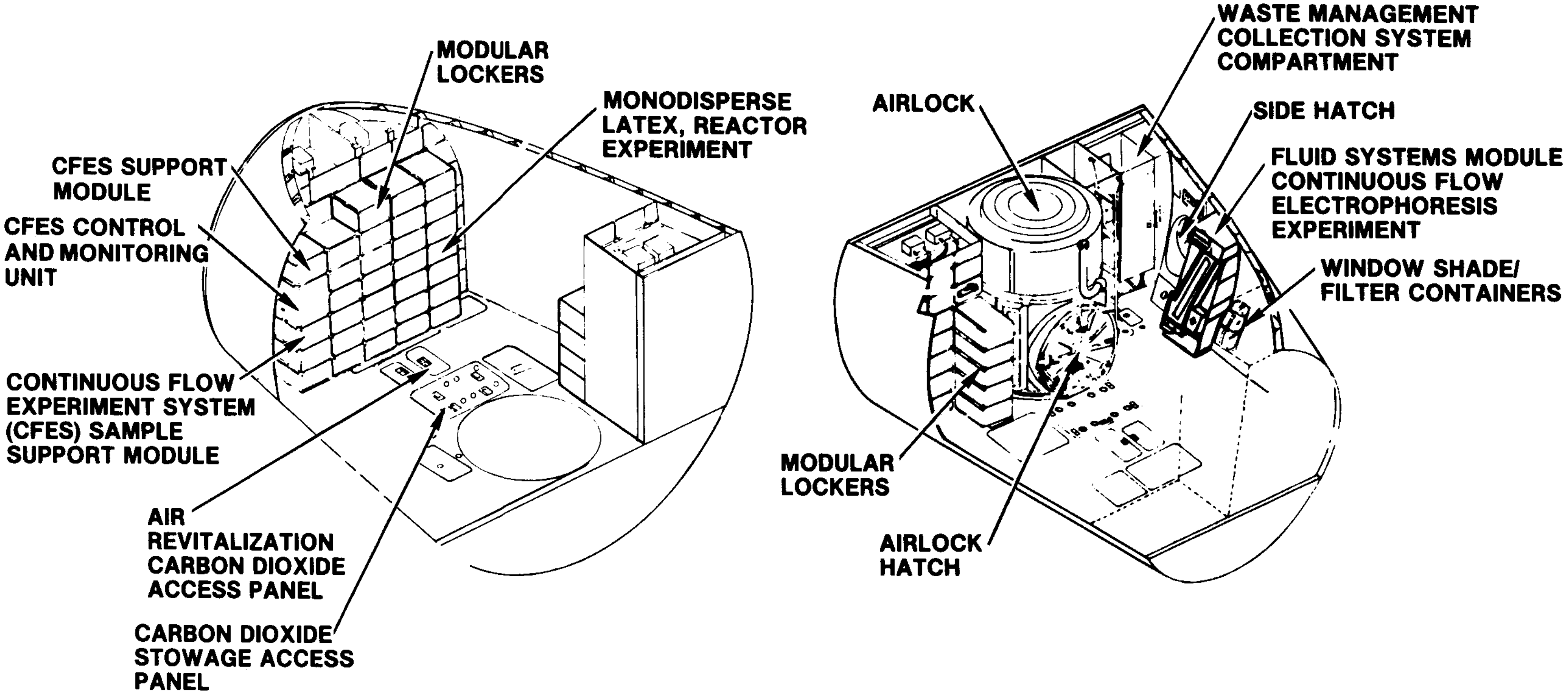
The monodisperse latex reactor (MLR) experiment on the STS-4 prevented the chemical process from taking place as planned due to a malfunction in the dc-dc converter during the mission. Four batches of latex "seed" particles from the STS-3 flight were expected to grow in a range of sizes up to 10 microns. Due to the malfunction, the chemical process was only 55 percent completed.

During the STS-6 mission, latex particles in the 10 micron diameter range are expected to be produced.

This process was discovered more than 30 years ago when Dr. J. W. Vanderhoff of Lehigh University was with Dow Chemical Company. However, since Vanderhoff discovered the process, they have been limited to a maximum size of about five microns in size and still be monodisperse because gravity causes convection and other effects that limit the reaction to very small yields at great expense and effort. The experiment will help determine if much larger (perhaps as large as 40 microns) monodisperse beads can be produced practically and econom-



MLR Experiment in Mid-Deck



Mid-Deck Configuration for STS-6

ically in space. One micron is a millionth of a meter. One inch is 25,400 microns long.

Possible applications for the spheres include measuring the size of pores in the wall of the human intestines in cancer research and measuring the size of pores in the human eye in glaucoma research as a carrier of drugs and radioactive isotopes for treatment of cancerous tumors.

If there is a major difference in pores within healthy and tumor cells, then the latex microspheres could become missiles that would stick inside tumors but not healthy tissues, thus carrying a higher drug dose in malignant tissue.

The National Bureau of Standards has also indicated its interest in routine use of the beads as calibration standards in medical and scientific equipment.

The experiment consists of four, 304 millimeter (12 inch) tall reactors, each containing a chemical latex forming recipe, housed in a 609 millimeter (24 inch) tall metal cylinder. The recipe is a suspension of very tiny (micron size) latex beads in water or another liquid which cause the beads to "grow" larger when the experiment is activated in space. In space, the latex mixture is heated to a constant 70 degrees Celsius (158°F) which initiates a chemical reaction to form the larger plastic beads.

Prior to launch, each side of the reactors are loaded with 100-cubic centimeters (6.102 cubic inches) of the chemical latex-forming recipe. A small onboard computer will control the experiment after the flight crew turns it on in orbit. A recorder will store all data produced during operation of the experiment. After 20 hours, the experiment turns itself off.

The reactor is removed from the *Challenger* spacecraft at the landing site and returned to the experimenters for sample and data analysis. After a cleanup and refurbishment of the experiment hardware, it will be ready for another flight.

The MLR experiment is located in the crew compartment mid-deck. It occupies the space of three mid-deck stowage lockers. It requires electrical power from the spacecraft to maintain timing and provide intermittent stowing operations in orbit.

The principal investigator on the experiment is Dr. John W. Vanderhoff of Lehigh University. The three co-investigators are Drs. Fortunato J. Micale and Mohamed S. El-Aasser, of Lehigh University, and Dale M. Kornfield of the Marshall Space Flight Center, Huntsville, AL.

Marshall Space Flight Center Payload Project Office, supported by the Center's Space Sciences Laboratory is responsible for producing and testing the experiment. The Spacelab Payload Project Office is also responsible for experiment safety and interfacing requirements for Space Shuttle flights.

Design support and integration of the experiment was provided by Rockwell International's Space Transportation and Systems Group, Downey, CA. General Electric Company, Valley Forge, PA built the reactors.

CONTINUOUS FLOW ELECTROPHORESIS SYSTEM (CFES) EXPERIMENT

The continuous flow electrophoresis experiment (CFES) in the STS-4 flight processed about 500 times more biological material in the weightlessness of space than can be achieved in similar operations on earth. Two test mixtures were separated: a laboratory standard mixture of egg albumin and rat albumin and a cell culture fluid containing many type of proteins. The rat and egg albumin samples were processed at concentrations by weight of one percent, 10 percent and 25 percent compared with the typical concentration of about 0.2 percent that can be successfully processed in an earth-based electrophoresis unit.

In the STS-6 mission, McDonnell Douglas will seek to verify that CFES separates materials to purity levels four times higher than those possible on earth. Similar protein samples flown in the STS-4 mission will be separated in the STS-6 mission.

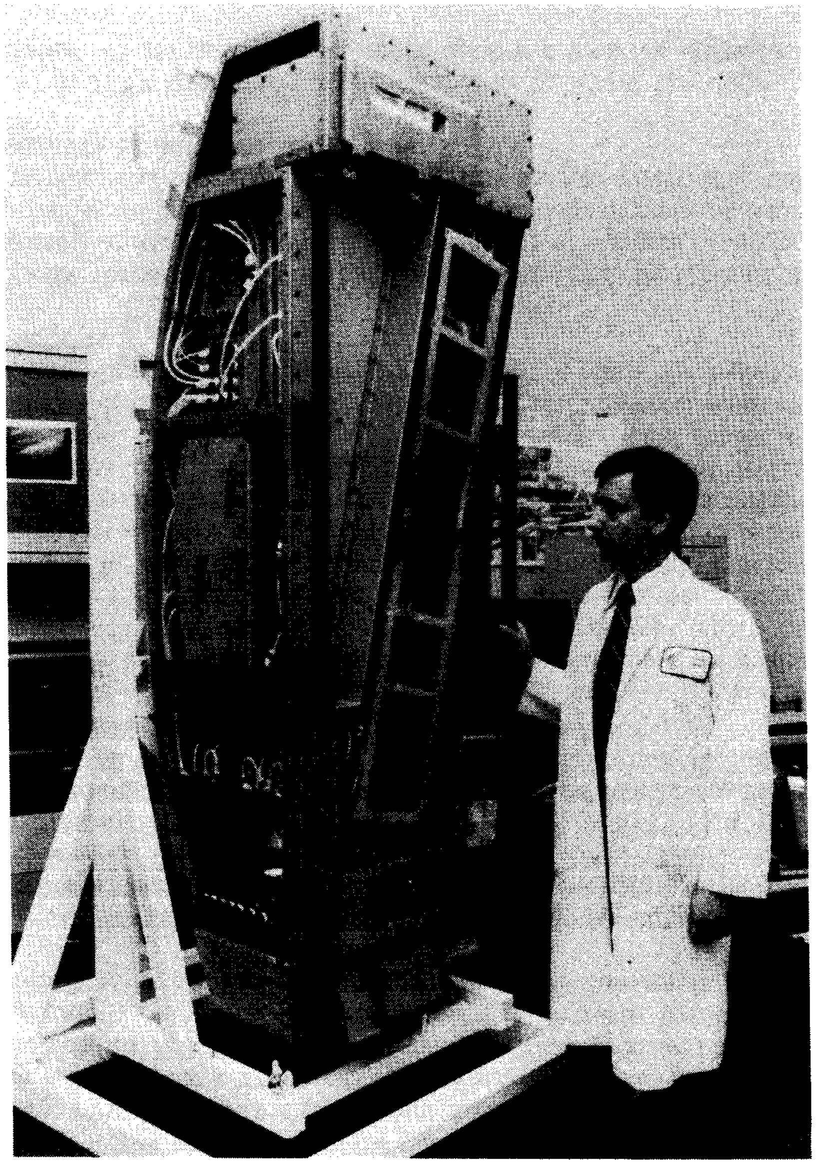
In the STS-6 mission, scientists of the Marshall Space Flight Center Space Sciences Laboratory will also use the CFES for their research. NASA's use of CFES is part of the consideration provided to the space agency under the terms of the NASA/McDonnell Douglas Joint Endeavor Agreement. This agreement 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. The primary NASA sample consists of hemoglobin, which will be the initial sample to run in the CFES during the mission. It is a high concentration of hemoglobin and will be used to evaluate the flow profile during CFES operation in weightlessness. The second NASA sample to be separated will be composed of a mixture of hemoglobin and a polysaccharide and is intended to evaluate resolution of the separation and investigate separation of different molecular configurations. NASA's experiments are being carried out by Dr. Robert Snyder, chief of the Separation Processes Branch at Marshall. He is assisted in the study by Dr. John Sloyer, a member of Snyder's staff. The joint endeavor agreement provides that general equipment performance data and the results from NASA's experiments using CFES will be made public.

The 249 kilogram (550 pound), 1.8 meter (6 feet) high electrophoresis operations in space (EOS) device is scheduled to be flown four more times in the mid-deck of the spacecraft to identify 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), 4.2 meter (14 feet) long prototype production unit to be carried in the spacecraft's payload bay on two future Space Shuttle flights. 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. 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



Continuous flow electrophoresis system 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.

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 biologicals (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.

Thus, the start of space testing is the next step. In addition, the conceptual design of a precommercial space flight pilot plant has been initiated. Present plans call for pilot plant demonstration in 1985 or 1986. Maintaining this schedule could result in commercial operation in 1986 or 1987.

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.

McDonnell Douglas anticipates that following successful experimental work, approximately six more years would be necessary before commercial operations can begin; five years would encompass product research and development, space flights to verify technology and to demonstrate a scale-up pilot plant. The additional year is to obtain final Food and Drug Administration approvals.

In this flight, experiment runs will develop data related to electrophoresis separation of six (6) biological samples, each sample running for about ten minutes.

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 flight crew will be required to operate the experiment twice during the early portion of the flight. Each operating time lasts approximately seven hours.

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.

NIGHT/DAY OPTICAL SURVEY OF LIGHTNING (NOSL)

NOSL will involve the orbiter flight crew in taking motion pictures and correlated photocell sensor signals of lightning and thunderstorm as seen from orbit. This experiment was flown on the STS-2 and STS-4 flights. In order to gain aditional weather data, NASA has scheduled the NOSL to fly on STS-6.

In the STS-4 mission, the most impressive bit of data gathered during the flight shows lightning bolts which formed a huge "Y" shape illuminating an area as large as 400 kilometers (248 statute miles). The photographs of the thunderstorms from orbit, taken over South America during a night pass, revealed lightning bolts as long as 40 kilometers (24 statute miles), and simultaneous occurrences of lightning at 100 kilometers (62 statute miles) from the apparent center of the storm activity. The data from the lightning survey may lead to a better understanding of the evolution of lightning in severe storms.

The area of the Earth's surface in the view of the orbiting spacecraft is so large that lightning storms will probably be visible on almost every orbit. Because of the high speed of the orbiter, these storms will remain in view only a short time, just a few minutes for storms directly beneath the flight path, somewhat longer for storms off to either side.

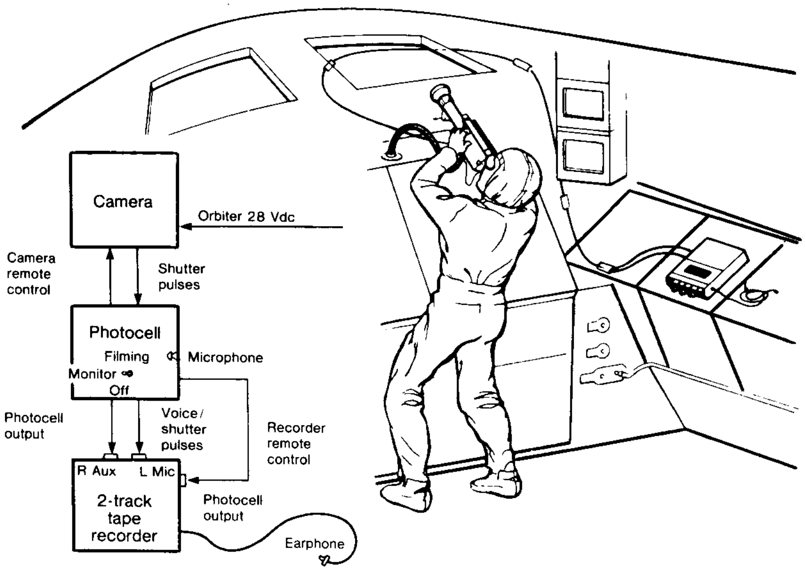
During passage over the dark side of the Earth, observers in the orbiter will readily recognize nocturnal storms by their lightning flashes, which should be visible for hundreds of kilometers (miles). On the sunlit side of the Earth, the crew will recognize storms by their prior familiarization with the appearance of cumulonimbus clouds and associated anvils as viewed from above. An observer can also locate lightning storms by listening to the audio signal from the photocell detector in monitor mode (as radiation is located using a Geiger counter).

Candidate storms for this experiment will be targeted for the astronauts by a team of scientists at Marshall Space Flight Center Space Science Laboratory using a sophisticated developmental weather system called the Man-computer Interactive Data Access System (McIDAS). When a potential storm is identified along the projected track path of the spacecraft, the coordinates are supplied to Mission Control at the Johnson Space Center so that the astronauts will be alerted at the appropriate time. McIDAS is a NASA- and -NOAA (National Oceanic and Atmospheric Administration)-sponsored system based at the University of Wisconsin, Madison, which furnishes the Marshall Center team and other research groups with a mix of vast amounts of ground data and satellite weather information.

When a target is in view, a crewmember will mount the camera so that it can photograph through the overhead window of the crew cabin. The tape recorder will be mounted on the aft bulkhead. Using both visual and audio clues, the observer will focus the camera on the target. The camera will film the lightning storm while audio signals corresponding to camera shutter pulses are recorded on one track of the stereo tape recorder and the photocell output is recorded on the other track.

The crew will use a motion picture camera to film the lightning flashes of nighttime thunderstorms. A diffraction grating will be attached to the camera lens during nighttime observations to provide lightning spectrographs, which can be used to determine the temperature, pressure, molecular species, electron density, and percent ionization in the lightning's path. During the day, lightning discharges will be delineated by a photo-optical system, which creates an audio pulse in response to the detection of a lightning flash. These pulses will be recorded on magnetic tape. A lightning event, which is visible as only one flash, is usually composed of many separate discharges, called strokes, which can be detected by the photocell. Thus, the photocell will also be used during the night to record lightning strokes. And the motion picture camera will be used during the day as well to film the cloud structure and the convective circulation in the storm. These techniques may be adaptable to identifying severe weather situations from future meteorological satellites.

The NOSL equipment consists of the camera, the attached photocell sensor, and the connected tape recorder. During launch, boost, and reentry, this equipment will be secured in stowage lockers in the crew compartment. In orbit, the equipment will be retrieved and assembled for use in the crew cabin. Because it is both stowed and used in crew quarters, the NOSL apparatus has been designed to withstand the same pressure, temperature, humidity, and acceleration conditions that human beings can tolerate.



Night/Day Optical Survey of Lightning (NOSL)

The motion picture camera is a 16-mm Data Acquisition Camera (DAC), a model which has been flight tested on Apollo and Skylab missions. The camera will run on 28 Vdc power supplied by the orbiter.

The photocell sensor is mounted on top of the camera, and its field of view is aligned with the camera's. The camera/sensor package is 40 centimeters (15 inches) long, 24 centimeters (9 inches) wide, and 20 centimeters (7 inches) high. The photocell/amplifier assembly contains its own battery power supply.

The stereo cassette tape recorder, 25 centimeters (9 inches) long, 18 centimeters (7 inches) wide, and 6 centimeters (2 inches) high, is a Sony TC 124, equipped with a plug-in earphone. The tape recorder interfaces with the photocell, which in turn interfaces with the camera, via connecting wires. The recorder is battery powered.

Twenty 42 meter (140 feet) film magazines, three 60-min. tape cassettes, and spare batteries will be kept in a stowage apron mounted on the crew cabin wall.

The NOSL has been planned by Principal Investigator Bernard Vonnegut of the State University of New York at Albany and by Co-Investigators Otha H. Vaughan, Jr., of NASA's Marshall Space Flight Center and Marx Brooks of the New Mexico Institute of Mining and Technology, Socorro. The equipment was developed by the Experiments Systems Division at the NASA Johnson Space Center.

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.

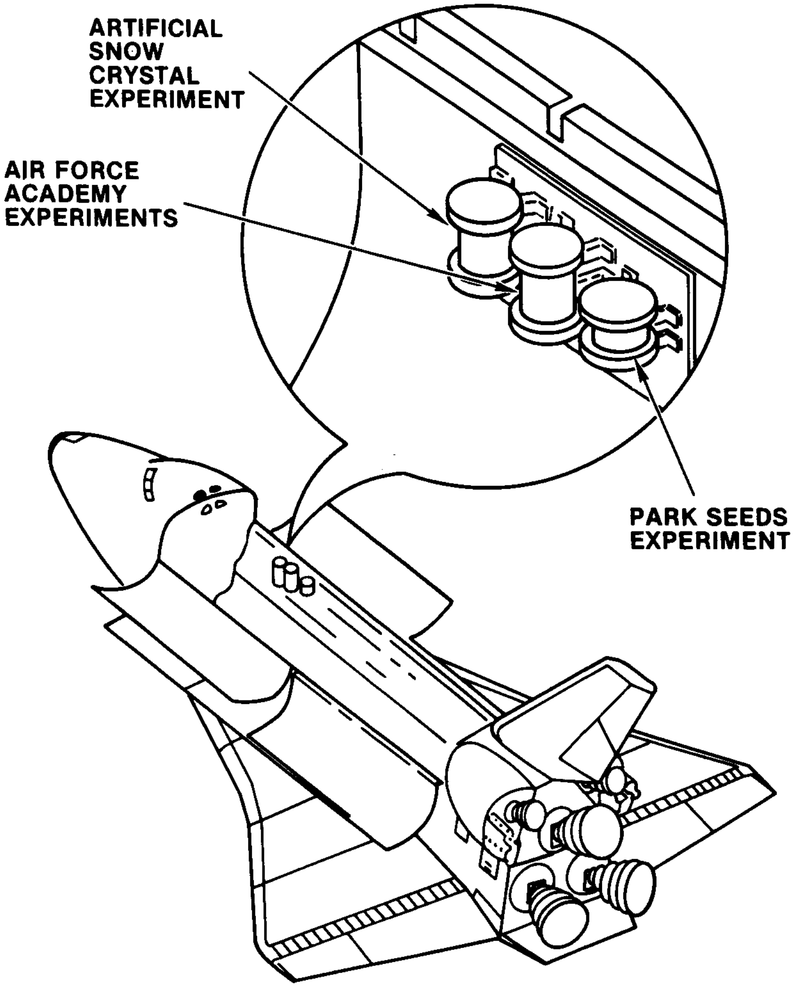
In flight, the flight crew will turn on and off up to three payload switches, but there will be no opportunity for flight crew monitoring of GAS experiments or any form of in-flight servicing.

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.



Getaway Special Experiments on STS-6

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.

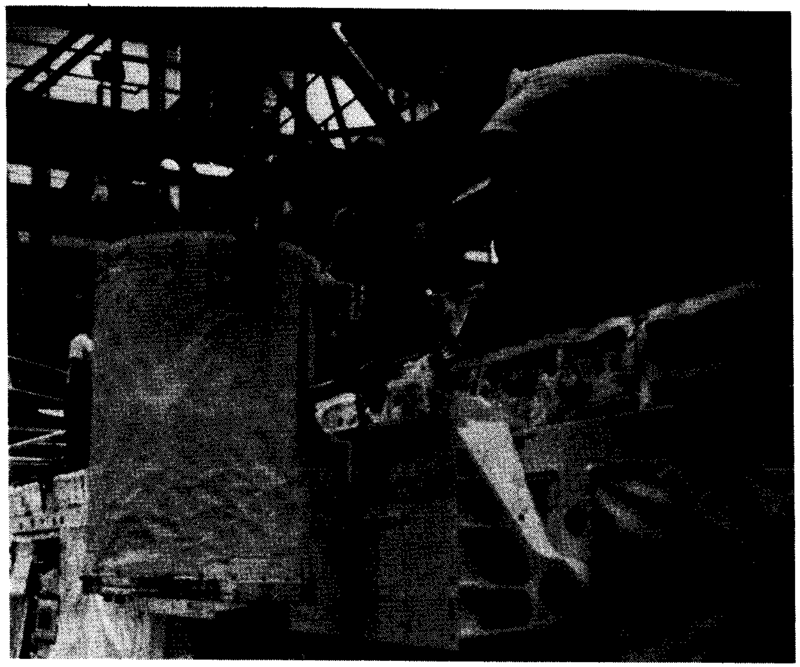
Three GAS experiments will be flown on STS-6. The three GAS containers are located on the starboard side of the *Challenger's* payload bay forward of the IUS-2/TDRS-A. Two of the experiments are 0.14 cubic meter (5 cubic feet) containers at $10,000 each and the remaining experiment is a 0.07 cubic meter (2.5 cubic feet) container at $3,000.

Artificial Snow Crystal Experiment. A 0.14 cubic meter (5 cubic feet) experiment sponsored by the Asahi Shimbun newspaper in Tokyo, Japan, one of the largest newspapers in Japan with a circulation of 8 million. The snow crystal experiment was selected from among 17,000 ideas solicited from its readers. The idea to make artificial snow flakes in the weightlessness of space was proposed by two Japanese high school students, Haruhiko Oda and Toshio Ogawa (both boys).

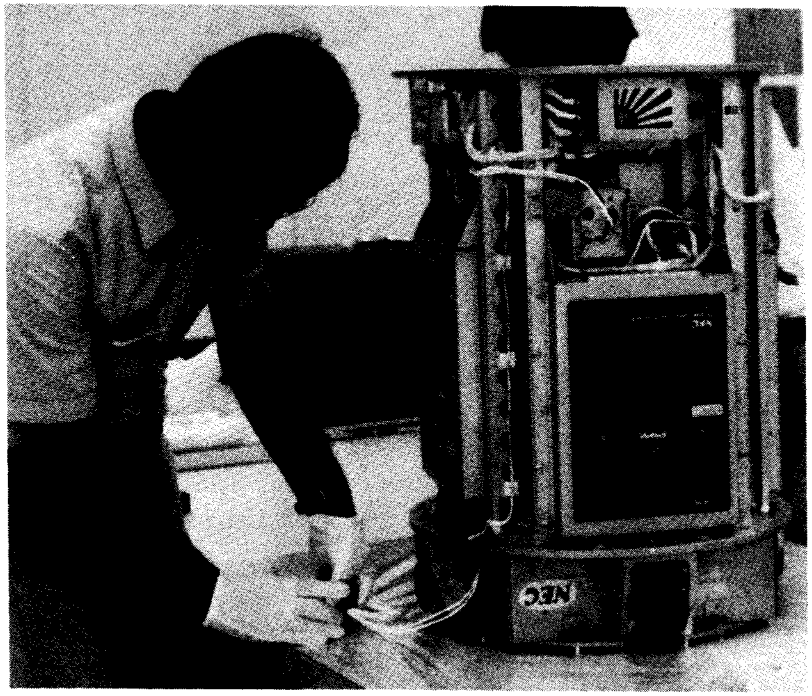
The reason Asahi Shimbun chose the snow experiment stems from the fact that the first artificial snow crystal in the world was made and investigated by a Japanese physicist, the late Ikichiro Nakaya, in 1936. Thus, Asahi Shimbun is planning to make the world's first snow crystals in space.

The heart of the payload is two identical small copper boxes 38 millimeters x 38 millimeters x 99 millimeters (1.5 inches x 1.5 inches x 3.9 inches). Two semiconductor cooling modules are attached to each box to cool down the inside of the boxes to 15 degrees Celsius (5 degrees Fahrenheit). On the end of the box, there is a small container made of porous sintered metal in which 20 grams (0.7 of an ounce) of water is stored.

In the near weightlessness of space, the water in the container will be heated by a simple electrical heater up to 20 to 30 degrees Celsius (68 to 86 degrees F) to generate water vapor which will be supplied continuously into the cooled box. Then, a very small platinum heater on which a few milligrams of silver



Getaway Special Container



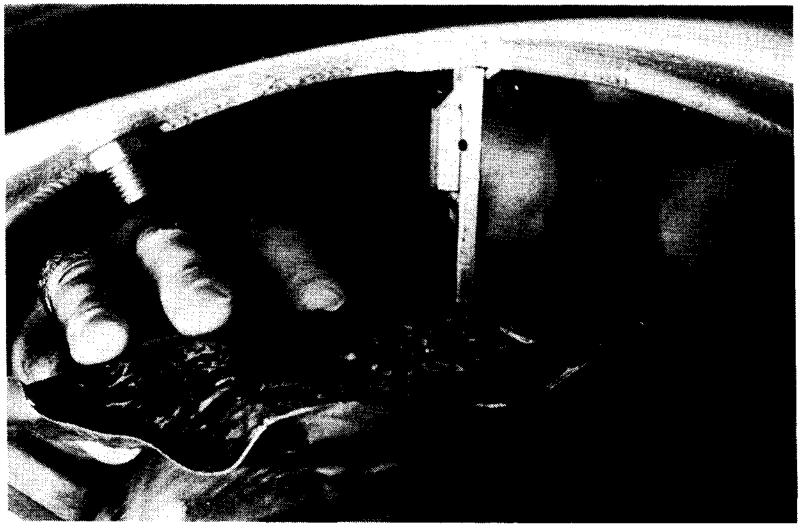
Japanese Snowflake Getaway Special Experiment iodine is attached will be heated up. The silver iodine will sublimate and small particles of the silver iodine will serve as seeds of nuclei for artificial snow crystals.

Scientists have speculated that there will be very symmetrical snow crystals in weightlessness or that some spherical crystals may be formed in space, but no one knows the correct answer.

The snow crystals formed in space will be recorded on videotape with four TV cameras and four video tape recorders within the container. The lenses of the TV cameras will magnify the images of the crystals. This experiment is self-contained, it does not use any of the orbiter services such as power, thermal control, computers, etc.

The experiment is expected to contribute to crystallography, especially the crystal growth of semi-conductors or other materials from a vapor source.

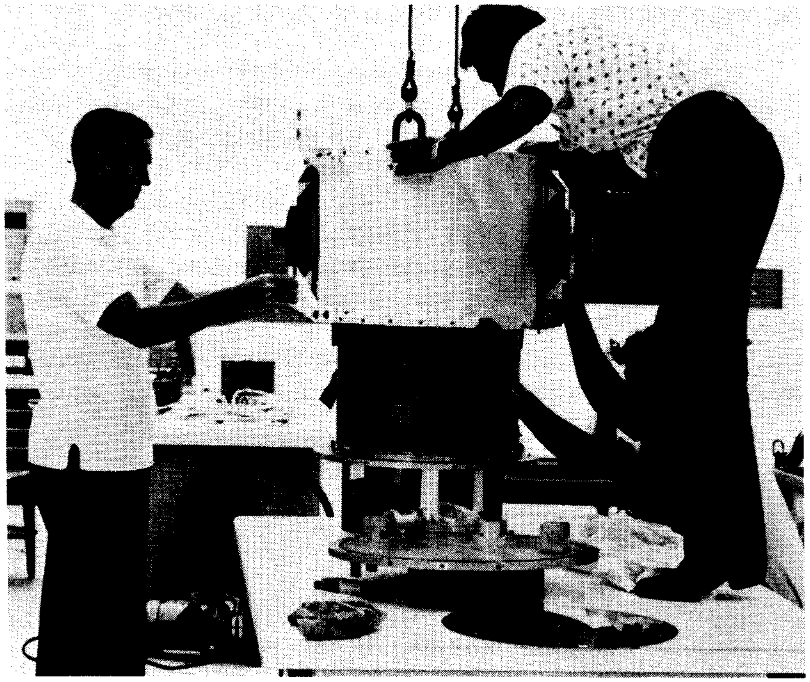
The payload was designed and manufactured by Nippon Electric Co. (NEC), which is the leading satellite maker in Japan. NEC has made 15 out of 23 Japanese satellites. Shigeru Kimura is manager of the analyses and research center for the newspaper and manager for the payload.



Greenwood, S. C. – George W. Park Seed Company's Research Director, Dr. Jim Alston, places seed in the canister.

Seed Experiment. A 0.07 cubic meter (2.5 cubic feet) experiment by the George W. Park Seed Company of Greenwood, South Carolina will send 11 kilograms (25 pounds) of some 46 different flowers and vegetables seed into space. The immediate purpose is to provide George W. Park Seed Company scientists with information about the effects of space travel on seeds. The company horticulturists will study germination rate, dormancy, vigor, and genetic mutation.

The sending of seed into space marks the first commercial or industrial application of NASA's GAS program. This is also



Kennedy Space Center, Fl. – Ground crew covers George W. Park Seed Company container with NASA's "Get Away Special" canister.

the first time that a small company has ever sent a payload into space. This is the first non-military experiment where the seeds are sealed off only by a porous filter, and will be exposed to the "raw space" environment. Previously GAS experiments have been in sealed containers.

The GAS canister will contain flower, herb, and vegetable seed as Marigold Janie Yellow, Portulaca Afternoon Delight, Salvia Hotline, Basil, Sesame, Watermelon Bush Baby Hybrid, Squash Kuta Hybrid, and Tomato Park's Whopper VFNT Hybrid. These and some other 38 varieties provide a wide range of physically different types of seed as possible to measure the different responses to a vacuum environment. They also restricted the choice to economically applicable crops such as edible soybeans which might someday be produced in space. These varieties have been tested on earth and their performance characteristics are known.

After the seed returns to earth in the *Challenger,* they will go to the Park laboratories in Greenwood, South Carolina where they will be analyzed. Park horticulturists will sow the seed to see if it performs differently from those same varieties which remained on the ground at the Kennedy Space Center or those which never left the climatically controlled seed storage rooms in South Carolina.

The Park experiment will study the impact of temperature fluctuation, vacuum, gravity forces, and radiation on germination rate, seed vigor, induced dormancy, the seed coat integrity (splits), and varietal purity (mutation rate).

Park scientists hope to use the data to develop new methods of seed packaging and storage for outer space to insure that seed will survive space travel and then produce fresh flowers and vegetables. Personnel in the first large permanently occupied space station will need these to live in good health.

The experiment will have a wider application for science in the future because analysis of the material captured in George W. Park seed's filter will have implications for all organic materials sent into outer space.

Some of the seeds are packaged in simple dacron bags, and others are sealed airtight in plastic pouches. One seed batch will be packed along the perimeter of the metal GAS container that houses the experiment, leaving it exposed to severe temperatures and cosmic radiation. Another batch of seeds will be sealed in the center of the container where there is greater shielding from the space environment.

The Park company has its own researchers among its 300 employees. The researchers plan to study the effects of the extreme temperature changes and radiation on the seeds. In some instances, extra doses of radiation may be beneficial to farmers who welcome a greater probability of seed mutations. With mutations come a genetic diversity that might mean hardier breed of plants.

Extreme fluctuations in temperature, on the other hand might take their toll. Park believes this experiment will provide some ground rules for the future transport of food in space.

The George W. Park Seed Company was founded after the Civil War and now sells 3,000 varieties of seeds.

SCENIC FAST Experiment. A 0.14 cubic meter (5 cubic feet) experiment designed by the U.S. Air Force Academy cadets at Colorado Springs, Colorado contains six separate experiments. SCENIC means Standing Academy Project Designation. FAST means Falcon Shuttle Test. The six experiments were developed in an engineering design course during the past five years.

The metal beam joiner will demonstrate that soldering of beams can be accomplished in space. The project cadet is Cadet First Class Harry N. Gross.

The metal alloy will determine if tin and lead will combine more uniformly in a zero gravity environment. The project cadet is Cadet First Class Mark Amedon.

The foam metal experiment is to foam metal in zero gravity to form a metallic sponge. The project cadet is Cadet First Class Richard R. Neel, II.

Metal purification experiment is to test the effectiveness of the zone – refining methods of purification in a zero gravity environment. The project cadet is Cadet First Class Joseph M. Streb.

Electroplating experiment is to determine how evenly a copper rod can be plated in a zero gravity environment. The project cadet is Cadet First Class Lawrence J. Peter.

Micro-biology experiment will test the effects of weightlessness and space radiation on micro-organism development. The project cadet is Cadet First Class Kenneth R. Shriner.

Four of the experiments are controlled by an internal sequencer, while the other two will be turned on separately. The two have independent battery power and one of the flight crew will turn on two switches to start the electronically-sequenced experiments at a designated time in the flight.

The integration of all of the experiments and preparing them for spaceflight is the responsibility of Major John E. Hatelid, an assistant professor of Astronautics, and the six First Class (Senior) cadets.

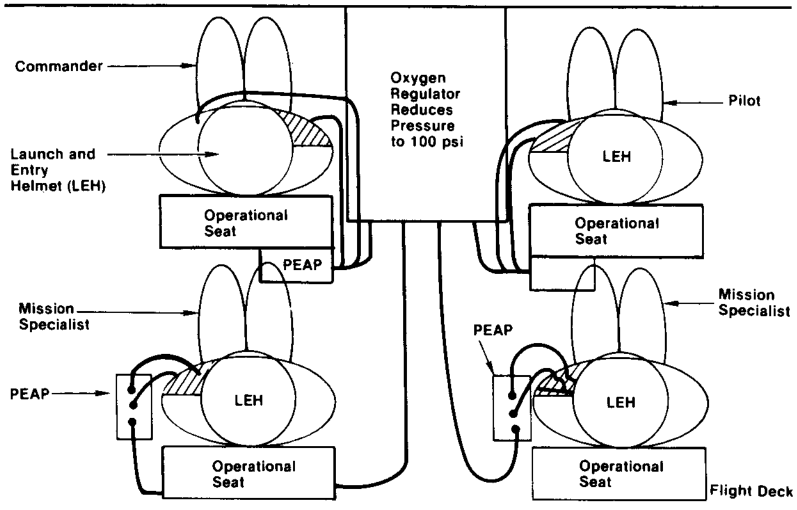
Upon return from space, the experiment samples will be compared to base-line samples produced on earth.

PERSONAL EGRESS AIR PACKS

The portable oxygen system used in the *Challenger* are Personal Egress Air Packs (PEAP's).

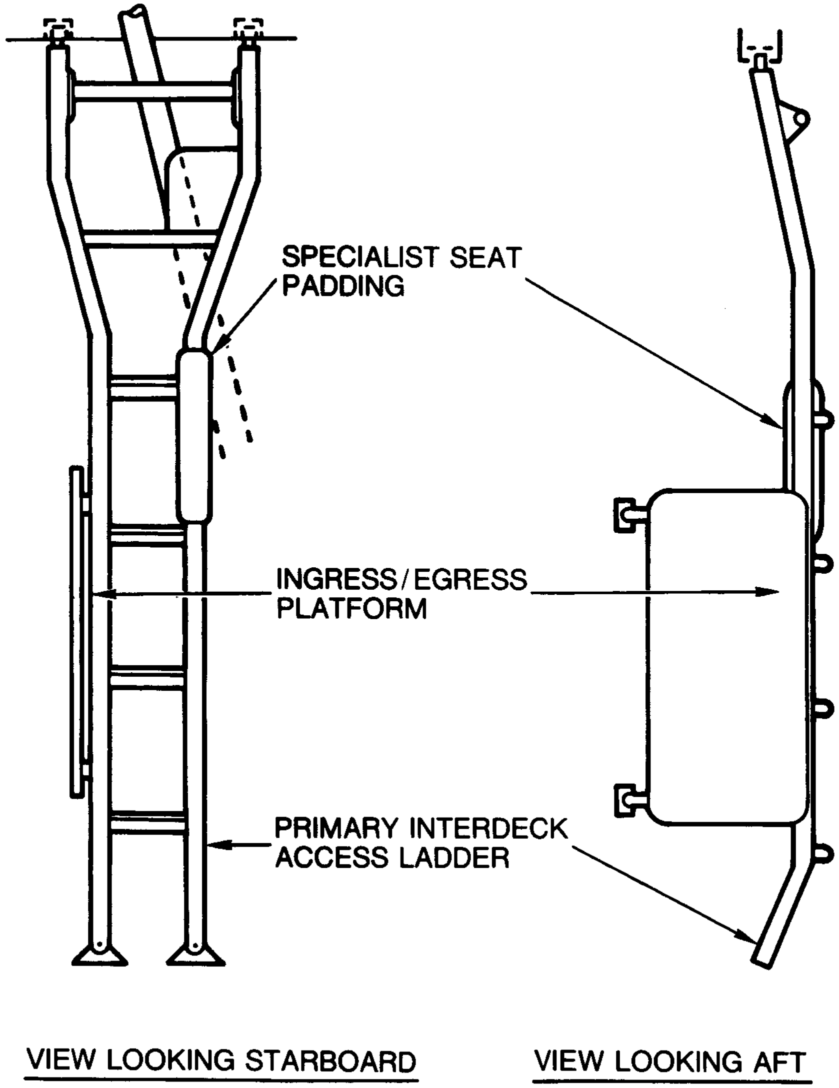
The PEAP's are designed to be used with the Launch Entry Helmet (LEH) that will be worn by each flight crew member. The LEH's are used during launch and entry and may be used for EVA prebreathing to denitrogenize the flight crew member's circulatory system.

The PEAP located at each flight crew member's seat is supplied with oxygen from the atmospheric revitalization system (ARS). Two oxygen regulators are installed to reduce the oxygen pressure to 5,175 millimeters of mercury (mmhg) (100 psi) for each PEAP. Oxygen is supplied from the regulator to each PEAP through quick disconnect flexible hoses. Each PEAP will supply that crew member with an approximate six minute walk-around capability when disconnected from the oxygen supply system.



Personal Egress Air Packs (PEAP)

Integrated Harness Restraint, Launch and Entry Helmet, and Personal Egress Air Pack



Mid-Deck Ladder Ingress/Egress Platform

Personal Egress Air Pack Launch Entry Helmet Anti-"G" Suit for Entry

HEAD UP DISPLAY

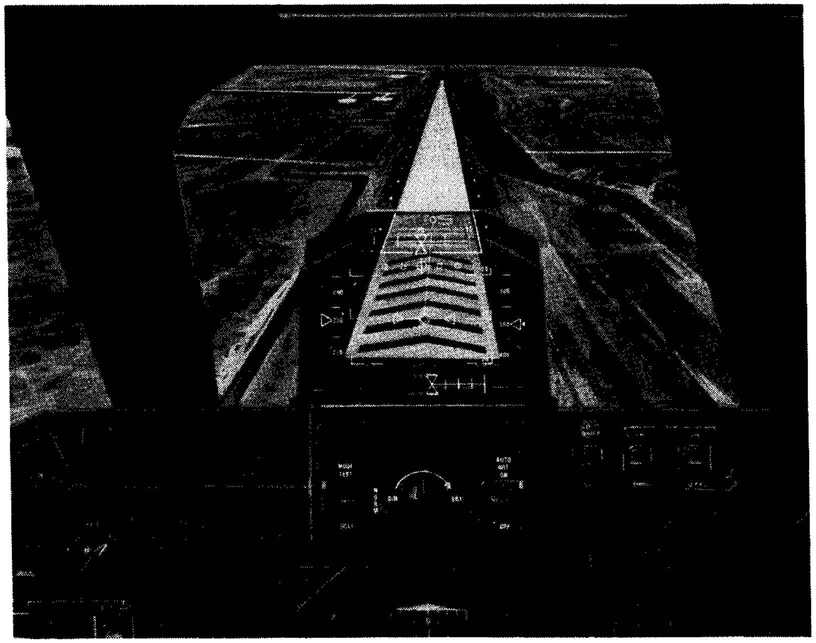
In September 1979 the NASA directed Rockwell International's Shuttle Orbiter Division to add a Head Up Display (HUD) System to the Shuttle Orbiter. This was the result of approximately two years of study activity by the NASA and Rockwell with the support of several HUD subcontractors. Rockwell awarded a letter contract to Kaiser Electronics, San Jose, California, in June, 1980 to provide a HUD system for the orbiter. The program is progressing on schedule and a pre-production hardware set was delivered to Rockwell in November, 1980 for use in the Avionics Development Laboratory for preliminary interface testing.

A head up display system allows an out of the window view while providing flight commands and information to the flight crew by superimposing this information on a transparent combiner in the out the window field of view. The baseline orbiter like most commercial aircraft utilizes conventional electromechanical displays on a display panel beneath the glareshield which necessitates that the flight crew look down for information and then up for the out the window information. During critical flight phases, in particular the approach and landing case, this is not an easy task. In the orbiter with its unique vehicle dynamics and approach trajectories this situation is even more critical.

Since the orbiter is intended to be in service for several years, it was considered appropriate that the orbiter be equipped with this system. In the study phase, it was determined that most recent military aircraft include HUD systems and that the airliners used by several European countries also contain HUD's. Additionally, it was apparent that the display portion of some existing HUD systems would lend themselves to modification for installation in the orbiter. So as to minimize development costs, the HUD system requirements for the orbiter were patterned after existing hardware.

While the display portion of the orbiter system could be similar to existing HUD systems, the drive electronics could not. The orbiter avionics is digital and since minimal impact to the orbiter was paramount, the HUD drive electronics are designed to receive data from the orbiter data buses. Most existing HUD drive electronics use analog data or a combination analog/digital interface. In the orbiter system, the HUD drive electronics utilizes to the maximum extent possible the same data which drives the existing electromechanical display devices to minimize impact on the orbiter software.

The orbiter display device as designed by Kaiser Electronics uses a cathode ray tube (CRT) to create the image which is then projected through a series of lenses on a combining glass which is very similar to a system they developed and produce for the Cobra Jet Aircraft. Certain orbiter design requirements including vertical viewing angles, brightness and unique mounting requirements dictated some changes from the Cobra Jet configuration.



Head Up Display

On the orbiter, a HUD will be installed at each flight station (Commander and Pilot). Each HUD system is single string although connected to two data buses, all redundancy is achieved and by the fact that a system is installed at each station (station redundancy similar to that used for the present displays) and the fact that the existing displays can be used in the event of one HUD failure.

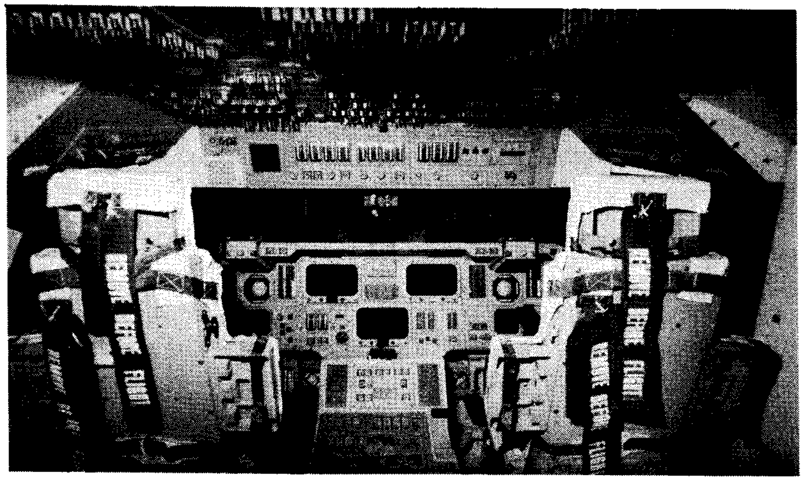
It is planned to install the HUD system on the orbiter in line in the production flow for OV-099, OV-103 and OV-104 and to build a kit which supports installation of the HUD on OV-102. In addition, several other systems are being built for test sites and simulators.

A new improved display format is being developed for the head-up display which will further reduce the commander/pilot workload during approach and landing. This improved format will be implemented on future Space Shuttle missions.

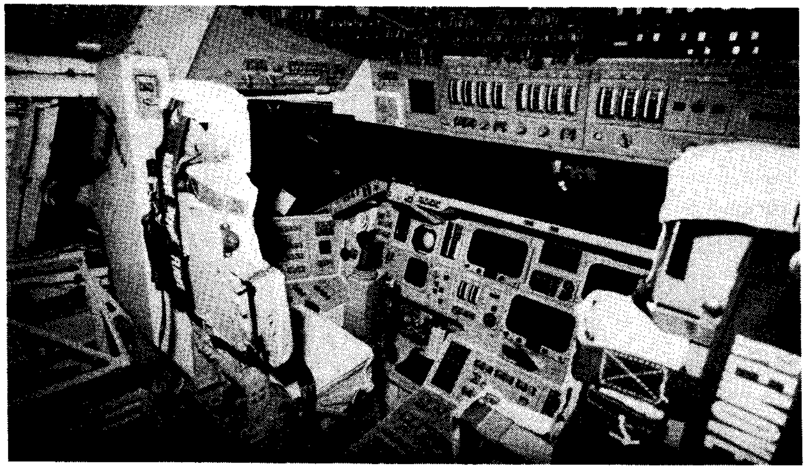
The HUD is an electronic/optical device with a set of combiner glasses located above the glareshield and in the direct line of sight of the Commander and the Pilot. Essential flight information for vehicle guidance and control during approach and landing is projected on the combiner glasses and is collimated at infinity.

In the example shown, the orbiter is in the final phase of the preflare maneuver with EAS (equivalent airspeed) = 280 kts, (knots) (left scale), altitude = 500 feet (right scale), with orbiter heading (+) slightly to the left of runway centerline – which indicates a light crosswind from the left. The velocity vector ▷ -○- ◁, is shown just crossing runway overrun. The guidance diamond is shown centered inside the velocity vector symbol. The flare triangles on the wing tips show that the pilot is precisely following the flare command. The lighted outline of the start of the runway can be seen at the top of the combiner. The HUD is capable of displaying speed brake command and position, discrete messages such as "GEAR", and during rollout, deceleration and wing leveling parameters.

The images are generated by a small cathode ray tube (CRT) and passed through a series of lenses before being displayed to the flight crew on the combiners as lighted symbology. The transmissiveness of the combiner is such that the crew can look through them and see actual targets, i.e. runway, etc. Example: Assume the crew is conducting an instrument approach and is currently at 2,133 meters (7,000 feet) on the final approach



Challenger Control and Display Panels at Commander and Pilot Station



Challenger Control and Display Panels at Commander and Pilot Station course in a solid overcast, the base of which is at 1,524 meters (5,000 feet). The lighted outline of the runway would be displayed on the combiner. Then, when the orbiter exited the overcast at 1,524 meters (5,000 feet), the lighted outline of the runway would be superimposed on the real runway.

As the orbiter proceeds down the steep glideslope, the velocity vector is superimposed over the steep glideslope aim point. At preflare altitude, the flare triangles move up to command the pullout. The pilot maintains the velocity vector symbol between the triangles. After a short period of stabilized flight on the shallow glideslope, the guidance diamond then commands a pitch-up until the nose is about 8 degrees above the horizon – which is essentially the touchdown attitude. After touchdown, during the rollout phase, the commander/pilot maintains the touchdown attitude, approximately plus 6 degrees theta (nose above the horizon) until 180 KEAS (knots equivalent airspeed), then a de-rotation maneuver is executed at one degree per second.

The HUD is an excellent landing aid and is considered the primary pilot display during this phase. As the system matures, it is anticipated that the HUD will be used for star/land mark sightings as well as rendezvous with other orbiting vehicles, space platforms, etc.

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.

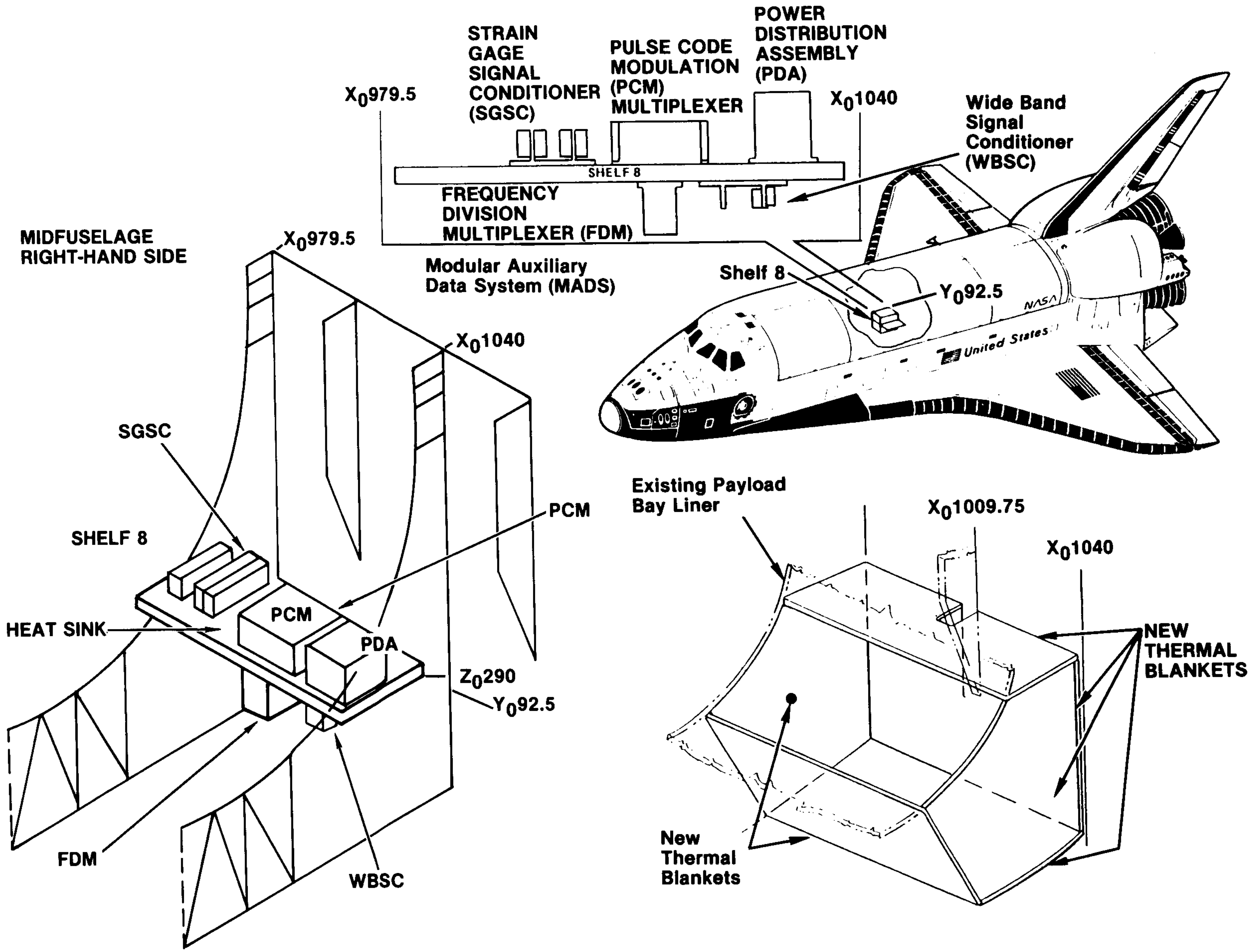
The MADS interfaces with the orbiter through the orbiter electrical distribution system and the inputs to the operational instrumentation for MADS status monitoring. Coaxial cables and wire harnesses from the sensors are routed through the orbiter payload bay harness bundles to the signal conditioners, 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-O 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 will be recording ACIP flight acceleration safety cutoff



Modular Auxiliary Data System (MADS) Mid-Fuselage

(FASCO), ET, SRB, WB, and PCM data. The MADS PCM will have a bit rate of 64 kilo-bits-per second (kbps).

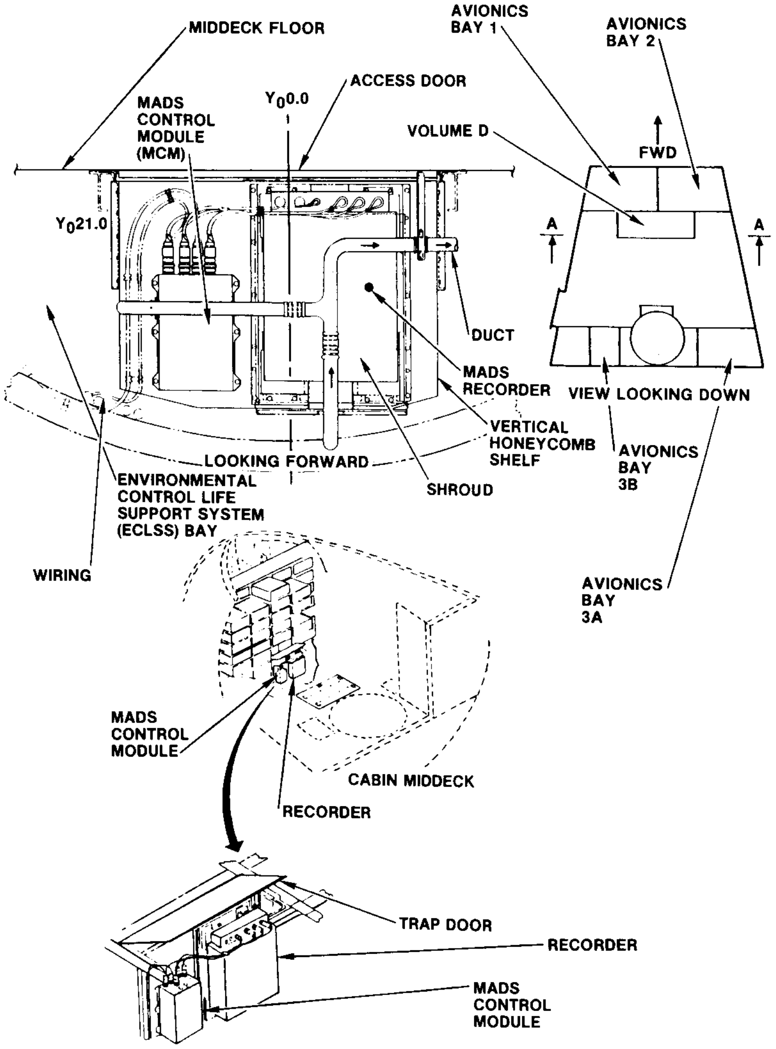
The wideband (WB) only mode will be used only during the prelaunch automatic (AUTO) and manual (MAN) calibrations. In this mode, the recorder will be recording the AC and DC current calibration levels provided by the FDM. Each manual calibration level will be recorded for 10 seconds at a tape speed of 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.

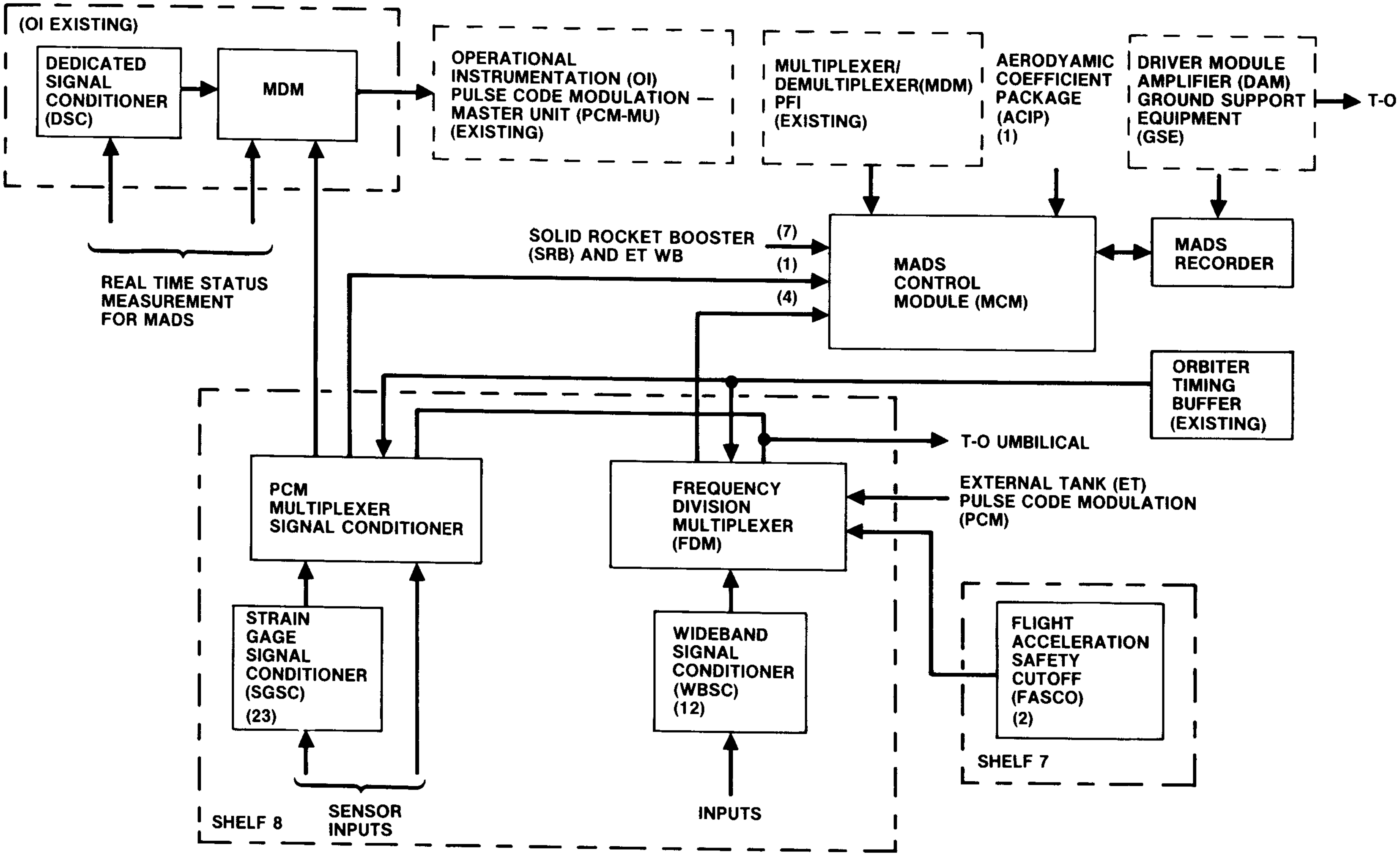
At two minutes prior to the OMS-2 thrusting period, commands will be given to put the MADS back into the full system mode until the thrusting period is completed. At this time, commands will be given to put the MADS into the PCM only mode, which will continue during the orbit until a quiescent period 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 allow the 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.

At two minutes before the deorbit thrusting period, the



Modular Auxiliary Data System (MADS) Crew Compartment



Modular Auxiliary Data System (MADS) Block Diagram

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 postlanding 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 installation 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 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-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)

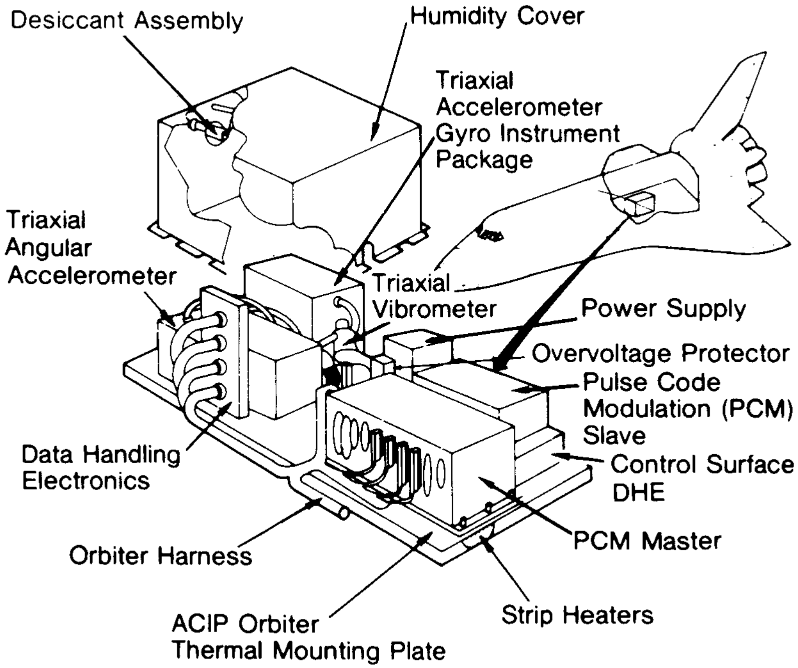
The ACIP is a sensor package installed below the payload bay area in the aft area of the mid-fuselage at station $X_0$1069. It contains a rate gyro package, a linear accelerometer package, an angular accelerometer package, and associated electronics.

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



Aerodynamic Coefficient Identification Package (ACIP) Experiment 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.

MODIFICATIONS TO *COLUMBIA* FOR STS-9 SPACELAB MISSION

1982	
Dec. 20	Start Spacelab-1 modifications
1983	
May 2	Install FRCS
May 9-11	Install SSME's
May 16	Install OMS/RCS Pods
May 23	Post mod power-up
July 1	Complete Spacelab-1 modifications
Aug. 3	Install Spacelab
Aug. 24	Transfer *Columbia* from Orbiter Processing Facility to Vehicle Assembly Building
Sept. 2	Transfer Space Shuttle *(Columbia)* from Vehicle Assembly Building to Launch Complex 39A
Sept. 30	Launch STS-9 Spacelab-1

MODIFICATIONS

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

Thermal Protection System

Densification of remaining high temperature reusable surface insulation tiles (HRSI) bottom of mid-fuselage and wings

Approximately 314 tiles wings
Approximately 2,156 tiles mid-fuselage

Elevons ablators replaced with HRSI tiles

Addition of two additional operational seats in crew compartment mid-deck for two additional scientists

Add two additional personal egress air packs (PEAP's) in crew compartment mid-deck for two additional scientists

Removal of development flight instrumentation pallet from payload bay and removal of development flight instrumentation unit from crew compartment mid-deck. Panels M042F and M058F which are mounted on development flight instrumentation unit in mid-deck are relocated to operational location. Panels R11 and R12 are interchanged. All development flight instrumentation wiring and wire trays in mid fuselage will be removed. The instruments will not be removed and sensor pigtails will be stowed. All unused connectors will have protective caps. Wiring and sensors on payload bay doors will remain.

Partial incorporation of 100 development flight instrumentation measurements into operational instrumentation.

Remove and replace four main landing gear wheels and tires

Add wiring from T-O umbilical to X_O 1307 aft bulkhead for payload requirements

Addition of tunnel adapter in payload bay, hatch on payload bay side of crew compartment mid-deck airlock moved to spacelab side of tunnel adapter, add new hatch at top of tunnel adapter for extravehicular activity and new ventilation ducting. Airlock and tunnel permit intravehicular activity from crew compartment mid-deck to spacelab in a shirt sleeve environment. If an extravehicular activity is required, airlock and tunnel adapter only are depressurized after airlock hatch and tunnel adapter hatch to spacelab are closed. Upper hatch in tunnel adapter permits extravehicular access.

Add permanent stowage compartments under crew compartment mid-deck floor, hygiene kit in waste management system area, add stowage lockers above avionics bays I and II and adds stowage locker outboard of avionics bay IIIA.

Provide cabin oxygen (O_2) flow restrictors for flight crew of seven

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

Addition of galley and personal hygiene station in crew compartment mid-deck

Crew compartment mid-deck fire extinguisher relocated from avionics bay IIIA to on the airlock

Installation of multiple headset adapter to crew compartment mid-deck ceiling

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

Remove and replace main landing gear brakes

Remove 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. Add six thermal control system blankets on lower side of mid-fuselage wire trays

Change multilayer insulation material from Tedlar to Goldize Kapton in payload bay

Redesign aft payload distribution panel to relocate existing wiring and connectors to be compatible with standard mixed cargo harness (SMCH). Add 36 holes to support wire harnesses

Add attachments in secondary structure aft flight station for standard mixed cargo harness (SMCH), adds payload console access panel

Adds one more console to existing three consoles in mission kit at aft flight deck

Two additional sky genies installed aft of overhead ejection panels for emergency egress provisions for two additional flight crew members

Payload data interleaver and pulse code modulation master unit programmable read only memory and multiplexer/demultiplexer operational instrumentation rewire to insure compatibility with the onboard (20) software

Caution and warning programmable read only limit changes

Remove one payload timing buffer in aft flight deck and replace with modified timing buffer and install one modified operational configuration orbiter timing buffer at aft flight deck

Remove and replace eight quick disconnects on crew compartment crew panels, four on flight deck, two on each of two mid-deck panels for personal egress air packs for compatibility with launch/entry helmets

Revise oxygen hose clamps to accommodate revised Government Furnished Equipment hoses

Install new panel in aft face of crew compartment flight deck center console to provide reduced oxygen breathing supply to 100 psi regulation for compatibility with launch/entry helmets

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

Add S-band switch beam control assembly in crew compartment mid-deck avionics bay 3B, adds rotary antenna select switch on panel C3A7, adds 250 wire segments and remove and replace four S-band quad antennas. Switched beam S-band system provides higher gain, narrow beam, switchable fore and (nose to tail) for tracking data delay satellite S-band

Replace S-band signal processors, replaces one switch, adds one switch on panel A1A2 and adds 26 wires external to panel

Provide various secondary support structure in payload bay for Ku-band antenna installation in mid fuselage

Add Ku-band system. Adds two boxes in crew compartment avionics bay IIIA and one box in avionics bay IIIB. Adds deployment mechanism and deploy assembly on right hand (starboard) sill longeron in payload bay. Adds three harnesses from sill to deploy assembly and adds support bracketry.

Relocate Ku-band rigid coax to facilitate installation

Remove and rework two orbital maneuvering system engines to replace bi-propellant valve due to shaft seal leakage

Remove and replace forward propellant gauging probe in orbital maneuvering system fuel and oxidizer propellant tanks. Brackets added to provide helium line support at helium line/probe flange weld joint

Remove and replace aft fuel probe in aft orbital maneuvering system fuel propellant tanks

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

Redesign liquid oxygen cryogenic tanks with heavier fill line to withstand 100 mission vibration requirements

Remove and replace six forward and two aft mission kit radiators with diffusion coated radiators for extravehicular activities and Ku-band reflection problem

Remove secondary structure from X_O 1307 bulkhead and add new thermal control system configuration and add bulkhead to wire tray transition structure to accommodate standard mixed cargo harness

Remove and replace expansion hinges at No. 1 left hand (port) and right hand (starboard) radiator hinge panels. Remove and replace silver plated nuts at mid-aft and aft radiator panels

Change location of two payload and payload interrogator data buses and wires from X_O 693 to X_O 603 for new standard mixed cargo harness cable trays near forward end of cable trays, left hand (port) and right hand (starboard) side

Remove two substack fuel cells (three power plants) and replace with three substack fuel cells (three power plants) 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

Remove STS-5 cryogenic tank heater control assembly boxes and replace old configuration with new configuration high vibration heater control assemblies

Remove and replace four radiator structural box assemblies and hose line clamp at interface of radiator to eliminate torsion load with redesigned clamp

Flight acceleration monitoring system addition consists of 12 accelerometers installed (4 per engine) on the Space Shuttle main engines. Coax cables will be routed through the engine interface to 12 signal conditioners mounted in the aft fuselage avionics bays 4 and 5. The conditioned signals will be routed to the operational instrumentation multiplexer/demultiplexers. In STS-5, the flight acceleration safety cutoff system was wired to the development flight instrumentation and was a wideband system. With the development flight instrumentation removed, operational instrumentation does not have wideband capability.

Space Shuttle main engine electrical panel rework, aft thrust structure for Space Shuttle main engine changeout from 100 percent rated engines to 109 percent and incorporation of flight acceleration cutoff system

Relocate wiring at engine interface (30 wires) to be compatible with Space Shuttle main engines

Remove and replace two retention bolts/pump at main hydraulic pump solenoid valve with high strength bolts on valve mounting flange

Replace three signal conditioners for lightweight external tank. Heavyweight external tank requires 33 to 35 psia and lightweight external tank requires 32 to 34 psia.

Re-orifice existing main propulsion system gaseous hydrogen control valve in lieu of new gaseous hydrogen flow control valves to be compatible with new lightweight external tank pressurization (minimize gaseous hydrogen vent/hazardous gas) and accommodate Space Shuttle main engine gaseous hydrogen flow capability

Provide four payload feeders from orbiter power supply. Add four fuse/fuse holders, one connector and two new harnesses. With STS-5 configuration, a failure of one payload feeder could result in loss of power to all payloads.

External tank feedline temperature adds eight wires from T-O umbilical to external tank umbilical, new seal, new pressure sensor to be compatible with lightweight external tank interface.

Add provisions for Government Furnished Equipment text and graphics, consists of secondary structure shelf supports in avionics bay IIIB, installation of shelf 3 and 4, installation of 94 wire segments

Spacelab wiring kits

STS-5 SUMMARY

"We deliver," aptly describes the STS-5 mission (Nov. 11-16, 1982), which got down to the "real business" and purpose of the Space Transportation System . . . hauling cargo into low earth orbit.

The STS-5 crew of Vance D. Brand (commander), Robert F. Overmyer (pilot) and Joseph P. Allen and William B. Lenoir (mission specialists) came up with their "we deliver" motto after they deployed into orbit the second of the two commercial satellites carried in *Columbia's* cargo bay.

The Shuttle spacecraft had now performed, proven its flight capabilities and its "worth" just the way the Rockwell International Corporation's designers and builders had said it would – words they had been saying for the past 10 years.

Now, from NASA Administrator James H. Beggs, who proclaimed "This first operational success of the Space Shuttle . . . brought NASA and the nation to this new beginning. We can all be proud of our contribution as we embark on a new age in space, with all the significance of the first train to roll over the Golden Spike and inaugurate U.S. transcontinental rail service, or Lindbergh's first flight across the Atlantic."

STS-5 began with a flawless countdown and launch on Nov. 11, 1982 from NASA's Kennedy Space Center, Fla. (launch pad 39-A) and ended Nov. 16, 1982 at Edwards Air Force Base, Calif. (the Dryden Flight Research Facility). *Columbia* on its fifth mission, carried the Satellite Business Systems (SBS)-C satellite and Telesat's (Canadian) Anik-C to their respective drop-off points 160 nautical miles (184 statute miles) above the Earth. The veteran spacecraft logged 1.5 million nautical miles (1.8 million statute miles) on STS-5, raising its five-flight mileage log to more than 8 million nautical miles (10 million statute miles).

More important than the accumulated mileage, STS-5 confirmed the versatility of the STS system and the reliability of the components – the Solid Rocket Boosters, Shuttle Main Engines and complex, 75-ton Orbiter. This first fully commercial "pay for haul" flight demonstrated the basic purpose of the Space Shuttle – reusability.

The STS-5 mission was launched from KSC, Fla., at 07:18:59 (EST) hrs. (GMT 12:18:59) Nov. 11, 1982 and landed Nov. 16, 1982 at Edwards AFB, Calif. at 06:34:29 (PST) hrs. (GMT 14:34:29).

Primary purpose of deployment of the SBS-C and Anik-C satellites was successfully accomplished. An additional objective to perform an extra vehicular activity (space walk) was cancelled when problems developed with the EMUs (Extra Vehicular Mobility Unit).

Fifty-three of the 55 detailed test objectives and detailed supplementary objectives were carried out during the flight.

Ascent phase and system performance were nominal. Main Propulsion System and the External Tank operated properly and provided a nominal trajectory at main engine cutoff (MECO). The Solid Rocket Boosters performed nominally and the booster recovery system operated well and both boosters were successfully recovered and towed back to port.

Resultant orbit parameters following the first and second OMS (Orbital Maneuvering System) maneuvers (12:29:31 and 13:03:40 GMT respectively) were 160.2 by 160.1 nautical miles (184.3 by 184.2 statute miles), very close to the targeted 160 nautical mile (184 statute miles) circular orbit.

Day 315 Launch Day Nov. 11, 1982. Following a flawless and successful launch and insertion into orbit, STS-5 *Columbia* and its four-member "we deliver" crew settled down to business on the first few hours in space.

The first day, described by NASA as an "almost flawless operation," was highlighted by the successful deployment of the SBS-C satellite, the first commercial payload carried into orbit by the Space Transportation System. Deployed at the planned time of GMT 20:17:35, the satellites perigee motor PAM (Payload Assist Module)-D was fired on time 45 minutes later. The SBS satellite was quickly acquired and tracked by ground stations. All payload and pre-deployment operations and data were normal, including sunshield opening and mechanical sequence activities. Excellent on-board television was received of the satellite deployment activities.

Shortly after launch the crew reported problems with the cathode ray tube (CRT) No. 2, a TV screen which projects systems data to the crew. The crew reported the upper right quarter of the TV screen was displayed in the lower left quarter, indicating a power supply error. This problem was reported at GMT 13:13 but was subsequently corrected later on in the mission.

Later at GMT 22:14 after connecting the GAS (Getaway Special) payload controller, the crew reported an incorrect response received from the West German experiment Project MAUS, a materials experiment that makes use of X-ray recording to investigate the behavior of metallic dispersions. The MAUS GAS experiment is the first of 25 such Get-Away-Specials reserved for future Space Shuttle flights by the West Germans.

The crew subsequently connected the controller to the other standard switch panel and the proper response was received, indicating the experiment was operating. Another *plus* man's role in space.

All detailed test objectives and supplementary objectives scheduled for the first day were successfully accomplished. These included nine ascent test objectives, and data on payload bay door centerline latch cycling and communication system operation between the orbiter and a detached payload.

Day 316 – Mission Day Two. The Second day of STS-5 flight was a carbon copy of the first, with the on-time deployment of the second commercial payload into orbit, the Anik-C at GMT 20:14. From *Columbia's* systems standpoint all continue to perform nominally.

Prior to deployment of Anik-C (a satellite of the Canadian TELESAT corporation) the STS-5 crew initiated an orbital maneuvering system (OMS) thrusting period to place the *Columbia* in the precise position for deployment operations.

After deployment a OMS maneuver was performed to establish the desired separation distance before the PAM-D perigee motor was fired. As with SBS-C, the day earlier, the Anik-C PAM-D was initiated 45 minutes after the satellite left the orbiter's cargo bay. Initial acquisition of signal at the Anik ground station indicated reduced and varying signal strength. The problem was traced to an incorrect prelaunch spacecraft RF switch configuration. Proper switch configuration was commanded from the ground which then enabled the ground stations to receive proper satellite tracking data.

The crew also initiated two student experiments during the second day in orbit. The experiments were located in the crew cabin.

The first to be operated was the growth of PORIFERA, commonly known as sponge. Three of the six experiment runs were activated by the crew, with the remaining runs set for subsequent flight days.

The second student experiment was a crystal growth investigation to determine if geometrically perfect crystal of triglycine sulphate can be grown in zero g. The triglycine sulphate crystals are used on satellites. This experiment should provide information in the future commercial processing of materials in space.

Four of the five flight test objectives scheduled for mission day 2 were successfully executed. Those completed this day were the star tracker threshold test, the cold restart of the OMS engines, an antenna test and the initiation of the 40-hour duration side-sun attitude test.

The aft COAS (crew optical alignment sighting) calibration objective was attempted but was unsuccessful.

Because crew time requirements exceeded preflight estimates, only four of the scheduled seven supplementary objectives were carried out this day.

Day 317 – Mission Day Three. STS-5 mission day three progressed satisfactorily with six development test objectives planned and successfully completed. Because of minor "space sickness" reported by two of the four crew members Mission Control Center Houston (MCC-H) advised the crew to interchange planned activities, of day 4 and day 5. This would allow the crew members to get over their minor sickness.

Among tests conducted on day three was two operations of the star tracker, communications performance test, vernier RCS (reaction control system) single engine soakback thrusting periods, radiator performance test and measurements of any distortion of the airframe through theodolite measurements.

The SBS-C satellite apogee motor firing was accomplished placing the satellite in a geosynchronous orbit.

Telemetry data from *Columbia* confirmed to ground control that the orbiter's thermal protection tiles were dried out. Thunder showers, several days before launch, caused the tiles to absorb rain water. When in orbit the *Columbia* was placed in a bottom-to-sun attitude to dry out the tiles.

During the third day of the mission, the Missions Operations Computer (MOC) at (MCC-H), was temporarily out of commission due to the loss of MOC power. All power and MOC functions were restored and without impeding progress of the flight.

Day 318 – Mission Day Four. The fourth mission day was completed satisfactorily with the crew performing those activities originally scheduled for mission day five.

Five development test objectives were accomplished–these included aft RCS three engine and single soakback tests, radiator tests (in the closed position), and initiation of the nose-to-sun attitude thermal test. The aft COAS calibration which was not completed on day two was successfully accomplished on this day.

Also completed on the fourth day of the mission were specific payload activities which included: two separate thermal data takes for the PAM airborne support equipment; deactivation of the oxygen interaction experiment; deactivation of the GAS MAUS experiment, after operating for more than 55-hours; activation of the fifth packet of the student "sponge growth" experiment; and completion of the "convection zero G gravity" experiment, the third such student experiment flown aboard STS-5.

The scheduled firing of the Anik-C spacecraft apogee motor which was scheduled for mission day four was rescheduled to November 16, 1982, the scheduled end of mission for STS-5.

Columbia's structural temperatures were within expected ranges and appeared to have reached near-cyclic steady-state conditions after the orbiter had concluded a period of 46-hours in the starboard-to-sun attitude. Following an eight hour of nose-sun attitude vehicle temperatures were also within the acceptable range.

The planned space walk was cancelled on day four due to the failure in EV (Extravehicular)-1 (Allen's) suit fan and the inability of EV 2 (Lenoir's) pressure regulator to operate properly. Lenoir could not get the regulator to operate at the designed 4.3 psia.

Day 319 Mission Day Five. Final on orbit day activities included stowing the vehicle, preparing for entry and returning to earth.

On November 16 the payload bay doors were closed for the last time at GMT 10:24:47. The deorbit maneuver (OMS-7) was successfully performed at GMT 13:30:21.

During descent one push/pullup maneuver and six preprogrammed maneuvers were performed by spacecraft Commander Brand. The push/over maneuver at Mach 18 changed *Columbia's* angle of attack – 40-35-45-40 – degrees. This was within predicted levels in the pitch axis.

STS-5, for the first time, was utilizing the new option TAEM (terminal area energy management) guidance. Performance was as predicted when *Columbia* reached TAEM at mach 2.5 at 25,267 meters (82,900 feet) altitude.

Touchdown at Edwards AFB, CA occurred at GMT 14:34:29. Landing speed was recorded at 198 knots (227 miles per hour) with the left hand gear touchdown 498 meters (1,637 feet) past the threshold on runway 22 and the right hand gear setting down at 541 meters (1,778 feet) beyond the threshold. A braking test was initiated when *Columbia* was rolling at 140 knots (161 miles per hour) along the runway. The left main landing gear inboard wheel locked up in the last 15 meters (50 feet) of rollout.

Rollout distance, after landing, was reported at 2,911 meters (9,553 feet) or 3,410 meters (11,190 feet) beyond the threshold of runway 22. *Columbia* stopped at GMT 14:34:29.

The smooth landing prompted astronaut Allen (who rode in the third seat during entry and landing) to say "it was smooth as silk . . .Vance we landed but the three of us had to ask."

The first commercial satellite deployment mission of the Space Transportation System was successfully completed. The Anik-C now located at 112 degrees, above the Canadian Rockies is now in operation and the SBS, in a similar orbit at 94 degrees above central U.S.A. will be put in service later this spring.

STS-5 MISSION FACTS

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

STS-5 TIMELINE

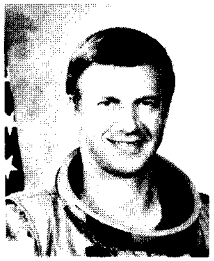
Day of Year	GMT* Hr:Min:Sec	Event
315	12:14:06	Auxiliary Power Unit (APU) No. 1 activation
	12:14:07	APU No. 2 activation
	12:14:08	APU No. 3 activation
	12:18:32.3	Solid Rocket Booster (SRB) Hydraulic Power Unit (HPU) activation command
	12:18:53.4	Main propulsion system start command
	12:19:00**	SRB ignition command from General Purpose Computer (GPC) liftoff
	12:19:35.1	Main engine throttle command to 65 percent thrust

Day of Year	GMT* Hr:Min:Sec	Event
	12:19:54.5	Main propulsion system throttle up command to 100 percent thrust
	12:20:11.0	Maximum dynamic pressure (Max Q)
	12:21:09.0	SRB separation command
	12:26:37.8	Main propulsion system throttle down for 3 "g" acceleration
	12:27:30.7	Main engine cutoff command
	12:27:48.8	External tank separation
	12:29:31.0	OMS (Orbital Maneuvering System)-1 ignition
	12:31:48.8	OMS-1 cutoff
	12:31:48.8	APU deactivation
	13:03:40.8	OMS-2 ignition
	13:05:37.6	OMS-2 cutoff
	13:53:28.0	Payload bay doors open
	20:18:00	Satellite Business Systems (SBS)-C release
	20:32:35.1	OMS-3 ignition
	20:32:44.4	OMS-3 cutoff
316	13:04:00.4	OMS-4 ignition
	13:04:02.4	OMS-4 cutoff
	13:08:05.4	OMS-5 ignition
	13:08:20.9	OMS-5 cutoff
	20:24:11	Telesat-E release
	20:39:11.1	OMS-6 ignition
	20:39:20.4	OMS-6 cutoff
317	16:25:00	Glow activation
	17:09:00	Glow deactivation
320	10:24:47	Close payload bay door
	13:31:19	APU 3 activation
	13:36:21	Deorbit maneuver ignition (OMS-7)
	13:38:43.4	Deorbit maneuver cutoff
	13:50:11	APU1 and 2 activation
	14:03:11	Entry interface
	14:19:47	End blackout
	14:27:15	Terminal area energy management
	14:33:26	Main landing gear contact
	14:33:34	Nose landing gear contact
	14:34:29	Wheels stop
	14:52:46	APU deactivation complete

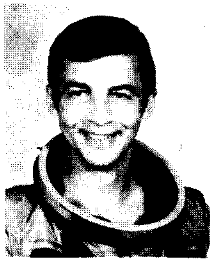
*GMT–Subtract 5 hours for EST
6 hours for CST
7 hours for MST
8 hours for PST

**Lift-off time has been rounded from day 315:12:18:59.997 G.M.T.

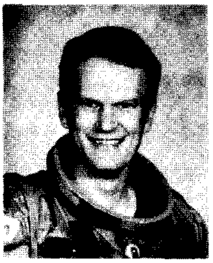
STS-6 FLIGHT CREW



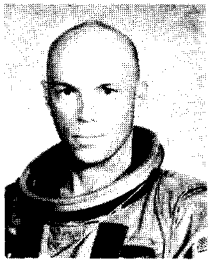
PAUL J. WEITZ is the commander for the STS-6 flight. He was the pilot in the Skylab 2 mission, logging 672 hours and 49 minutes aboard the Skylab workshop in addition to 2 hours and 11 minutes in extravehicular activities. Weitz retired from the Navy in 1976 with 22 years of service and remains with NASA as a civilian astronaut. Weitz received his commission as an Ensign through the ROTC program at Pennsylvania State University in 1954 and received his wings in 1956. He was an A-4 Tactics Instructor at the Naval Air Station in Jacksonville, Fla. from 1956 to 1960, a project officer at China Lake, Calif. in various air-to-ground delivery tactic projects from 1960 to 1962, completed the U.S. Naval Postgraduate School in 1964, was assigned to the Naval Air Station at Widbey Island, Washington in 1964 and was selected as a NASA astronaut in 1966. He received a bachelor of science degree in Aeronautical Engineering from Pennsylvania State University in 1954 and a masters degree in Aeronautical Engineering from the U.S. Naval Postgraduate School in Monterey, Calif., in 1964. Weitz was awarded the NASA Distinguished Service Medal, the Navy Distinguished Service Medal, the Federal Aviation Agency's Space Mechanic Technician Award, the Los Angeles Chamber of Commerce Kitty Hawk Award, the Robert J. Collier Trophy, the AAS Flight Achievement Award, the AIAA Haley Astronautics Award, the FAI V. M. Komarov Diploma, the Dr. Robert H. Goddard Memorial Trophy and the Harman International Trophy. He has logged more than 6,200 flying hours time, 5,100 hours in jet aircraft. Weitz is married and has two children. He was born in Erie, Pa., July 25, 1932. He is 5'10" in height and weighs 180 pounds. He has blond hair and blue eyes.



DONALD H. PETERSON is a mission specialist on the STS-6 flight. He served on the astronaut support crew for Apollo 16. He received a bachelor of science degree from the United States Military Academy at West Point in 1955 and a masters degree in Nuclear Engineering from the Air Force Institute of Technology, Wright-Patterson AFB, Ohio in 1962. His USAF assignments included 4 years as a flight instructor and military training officer with the Air Training Command and 3 years as a nuclear systems analyst with the Air Force Systems Command. He is a graduate of the Aerospace Research Pilot School and was assigned to the USAF Manned Orbiting Laboratory Program. He became a NASA astronaut in 1969. He has retired from the USAF after 24 years of active service but continues his assignment as a NASA astronaut in civilian capacity. He has logged over 4,900 hours of flying time including more than 4,180 hours in jet aircraft. He has received the Air Force Commendation, the Meritorious Service Medal and the JSC Group Achievement Award. He is married and has three children. He was born in Winona, Miss., October 22, 1933. He is 5'8" in height and weighs 147 pounds. He has blond hair and green eyes.

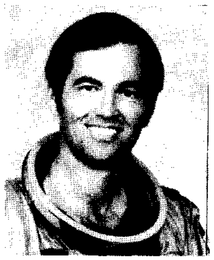


KAROL J. BOBKO is the pilot for the STS-6 flight. He was a member of the Skylab Medical Experiments Altitude Test (SMEAT) – a 56 day simulation of the Skylab mission – and a member of the astronaut support crew for the ASTP mission and a member of the support crew for the Space Shuttle Approach and Landing Test program. He was then involved with the ground test and checkout of the *Columbia*. He received a bachelor of science degree from the Air Force Academy in 1959 and a master of science degree in Aerospace Engineering from the University of Southern California in 1970. Bobko received his wings in 1960 and flew F-100 and F-105 aircraft from 1961 to 1965, then attended the Aerospace Research Pilots school and was assigned as an astronaut in the USAF Manned Orbiting Laboratory Program in 1966 and became a NASA astronaut in 1969. He has logged over 4,800 hours of flying time in the F-100, F-104, F-105, T-33 and T-38. Bobko was awarded the NASA Exceptional Service Medal, three JSC Group Achievement Awards and two USAF Meritorious Service Medals. He is married and has two children. He was born in New York, New York December 23, 1937. He is 5'11" in height and weighs 190 pounds. He has blond hair and blue eyes.



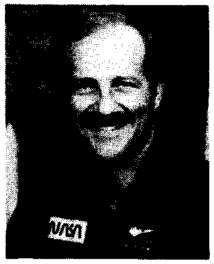
STORY MUSGRAVE is a mission specialist on the STS-6 flight. Dr. Musgrave was selected as a scientist astronaut in 1967. He worked on the design and development of the Skylab program, as a back-up science pilot for the first Skylab mission and has been participating in the design and development of all Space Shuttle extravehicular activity equipment. He received a bachelor of science degree in mathematics and statistics from Syracuse University in 1958, a master of business adminstration degree in Operations Analysis and Computer Programming from the University of California at Los Angeles in 1959, a bachelor of arts degree in chemistry from Marietta College in 1960, a doctorate in Medicine from Columbia University in 1964. He served his surgical internship at the University of Kentucky Medical Center in Lexington from 1964 to 1965 and continued there as a USAF post-doctoral fellow working in aerospace medicine and physiology from 1965 to 1966 and received his master of science in Physiology and Biophysics from the University of Kentucky in 1966. From 1966 to 1967, as a National Heart Institute post-doctoral fellow, Dr. Musgrave was teaching and doing research in cardiovascular and exercise physiology. He is continuing clinical and scientific training as a part-time surgeon at the Denver General Hospital and as a part-time professor of physiology and biophysics at the University of Kentucky Medical Center. He has flown 90 different types of civilian and military aircraft, logging over 13,200 flying hours, including 5,500 in jet aircraft, and holds instructor, instrument instructor, glider instructor and airline transport ratings. He has received the National Defense Service Medal, USAF Post-doctoral Fellowship, National Heart Fellowship, American College of Surgeons I. S. Ravdin Lecture, NASA Exceptional Service Medal and Flying Physicians Association Airmen of the Year Award. He has five children. He was born in Boston, Mass., August 19, 1935 but considers Lexington, Ky. his hometown. He is 5'10" in height and weighs 149 pounds. He has blond hair and blue eyes.

STS-7 FLIGHT CREW

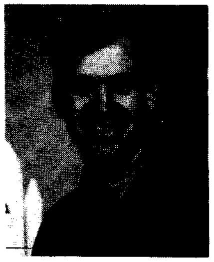


ROBERT L. CRIPPEN is the commander for the STS-7 flight. He was the pilot in the 54-1/2 hour STS-1 flight. He has logged more than 4,980 hours of flying time—most of it in jet-powered aircraft—as a U.S. Navy pilot and astronaut. A graduate of the University of Texas in aerospace engineering, Crippen 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.

SALLY K. RIDE is a mission specialist for the STS-7 flight. She was selected as an astronaut candidate by NASA in 1978. Dr. Ride received a bachelor of arts in English from Stanford University in 1973, a bachelor of science, a master of science, and doctorate degrees in Physics in 1973, 1975, and 1978, respectively from Stanford University. Dr. Ride has held teaching assistant and research assignments while a graduate student in the Physics Department at Stanford University. Her research includes one summer with the low-temperature group working in experimental general relativity and three years in X-ray astrophysics. She was born in Los Angeles, Calif., May 26, 1951 and considers Encino, Calif. her hometown. Dr. Ride is 5'5" in height and weighs 115 pounds. She has brown hair and blue eyes. She married Astronaut Steve Hawley on July 24, 1982.



FREDERICK H. HAUCK is the pilot for the STS-7 flight. He was a member of the support crew for STS-1 and capsule communicator during reentry for the STS-2 flight. He was selected as an astronaut candidate by NASA in 1978. Hauck received a bachelor of science degree in Physics from Tufts University in 1962 and a master of science degree in Nuclear Engineering from MIT in 1966. He was a Navy ROTC student at Tufts University and was commissioned upon graduation and served as communications officer and CIC officer on the USS Warrington. In 1964 he attended the U.S. Naval Post-graduate School, Monterey, Calif., in math and physics and studied Russian at the Defense Language Institute in Monterey. He was then selected for the Navy's Advanced Science Program. He received his wings in 1968. He flew 114 combat and combat support missions in the Western Pacific aboard the USS Coral Sea. He graduated from the U.S. Naval Test Pilot School in 1971. Hauck then served as a project test pilot for automatic carrier landing systems in the A-6, A-7, F-4 and F-14 aircraft. In 1974 he was asigned to the USS Enterprise flying A-6, A-7 and F-14 aircraft. He was an executive officer in February 1977 until he was selected as an astronaut. He was born in Long Beach, Calif., April 11, 1941 but considers Winchester, Mass., and Washington, D.C. as his hometown. He is married and has two children. He is 5'9" in height and weighs 175 pounds. He has blond hair and blue eyes.

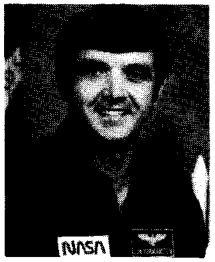


JOHN M. FABIAN is a mission specialist for the STS-7 flight. He was selected as an astronaut candidate in 1978. He received a bachelor of science degree in Mechanical Engineering from Washington State University in 1962, a master of science in Aerospace Engineering from the Air Force Institute of Technology in 1964 and a doctorate in Aeronautics and Astronautics from the University of Washington in 1974. Fabian was an Air Force ROTC student at Washington State University and was commissioned in 1962. He had various assignments in the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio, aeronautical engineer at San Antonio Air Material Area, Kelly AFB, Tex., then attended flight training at Williams AFB, Ariz., and spent five years as a KC-135 pilot at Wurtsmith AFB, Mich., and flew 90 combat missions in Southeast Asia. Following additional graduate work at the University of Washington, he served four years on the faculty of the Aeronautics Department at the USAF Academy in Colo. He has logged 3,400 hours flying time, including 2,900 hours in jet aircraft. He is a member of AIAA. He is married and has two children. He was born in Goosecreek, Tex., January 28, 1939, but considers Pullman, Wash., his hometown. He is 6' 1" in height and weighs 175 pounds. He has brown hair and green eyes.

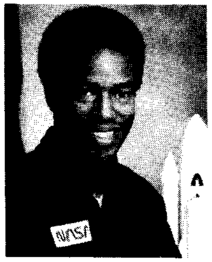
NORMAN E. THAGARD is a mission specialist on the STS-7 mission. He will conduct medical tests to collect additional data on several physiological changes that are associated with space adaptation syndrome. These tests will focus on the neurological system and are a continuation of the new approach to 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.

STS-8 FLIGHT CREW

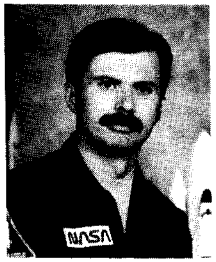
RICHARD H. TRULY is the commander for the STS-8 flight. He was the spacecraft pilot for the 54 hour, 24 minute STS-2 flight. He was an orbiter pilot during the successful Approach and Landing Test program, and as a naval pilot and astronaut has logged nearly 6,000 hours in jet aircraft. He graduated 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.

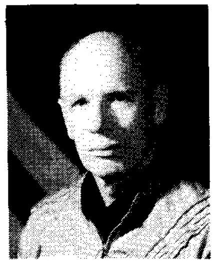


GUION S. BLUFORD JR. is a mission specialist for the STS-8 flight. He was selected as an astronaut candidate in 1978. He received a bachelor of science degree in Aerospace Engineering from Pennsylvania State University in 1964, a master of science degree with distinction in Aerospace Engineering from 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

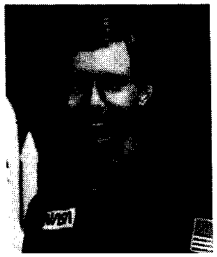


WILLIAM E. THORNTON is a mission specialist on the STS-8 mission. He will conduct medical tests to collect additional data on several physiological changes that are associated with the space adaptation syndrome. These tests will focus on the neurological system and are a continuation of the new approach 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.

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.

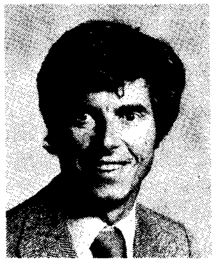


BREWSTER A. SHAW is the pilot for the STS-9 flight. Shaw was selected as an astronaut candidate in 1978. He received a bachelor and master of science degrees in Engineering Mechanics from the University of Wisconsin in 1968 and 1969 respectively. Shaw entered the Air Force in 1968 and after completing 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.

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

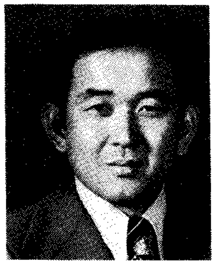
BYRON K. LICHTENBERG is one of the payload specialists in the STS-9 flight. Payload specialists are normally career scientists selected to go into space aboard a particular Spacelab mission, in this case, Spacelab 1. His profession is biomedical engineer/pilot. Lichtenberg received his science degree 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.



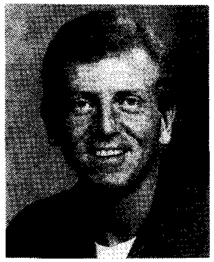
ULF MERBOLD is one of the payload specialists in the STS-9 flight. His profession is physicist. Merbold received a diploma in physics in 1968 and a doctorate in science from Stuttgart University in 1976. He joined the Max-Planck Gesellschaft at Stuttgart, Germany, first on a scholarship in 1968, and 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.

STS-10 FLIGHT CREW

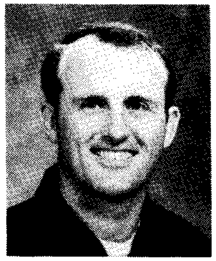
THOMAS K. MATTINGLY, II is the commander for the STS-10 mission. He was also the commander in the STS-4 flight. He was the backup commander for the STS-3 flight and STS-2 flight. From 1979 to 1981 he headed the astronaut ascent/entry group. Mattingly was previously assigned as technical assistant for 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 weighs 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 Organizational 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 weighs 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 private 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.

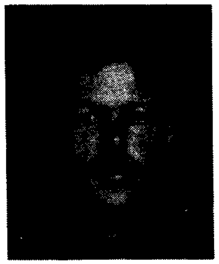


JAMES F. BUCHLI is a mission specialist on the STS-10 mission. He received a bachelor of science degree in Aeronautical Engineering from the United States Naval Academy in 1967 and a master of science degree in Aeronautical Engineering Systems from the University of West Florida in 1975. He received 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.

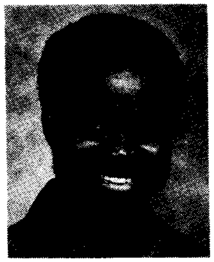
STS-11 FLIGHT CREW

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 Space Award, the FAI Yuri Gagarin Gold Medal, the AIAA Special Presidential Citation and the Haley 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.

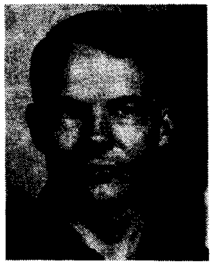


ROBERT L. GIBSON is the pilot for the STS-11 flight. He received a bachelor of science degree in aeronautical engineering from California Polytechnic State University in 1969. Gibson entered active duty with the Navy in 1969. He received primary and basic flight training at Naval Air Stations in Florida 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.

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 to 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 Shuttle 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" and weighs 165 pounds. He has brown hair and hazel 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.

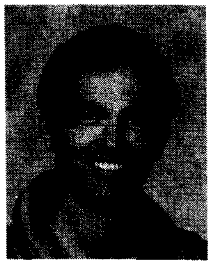
MICHAEL L. COATS is the pilot for the STS-12 flight. He received a bachelor of science degree from the United States Naval Academy in 1968, a master of science in administration of science and technology from George Washington University in 1977, and master of science in aeronautical engineering from 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.

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.

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.

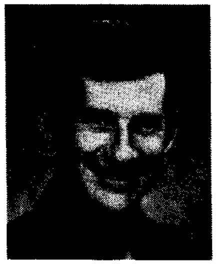
STS-13 FLIGHT CREW



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 is the commander for the 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.

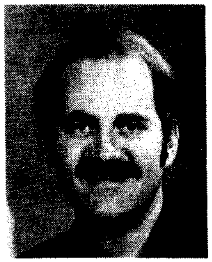
GEORGE D. NELSON is a mission specialist for the STS-13 flight. Nelson received a bachelor of science degree in physics from Harvey Mudd College in 1972 and a master of science and a doctorate in astronomy from the University of Washington in 1974 and 1978, respectively. Dr. Nelson has performed various 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.

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.



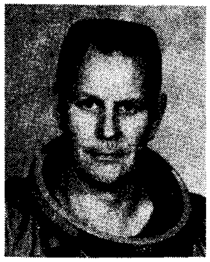
TERRY J. HART is a mission specialist for the STS-13 flight. Hart received a bachelor of science degree in mechanical engineering from Lehigh University in 1968, a master of science in mechanical engineering from the Massachusetts Institute of Technology in 1969, and a master of science in electrical 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 Pittsburgh, Pennsylvania. Hart is married and has two children. He has brown hair and brown eyes. He is 5'8" and weighs 145 pounds.

STS-13 FLIGHT CREW



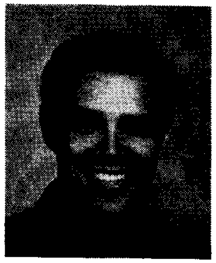
JAMES D. van HOFTEN is a mission specialist for the STS-13 flight. He received a bachelor of science degree in civil engineering from the University of California, Berkeley, in 1966; and a master of science degree in hydraulic engineering and a doctor of philosophy in fluid mechanics from Colorado State 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 in 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.

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.

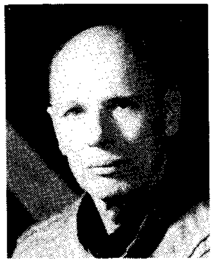
NORMAN E. THAGARD is a mission specialist on the STS-18 mission. He is a mission specialist on the STS-7 flight and will conduct medical tests to collect additional data on several physiological changes that are associated with space adaptation syndrome. These tests will focus on the neurological system 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.

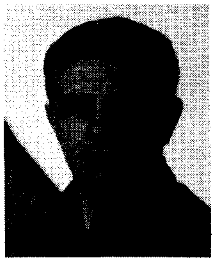
DON LESLIE LIND is a mission specialist for the STS-18 flight. Lind received a bachelor of science with high honors in physics from the University of Utah in 1953 and a doctor of philosophy degree in high energy nuclear physics in 1964 from the University of California, Berkeley and performed post-doctoral 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 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-24 FLIGHT CREW



KARL G. 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 University 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 1956 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.