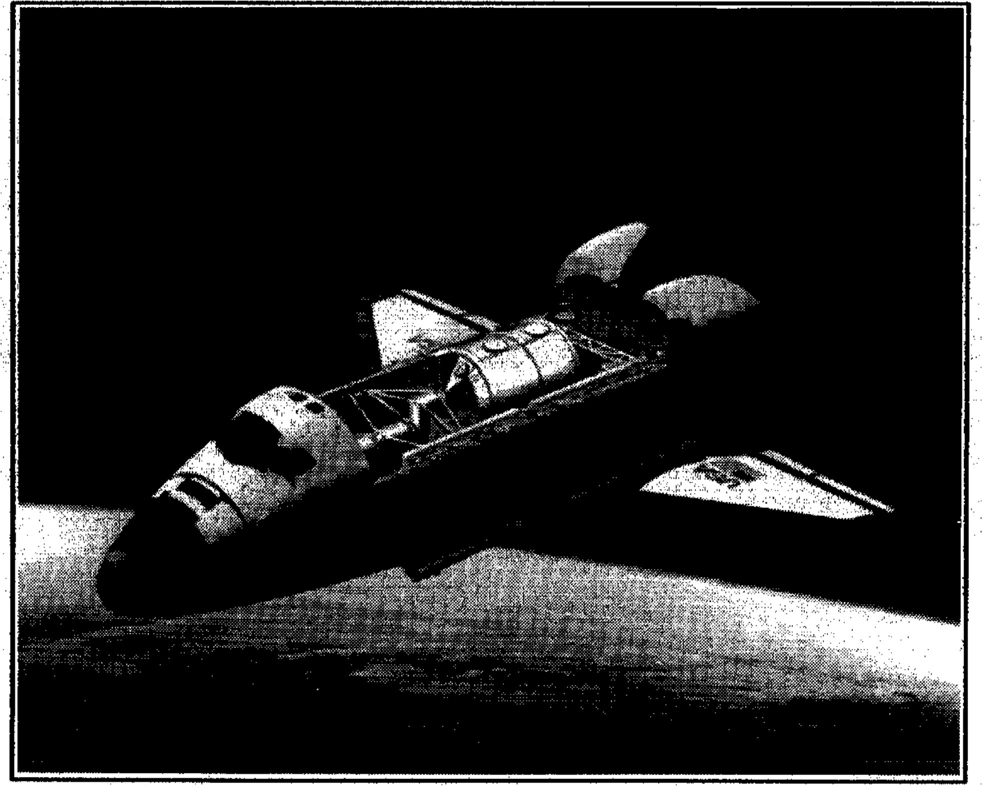

STS-55

PRESS INFORMATION

March 1993

Rockwell International
Space Systems Division

Office of External Communications &
Media Relations

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CONTENTS

MISSION OVERVIEW

This is the 14th flight of Columbia and the 54th for the space shuttle.

The flight crew for the nine-day STS-55 mission is commander Steven (Steve) R. Nagel; pilot Terence (Tom) T. Henricks; payload commander Jerry L. Ross; mission specialists Bernard A. Harris, Jr. and Charles (Charlie) J. Precourt; and payload specialists Hans Schlegel and Ulrich Walter of Germany. The crew will be divided into a blue team, consisting of Nagel, Henricks, Ross, and Walter, and a red team, comprising Precourt, Harris, and Schlegel. Each team will work alternating 12-hour shifts, providing for around-the-clock operations.

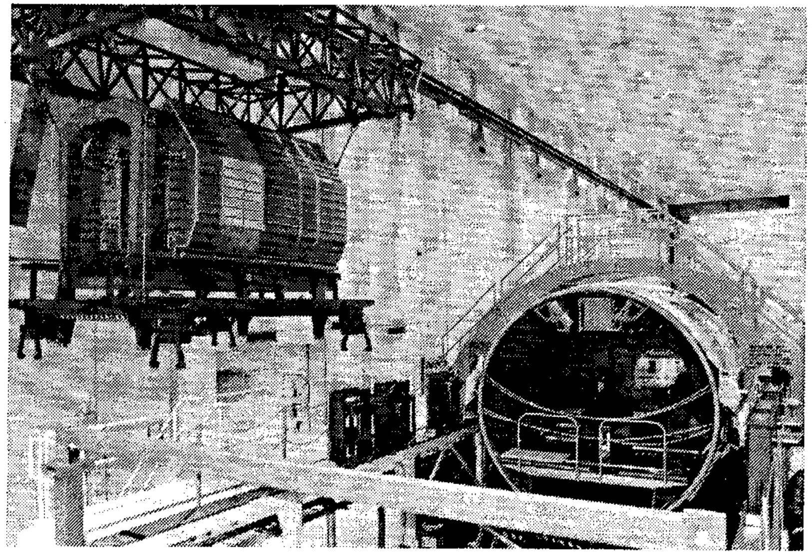
STS-55's primary mission objective is to successfully launch, operate, and return Spacelab D-2, a German-sponsored payload that is designed for conducting research in a microgravity environment. The payload is composed of the Spacelab long module with transfer tunnel, a unique support structure (USS) for mounting experiments outside the module, and a complex autonomous shuttle payload: Reaction Kinetics in Glass Melts (RKGM). Module experiments will investigate material and life sciences, space technology, and automation and robotics. USS experiments will conduct Earth and stellar observations.

Spacelab D-2 is the second German Spacelab mission (Spacelab D-1 flew in October/November 1985 on STS-61A). It is under German mission management, and Germany is responsible for its operation. In addition to continuing research and scientific experiments from Spacelab D-1, Spacelab D-2 will investigate and qualify technical and operational techniques and procedures in preparation for the operation of space station Freedom.

Some of the specific areas of investigation are described below.

Material Science—The material science experiments are in the areas of fluid physics, nucleation, and solidification. The fluid physics experiments include the study of capillarity and instability, change of phases, and heat transfer and diffusion. The nucleation and solidification experiments will study nucleation, dynamics of the solidification boundary, and production of monocrystals.

The Holographic Optics Laboratory (HL) will investigate transient heat transfer, mass transfer, surface convection, and particle motion in optical transparent media via holographic methods. Four different experiments will be performed in the HL: *Interferences par Diffusion de Liquides dans L'Espace (IDILE)*, Interfusion in Salt Melts (ISIS), Marangoni Convection in a Square Cavity (MAC), and Nucleation and Growth in Binary Mixtures With Miscibility Gap (NUGO).



Experiment Racks, Upper Left, Ready for Installation in Spacelab Module in Test Stand in Operations and Checkout Building

The Werkstofflabor (WL) consists of seven separate experiment facilities. Experiments in these facilities will study several areas of metal processing, crystal growth for electronics applications, fluid boundary surfaces, and transparent phenomena.

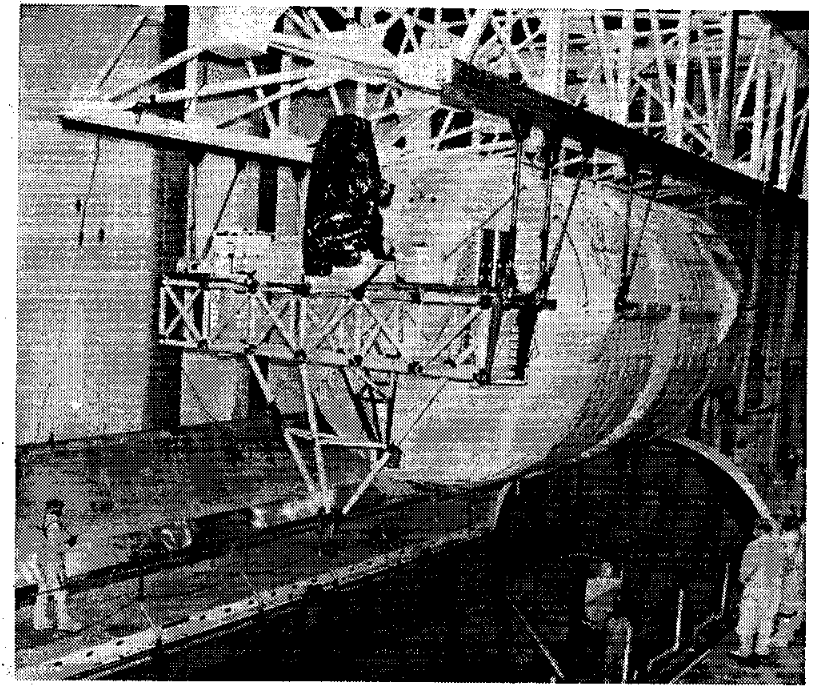
The Material Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA) accommodates three separate experiment facilities: the high-precision thermostat (HPT), gradient furnace with quenching (GFQ), and the elliptical mirror furnace (Elli). Material science and physical chemistry experiments will be carried out in the areas of critical-point phenomena, direction solidification of metallic crystals, and long-term crystallization.

Radiation Detectors (RDs) is a set of four experiments in which different types of material and biological probes will be exposed to different environmental conditions. The results of these tests will be used in the development of radiation protection in space.

Biological Science—The biological science experiments will study the electrofusion of cells, cell functions, reaction to gravity, development processes, radiation, and behavioral physiology. Human physiology experiments will be performed in the areas of cardiovascular systems, pulmonary functions, and hormonal adaptation.

Biolabor (BB) experiments will study the effects of the absence of gravity on plants and animal organisms and on single cells (gravitational biology). BB experiments will also investigate cultivation methods for different cells and electrofusion of plant and animal cells (biological methods).

Anthrorack (AR) will measure cardiac, pulmonary, and metabolic function in resting conditions and during challenges that are imposed to change the subject's cardiopulmonary function. The AR experiments will investigate fluid shifts, the hormonal system, lung circulation and ventilation, deconditioning of the cardiovascular system, and the body's reaction to different physical states.



Spacelab Module and Unique Support Structure About To Be Lowered Into Payload Canister for Transfer From Operations and Checkout Building to Orbiter Processing Facility

Baroreflex (BA) will investigate changes in the baroreceptor reflex that play a major role in the development of conditions responsible for the fall of blood pressure (orthostatic hypotension) after space flight.

The urine monitoring system will collect urine samples from each crew member. The urine samples will be analyzed for protein metabolism, fluid electrolyte regulation, and pathophysiology of mineral loss during space flight.

Technology—Technology areas of study will include automation and robotics and transfer functions. In the Robotics Technology Experiment (ROTEX), a robotic arm located in an enclosed work cell will be operated from both within the module and from the ground. ROTEX will employ teleprogramming and artificial intelligence to look at the design, verification, and operation of advanced autonomous systems.

The microgravity measurement assembly (MMA) will measure structural transfer functions at various locations in Spacelab, thus providing information about experiment environmental conditions for future Spacelab flights.

The Crew Telesupport Experiment (CTE) will demonstrate communication between on-board and ground computer-based documentation files (text, graphics, and photos) combined with real-time graphical inputs by crew members and the ground. The CTE is intended to enhance the effectiveness of payload operations, maintenance, and scientific return.

Earth Observation—The Modular Optoelectronic Multispectral Scanner (MOMS), an Earth-observing instrument located on the USS platform, is an imaging and sensing instrument that will provide photogrammetic mapping and thematic mapping applications.

Astronomy—The Galactic Ultrawide-Angle Schmidt System (GAUSS) camera, located on the USS, will be used to study the Milky Way.

Atmospheric Physics—Various materials will be exposed to the atmosphere, and the effects of the exposure will be observed. The Atomic Oxygen Exposure Tray (AOET) will obtain in-situ reaction rate measurements for various materials that interact with atomic oxygen.

Crew Insignia

RKGM—This getaway special experiment will study the processes involved in the formation of a glass melt, specifically the process of mass transport by diffusion. Mass transfer is controlled by either diffusion or buoyancy convection. On orbit, the crew will activate the RKGM payload, and then experiment electronics will run an automatic experiment control sequence.

The shuttle orbiter Columbia plays the role of "mother ship" to the Spacelab D-2 payload, serving as a stable and reliable platform for microgravity investigations and providing a stable attitude, power, and cooling needs.

STS-55's secondary objective is to perform the operations of the Shuttle Amateur Radio Experiment (SAREX) II payload.

SAREX, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, will establish crew voice communication with amateur radio stations. SAREX will be operated at the discretion of the licensed crew members. On this mission, a modified configuration of SAREX will be used. This configuration can be operated in either voice or data mode during communications with amateur stations within the line of sight of the orbiter. It can also be operated in the attended mode for voice communication and either attended or automatic mode for data communications.

Eleven development test objectives and 10 detailed supplementary objectives are scheduled to be flown on STS-55.

MISSION STATISTICS

Vehicle: Columbia (OV-102), 14th flight

Launch Date/Time:

3/21/93	9:52 a.m., EST 8:52 a.m., CST 6:52 a.m., PST

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

Launch Window: Two hours, 30 minutes

Mission Duration: Eight days, 22 hours, five minutes. An additional day is highly desirable and may be added if consumables (e.g., fuel, oxygen) allow. Planning will accommodate the longer duration wherever appropriate. The mission can be extended two additional days for contingency operations and to avoid adverse weather conditions.

Landing: Nominal end-of-mission landing on orbit 143

3/30/93	7:57 a.m., EST 6:57 a.m., CST 4:57 a.m., PST

Runway: Nominal end-of-mission landing on concrete runway 15, KSC. Weather alternates are Edwards Air Force Base (EAFB), Calif., and Northrup Strip (NOR), White Sands, N.M.

Transatlantic Abort Landing: Banjul, The Gambia; alternates: Moron, Spain, and Ben Guerir, Morocco

Return to Launch Site: KSC

Abort-Once-Around: EAFB; alternates: KSC, NOR

Inclination: 28.45 degrees

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

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

Altitude: 160-nautical-mile (184-statute-mile) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2030
No. 2 position: Engine 2034
No. 3 position: Engine 2011

External Tank: ET-56

Solid Rocket Boosters: BI-057

Mobile Launcher Platform: 3

Editor's Note: The following weight data are current as of March 16, 1993.

Total Lift-off Weight: Approximately 4,518,784 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 255,252 pounds

Orbiter (Columbia) Empty and 3 SSMEs: Approximately 180,895 pounds

Payload Weight Up: Approximately 26,864 pounds

Payload Weight Down: Approximately 26,864 pounds

Orbiter Weight at Landing: Approximately 227,203 pounds

Payloads—Payload Bay: Spacelab D-2 with long module, unique support structure (USS), and Reaction Kinetics in Glass Melts (RKGM) getaway special

Payloads—Middeck: Shuttle Amateur Radio Experiment (SAREX) II

Flight Crew Members:

Red Team:

Mission Specialist 2: Charles (Charlie) J. Precourt, first space shuttle flight
Mission Specialist 3: Bernard A. Harris, Jr., first space shuttle flight
Payload Specialist 2: Hans Schlegel, Germany, first space shuttle flight

Blue Team:

Commander: Steven (Steve) R. Nagel, fourth space shuttle flight
Pilot: Terence (Tom) T. Henricks, second space shuttle flight
Payload Commander (Mission Specialist 1): Jerry L. Ross, fourth space shuttle flight
Payload Specialist 1: Ulrich Walter, Germany, first space shuttle flight

Nagel, Henricks, and Precourt make up the orbiter crew, which operates the shuttle and Spacelab systems monitored by the Mission Control Center at NASA's Johnson Space Center, Houston, Texas. Harris, Schlegel, Ross, and Walter form the science crew, which will operate the Spacelab D-2 experiments monitored by the German Space Operations Center (GSOC) in Oberpfaffenhofen, Germany.

Ascent Seating:

Flight deck, front left seat, commander Steven R. Nagel
Flight deck, front right seat, pilot Terence T. Henricks
Flight deck, aft center seat, mission specialist Charles J. Precourt
Flight deck, aft right seat, mission specialist Bernard A. Harris, Jr.
Middeck, payload specialist Hans Schlegel
Middeck, payload specialist Ulrich Walter
Middeck, mission specialist Jerry L. Ross

Entry Seating:

Flight deck, front left seat, commander Steven R. Nagel
Flight deck, front right seat, pilot Terence T. Henricks
Flight deck, aft center seat, mission specialist Charles J. Precourt
Flight deck, aft right seat, mission specialist Jerry L. Ross

Middeck, mission specialist Bernard A. Harris, Jr.
Middeck, payload specialist Hans Schlegel
Middeck, payload specialist Ulrich Walter

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: mission specialist Jerry L. Ross
EV-2: mission specialist Charles J. Precourt

Intravehicular Astronaut: pilot Terence T. Henricks

STS-55 Flight Directors:

Ascent/Entry/Orbit 1: Wayne Hale
Orbit 2 Team/Lead: Gary Coen
Orbit 3 Team: Milt Heflin

Entry: Automatic mode until subsonic; then control stick steering

Notes:

- The remote manipulator system is not installed in Columbia's payload bay for this mission.
- The shuttle orbiter repackaged galley is installed in Columbia's middeck.

Members of the crew for Spacelab D-2 mission are (seated, from left) pilot Terence T. (Tom) Henricks, mission commander Steven R. Nagel, and mission specialist Charles J. Precourt. Standing are mission specialist Bernard A. Harris, Jr., payload specialist Hans Schlegel, payload commander Jerry L. Ross, and payload specialist Ulrich Walter.

MISSION OBJECTIVES

- Primary objective
  - Spacelab D-2 operations
- Secondary objectives
  - Shuttle Amateur Radio Experiment (SAREX) II
- 11 development test objectives/10 detailed supplementary objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Payload bay doors open
Spacelab D-2 activation
Payload activation
Priority Group B power-down
Unstow cabin

Flight Day 2

Spacelab operations

Flight Day 3

Spacelab operations

Flight Day 4

Spacelab operations

Flight Day 5

Spacelab operations

Flight Day 6

Spacelab operations

Flight Day 7

Spacelab operations

Flight Day 8

Spacelab operations

Flight Day 9

Spacelab operations
FCS checkout
RCS hot fire

Flight Day 10

Spacelab deactivation
Priority Group B power-up
Cabin stow
Deorbit preparation
Deorbit burn
Landing

Note:

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

CREW ASSIGNMENTS

Commander (Steven R. Nagel)

- Overall mission decisions
- Orbiter—IFM (Spacelab systems)
- Payload—MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
- DTOs/DSOs—DTOs 251, 623, 660, 663, 665, 805; DSOs 323, 617, 618

Pilot (Terence T. Henricks)

- Orbiter—IFM
- Payload—IFM (Spacelab systems), MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
- DTOs/DSOs—DTOs 251, 623, 660, 663, 665; DSOs 323, 603, 617, 618, 625
- Other—Earth observations

Payload Commander (Mission Specialist 1) (Jerry L. Ross)

- Payload—IFM (Spacelab systems), IFM (Spacelab experiments), Spacelab module experiments, Baroreflex, UMS
- DTOs/DSOs—DTO 312; DSO 603
- Other—EV-1, medic

Mission Specialist 2 (Charles J. Precourt)

- Orbiter—IFM
- Payload—IFM (Spacelab systems), MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
- DTOs/DSOs—DTOs 623, 660, 663, 665; DSOs 323, 486, 603, 617, 618
- Other—IV, photo/TV

Mission Specialist 3 (Bernard A. Harris, Jr.)

- Payload—Spacelab module experiments, IFM (Spacelab systems), IFM (Spacelab experiments), Baroreflex, UMS
- DTOs/DSOs—DSO 486
- Other—EV-2, medic

Payload Specialist 1 (Ulrich Walter)

- Payload—Spacelab module experiments, Baroreflex, UMS, IFM (Spacelab experiments)

Payload Specialist 2 (Hans Schlegel)

- Payload—Spacelab module experiments, Baroreflex, UMS, IFM (Spacelab experiments)

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- Ascent aerodynamic distributed loads verification (DTO 236)
- Entry aerodynamic control surfaces test (part 6) (DTO 251)
- Ascent structural capability evaluation (DTO 301D)
- Entry structural capability evaluation (DTO 307D)
- ET TPS performance, methods 1 and 2 (DTO 312)
- Orbiter drag chute system (DTO 521)
- Cabin air monitoring (DTO 623)
- Thermal impulse printer system demonstration (DTO 660)
- Acoustical noise dosimeter (DTO 663)
- Acoustical noise sound level data (DTO 665)
- Crosswind landing performance (DTO 805)

DSOs

- Urine monitoring system evaluation (DSO 323)
- Physical examination in space (DSO 486)
- Orthostatic function during entry, landing, and egress (DSO 603B*)
- Evaluation of functional skeletal muscle performance following space flight (DSO 617*)
- Effects of intense exercise during space flight on aerobic capacity and orthostatic functions (DSO 618*)
- Measurement of blood volume before and after space flight (DSO 625*)
- Educational activities (objectives 1 and 2) (DSO 802)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)

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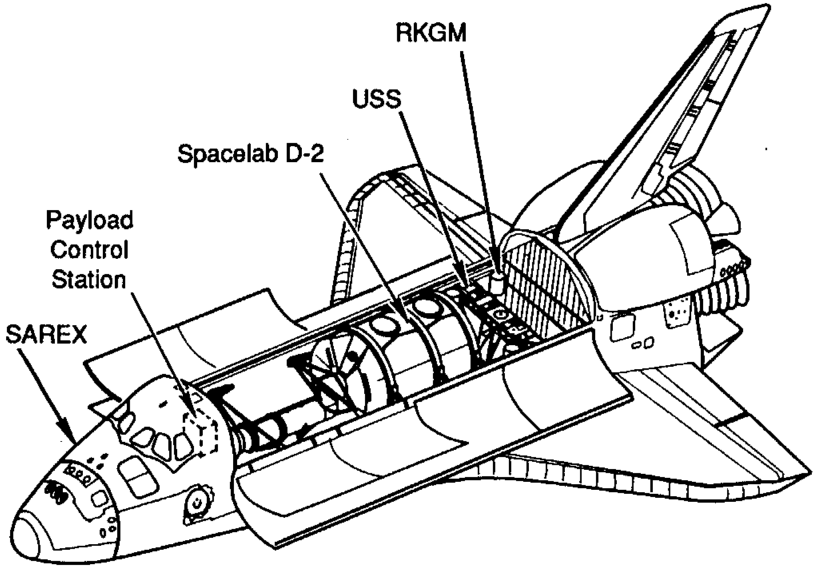
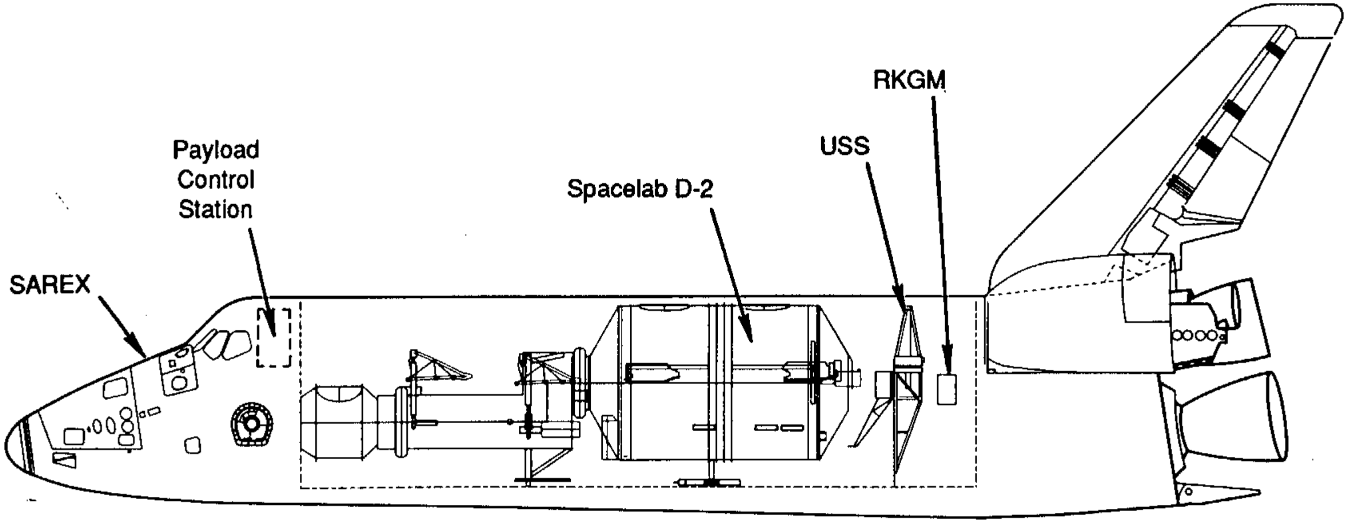
*EDO buildup medical evaluation

STS-55 PAYLOAD CONFIGURATION





SPACELAB

Spacelab is a unique laboratory facility carried in the cargo bay of the space shuttle orbiter that converts the shuttle into a versatile on-orbit research center. The reusable laboratory can be used to conduct a wide variety of experiments in such fields as life sciences, plasma physics, astronomy, high-energy astrophysics, solar physics, atmospheric physics, materials sciences, and Earth observations.

Spacelab is developed on a modular basis and can be varied to meet specific mission requirements. Its four principal components are the pressurized module, which contains a laboratory with a shirt-sleeve working environment; one or more open pallets that expose materials and equipment to space; a tunnel to gain access to the module; and an instrument pointing subsystem. Spacelab is not deployed free of the orbiter. The pressurized module will be used on STS-55.

The European Space Agency developed Spacelab as an essential part of the United States' Space Transportation System. Eleven European nations are involved: Germany, Belgium, Denmark, Spain, France, United Kingdom, Ireland, Italy, the Netherlands, Switzerland, and, as an observer state, Austria. On Sept. 24, 1973, ESA and NASA signed a memorandum of understanding to design and develop Spacelab with NASA's George C. Marshall Space Flight Center as lead center for ESA.

An industrial consortium headed by ERNO-VFW Fokker (Zentralgesellschoft VFW-Fokker mbh) was named by ESA in June 1974 to build the pressurized modules. Five 10-foot-long, unpressurized, U-shaped pallet segments were built by the British Aerospace Corporation under contract to ERNO-VFW Fokker. The IPS is built by Dornier.

Spacelab is used by scientists from countries around the world. Its use is open to research institutes, scientific laboratories, industrial companies, government agencies, and individuals. While many missions are government sponsored, Spacelab is also intended to provide services to commercial customers.

Each experiment accepted has a principal investigator assigned as the single point of contact for that particular scientific project. The principal investigators for all experiments on a given mission form what is called the Investigators Working Group. This group coordinates scientific activities before and during the flight.

The investigators prepare the equipment for their experiments in accordance with size, weight, power, and other limitations established for the particular mission.

Responsibility for experiment design, development, operational procedures, and crew training rests with the investigator. Only after it is completed and checked out is the equipment shipped to the Kennedy Space Center for installation on Spacelab.

Each mission has a mission scientist, a NASA scientist who, as chairman of the Investigators Working Group, serves as the interface between the science-technology community and NASA's payload management people. Through the mission scientist, the science-technology needs of the mission and the investigators' goals are injected into the decision-making process.

NASA astronauts called mission specialists, as well as non-career astronauts called payload specialists, fly aboard Spacelab to operate experiments. Payload specialists are nominated by the scientists sponsoring the experiments aboard Spacelab. They are accepted, trained, and certified for flight by NASA. Their training includes familiarization with experiments and payloads as well as information and procedures to fly aboard the space shuttle. From one to four payload specialists can be accommodated for a Spacelab flight. These specialists ride into space and return to Earth in the orbiter crew compartment cabin, but they work with Spacelab on orbit. Because Spacelab missions, once on orbit, may operate on a 24-hour basis, the flight crew is usually divided into two teams. The STS-55 crew will work two 12-hour shifts.

PRESSURIZED MODULE

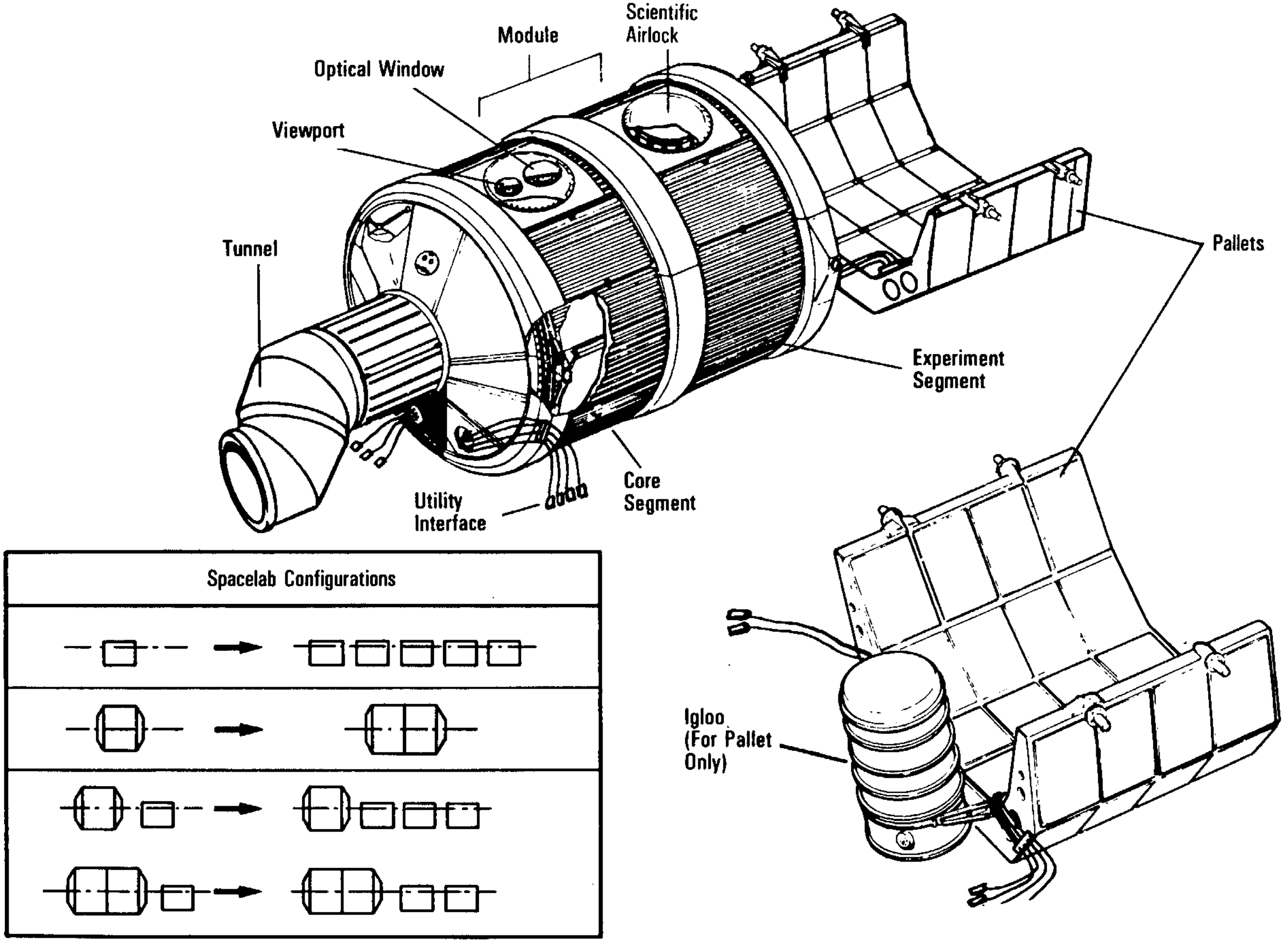
The pressurized module, or laboratory, is available in two segments. One, called the core segment, contains supporting systems, such as data processing equipment and utilities for the pressurized modules and pallets (if pallets are used in conjunction with the pressurized modules). The laboratory has fixtures, such as floor-mounted racks and a workbench. The second, called the experiment segment, provides more working laboratory space and contains only floor-mounted racks. When only one segment is needed, the core segment is used. Each pressurized segment is a cylinder 13.1 feet in outside diameter and 9 feet long. When both segments are assembled with end cones, their maximum outside length is 23 feet.

The pressurized segment or segments are structurally attached to the orbiter payload bay by four attach fittings consisting of three longeron fitting sets (two primary and one stabilizing) and one keel fitting. The segments are covered with passive thermal control insulation.

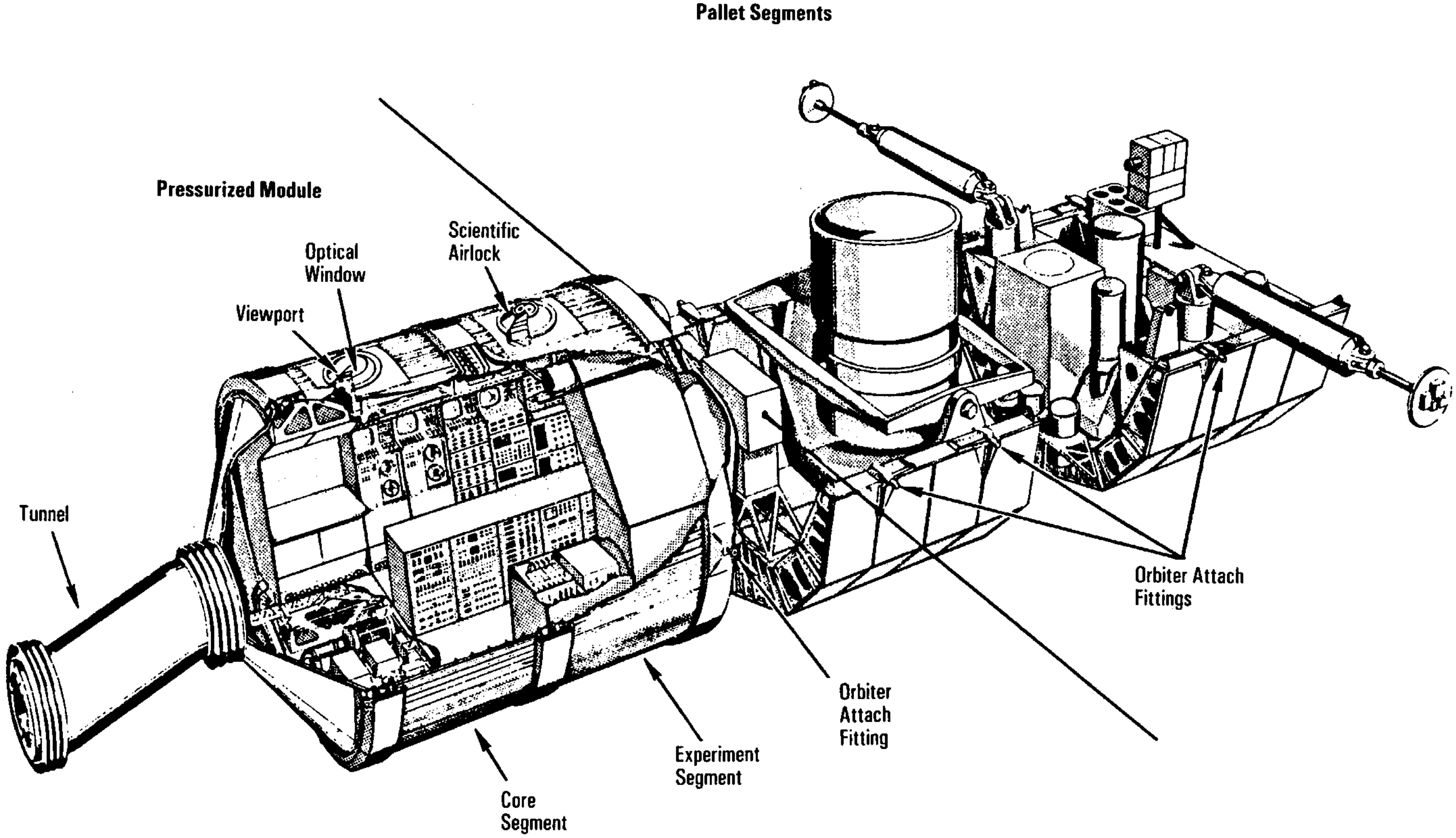
The ceiling skin panel of each segment contains a 51.2-inch-diameter opening for mounting a viewport adapter assembly, a Spacelab window adapter assembly, or scientific airlock; if none of these items are used, the openings are closed with cover plates that are bolted in place. The module shell is made from 2219-T851 aluminum plate panels. Eight rolled integral-machined waffle patterns are butt-welded together to form the shell of each module segment. The shell thickness ranges from 0.6 of an inch to 0.14 of an inch. Rings machined from aluminum-roll ring forgings are butt-welded to the skin panels at the end of each shell. Each ring is 20 inches long and 195.8 inches in diameter at the outer skin line. Forward and aft cones bolted to the cylinder segments consist of six aluminum skin panels machined from 2219-T851 aluminum plate and butt-welded to each other and to the two end rings. The end rings are machined from aluminum-roll ring forgings. The end cones are 30.8-inch-long truncated cones whose large end is 161.9 inches in outside diameter and whose small end is 51.2 inches in outside diameter. Each cone has three 16.4-inch-diameter cutouts: two located at the bottom of the cone and one at the top. Feedthrough plates for routing utility cables and lines can be installed in the lower cutouts of both end cones. The Spacelab viewport assembly can be installed in the upper cutout of the aft end cone, and the upper cutout of the forward end cone is for the pressurized module vent and relief valves. The pressurized modules are designed for a lifetime of 50 missions. Nominal mission duration is seven days.

Racks for experiment equipment that goes into the habitable module are standardized. The 19-inch-wide (48-centimeter) racks are arranged in single and double assemblies. Normally, the racks and floor are put together outside the module, checked out as a unit, and slid into the module where connections are made between the rack-mounted experiment equipment, the subsystems in the core segment, and the primary structure.

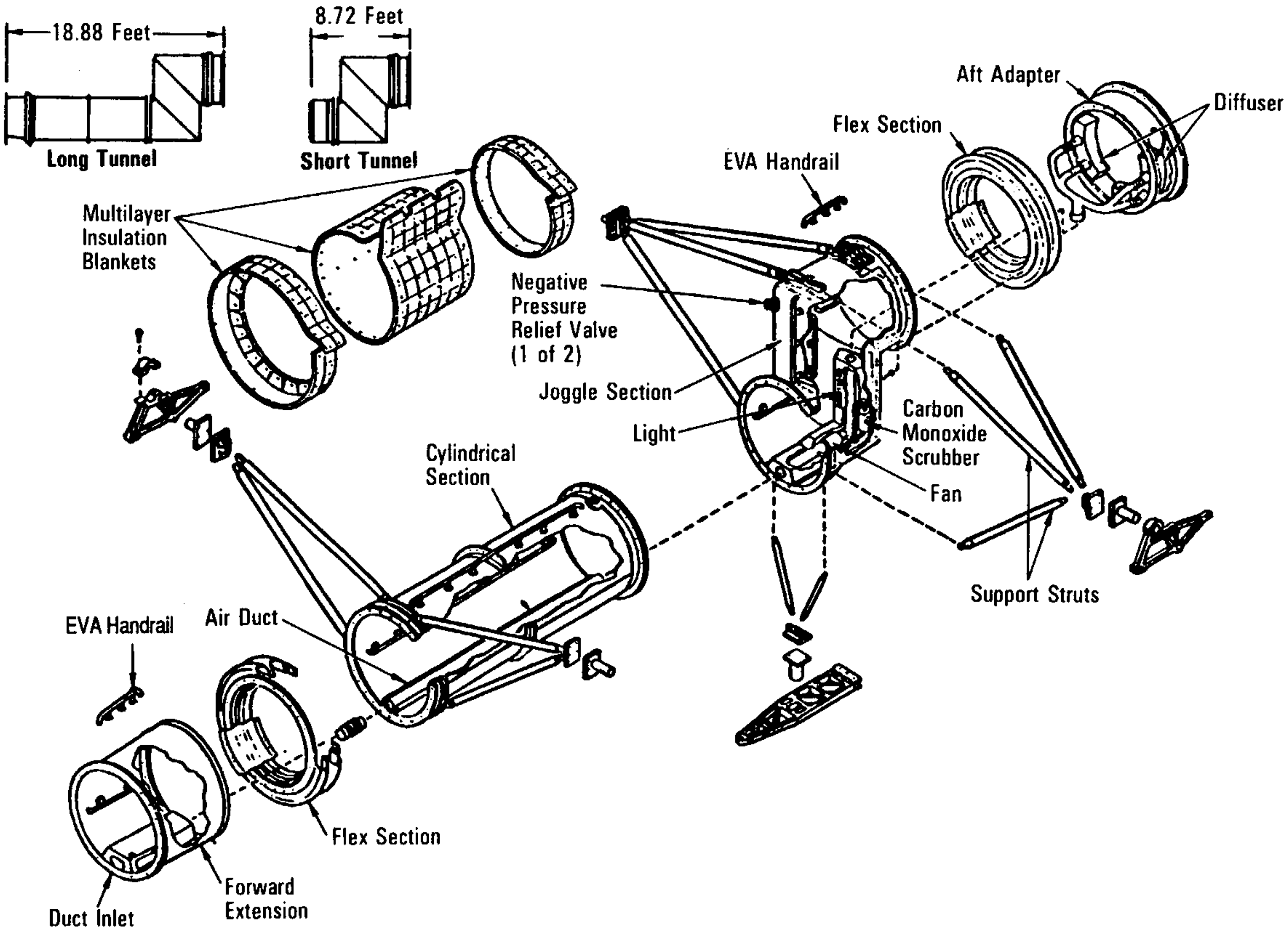
Because of the orbiter's center-of-gravity conditions, the Spacelab pressurized modules cannot be installed at the forward end of the payload bay. Therefore, a pressurized tunnel is provided for equipment and crew transfer between the orbiter's pressurized crew compartment and the Spacelab pressurized modules. The transfer tunnel is a cylindrical structure with an internal unobstructed diameter of 40 inches. The cylinder is assembled in sections to allow length adjustment for different module configurations. Two tunnel lengths can be used—a long tunnel of 18.88 feet and a short tunnel of 8.72 feet. The joggle section of the tunnel compensates for the 42.1-inch vertical offset of the orbiter middeck to the Spacelab pressurized module's centerline. There are flexible sections on each end of the tunnel near the orbiter and Spacelab interfaces. The tunnel is



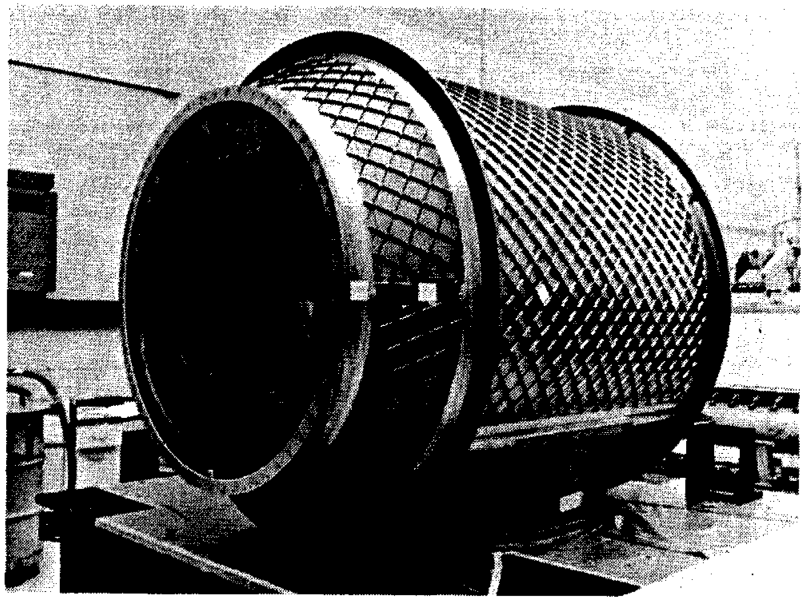
Spacelab External Design Features



European Space Agency's Spacelab



Spacelab Transfer Tunnel



Tunnel Adapter

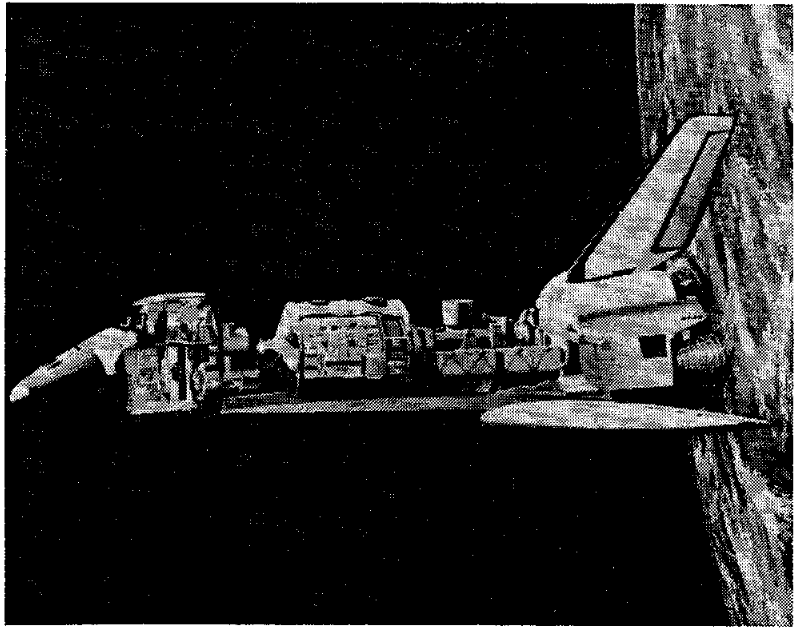
built by McDonnell Douglas Astronautics Company, Huntington Beach, Calif.

The airlock in the middeck of the orbiter, the tunnel adapter, hatches, the tunnel extension, and the tunnel itself permit the flight crew members to transfer from the orbiter middeck to the Spacelab pressurized module or modules in a pressurized shirt-sleeve environment. The airlock, tunnel adapter, tunnel, and Spacelab pressurized modules are at ambient pressure before launch. In addition, the middeck airlock, tunnel adapter, and hatches permit crew members outfitted for extravehicular activity to transfer from the airlock/tunnel adapter in space suits to the payload bay without depressurizing the orbiter crew compartment and Spacelab modules. If an EVA is required, no flight crew members are permitted in the Spacelab tunnel or module.

INSTRUMENT POINTING SUBSYSTEM

Some research to be accomplished on Spacelab missions requires that instruments be pointed with very high accuracy and stability at stars, the sun, the Earth, or other targets of observation. The IPS provides precision pointing for a wide range of payloads, including large single instruments or a cluster of instruments or a single small-rocket-class instrument. The pointing mechanism can accommodate instruments of diverse sizes and weights (up to 15,432 pounds) and can point them to within 2 arc seconds and hold them on target to within 1.2 arc seconds.

The IPS consists of a three-axis gimbal system mounted on a gimbal support structure connected to the pallet at one end and to the aft end of a payload at the other, a payload clamping system to support the mounted experiment elements during launch and landing,

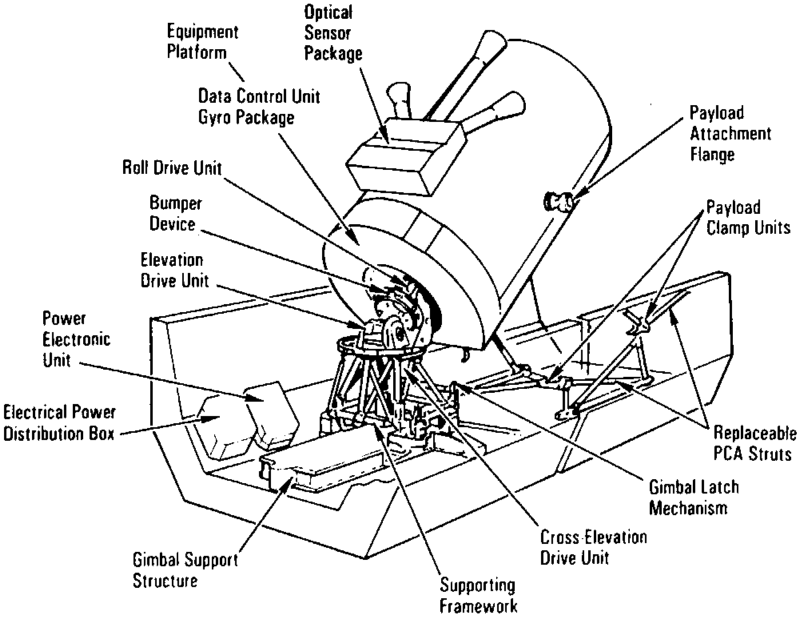


Spacelab

and a control system based on the inertial reference of a three-axis gyro package and operated by a gimbal-mounted minicomputer.

The basic structural hardware is the gimbal system, which includes three bearing/drive units, a payload/gimbal separation mechanism, a replaceable extension column, an emergency jettisoning device, a support structure and rails, and a thermal control system. The gimbal structure itself is minimal, consisting only of a yoke, an inner gimbal, and an outer gimbal to which the payload is attached by the payload-mounted integration ring.

The three identical drive units are so arranged that their axes intersect at one point. From pallet to payload, the order of the axes is elevation, cross-elevation, and azimuth. Each drive assembly includes three wet-lubricated ball bearings, two brushless dc-torquers, and two single-speed/multispeed resolvers.



Instrument Pointing Subsystem

The gimbal/payload separation mechanism is located between the outer gimbal and the payload integration ring. This device prevents the payload and the pointing mechanism from exerting excessive loads on each other during launch and landing. For orbital operations, the outer gimbal and integration ring are pulled together and locked.

The operating modes of the different scientific investigations vary considerably. Some require manual control capability; others require long periods of pointing at a single object, slow scan mapping, or high angular rates and accelerations. Performance in all these modes requires flexibility, which is achieved by computer software. The IPS is controlled through the Spacelab subsystem computer and a data display unit and keyboard. It can be operated either automatically or by the Spacelab crew from the pressurized module and also from the payload station on the orbiter aft flight deck.

The IPS has two operating modes, which depend on whether the gimbal resolver or gyro is used for feedback control of attitude. An optical sensor package consisting of one boresighted fixed-head star tracker and two skewed fixed-head star trackers is used for attitude correction and also for configuring the IPS for solar, stellar, or Earth viewing.

PALLET ONLY

Each pallet is more than a platform for mounting instrumentation; with an igloo attached, it can also cool equipment, provide electrical power, and furnish connections for commanding and acquiring data from experiments. When only pallets are used, the Spacelab pallet portions of essential systems required for supporting experiments (power, experiment control, data handling, communications, etc.) are protected in a pressurized, temperature-controlled igloo housing.

The pallets are designed for large instruments, experiments requiring direct exposure to space, or systems needing unobstructed or broad fields of view, such as telescopes, antennas, and sensors (e.g., radiometers and radars). The U-shaped pallets are covered with aluminum honeycomb panels. A series of hard points attached to the main pallet structure is provided for mounting heavy payload equipment. Up to five segments can be flown on a single mission. Each pallet train is held in place in the payload bay by a set of five attach fittings: four longeron sill fittings and one keel fitting. Pallet-to-pallet joints are used to connect the pallets to form a single rigid structure called a pallet train. Twelve joints are used to connect two pallets.

The pallets are uniform. Each is a U-shaped aluminum frame and panel platform 13.1 feet wide and 10 feet long.

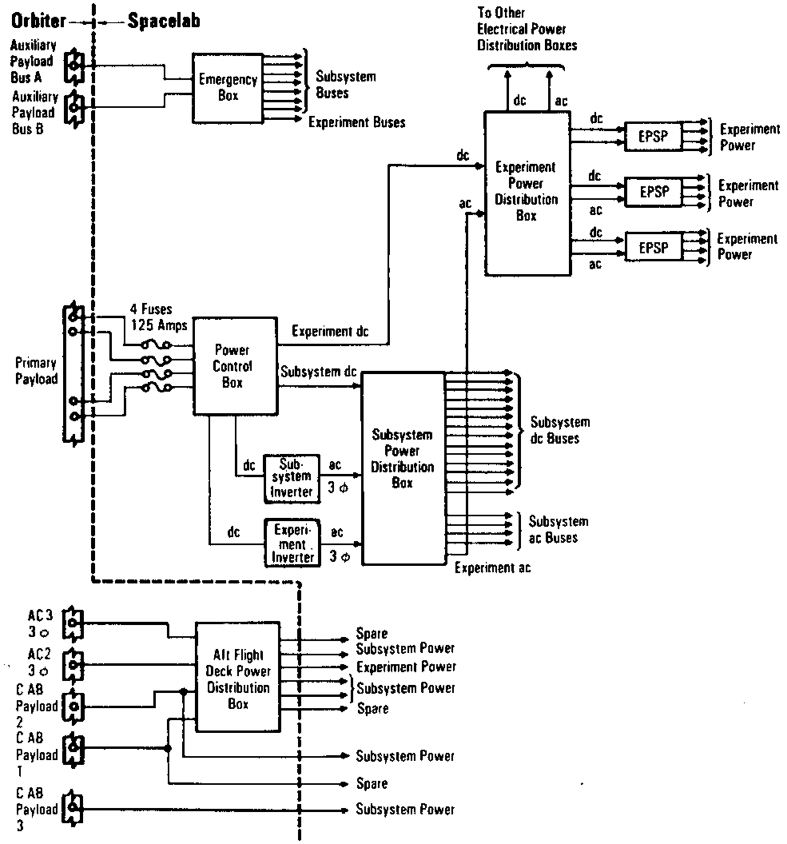
Cable ducts and cable support trays can be bolted to the forward and aft frame of each pallet to support and route electrical cables to and from the experiments and subsystem equipment mounted on the pallet. All ducts mounted on the right side of the pallet are used to route subsystem cables, and all ducts on the left side carry experiment utility cables. The ducts and cable trays are made of aluminum alloy sheet metal. In addition to basic utilities, some special accommodations are available for pallet-mounted experiments.

The igloo is attached vertically to the forward end frame of the first pallet. Its outer dimensions are approximately 7.9 feet in height and 3.6 feet in diameter. The igloo is a closed cylindrical shell made of aluminum alloy. A removable cover allows full access to the interior. The igloo houses subsystems and equipment in a pressurized, dry-air environment at sea-level atmospheric pressure (14.7 psia). Two feedthrough plates accommodate utility lines and a pressure relief valve. The igloo is covered with multilayer insulation.

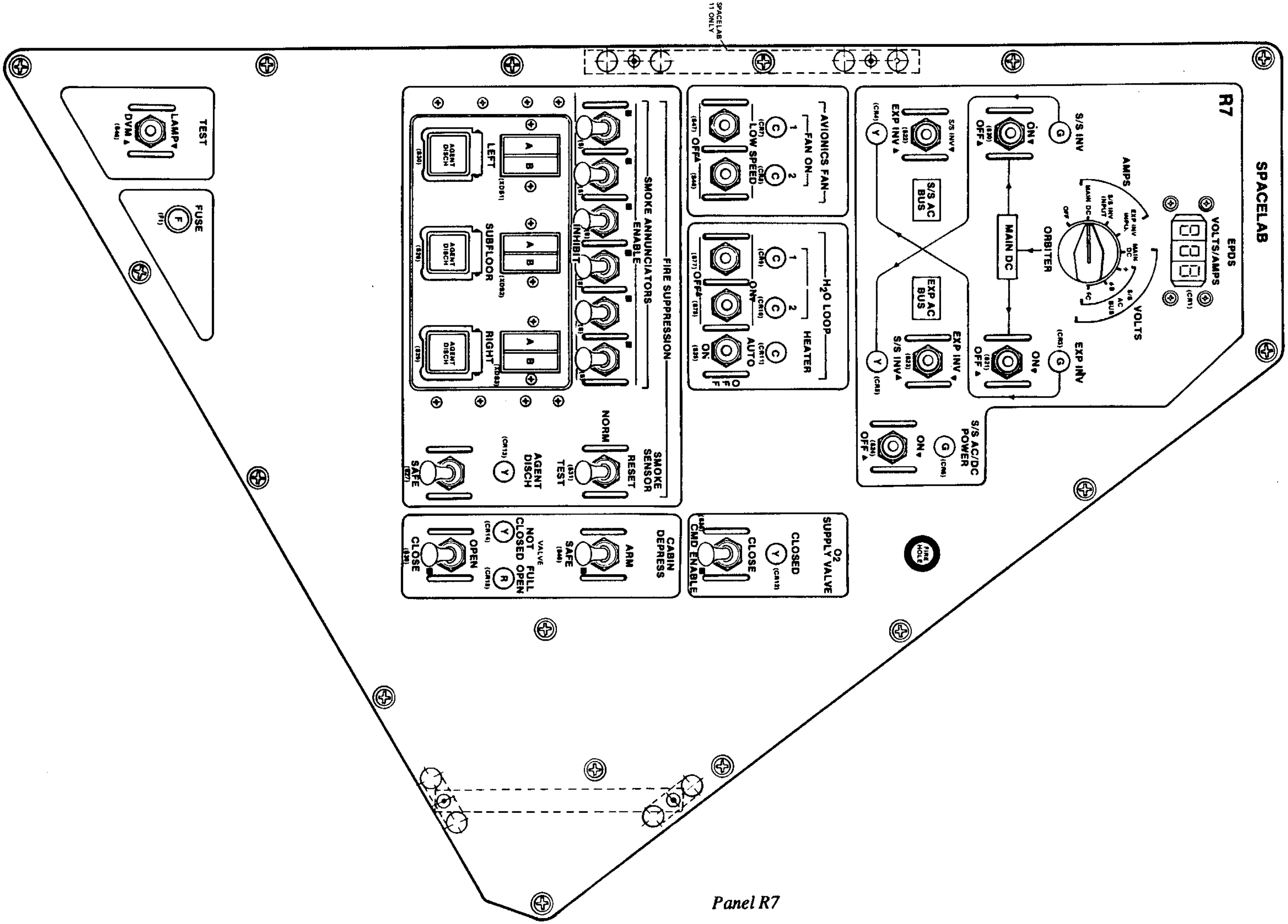
ELECTRICAL POWER

The Spacelab electrical power distribution subsystem controls and distributes main, essential, and emergency dc and ac power to Spacelab subsystems and experiment equipment. Orbiter fuel cell power plants 2 and 3 provide dc power to orbiter main buses B and C, respectively. In addition, through the orbiter main bus tie system (managed and controlled from orbiter display and control panels R1 and F9), dc power is distributed from orbiter main bus C to the orbiter primary payload 1 bus and the Spacelab power control box through four (redundant) main dc power feeders. The orbiter electrical power distribution system is capable of distributing 7 kilowatts maximum continuous (12 kilowatts peak) power to Spacelab subsystems and experiments during on-orbit phases. This is equivalent to supplying 14 average homes with electrical power. If a single fuel cell fails on orbit, the system remains operational with a maximum power level of 5 kilowatts continuous and 8 kilowatts peak.

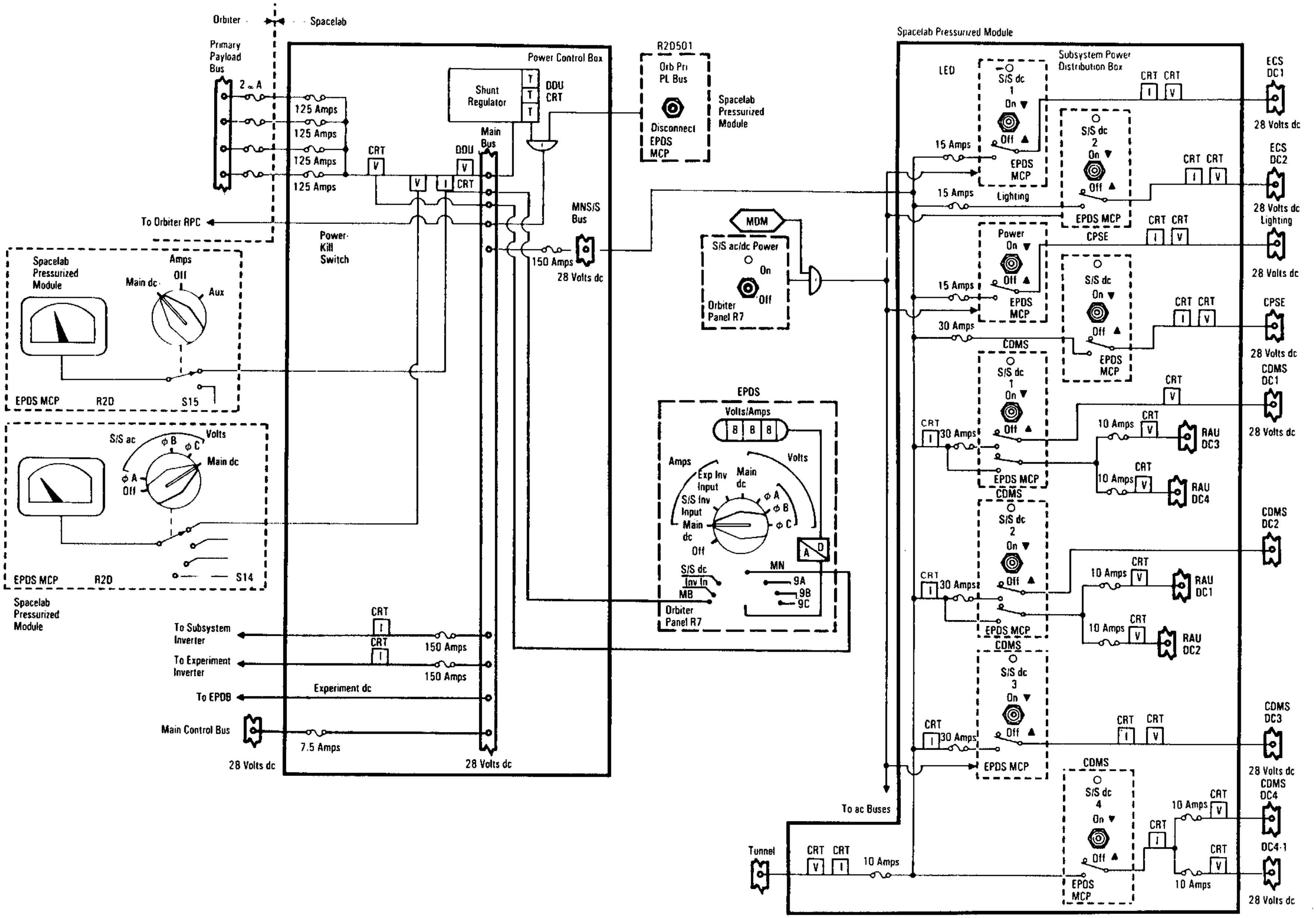
The primary dc power received in the Spacelab from the orbiter primary payload bus is nominally 28 volts, a maximum of 32 volts,



Orbiter Spacelab Electrical Power Distribution


R7
SPACELAB
SPACELAB 11 ONLY
TEST
LAMP
DVM
FUSE
F
FIRE SUPPRESSION
SMOKE ANNUNCIATORS
ENABLE
INHIBIT
LEFT
SUBFLOOR
RIGHT
AGENT DISCH
A
B
SMOKE SENSOR
NORM
RESET
TEST
AGENT DISCH
SAFE
AVIONICS FAN
FAN ON
LOW SPEED
OFF
H2O LOOP
HEATER
ON
AUTO
OFF
S/S INV
EXP INV
S/S AC BUS
EXP AC BUS
MAIN DC
ORBITER
AMPS
VOLTS
EPDS
VOLTS/AMPS
S/S AC/DC POWER
CABIN DEPRESS
ARM
SAFE
VALVE
NOT CLOSED
FULL OPEN
OPEN
CLOSE
O2 SUPPLY VALVE
CLOSED
CLOSE
CMD ENABLE
FIRE HOLE

Panel R7



Orbiter-to-Spacelab Electrical Power Distribution—Subsystem dc Power Distribution

:r line feeds several subsystem power buses controlled by
ı the electrical power distribution subsystem monitoring
| panel. In the pallet-only configuration, all outputs are
vitched by latching relays.

; Spacelab systems' operations are controlled on orbit
R7 in the orbiter crew compartment aft flight station. In
illet-only or pressurized module configuration, Spacelab
ection circuits and command activation are controlled
mote amplification and advisory box. The subsystem
ibution box is controlled by the *S/S ac/dc power on/off*
e orbiter aft flight deck panel R7 or by an item command
rbiter CRT Spacelab displays. The status of this switch
is displayed on the orbiter CRT and indicated by a green
the manual switch on panel R7. The voltages and cur-
various Spacelab subsystem buses are also available to
ew on the orbiter CRT Spacelab subsystem power dis-

power in the Spacelab power control box is directed
parallel 150-amp fuses, one to the Spacelab subsystem
er and the other to a Spacelab experiment dc/ac inverter.
nly the subsystem inverter is used to power both subsys-
eriment ac requirements, and the experiment inverter is
ckup. Each inverter generates three-phase ac power at
ts, 400 hertz. It is possible to connect the ac experiment
bsystem inverter and, conversely, the subsystem ac bus
iment inverter.

pacelab pressurized module configuration, the inverters
l on cold plates in the control center rack of the core seg-
pallet-only configuration, the inverters are mounted on
n the first (forward) pallet in the orbiter payload bay.

celab subsystem inverter is activated by the *S/S inv on/*
n panel R7 or by orbiter Spacelab CRT command. Posi-
witch to *on* activates the subsystem inverter, and a green
the switch on panel R7 is illuminated, indicating the

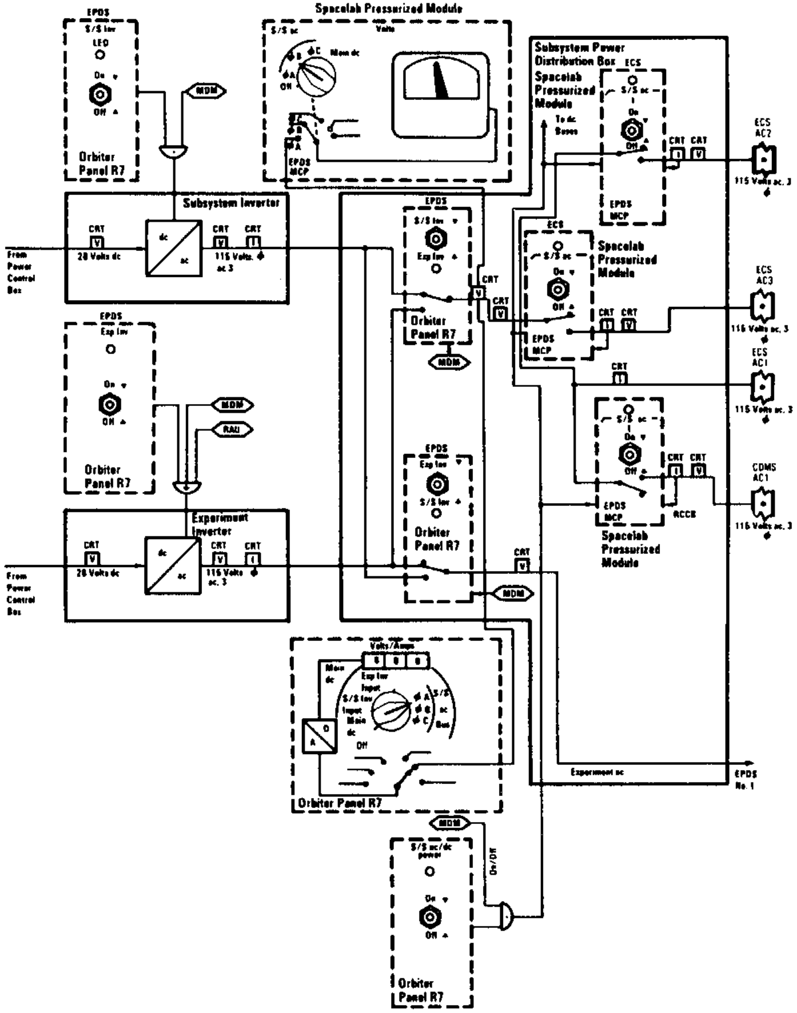
inverter is operating. Positioning the momentary left *S/S inv, exp inv* switch to *S/S inv* permits the subsystem inverter to supply ac power to the Spacelab subsystem ac bus. Similarly, positioning the momentary right *S/S inv, exp inv* switch to *S/S inv* supplies ac power to the experiment ac bus, and the yellow light below the switch is illuminated to indicate the subsystem inverter is supplying the experiment ac bus.

The Spacelab experiment inverter is activated by the *exp inv on/off* switch on panel R7 or by orbiter Spacelab CRT command. Positioning the switch to *on* activates the experiment inverter, and a green LED light above the switch is illuminated, indicating the inverter is in operation. Positioning the momentary right *exp inv, S/S inv* switch to *exp inv* supplies ac power to the experiment ac bus. Positioning the momentary left *S/S inv, exp inv* switch to *exp inv* supplies ac power to the subsystem ac bus, and the yellow light below the switch is illuminated to indicate the experiment inverter is supplying the subsystem ac bus.

The switching of Spacelab inverters between the two ac power buses may also be commanded and monitored through the orbiter CRT Spacelab subsystem ac power supply. Readings presented on the orbiter CRT display include inverter on/off status, inverter output voltage, inverter input voltage, and inverter output current. The subsystem inverter input, experiment inverter input, and main dc amps are available via the digital readout and rotary switch on panel R7. The main dc and subsystem ac bus phase A, B, and C volts also are available via the digital readout and rotary switch on panel R7. In the Spacelab pressurized module configuration, the Spacelab EPDS monitoring and control panel provides a color readout of each subsystem ac phase.

The Spacelab inverters are protected against overvoltage and overcurrent. They are shut down automatically if the voltage exceeds 136 volts root mean square per phase. Current levels are limited to 12 amps rms per phase, and all three phases are shut down if one phase draws a current of 10 amps rms for 120 seconds.

In the pressurized module configuration, the subsystem power distribution box ac bus feeds several Spacelab subsystem power buses controlled by switches on the Spacelab EPDS MCP. All functions on this panel can be initiated simultaneously by the *S/S ac/dc*



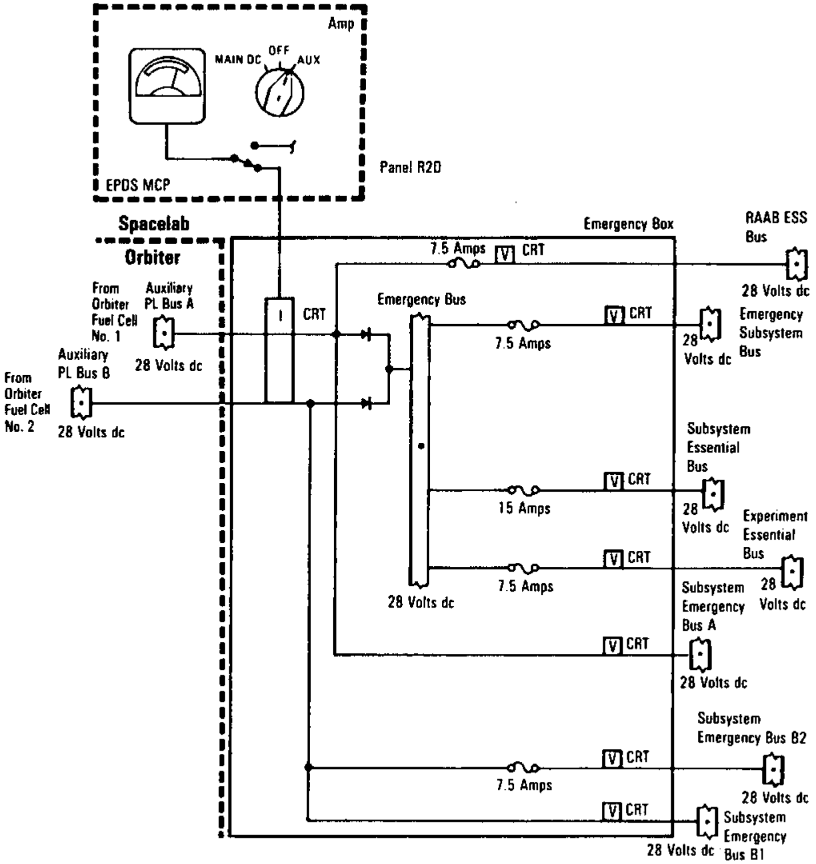
Spacelab Electric Power Distribution— Subsystem ac Power Distribution *power on/off* switch on orbiter panel R7 or by item commands from the orbiter CRT Spacelab displays. The status of the commanded relays is available via orbiter CRT Spacelab displays and indicated by the green LED light above the respective switch on panel R7.

In the pallet-only configuration, subsystem ac bus power feeds several Spacelab subsystems' power buses, which can be initiated by the *S/S ac/dc power on/off* switch on orbiter panel R7 or by item commands from the orbiter CRT Spacelab displays. The status of the commanded relays is available via orbiter CRT Spacelab displays and the green LED light above the respective switches on panel R7.

Emergency and essential dc power for the pressurized module configuration is provided by the orbiter auxiliary payload buses A and B to the Spacelab emergency box. The Spacelab emergency box supplies emergency and essential power for Spacelab critical environmental control subsystem sensors and valves, fire and smoke suppression equipment, ECS water line heaters, module emergency lighting, tunnel emergency lighting, the Spacelab intercom system, and the Spacelab caution and warning panel. The outputs are protected by fuses. One separately fused outlet, an experiment essential bus, is dedicated to experiments. This power is available during all flight phases and when degraded power is delivered to Spacelab. The Spacelab emergency box is located in the subfloor of the core segment.

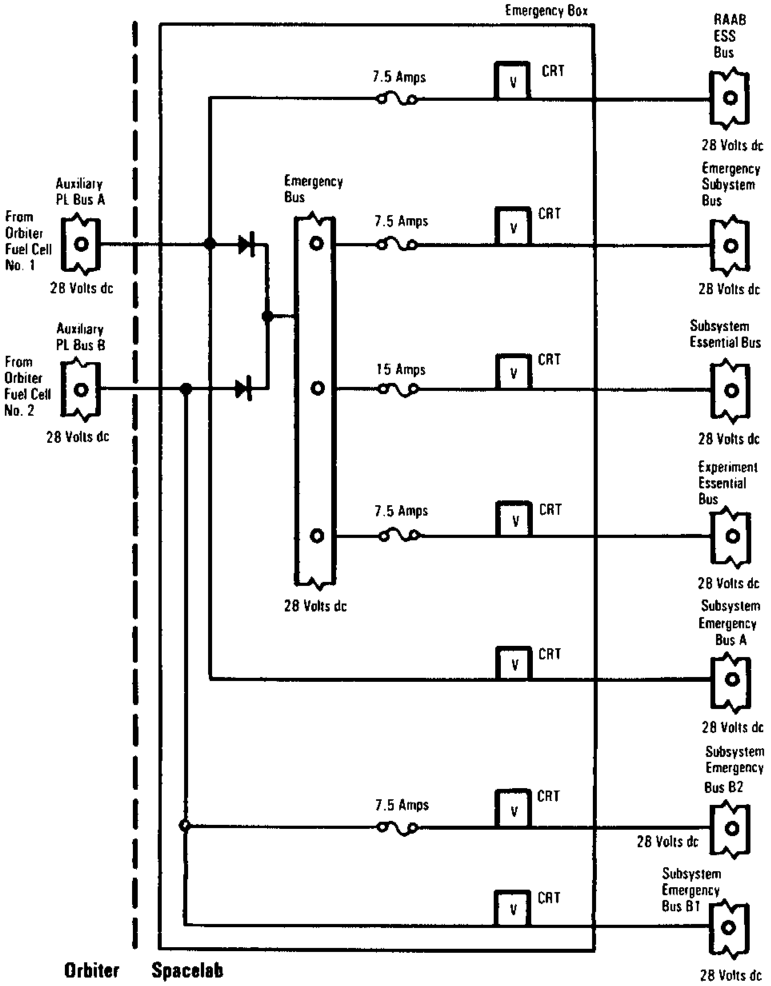
Emergency and essential dc power for the pallet-only configuration is also provided by orbiter auxiliary payload buses A and B, which send dc power to the Spacelab emergency box located in the igloo. The Spacelab emergency box provides emergency or essential power to Spacelab subsystem equipment. The outputs are protected by fuses. One separately fused outlet, an experiment essential bus, is dedicated to experiments. The Spacelab emergency box is in the igloo. This power is available during all flight phases and when degraded power is delivered to Spacelab.

In the Spacelab pressurized module configuration, experiment power distribution boxes provide distribution, control, and monitoring facilities for the experiment electrical power distribution system, which consists of a nominal redundant 28-volt experiment main dc supply and a 115-volt, 400-hertz ac experiment supply. One distribution box (EPDB 1) is located under the core segment floor on a support structure; for the long module configuration, two additional units (EPDBs 2 and 3) are installed. In the pallet-only configuration,



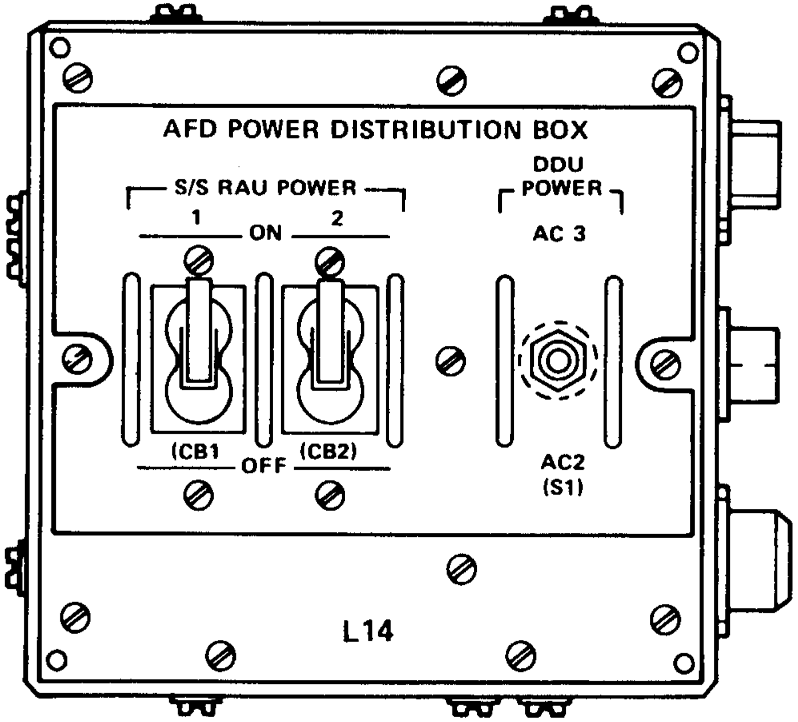
Spacelab Pressurized Module Emergency and Essential Power Distribution the experiment power distribution box is mounted with other assemblies with an adapter plate on a cold plate that is fitted on a support structure and attached to the pallet.

The orbiter pressurized module CRT Spacelab displays present emergency and essential bus current, voltages for auxiliary buses A and B, output voltages for Spacelab subsystem emergency buses, output voltage for the Spacelab subsystem essential bus, and output voltage for the Spacelab remote amplification and advisory box essential bus. The orbiter CRT Spacelab displays for activation/deactivation, subsystem dc power, and system summary indicate an undervoltage condition for auxiliary buses A and B. Nominal auxiliary bus amperage from the orbiter can be monitored on the *amps* meter (color zone only) of the Spacelab EPDS monitoring and control panel.



Spacelab Pallet Emergency and Essential Power Distribution

In the pallet-only configuration, the orbiter CRT Spacelab displays include emergency and essential bus current, voltages for auxiliary buses A and B, output voltages for Spacelab subsystem emergency buses, output voltage for the Spacelab subsystem essential



Panel L14

bus, and output voltage for the Spacelab remote amplification and advisory box essential bus. The orbiter CRT Spacelab activate/deactivate, Spacelab subsystem dc power, and Spacelab system summary displays will indicate an undervoltage condition for auxiliary buses A and B.

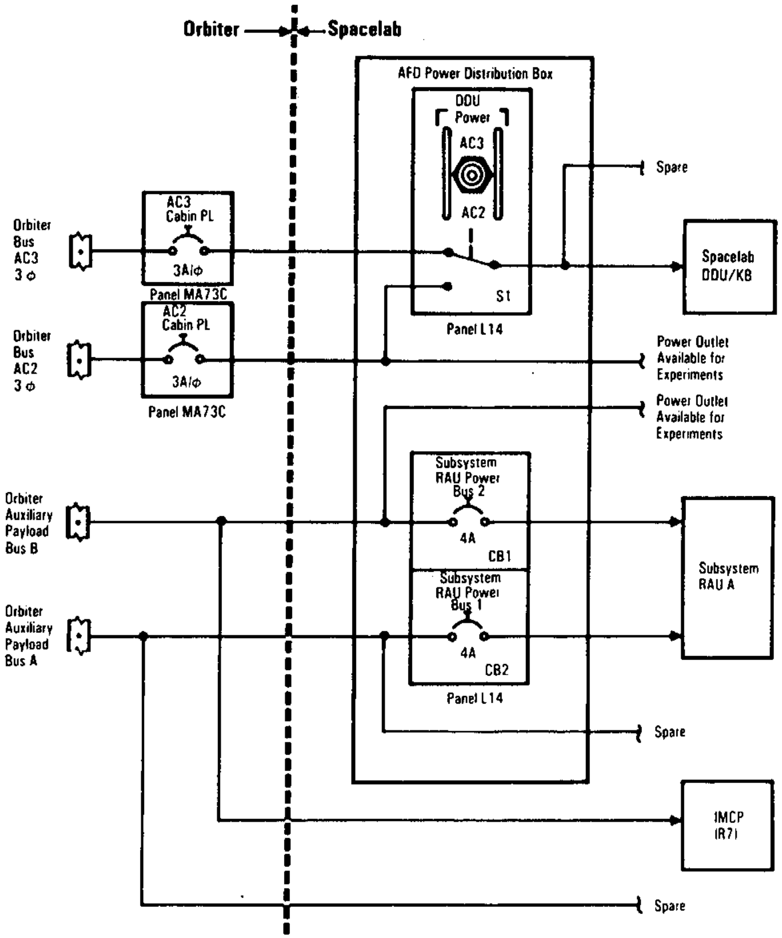
The Spacelab power distribution box at the orbiter aft flight deck payload station distributes dc and ac power to the Spacelab subsystem remote acquisition unit and the Spacelab data display system (a data display unit and keyboard). When a Spacelab data display system is installed at the mission station, ac power is provided from orbiter ac bus 2 or 3 via the orbiter mission station distribution panel.

Spacelab subsystem remote acquisition unit dc power comes from orbiter fuel cell 1 main bus A through auxiliary payload bus A and from orbiter fuel cell 2 main bus B to auxiliary payload bus B through the payload station distribution panel. This power is not affected by the kill switch of the primary payload bus. The aft flight deck power distribution panel L14 *S/S RAU power 1 on/off* and *S/S RAU power 2 on/off* circuit breakers are used to feed power to the RAU from either bus.

Control of the ac power supplied to the Spacelab DDU and keyboard from orbiter ac buses 2 and 3 is made possible by positioning the panel L14 *DDU power* switch to *AC2* or *AC3*. This 115-volt ac, three-phase, 400-hertz power is available only during on-orbit flight phases. Panel L14 provides no fuse protection.

In the pallet-only configuration, ac power is supplied to the Spacelab pallet or pallets from orbiter ac buses 2 and 3 by positioning the panel L14 *DDU power* switch to *AC2* or *AC3*. This power (115 volts ac, three phase, 400 hertz) is available only during on-orbit flight phases.

In the Spacelab module, the experiment power switching panel provides facilities for branching and switching dc and ac power delivered by a dedicated experiment power control box. The dc and ac output is distributed to experiments and experiment-supporting RAUs (dc only). The number of switching panels and their locations depend on the mission configuration.



Pressurized Module Configuration—Orbiter Aft Flight Deck Power Distribution

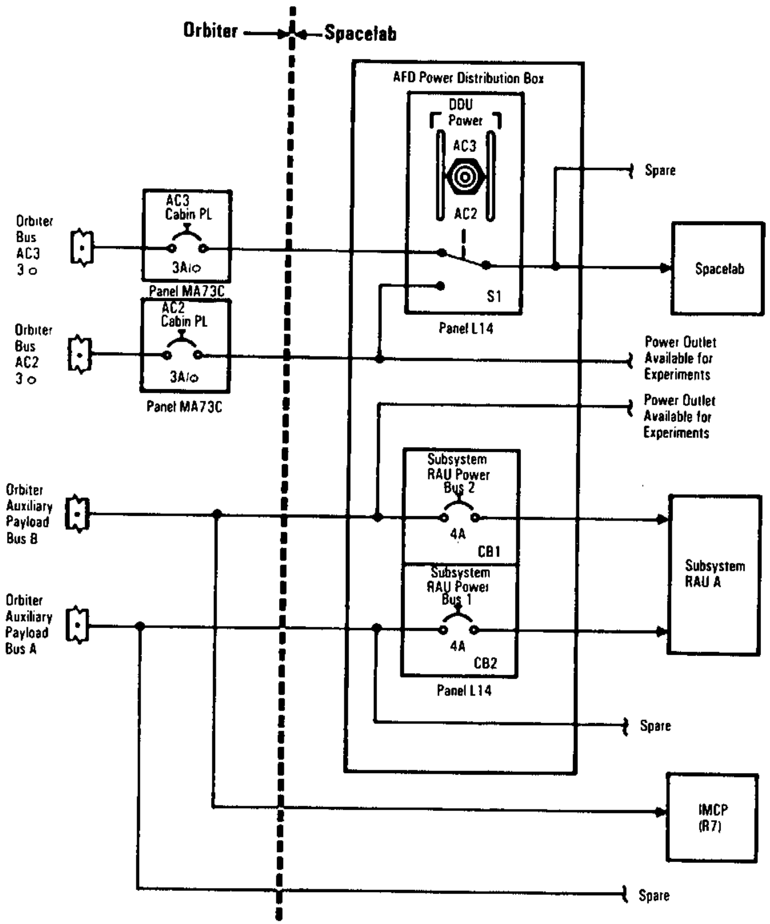
The orbiter crew compartment aft flight deck panel configurations vary for Spacelab pressurized module configurations and pallet-only configurations. A Spacelab pressurized module configuration may consist of a payload specialist station data display unit at panel L11, a standard switch panel at panel L12, a keyboard at panel L11, a systems management tone generator and interconnect station at panel L14, a mission specialist station with a data display system and interconnect station at panel R14, and a floor-mounted remote acquisition unit at the payload station.

A pallet-only configuration may consist of a payload specialist station data display system at panel L11, a Spacelab-unique switch panel at panel L12, a video tape recorder at panel R11, a high-data-rate recorder at panel L10, a systems management tone generator and interconnect station at panel L14, a Spacelab power distribution box at panel L14, and a floor-mounted Spacelab RAU at the payload station.

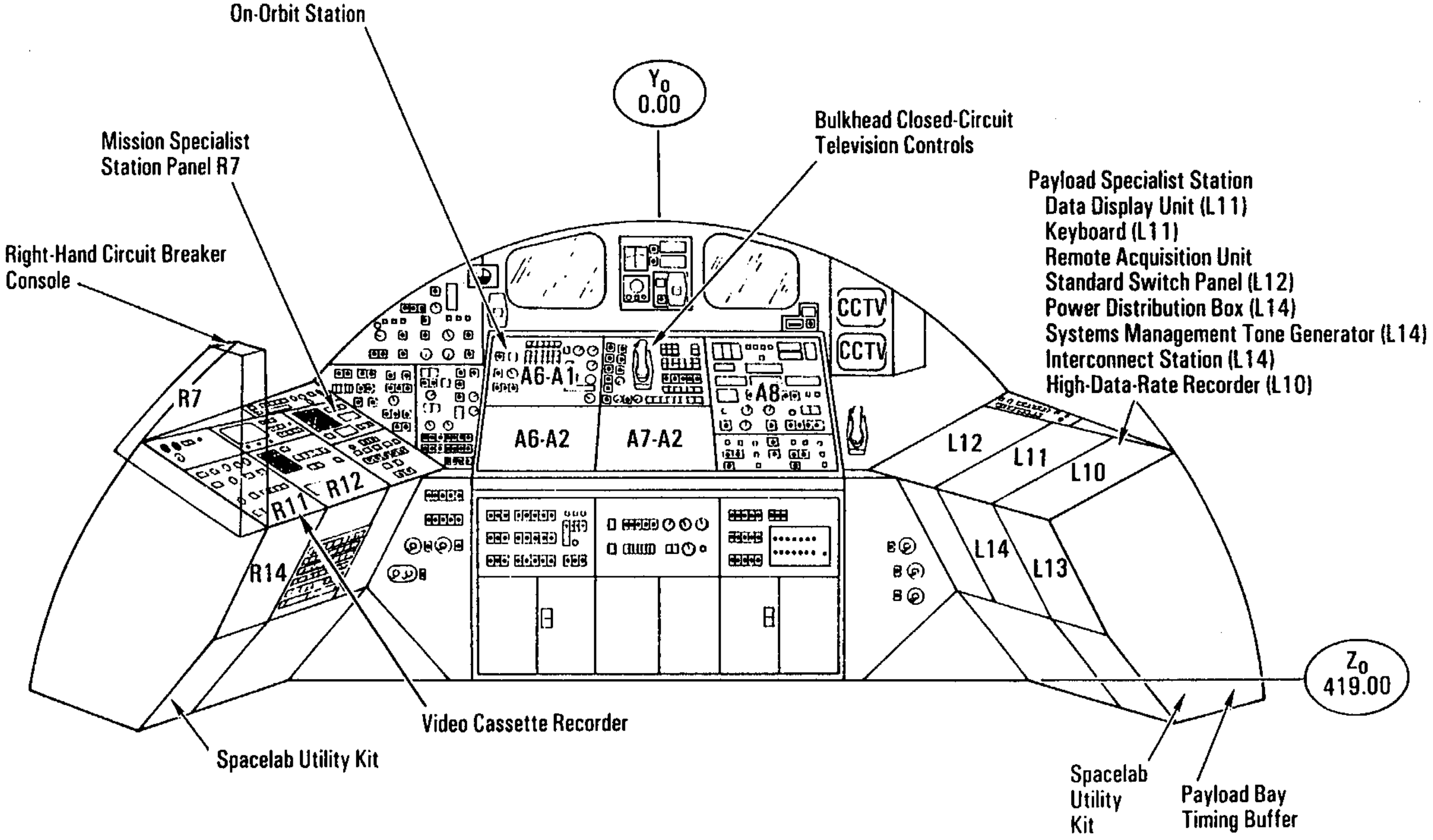
COMMAND AND DATA MANAGEMENT SYSTEM

The Spacelab command and data management system provides a variety of services to Spacelab experiments and subsystems. Most of the CDMS commands are carried out through the use of the computerized system aboard Spacelab, called the data processing assembly. The DPA formats telemetry data and transfers the information to the orbiter for transmission, receives command data from the orbiter and distributes them to Spacelab subsystems, transfers data from the orbiter to experiments, and distributes timing signals from the orbiter to experiments.

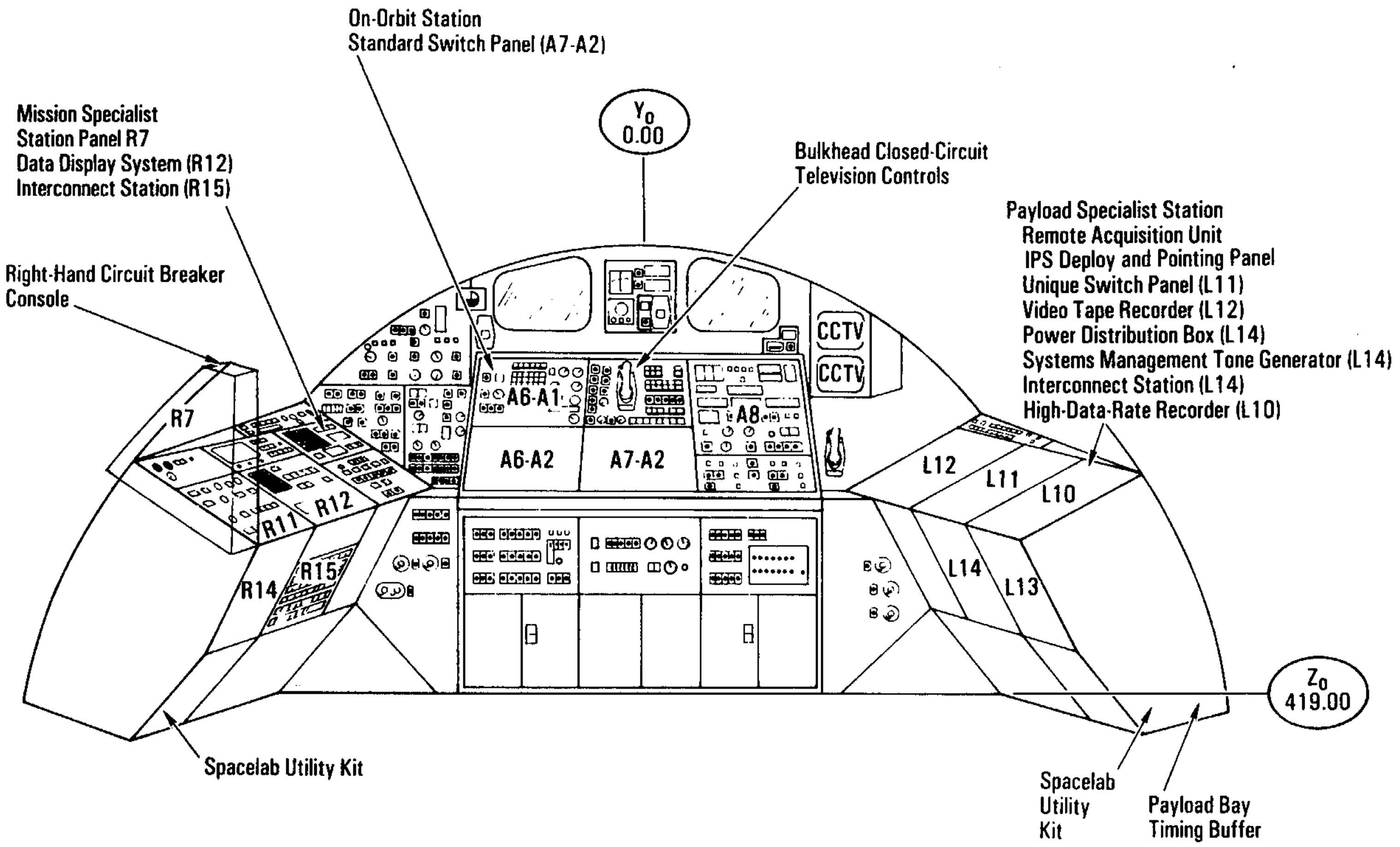
The CDMS includes three identical computers and assorted peripherals. One computer is dedicated to Spacelab experiments, one supports Spacelab subsystems, and the third is a backup. The flight crew monitors and operates Spacelab subsystems and payload experiments through data display and keyboard units. The previously used three identical MATRA 125/MS computers have been changed to the upgraded AP-101SL orbiter computers. The experiment computer activates, controls, and monitors payload operations and provides experiment data acquisition and handling. The subsystem computer provides control and data management for basic Spacelab services that are available to support experiments, such as electrical power distribution, equipment cooling, and scientific air-



Pallet-Only Configuration—Orbiter Aft Flight Deck Power Distribution



Example of a Spacelab Pressurized Module Aft Flight Deck Panel Configuration



Example of a Spacelab Pallet-Only Aft Flight Deck Panel Configuration lock operations (in the case of the pressurized module). The backup computer can function in the place of either computer.

An input/output unit buffers all communications between the computer and the rest of the subsystem. The experiment computer also has at least one RAU (and as many as eight, depending on the payload) for interfacing between experiments and the subsystem. The subsystem computer may have as many as nine acquisition units, depending on the Spacelab configuration.

The experiment and subsystem computers and their associated input/output units, as well as the shared mass memory unit and backup computer, are located in the workbench rack of the pressurized module core segment. In the pallet-only configuration, they are located in the igloo.

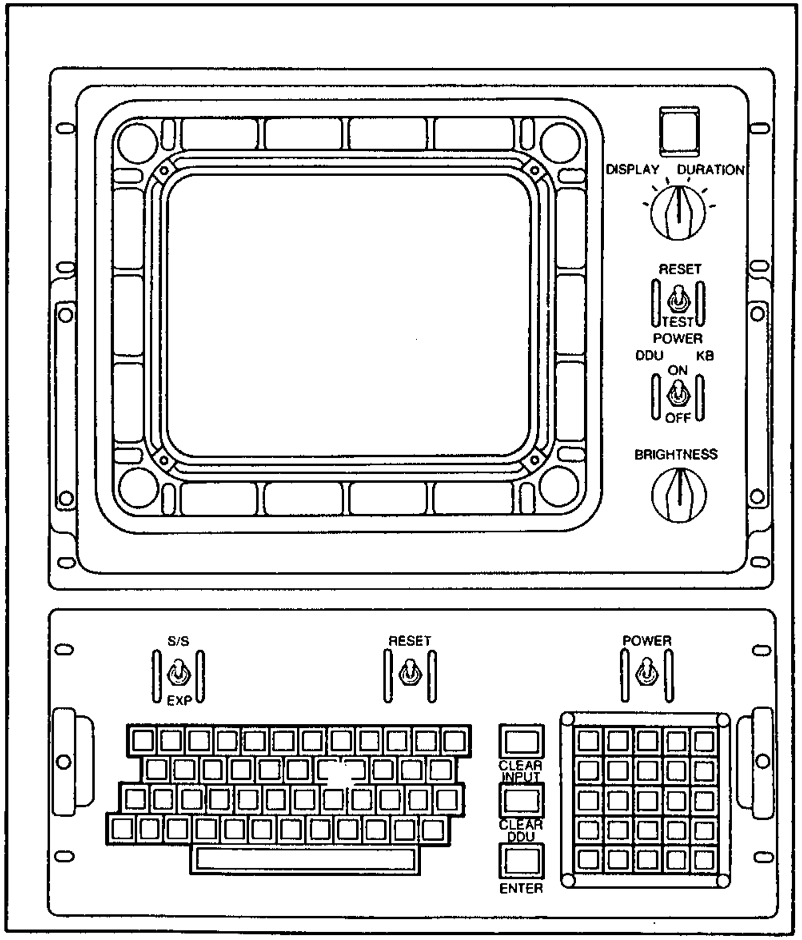
Mass Memory Unit

The MMU is a tape recorder that contains all of the operating system and applications software for the subsystem and experiment computers. The memory unit provides the initial program load for the Spacelab subsystem, experiment, and backup computers; it can also be used to completely reload computer memory if required. The MMU stores various files, time lines, and displays. Writing onto the unit during flight is possible. Approximately half of the unit's storage capability is available for software and data supporting Spacelab experiments.

Data Display Systems

The data display systems are the primary on-board interface between the CDMS and the Spacelab flight crew. Each display system consists of a keyboard and a CRT data display unit. One display is located at the orbiter aft flight deck station, one at the control center rack in the pressurized module, and, possibly, one at the experiment rack in the pressurized module. In the pallet-only configuration, two CRTs and DDUs can be located at the crew compartment aft flight deck station.

The keyboard consists of 25 function keys and 43 alphabet, numeral, punctuation, and symbol keys of the familiar standard typewriter keyboard as well as the standard typewriter action keys, such as space and backspace. The data display unit is a 12-inch diagonal CRT screen providing a 22-line display (47 characters per line)



Data Display Unit and Keyboard

in three colors (green, yellow, and red). In addition to 128 alphanumeric symbols, the unit can also display vector graphics (1,024 different lengths and 4,096 angles). A high-intensity green flashing mode is also provided.

The display units are connected to the experiment and subsystem input/output units. Each data display unit can present information from both computers simultaneously, and each keyboard can communicate with either computer. Flight crew members can call various displays onto the screen from the keyboard for experiment evaluation and control.

Command and data management system software consists of experiment computer software and subsystem computer software, each of which includes operating systems and applications. Within the experiment computer, both the operating system and the application software are wholly dedicated to the direct support of Spacelab payload experiments. The operating system provides such general services as activation, control, monitoring, and deactivation of experiments as well as experiment data acquisition, display, and formatting for transmission. Application software is developed for experiments that have data handling requirements beyond the capabilities of the operating system.

The subsystem computer functions mainly to monitor and control other Spacelab subsystems and equipment, such as the electrical power distribution subsystem and the environmental control subsystem. These functions are performed by the subsystem computer operating software.

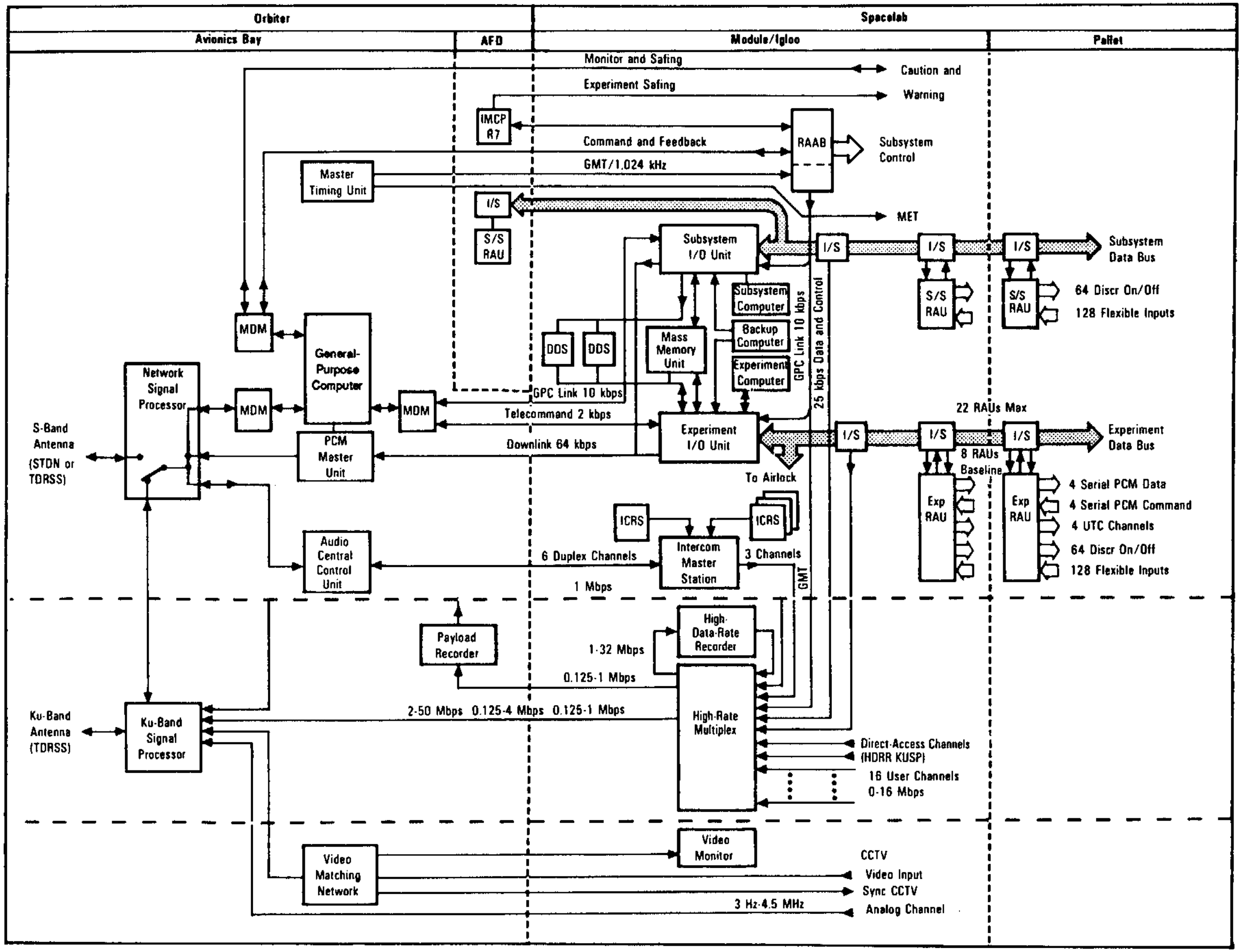
Two orbiter payload multiplexers/demultiplexers (PF1 and PF2) are used for data communications between the orbiter general-purpose computers and the Spacelab CDMS computers. The payload MDMs are under orbiter GPC control. The orbiter pulse code modulation master units under control of the orbiter computers can access Spacelab data for performance monitoring and limit sensing. The PCMMUs contain a fetch command sequence and a random-access memory for storing fetched data. Data from the PCMMU RAM are combined with orbiter pulse code modulation data and sent to the orbiter network signal processors for transmission on the return link (previously referred to as downlink) through S-band or Ku-band. The 192-kbps data stream normally carries 64 kbps of Spacelab experiment and subsystem data.

The Spacelab experiment computer interfaces with two telemetry systems. The orbiter PCMMU allows the orbiter to acquire data for on-board monitoring of systems and provides the Mission Control Center in Houston with system performance data for real-time display and recording through the orbiter network signal processor and S-band or Ku-band. The other telemetry system, the Spacelab high-rate multiplexer, is a high-rate link to the Ku-band signal processors that sends scientific data to the Payload Operations Control Center for real-time display and to the Goddard Space Flight Center for recording.

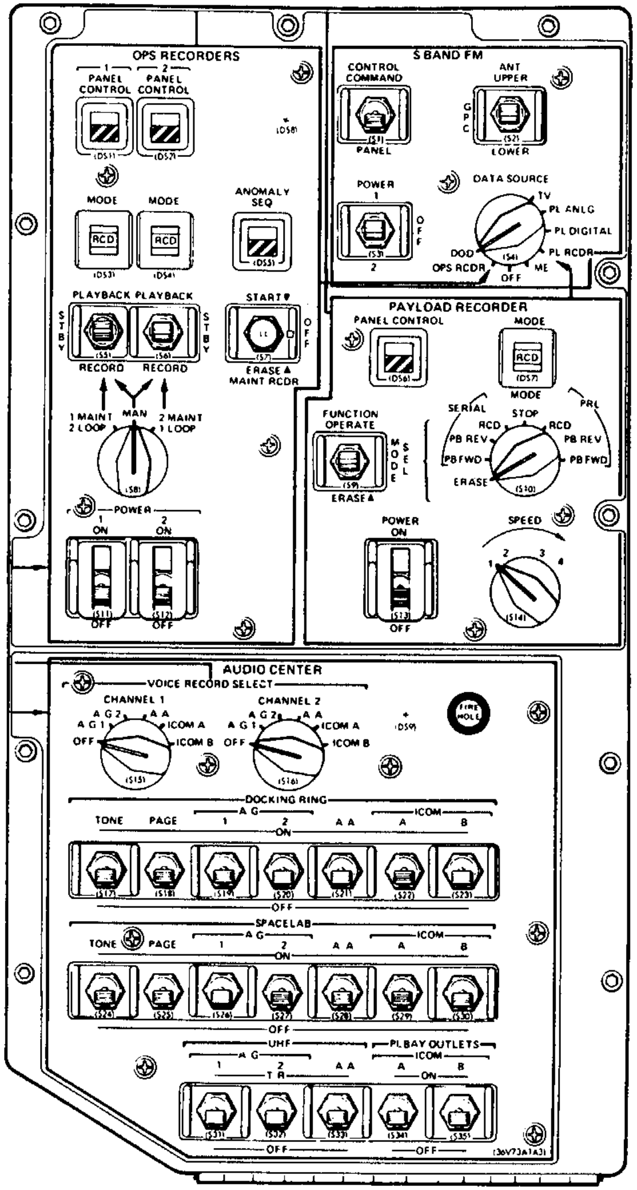
Spacelab high-rate data acquisition is provided by a high-rate multiplexer and a high-data-rate recorder. The HRM multiplexes up to 16 experiment channels, each with a maximum of 16 Mbps; two direct-access channels with data rates up to 50 Mbps; data from the Spacelab subsystem computer; experiment data from the Spacelab experiment computer; and up to three analog voice channels from the Spacelab intercom master station in the pressurized module configuration. The three digitized channels are premultiplexed onto a single 128-kbps channel for interleaving in the format along with Greenwich mean time signals from the orbiter master timing unit. This composite output data stream is routed to the Ku-band signal processor for transmission on Ku-band or is sent to one of the two recorders. The HRM is located on the control center rack in the pressurized module and in the igloo for the pallet-only configuration.

In the pressurized module, the high-data-rate recorder is located at the control center rack next to the data display system; in the pallet-only configuration, it is at the aft flight deck panel L10. It records real-time, multiplexed data or data from two direct-access channels and stores the information at rates from 1 to 32 Mbps during mission

DDS – Data Display System
I/O – Input/Output
MDM – Multiplexer/Demultiplexer
PCM – Pulse Code Modulation
RAU – Remote Acquisition Unit
S/S – Subsystem



Spacelab Command and Data Management System Interfaces With the Orbiter



Panel AIA3

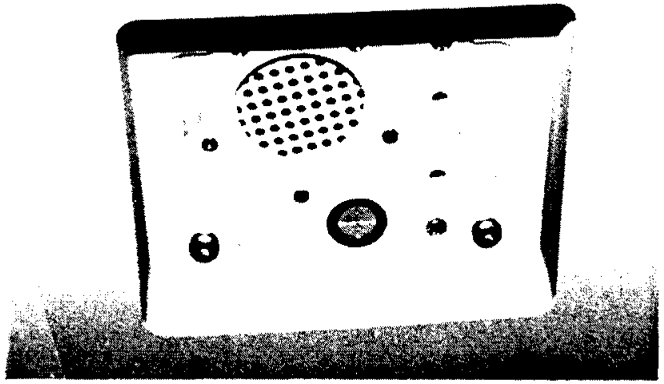
periods with no downlink capability or degraded downlink capability for playback when the capability is available. The HDRR dumps in reverse order at 2, 4, 8, 12, 16, 24, or 32 Mbps. At a rate of 32 Mbps, a tape runs for 20 minutes. The recorder can be changed manually by the flight crew; however, no tape changes are planned because the time required to change tapes is very long and it is much more efficient to dump the tape.

The orbiter payload recorder serves as a backup for the Spacelab HDRR for data rates from 0.125 to 1 Mbps and can record only real-time, multiplexed data. The orbiter payload timing buffer provides mission elapsed time and Greenwich mean time; and the master timing unit provides 100-hertz, 1-kHz, 1,024-kHz, and 4,608-kHz timing signals to the Spacelab data processing assembly. Activation of the Spacelab DPA is controlled and monitored from the orbiter CRT Spacelab displays.

Closed-Circuit Television

The Spacelab pressurized module video system interfaces with the orbiter closed-circuit television system and the orbiter Ku-band signal processor. The orbiter CCTV system accepts three video inputs from the Spacelab system. The orbiter monitors the TV received and/or transmits it to telemetry. A sync command signal provided by the orbiter synchronizes and remotely controls cameras within Spacelab. The orbiter also has one video output for a Spacelab TV monitor. The Spacelab accommodates a video switching unit that enables Spacelab video recorder capability. The Spacelab analog channel for experiments is directed to the orbiter Ku-band signal processor at 3 to 4.5 MHz.

In the pallet-only configuration, the orbiter's CCTV can be used along with a video tape recorder. The TV cameras installed in the payload bay vary according to mission requirements. Television data downlinked on Ku-band channel 3 are time-shared by the orbiter's CCTV system, the Spacelab TV/analog output, and the Spacelab high-rate multiplexer data.



Spacelab Pressurized Module Aural Annunciator Located Below Panel L14

Pressurized Module Intercom

The Spacelab intercom master station interfaces with the orbiter audio central control unit and the orbiter EVA/ATC transceiver for communications through orbiter duplex (simultaneous talk and listen) audio channels. Audio channel 1 is air-to-ground 2, channel 2 is intercom B, and channel 3 is air-to-ground 1.

Each orbiter channel, with the exception of page, may be selected on each of the three Spacelab full-duplex channels—A/G 1 for the Payload Operations Control Center, Spacelab and A/G 2 for the orbiter/Mission Control Center—using rotary switches on the Spacelab intercom master station. The page channel is used for general address and calling purposes. Page signals can originate in the orbiter, Spacelab, or both.

Access to orbiter channels is controlled within the orbiter. Normal voice recordings are made on the orbiter operations recorders. The Spacelab talk and listen lines are combined for distribution to the Spacelab voice digitizer in the Spacelab high-rate multiplexer for all three Spacelab channels.

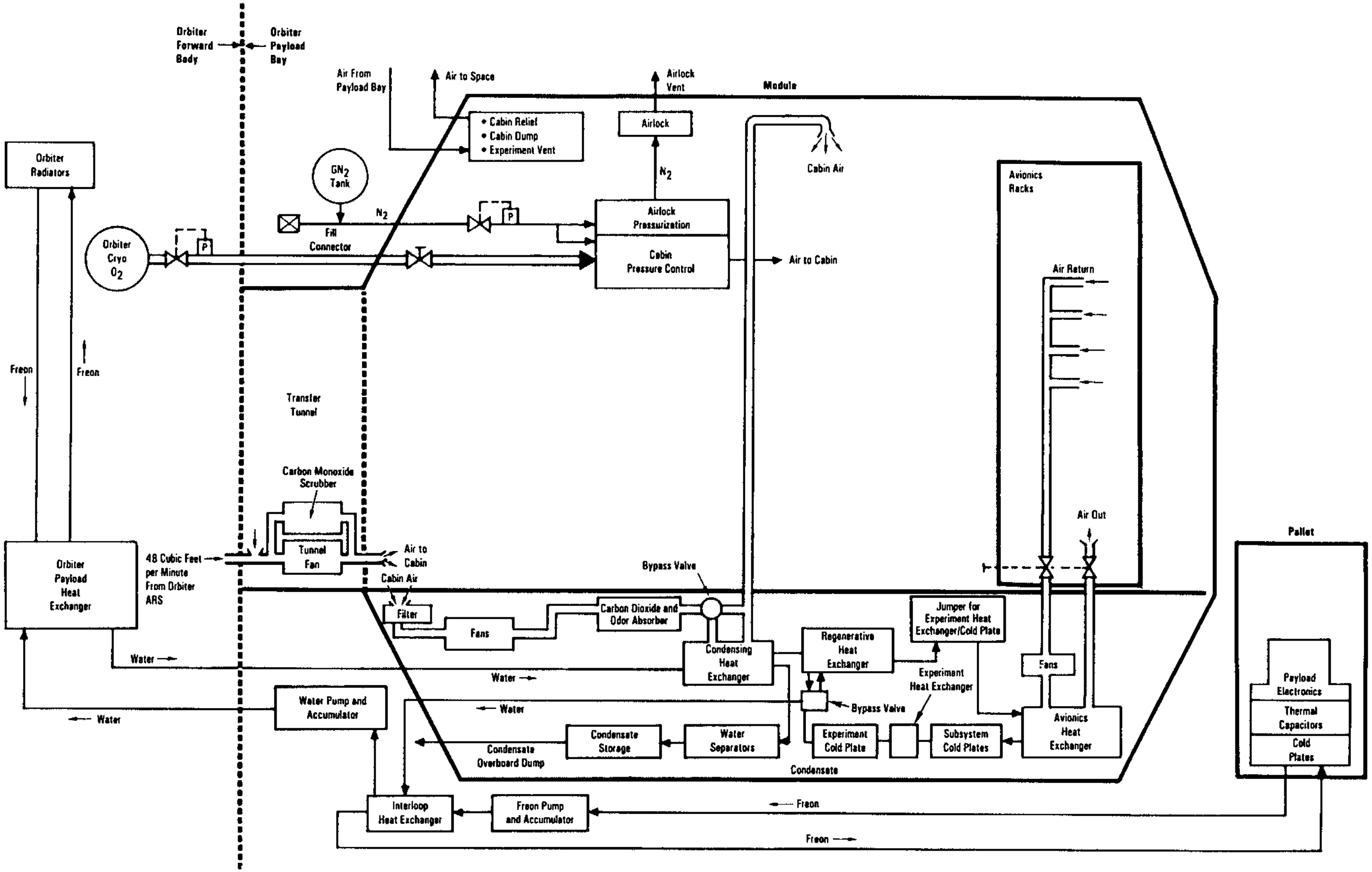
PRESSURIZED MODULE ENVIRONMENTAL CONTROL SUBSYSTEM AND LIFE SUPPORT

The Spacelab environmental control subsystem consists of the atmosphere storage and control subsystem and the atmosphere revitalization system.

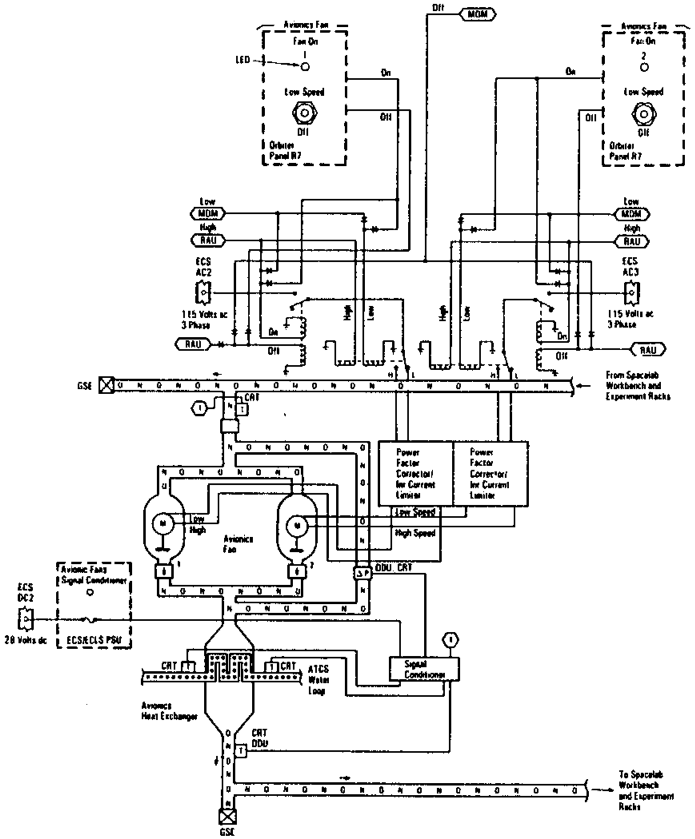
The atmosphere storage and control subsystem receives gaseous oxygen from the orbiter power reactant storage and distribution system and gaseous nitrogen from a tank located on the Spacelab module's exterior. The Spacelab ASCS regulates the gaseous oxygen and nitrogen pressure and flow rates to provide a shirt-sleeve environment for the Spacelab module compatible with the orbiter cabin atmosphere.

Gaseous oxygen from the orbiter PRSD enters the Spacelab module through the upper feedthrough in the Spacelab forward end cone at 100 psi and a maximum flow rate of 14 pounds per hour. A motor-controlled valve in the Spacelab module controls the flow of gaseous oxygen. This valve, operated by Spacelab RAU commands, opens when the *O_2 supply valve* switch on panel R7 is in the *cmd enable* position. It closes when the switch is in the *close* position for such situations as contingency cabin atmosphere dump. A yellow LED above the switch on panel R7 is illuminated to indicate that the valve is closed. The oxygen supply valve receives 28 volts from the Spacelab emergency bus.

The Spacelab cabin depressurization assembly is primarily for contingency dump of Spacelab cabin atmosphere in case of fire that cannot be handled by the Spacelab fire suppression system. It consists of a vent with two filters, a manual shutoff valve, and a motor-driven shutoff valve. The motor-driven shutoff valve is powered by



Spacelab Pressurized Module and Orbiter Environmental Control and Life Support System Interface



Spacelab Avionics Loop

the Spacelab environmental control subsystem emergency bus and controlled by the *cabin depress valve open/close* switch, a *cabin depress arm/safe* switch, and valve status LEDs on orbiter panel R7. The *cabin depress arm* switch arms the Spacelab cabin depressurization motor-driven valve; and when the *cabin depress valve* switch is positioned to *open*, the Spacelab cabin depressurization assembly in the Spacelab forward end cone opens, depressurizing the Spacelab module at 0.4 pound per second. The red LED above the switch on panel R7 is illuminated to indicate that the motor-operated depressurization valve is fully open. The yellow LED above the switch on panel R7 is illuminated to indicate that the Spacelab cabin depressurization valve is not closed when the *cabin depress* switch is in *arm* and the *cabin depress valve* switch is in the *closed* position.

Air in the Spacelab avionics air loop is circulated by one of two dual-redundant fans, with check valves to prevent recirculation through the inactive fan and a filter upstream to protect both fans. For ascent and descent flight phases, as well as low-power modes on orbit, the avionics fans operate when only a few experiments are operating and require cooling.

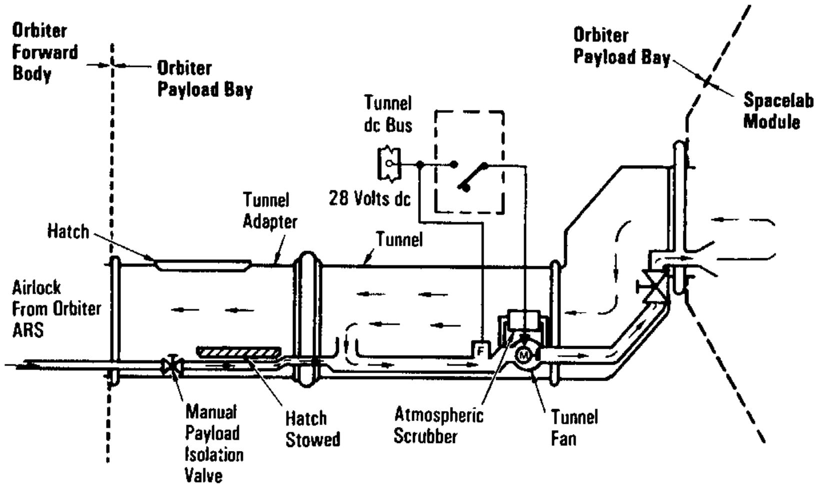
The fans are designed to switch from four-pole to eight-pole operation. The air flow through one fan is reduced from 1,923 to 639 pounds per hour, and the power is reduced from 643 to 110 watts. The two fans, powered by separate 115-volt ac buses, are activated and deactivated at low speed (eight-pole) by the *avionics fan 1/2 low speed/off* switches on orbiter panel R7. Each switch has a yellow LED that is illuminated above the respective switch to indicate that the respective fan is activated. The fans' on/off status is also available on orbiter CRT displays and the Spacelab DDU avionics power/cooling display.

The Spacelab avionics fans can also be activated in the low-speed mode by commands from the orbiter CRT keyboard. The fans are activated in the high-speed mode (four-pole) by commands from the orbiter CRT keyboards. The orbiter MDM deactivation command deactivates both fans simultaneously, and the Spacelab RAU deactivation command turns off each fan separately. The high-speed status of the Spacelab avionics fans is available on the orbiter CRT display and the Spacelab DDU display.

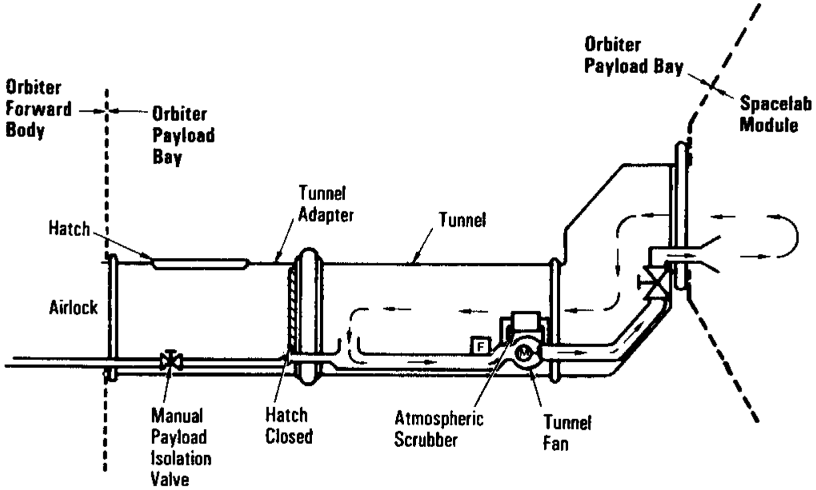
Pressurized Module/Tunnel Air Loop

The switch for the fan located in the transfer tunnel cannot be accessed until the tunnel/Spacelab hatch is opened and the flight crew initially transfers to the Spacelab from the orbiter.

When the airlock hatch and the tunnel adapter/Spacelab hatches are open, the orbiter air revitalization system provides air at 48 cubic feet per minute through a duct that branches off of the orbiter cabin



Tunnel Adapter Hatch Open—48-Cubic-Feet-Per-Minute Duct Operating



Tunnel Adapter Hatch Closed—48-Cubic-Feet-Per-Minute Duct Not Operating

air loop downstream of the orbiter cabin heat exchanger and enters the tunnel adapter. In the tunnel adapter, the duct can be controlled by a manual shutoff valve before it passes into the transfer tunnel itself. For the transfer tunnel to be entered, the tunnel adapter/Spacelab hatch must be opened and the duct passed through the tunnel hatch, where the duct expands. The fan located in the transfer tunnel draws additional air into the duct through an air inlet located just on the tunnel side of the tunnel adapter hatch.

The fan draws in additional air at a rate of 77 cubic feet per minute for a total nominal duct flow of 125 cubic feet per minute. This flow rate is delivered to the Spacelab cabin. The return air passes through the transfer tunnel itself, initially at 125 cubic feet per minute. However, 77 cubic feet per minute of air is sucked into the duct inlet at the Spacelab side of the tunnel/adapter hatch, and 48 cubic feet per minute of air enters the orbiter cabin through the tunnel adapter and airlock hatch. A scrubber in the tunnel duct removes carbon monoxide. The scrubber, located in parallel with the tunnel fan, produces an air flow of 1.5 to 4 cubic feet per minute.

The tunnel fan receives dc power from the Spacelab electrical power distribution subsystem. A delta pressure sensor located in the tunnel provides telemetry data for calculating air flow. If the Spacelab module is operating with the tunnel adapter hatch closed, air exchange is not possible. In this case, the tunnel fan can be used to circulate air at 125 cubic feet per minute in the tunnel.

Pressurized Module Active Thermal Control Subsystem

The Spacelab active thermal control subsystem consists of a water loop to remove heat from the Spacelab module and a Freon loop to remove heat from equipment on any pallets that may be flown with the pressurized module. The water loop is normally active only during on-orbit flight phases, but the need to cool experiments during ascent and descent requires operation of the water loop in a degraded performance mode during these phases.

The Spacelab water loop is circulated by a water pump package consisting of dual-redundant pumps (primary and backup) with inlet filters, manually adjustable bypass valves, check valves to prevent recirculation through the inactive pump, and an accumulator assembly to compensate for thermal expansion within the loop and maintain a positive pump inlet pressure.

The pump package is contained in a housing and mounted on the outside of the Spacelab module's forward end cone. The nominal flow rate through one pump is 500 pounds per hour.

The Spacelab water pumps are powered by separate 115-volt buses. They are activated and deactivated by the *H_2O loop pump 1/2 on/off* switches on orbiter panel R7 or by commands from the orbiter CRT keyboards. The green LED above each switch on panel R7 is illuminated to indicate that the pump is in operation. The on/off status of the Spacelab water pumps is also shown on the orbiter CRT displays.

The Spacelab Freon coolant loop removes heat from any pallets that may be flown with the pressurized module and transfers the heat of the interloop heat exchanger to the Spacelab water loop system. The flow rate is approximately 3,010 pounds per hour. From the Spacelab water loop system, the water passes through the orbiter payload heat exchanger, which transfers all the heat it has collected to the orbiter Freon coolant loops.

Pressurized Module Caution and Warning

The orbiter receives caution and warning inputs from Spacelab through the orbiter payload MDMs. Four channels in the Spacelab systems are dedicated to sending payload warning signals to the orbiter, and four channels in the Spacelab systems send payload caution signals to the orbiter. Nineteen remaining caution and warning input channels to the orbiter payload MDMs are available for Spacelab experiment limit sensing in the orbiter GPCs. The orbiter provides a maximum of 36 safing commands for use in response to Spacelab caution and warning conditions with 22 reserved for experiment safing commands. All safing commands are initiated at the orbiter CRT and keyboard.

The orbiter GPC can obtain data from the Spacelab command and data management system through the orbiter PCMMU as an alternative source for caution and warning.

Pressurized Module Emergency Conditions

There are two categories of Spacelab emergency conditions: fire/smoke in the Spacelab module and rapid Spacelab cabin depressurization. The orbiter and Spacelab annunciate these conditions and can issue safing commands if they occur. These signals are available during all flight phases.

Redundant Spacelab fire/smoke inputs are generated by two ionization chamber smoke sensors at three locations in the Spacelab. The six fire/smoke discrete signals are hard-wired to six annunciator indicators located on panel R7. These indicators are divided into three pairs labeled *left A&B, subfloor A&B,* and *right A&B*. The six *smoke annunciators enable/inhibit* switches on panel R7 can be used to inhibit each fire/smoke sensor's output individually. The *smoke sensor reset/norm/test* switch on panel R7 is used to reset or test all six sensors simultaneously.

Three signals, each from a different sensor location, are ORed (run through an OR gate) and connected to orbiter panel L1, which has a payload fire/smoke detection light. The three remaining signals are treated in the same manner.

When a Spacelab fire/smoke signal is detected, an emergency tone (siren) generated by the orbiter caution and warning circuitry is transmitted by the orbiter audio central control unit and announced in the Spacelab module by the loudspeaker, and the Spacelab *master alarm* light is illuminated. The six fire/smoke signals are also connected to six orbiter MDM inputs for display as emergency alert parameters on the orbiter CRT and for telemetry.

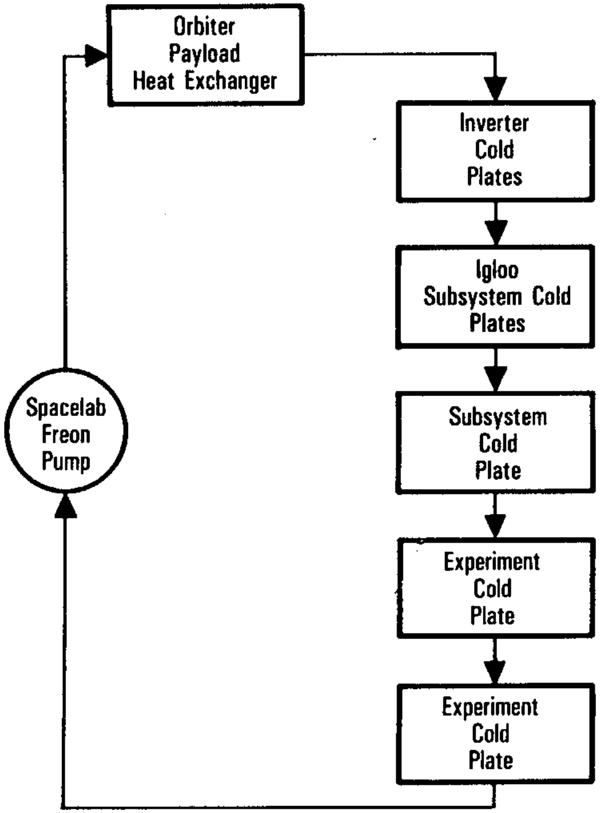
Two methods are provided for extinguishing a fire in the Spacelab module: discharging a fire suppressant into the affected area or dumping the Spacelab cabin atmosphere, when appropriate. The fire suppressant discharge consists of 15 orbiter-common fire suppression modules, each filled with the Freon 1301 suppressant agent.

The *agent discharge arm/safe* switch on orbiter panel R7 or the panel in the Spacelab module is used to safe or arm the discharge function. Each panel has a yellow indicator light that is illuminated when the discharge circuit is armed. The arming of the suppressant discharge function also shuts off the Spacelab module cabin and avionics fans to avoid diluting the suppressant's concentration. The agent can be discharged from either orbiter panel R7 or the panel in the Spacelab module by three identical sets of *agent discharge* switches, one each for the left, subfloor, and right areas. The switches are protected by individual guards. Positioning one of these switches completely discharges the contents of all suppressant bottles in the indicated area of the Spacelab module. In addition, the Spacelab module *O_2 supply valve close/cmd enable* switch on orbiter panel R7 can be used to close off the oxygen supply from the orbiter oxygen system to deprive the fire of oxygen. Spacelab cabin atmosphere dumping is controlled by the *cabin depress arm/safe* and *valve open/close* switches on orbiter panel R7. The Spacelab motor-controlled cabin dump valve's status is indicated by the yellow *not closed* and the red *full open* indicators on orbiter panel R7 as well as by the orbiter CRT.

PALLET-ONLY ENVIRONMENTAL CONTROL SUBSYSTEM

The environmental control subsystem provides thermal control of Spacelab experiments and subsystems. The Spacelab Freon-21 coolant loop services the pallet systems and collects heat dissipated by the subsystem and experiment equipment. The Spacelab Freon-21 coolant loop collects heat from the pallet-mounted subsystems and experiments through cold plates, some of which have thermal capacitors to store peak heat loads. The cold plates in the Freon loop are bolted to an intermediate support structure that is attached to the pallet. A maximum of eight cold plates can be used on the pallets for a particular mission.

The subsystem equipment mounted in the igloo is also serviced by the Freon loop, which interfaces directly with the orbiter's payload heat exchanger. The Freon pump package is mounted on the front frame of the first pallet (forward) in the orbiter payload bay. Thermal coatings are applied to minimize heat leakage and the effects of solar radiation. A special paint is used to reduce the hot-case temperature of the pallet structure itself. An insulated shield installed between the pallet-mounted cold plates and the pallet structure reduces radiation exchange between them. Multilayer insulation thermal tents also protect pallet-mounted subsystems; any unused tents are available for experiments.



Freon-21 Coolant Loop for Spacelab Pallets

SPACELAB D-2

The German Spacelab D-2 mission is a comprehensive international scientific venture that will carry out investigations in several disciplines and will serve as a model for the use and operation of the planned European space station module Columbus. Two German astronauts, supported by two NASA mission specialists, will perform 90 experiments in material and life sciences, advanced technology, atmospheric physics, Earth observations, and astronomy on board the shuttle Columbia.

Spacelab D-2 will continue the investigations begun on the D-1 mission and conduct new studies as well. The focus of most of the experiments is the effect of microgravity on humans, other living organisms, and materials.

Most of the experiments will be conducted in the shirt-sleeve environment of the European Space Agency's pressurized Spacelab module in Columbia's 60-foot-long cargo bay.

This is the second German Spacelab mission. The first—Spacelab D-1—was flown in 1985.

The German Research Establishment for Aerospace (DLR) is responsible for managing this Spacelab mission. DLR provided training for the American and German astronauts, planned the mission, and will be in charge of flight and payload operations during the mission. Spacelab D-1 and D-2 are the only missions with payload operations controlled by a foreign country.

SPACELAB D-2 PAYLOADS

DLR has furnished 16 experiments that are oriented toward achieving Germany's space utilization goals. The European Space Agency has provided 21 experiments as part of its microgravity research program. NASA, the French space agency CNES, and Japan are also participating in the mission.

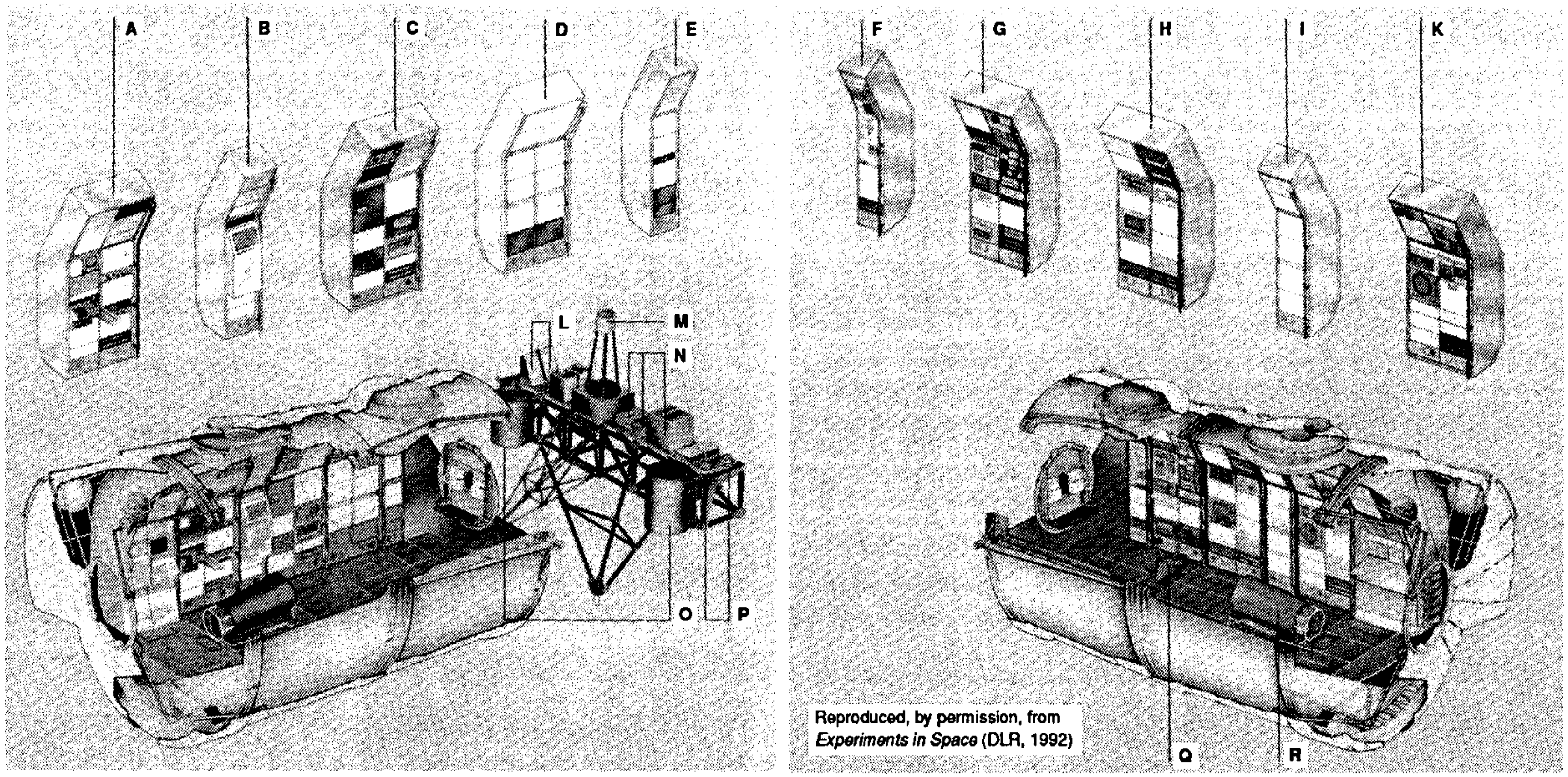
DLR will control the operation of the Spacelab experiments from its German Space Operations Center (GSOC) in Oberphaffenhofen, Germany, in close cooperation with NASA's Mission Control Center in Houston, which will control shuttle flight operations. Experiment data will be transmitted via satellite to the GSOC, where a team of investigators will monitor and direct the experiments in real time.

The Germans will use a technique called telescience to conduct experiments involving fluid physics, crystal growth, cell electrofusion, and human physiology. Video pictures of the experiments will be transmitted to the ground so that scientists can watch their experiments and intervene themselves in the test or direct the astronauts to intervene. Telescience will be an important element of the operation of the European space station module.

Most of the experiments are contained in single or double racks inside the Spacelab module. Two racks are used as workbenches for assembling equipment and examining samples. Experiments that must be exposed directly to space are mounted on the unique support structure in the payload bay behind the Spacelab module.

Material Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA)

MEDEA consists of three furnaces that will be used to study the growth and solidification of crystals and the behavior of metals in microgravity. The elliptical mirror furnace focuses light on a moving sample to melt the sample and grow a crystal. The gradient furnace with quenching uses metallic crystals grown at high temperatures to investigate direct solidification of materials in space. The



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Starboard Configuration

Port Configuration

A. System Rack
- On-board TV System
- Water Cooling System
- Vacuum Measurement System
- Cooler for Biolabor

B. ROTEX Rack
- Remote-Controlled Robot Arm
- Working Cell

C. Material Sciences Laboratory
- High-Temperature Thermostat
- Furnace for Turbine Blade Geometry Specimens
- Isothermal Heating Furnace
- Fluid Physics Module
- Gradient Heating Furnace
- Cryostat

D. Stowage Rack
- Payload Parts and Samples
- Spacelab System Parts
- Dosimeter for Cosmic Radiation

E. Experiment Rack
- Baroreflex (Blood Pressure Equipment With Cardiac Reflex Measurement)
- Microgravity Measurement Apparatus
- Stowage Space for Small Parts

F. Experiment Rack
- Holographic Interferometer
- Dosimeter for Cosmic Radiation
- Video Monitor

G. Anthrorack (Human Physiology Laboratory)
- Respiratory Monitoring System
- Echocardiograph
- High-Speed Centrifuge
- Blood Pressure Measurement Systems
- Blood Sample Instrumentation
- Ultrasonic Measurement Apparatus

H. Biolabor
- Electrofusion of Cells
- Cell Cultivation
- Botany Experiments
- Zoological Experiments

I. Stowage Rack
- Payload Parts and Samples
- Spacelab System Parts
- Dosimeter for Cosmic Radiation

K. MEDEA
- Elliptical Mirror Furnace
- Gradient Furnace With Fast Sample Cooling
- High-Precision Thermostat

L. Exposure Facility With Material Samples

M. Galactic Ultrawide-Angle Camera

N. Modular Optoelectronic Multispectral Scanner

O. Containers With Independent Material Science Experiments

P. Biological Samples for Investigation of Cosmic and UV Radiation

Q. Bicycle Ergometer

R. Lower Body Negative Pressure Device

MTD 930309-4198

Spacelab D-2 Long Module

Spacelab D-2 Experiments Listed According to Experimental Facilities

Payload Element	Experiment
Anthrorack	Leg Fluid Distribution
	Determination of Segmental Fluid Content and Perfusion
	Left Ventricular Function
	Cardiovascular Regulation
	Hemodynamic Adaptation During Rest/Exercise and Lower Body Negative Pressure
	Intraocular Pressure
	Central Venous Pressure
	Tissue Thickness and Compliance Along Body Axis
	Cardiovascular Response to LBNP and Fluid Loading
	Changes in the Rate of Whole-Body Nitrogen Turnover, Protein Synthesis, and Protein Breakdown
	Regulation of Volume Homeostasis
	Glucose Tolerance
	Endocrine and Renal Elements of Volume Homeostasis
	Pituitary-Gonad-Adrenalin Functions
	Adapting to Microgravity and Readapting to Earth
	Pulmonary Stratification and Compartment Analysis
	Pulmonary Perfusion and Ventilation During Rest and Exercise
	Ventilation Distribution
	Dynamics of Gas Exchange, Ventilation, and Heart Rate
Baroreflex	Influence of Microgravity Upon the Carotid Baroreceptor-Cardiac Reflex Response
Biolabor	Culture and Electrofusion of Plant Cell Protoplasts
	Enhanced Hybridoma Production
	Yeast Experiment to Investigate Metabolism
	Fruiting Body Development of Fungi
	Significance of Gravity and Calcium Ions on the Production of Secondary Metabolites in Cell Suspension
	Gravisensitivity of Cress Roots
Biolabor (Cont)	Cell Polarity and Gravity
	Fluctuation Test of Bacteria Cultures
	Expression and Stability of Genetic Information in Bacteria
	Connective Tissue Biosynthesis
	Antigen-Specific Activation of Regulatory T-Lymphocytes and Lymphokine Production
	Growth of Lymphocytes Under Microgravity Conditions
	Development of Vestibulo-ocular Reflexes in Amphibia and Fishes
	Structural Development and Function of the Gravity-Perceiving Organ
	Structure- and Function-Related Neuronal Plasticity of the CNS of Aquatic Vertebrates During Early Ontogenetic Development
	Immunoelectron Microscopic Investigation of Cerebellar Development
Radiation complex	Biological HZE-Particle Dosimetry With Biostack
	Personal Dosimetry—Crew Exposure to Ionizing Radiation
	Biological Response to Extraterrestrial Solar UV Radiation and Space Vacuum
	Chromosome Aberration
	Spacelab Internal Locations With Different Shielding Against Cosmic Radiation
MEDEA	Floating-Zone Growth of GaAs
	Growth of GaAs From Gallium Solutions
	Floating-Zone Crystal Growth of Gallium-Doped Germanium
	Crystal Growth of GaAs by the Floating-Zone Method
	Directional Solidification of Ge/GaAs Eutectic Composites
	Cellular-Dendritic Solidification With Quenching of AlLi Alloys

Spacelab D-2 Experiments Listed According to Experimental Facilities (Cont)

Payload Element	Experiment
MEDEA (Cont)	Directional Solidification of a CuMn Alloy
	Thermoconvection at Dendritic-Eutectic Solidification of an $AlSi_{11}$ Alloy
	Diffusion of Nickel in Liquid Copper-Aluminum and Copper-Gold Alloys
	Hysteresis of the Specific Heat CV During Cooling Through the Critical Point
Werkstofflabor	Crystallization of Nucleic Acids and Nucleic Acid-Protein Complexes
	Crystallization of Ribosomal Particles
	Higher Modes and Their Instabilities of Oscillating Marangoni Convection in a Large Cylindrical Column
	Liquid Column Resonances
	Marangoni-Benard Instability
	Stability of Long Liquid Columns
	Onset of Oscillatory Marangoni Flows
	Convective Effects on the Growth of GaInSb Crystals
	Stationary Interdiffusion in a Nonisothermal Molten Salt Mixture
	Cellular-Dendritic Solidification at Low Rate of AlLi Alloys
	Vapor Growth of InP Crystal With Halogen Transport in a Closed Ampoule
	Directional Solidification of the $LiF-LiBaF_3$-Eutectic
	Oxide Dispersion Strengthened Superalloy Improved by Resolidification in Space
	Self-Diffusion in Pure Metals
	Impurity Diffusion and Interdiffusion in Different Systems
	Separation Behavior of Monotectic Alloys
Werkstofflabor (Cont)	Heating and Remelting of an Allotropic FeCSi Alloy in a Ceramic Skin and Volume Change
	Interfacial Tension and Heterogeneous Nucleation in Immiscible Liquid Metal Systems
	Solution Growth of GaAs Crystals Under Microgravity
	Impurity Transport and Diffusion in InSb Melt Under Microgravity Environment
	Nucleation and Phase Selection During Solidification of Undercooled Alloys
HOLOP	Phase Separation in Liquid Mixtures With Miscibility Gap
	Interferometric Determination of the Differential Interdiffusion Coefficient of Binary Molten Salts
	Measurement of Diffusion Coefficients in Aqueous Solution
	Marangoni Convection in a Rectangular Cavity
AOET	Atomic Oxygen Exposure Tray
MMA	Residual Acceleration in Spacelab D2
	Transfer Function
ROTEX	Robotics Technology
MAUS	Gas Bubbles in Glass Melts
	Reaction Kinetics in Glass Melts
	Pool Boiling
GAUSS	UV Investigation of the Milky Way and Upper Atmosphere
MOMS	MOMS-02/Digital Stereo-Photogrammetry
	Thematic Mapping
	Stereo and Multispectral Data Combination

Experiments Listed According to Disciplines

Research Topic	Experiment
Cardiovascular system	Leg Fluid Distribution
	Determination of Segmental Fluid Content and Perfusion
	Left Ventricular Function
	Cardiovascular Regulation
	Hemodynamic Adaptation During Rest/Exercise and Lower Body Negative Pressure
	Intraocular Pressure
	Influence of Microgravity Upon the Carotid Baroreceptor-Cardiac Reflex Response
	Central Venous Pressure
	Tissue Thickness and Compliance Along Body Axis
	Cardiovascular Response to LBNP and Fluid Loading
Hormonal system	Changes in the Rate of Whole-Body Nitrogen Turnover, Protein Synthesis, and Protein Breakdown
	Regulation of Volume Homeostasis
	Glucose Tolerance
	Endocrine and Renal Elements of Volume Homeostasis
	Pituitary-Gonad-Adrenalin Functions
	Adapting to Microgravity and Readapting to Earth
Pulmonary system	Pulmonary Stratification and Compartment Analysis
	Pulmonary Perfusion and Ventilation During Rest and Exercise
	Ventilation Distribution
	Dynamics of Gas Exchange, Ventilation, and Heart Rate
Cell functions	Yeast Experiment to Investigate Metabolism
	Significance of Gravity and Calcium Ions on the Production of Secondary Metabolites in Cell Suspension
	Fluctuation Test of Bacteria Cultures
	Expression and Stability of Genetic Information in Bacteria
	Connective Tissue Biosynthesis
	Antigen-Specific Activation of Regulatory T-Lymphocytes and Lymphokine Production
	Growth of Lymphocytes Under Microgravity
Gravisensitivity	Vestibulo-ocular Reflexes in Amphibia and Fishes
	Structural Development and Function of the Gravity-Perceiving Organ
	Structure- and Function-Related Neuronal Plasticity of the CNS of Aquatic Vertebrates During Early Ontogenetic Development
	Immunoelectron Microscopic Investigation of Cerebellar Development
	Fruiting Body Development of Fungi
	Cell Polarity and Gravity
	Gravisensitivity of Cress Roots
Cell fusion processes	Culture and Electrofusion of Plant Cell Protoplasts
	Enhanced Hybridoma Production
Radiation	Biological HZE-Particle Dosimetry With Biostack
	Personal Dosimetry—Crew Exposure to Ionizing Radiation
	Chromosome Aberration
	Spacelab Internal Locations With Different Shielding Against Cosmic Radiation
	Biological Response to Extraterrestrial Solar UV Radiation and Space Vacuum
Capillarity	Liquid Column Resonances
	Stability of Long Liquid Columns
Marangoni convection	Higher Modes and Their Instabilities of Oscillating Marangoni Convection in a Large Cylindrical Column
	Marangoni-Benard Instability
	Onset of Oscillatory Marangoni Flows
	Marangoni Convection in a Rectangular Cavity
Diffusion	Stationary Interdiffusion in a Nonisothermal Molten Salt Mixture
	Gas Bubbles in Glass Melts
	Reaction Kinetics in Glass Melts
	Self-Diffusion in Pure Metals
	Impurity Diffusion and Interdiffusion in Different Systems
	Interferometric Determination of the Differential Interdiffusion Coefficient of Binary Molten Salts

Experiments Listed According to Disciplines (Cont)

Research Topic	Experiment
Diffusion (cont)	Measurement of Diffusion Coefficients in Aqueous Solution Diffusion of Nickel in Liquid Copper-Aluminum and Copper-Gold Alloys Impurity Transport and Diffusion in InSb Melt Under Microgravity Environment
Critical phenomena and heat transfer	Measurement of the Molecular Transport of Heat Energy of a Binary Liquid Mixture of Low Viscosity Hysteresis of the Specific Heat CV During Cooling Through the Critical Point Pool Boiling
Solidification front dynamics	Directional Solidification of Ge/GaAs Eutectic Composites Cellular-Dendritic Solidification With Quenching of AlLi Alloys Cellular-Dendritic Solidification at Low Rate of AlLi Alloys Directional Solidification of a CuMn Alloy Thermoconvection at Dendritic-Eutectic Solidification of an AlSi$_{11}$ Alloy Directional Solidification of the LiF-LiBaF$_3$-Eutectic
Composites	Separation Behavior of Monotectic Alloys Heating and Remelting of an Allotropic FeCSi Alloy in a Ceramic Skin and Volume Change Oxide Dispersion Strengthened Superalloy Improved by Resolidification in Space Phase Separation in Liquid Mixtures With Miscibility Gap Interfacial Tension and Heterogeneous Nucleation in Immiscible Liquid Metal Systems

Research Topic	Experiment
Crystal growth	Floating-Zone Growth of GaAs Growth of GaAs From Gallium Solutions Floating-Zone Crystal Growth of Gallium-Doped Germanium Convective Effects on the Growth of GaInSb Crystals Crystallization of Nucleic Acids and Nucleic Acid-Protein Complexes Crystal Growth of GaAs by the Floating-Zone Method Vapor Growth of InP Crystal With Halogen Transport in a Closed Ampoule Solution Growth of GaAs Crystals Under Microgravity Crystallization of Ribosomal Particles
Technology	Residual Acceleration in Spacelab D2 Robotics Technology Experiment Transfer Function
Atmospheric physics	Atomic Oxygen Fluence Detector Atomic Oxygen Exposure Tray Micrometeorite and Dust Flux in Low Earth Orbits Gas Surface Interactions Pressure-Temperature Measurements During Reentry
Earth observation	MOMS-02/Digital Stereo-Photogrammetry Thematic Mapping Stereo and Multispectral Data Combination
Astronomy	UV Investigation of the Milky Way and Upper Atmosphere
Nucleation	Nucleation and Phase Selection During Solidification of Undercooled Alloys

high-precision thermostat studies the critical phenomena exhibited by metals under precisely controlled temperatures.

Floating-Zone Growth of Gallium Arsenide. This experiment will attempt to grow a crystal of gallium arsenide 20 mm in diameter, and investigators will examine the crystal to determine if, as expected, it has fewer structural defects than crystals grown using the CZ or Bridgman techniques. Because of gravitational effects, gallium arsenide crystals grown on Earth can reach only a few millimeters in diameter. Gallium arsenide is the best material for use in high-speed electronic circuits.

Floating-Zone Crystal Growth of Gallium-Doped Germanium. Two samples of gallium-doped germanium will be processed in this experiment. Several runs of the first sample will be conducted to investigate the influence of processing parameters on the growth of the crystal. The results will be used to optimize the processing of the second sample. During the processing of the samples, nonstationary, thermocapillary-driven flows will be controlled through the use of Seebeck measurements. After the flight, the effects of convection will be analyzed.

Hysteresis of Specific Heat CV During Heating and Cooling Through the Critical Point. In this experiment, investigators will study relaxational effects on the CV of the substance SF6. Scientists believe that relaxational effects were responsible for the surprising CV measurements obtained on the first German Spacelab mission in 1985.

A spherical cell which has been added to the high-precision thermostat for this experiment will be heated and cooled by radiation from the shell that surrounds the cell. The difference in the temperature of the cell and shell will determine the CV of the test substance. Several thermistors also measure the temperature field in the fluid to help resolve the question of the temperature equilibration at the critical point.

Diffusion of Nickel in Liquid Copper-Aluminum and Copper-Gold Alloys. This experiment will determine the diffusion coefficient of nickel with respect to the concentration of the solute atoms of aluminum and gold in the presence of minimized convection.

Directional Solidification of Germanium/Gallium Arsenide Eutectic Composites. Investigators will study the effects of gravity on the microstructures of melted germanium/gallium arsenide during unidirectional solidification.

Cellular-Dendritic Solidification With Quenching of Aluminum-Lithium Alloys. Critical investigations of aluminum-lithium alloys will be conducted in the cellular and dendritic regimes. At the end of the experiments, quenching will retain the tip radius and the microsegregation, which will yield reliable data for three-dimensional solidification with pure diffusion in the liquid phase. This data will be used to test theories of pattern formation and selection. The samples obtained in space will be compared to samples produced on Earth to determine the effects of convection.

Directional Solidification of a Copper-Manganese Alloy. This experiment will investigate the transition from diffusive transport to diffusive-convective transport within the melt of a copper-manganese alloy in front of a planar moving solidification interface. Investigators will study the onset of convection with increasing instability produced by the solidification parameters and will also analyze the impact of g-gitters on the transport mechanisms and the concentration of the solidified crystal. Later, the investigators will perform a microanalysis of metallographic cross sections of the concentration of the solid and correlate the variations with the variations of the experiment parameters.

Thermoconvection at Dendritic-Eutectic Solidification of an Aluminum-Silicon Alloy. A follow-up to a Spacelab D-1 experiment, this investigation will use a close eutectic aluminum-silicon alloy to determine the influence of the alloy's silicon content and the crystallization parameters on its dendrite morphology and eutectic microstructure.

Growth of Gallium Arsenide From Gallium Solutions. The objective of this experiment is to improve the quality of gallium arsenide crystals grown in zero gravity and on Earth. Investigators will study—

- Dopant inhomogeneities on large and small scales
- Crystal perfection with respect to low defect density and the distribution of defects
- Crystal perfection with respect to stoichiometry and the concentration of residual impurity
- Studies of the influence of different transport phenomena in the solution
- Studies of growth kinetics and mechanisms of incorporating dopants

Werkstofflabor Material Sciences Laboratory

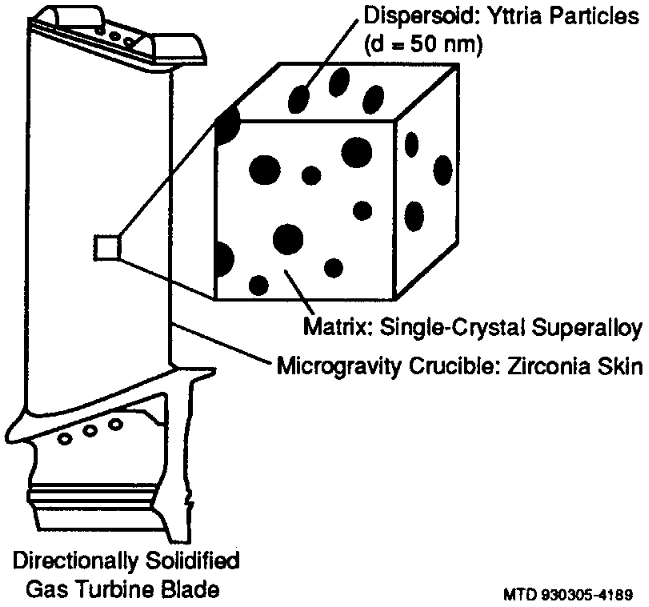
The Material Sciences Laboratory experiments will investigate metal processing, crystal growth, fluid boundary surfaces, and transport phenomena. It comprises the following equipment:

- The isothermal heating facility is a high-temperature furnace that will process metal samples.
- The turbine blade facility will process special metallic alloys and cast them in the shape of turbine blades. Researchers hope that the process will lead to blades that are highly resistant to heat and stress for use in aircraft engines.
- The gradient heating facility will furnish the heating and cooling required for experiments that investigate crystal growth, solidification, and eutectics.
- The advanced fluid physics module will enable investigators to study the behavior of fluids in microgravity.
- Diffusion processes in liquid metals will be studied in two high-temperature thermostats.
- A cryostat will be used to attempt to grow high-quality crystals of biochemical macromolecules.

Oxide Dispersion-Strengthened Superalloy Improved by Resolidification in Space. A joint effort of four German companies and a German research institution, this experiment will attempt to produce a single-crystal material reinforced with finely distributed particles in microgravity. Researchers will produce a material shaped like a turbine blade that should have superior heat-resistant properties to similar bodies produced on Earth by solidifying a nickel-based alloy matrix with a dispersion of yttrium oxide particles. Researchers hope this experiment will lead to the production of turbine blades for higher-performance, longer-life aircraft engines.

Impurity Transport and Diffusion in InSb Melt Under Microgravity Environment. The impurity transport and diffusion behavior of the compound indium antimony, which is used in semiconductors, will be observed in the isothermal heating facility. Zinc, gallium, arsenic, selenium, and tellurium will be used as impurities. Researchers will note the diameter effects and temperature dependency on diffusion as well as the function of plug structure at the diffusion couple edges.

Cellular-Dendritic Solidification at Low Rate of Aluminum-Lithium Alloys. In this experiment, researchers will investigate the deep cell-dendrite transition of aluminum-lithium alloy by solidifying three samples in the gradient heating facility. They will construct a three-dimensional representation from the data points for the pri-



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Oxide Dispersion-Strengthened Superalloy Improved by Resolidification in Space

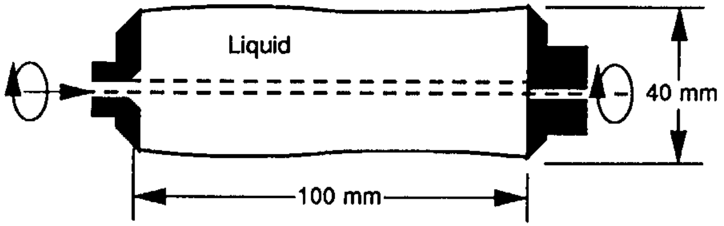
mary spacing and will analyze the micro- and macrosegregation of lithium. The researchers will also study the organization of the cellular and dendritic arrays. The samples processed in space will be compared with samples produced on the ground to determine the influence of convection.

Directional Solidification of the LiF-LiBaF$_3$-Eutectic. After directionally solidifying LiF-LiBaF$_3$ in the gradient heating furnace, investigators will examine the influence of gravity, melt composition, growth velocity, and temperature gradient on the eutectic microstructure of the solid.

Separation Behavior of Monotectic Alloys. This experiment will study the transport mechanisms of droplets in aluminum melts, and the results may improve terrestrial industrial casting processes. Sandwichlike samples made of periodically arranged cylinders of an aluminum-silicon alloy in which bismuth droplets are dispersed will be melted directionally. A temperature gradient ahead of the melting front causes the droplets to move freely in the matrix melt. At the end of the experiment, researchers will draw conclusions about the transport of bismuth droplets in a temperature gradient from the spatial arrangement of the droplets and a comparison of the process with a computer simulation.

Liquid Column Resonances. Investigators will determine the resonance curves of liquid columns by studying two liquids with different viscosities and surface tensions in several volumes and surface shapes. Liquid columns are of interest because they have numerous applications in floating-zone and traveling techniques for growing crystals. Position and pressure sensors will record the response of the liquid columns as circular disks are vibrated by varying frequencies in the advanced fluid physics module.

Stability of Long Liquid Columns. This experiment will measure the deformation of long liquid bridges subjected to mechanical disturbances, such as geometry, rotation, and vibration. Data from this experiment will be used to validate theoretical predictions regarding equilibrium shapes, stability limits, and the dynamics of stable and unstable bridges to enable researchers to develop more complex and realistic models.



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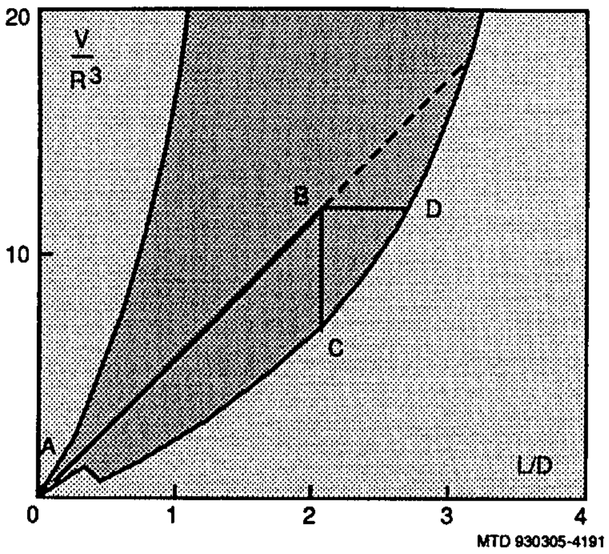
Long Liquid Bridge



Stability Limits of a Quiescent Liquid Bridge Between Equal Discs in Weightlessness

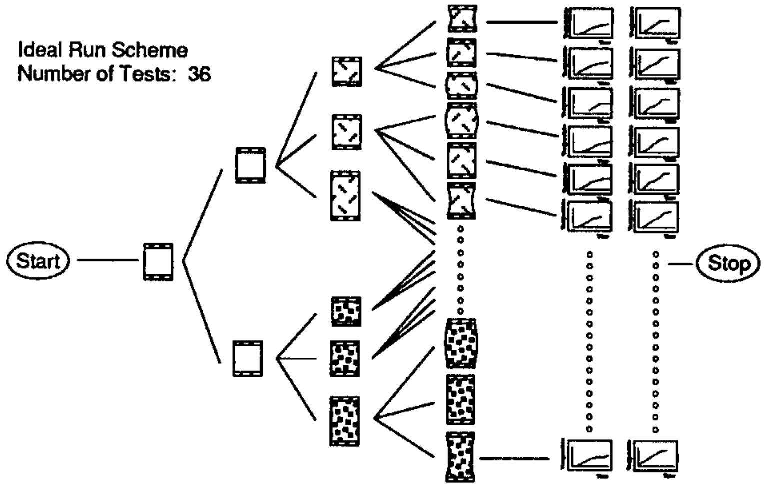
Higher Modes and Their Instabilities of Oscillating Marangoni Convection in a Large Cylindrical Liquid Column. Researchers will use the advanced fluid physics module to investigate the effect of the aspect ratio (height:diameter) of a large liquid column and the Marangoni numbers on higher oscillating modes of Marangoni convection and the modes' transitions to turbulent convections. Marangoni effects refer to the different types of liquid motion (or convection) caused by inhomogeneities of the interfacial tension in a free liquid surface.

Marangoni-Benard Instability. Investigators will measure the critical Marangoni number and observe inverse bifurcation behavior in a sample by studying its Marangoni-Benard instability in the steady state. They will also study the effect of a nondistribution and will observe transverse capillary-gravity waves by heating the sample in the opposite direction.

Onset of Oscillatory Marangoni Flows. In this experiment, investigators will determine the influence of sample geometry on the onset of oscillations and obtain a better understanding of flow organization during oscillatory conditions by studying a series of cylindrical floating zones with different aspect ratios.

Marangoni Convection in a Rectangular Cavity. This experiment will investigate thermocapillary convection caused by temperature gradients parallel to the free liquid-gas surface. Researchers hope the investigation will reduce the complexity of the highly nonlinear coupled hydrodynamic system on Earth.

Stationary Interdiffusion in a Nonisothermal Molten Salt Mixture. In this follow-up to a Spacelab D-1 experiment, investigators will attempt to attain a stationary state in a molten salt mixture by continuing the experiment for 24 hours. In the first experiment,



Parameter	Disk Diameter	Oil Viscosity	Aspect Ratio	Shape	Heating Ramp
Operation	Disk Mounting	Reservoir Mounting	Length Variation	Volume Variation	Heating

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Onset of the Oscillatory Marangoni Flows the stationary state was not reached because the interdiffusion coefficient was smaller than predicted.

Transport Kinetics and Structure of Metallic Melts. On Earth, diffusion processes in melts are disturbed by gravitationally caused convection. This experiment will attempt to determine the temperature dependence of the diffusion coefficients of materials that are as different from tin as possible.

Nucleation and Phase Selection During Solidification of Undercooled Alloys. During this experiment, melts of various alloys that are embedded in a liquid matrix will be cooled below their solidification temperature. Because sedimentation is greatly reduced in microgravity, the melts will not contact the crucible, which will eliminate heterogeneous nucleation. The purpose of this experiment is to determine the degree of undercooling of different alloys by measuring the point at which the temperature of the cooling metals suddenly increases and comparing it to nucleation theory. Researchers will also investigate the effect of undercooling on grain size and phase selection.

Heating and Remelting of an Allotropic FeCSi Alloy in a Ceramic Skin. A sample containing different compositions of an FeCSi alloy will be remelted and solidified directionally. Investigators will then study the behavior of the remelted alloy's skin, the crystallization of the graphite, and the distribution of the elements in the transition zone.

Immiscible Liquid Metal Systems. This experiment will study the behavior of two immiscible liquid metals when they contact different ceramic materials.

Convective Effects on the Growth of GaInSb Crystals. The objective of this experiment is to obtain homogeneous crystals for use in semiconductors. Because of the effects of convection, this is not possible on Earth.

Vapor Growth of InP Crystal With Halogen Transport in a Closed Ampoule. This experiment will study the relationship between gravity and the quality of the epitaxial layer of a crystal of InP grown in microgravity. Gravity is known to affect mass transport phenomena.

Solution Growth of GaAs Crystals in Microgravity. The solution growth technique to be used to grow gallium arsenide crystals will prevent the convection induced by surface tension that destroys diffusion-controlled crystal growth even in the microgravity environment.

Crystallization of Nucleic Acids and Nucleic Acid-Protein Complexes. This experiment will attempt to crystallize ribosomal 5S ribonucleic acids, their protein complexes, and the elongation factor complex in microgravity so that researchers can determine their three-dimensional structure through X-ray analysis. The function of ribosomes, which are active in the synthesis of protein, depend on 5S RNAs and their binding proteins. The 5S RNA complexes may be good model systems for studying RNA-protein complexes.

Crystallization of Ribosomal Particles. This experiment will test whether more isotropic crystals of ribosomes can be grown in space than on Earth. The investigators plan to use X-ray crystallography supported by neutron diffraction and three-dimensional image reconstructions to obtain a clearer model of the ribosome.

Holographic Optics Laboratory

The Holographic Optics Laboratory uses holography, the technique of producing three-dimensional images, to learn more about the processes of heat and mass transfer and cooling in transparent materials that are of interest in metallurgy and casting. Video pictures of some of the experiments will be transmitted to the ground while they are being performed so that scientists can monitor their experiments and intervene. These telescience experiments will be carried out from DLR's Microgravity Life Support Center at Cologne-Porz.

Marangoni Convection in a Rectangular Cavity. This experiment, which is identical to one that will be performed in the Material Sciences Laboratory, will investigate thermocapillary convection caused by temperature gradients parallel to the free liquid-gas surface. Researchers hope the investigation will reduce the complexity of the highly nonlinear coupled hydrodynamic system on Earth.

Interferometric Determination of the Differential Interdiffusion Coefficient of Binary Molten Salts. Investigators will use holographic interferometry to observe the diffusion process in potassium nitrate/silver nitrate and determine the diffusion coefficient. Interdiffusion coefficients are difficult to measure on Earth because of gravity-caused convection, but it is possible to obtain exact reference values for the coefficients in microgravity.

Measurements of Diffusion Coefficients in Aqueous Solution. This experiment will measure diffusion coefficients by using interferometric holography to observe refractive index changes caused by the evolution of concentration profiles as a function of time.

Phase Separation in Liquid Mixtures With Miscibility Gap. Holography will be used to observe phase separation of a demixing binary liquid mixture.

Baroreflex

The Baroreflex facility experiment will investigate the theory that the light-headedness and reduction in blood pressure experienced by astronauts after space flight may be caused by a change in the behavior of the human body's reflex system, which regulates blood pressure, after adapting to microgravity. Heart rates will be measured before, during, and after the flight to determine if the predicted impairment of the body's blood pressure sensors to control heart rate does occur. Although the postlanding condition, known as orthostatic hypotension, lasts only a few days, it does pose a danger to the health and safety of the crew, especially during landing, and its causes need to be better understood.

During this experiment, a crew member will wear a silicone rubber cuff, which applies pressure and suction pulses that mimic natural blood pressure. These pulses are transmitted to baroreceptors, and an electrocardiograph records the changes in heart rate caused by the pressure pulses.

Residual Acceleration in Spacelab

Any deviation from the shuttle's dynamic free-fall state, which creates the microgravity environment inside the spacecraft, can cause accelerations that can seriously affect the results of experiments being performed on board the shuttle. That is why it is important that experimenters have a history of residual accelerations when they analyze their results.

Spacelab D-2 is equipped with several measurement systems that will detect spatial and temporary variations of the acceleration vector. The primary acceleration measurement system is the microgravity measurement assembly. The MMA consists of six accelerometers. Four of the accelerometers are mounted in experiment racks; the other two can be placed anywhere in the Spacelab module.

The MMA will be used to measure the transfer function, or response, of the spacecraft's structure in one location to disturbances created at another location. Measurements of the transfer function will be used to substantiate and improve the understanding of the dynamic behavior of spacecraft structures in space. The results of this experiment will support preparations for later Spacelab missions and future orbital spacecraft.

Robotics Technology Experiment (ROTEX)

ROTEX will provide investigators with basic information on the operation of a robot in microgravity and proof of the maturity of advanced robotics technology for manipulating payloads and experiments and moving equipment in space. This experiment is Germany's first step toward using automation and robotics to make more efficient use of crew time on the Spacelab mission and later on Columbus missions. The precise robotic arm will perform a variety of tasks, such as building a small tower of cubes and retrieving a small floating object. The robot will be tested from on board the shuttle and from the ground.

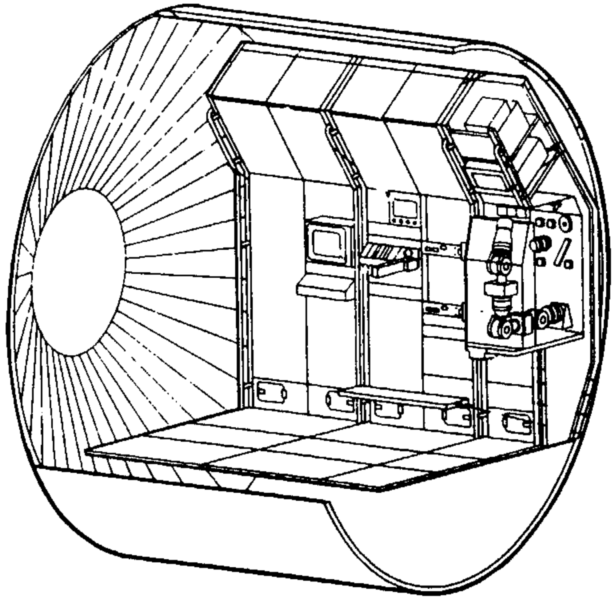
ROTEX consists of the following:

- An arm with six joints that can reach in all directions
- Two torque sensors to ensure the arm does not become overloaded
- A gripping assembly equipped with laser distance-measuring devices, tactile sensors, and stereo television cameras
- Two fixed video cameras to film the whole assembly

In the future, robotics will play an important role as part of the effort to reduce the operational costs of space flight and are expected to have valuable spin-off applications on Earth. In space, robots will carry out or help astronauts perform such tasks as handling manufacturing processes, making repairs and changing failed components, assembling structures, and supplying free-flying platforms.

Anthrorack

Anthrorack is the most advanced medical research facility to fly in space. It will be used to perform 20 different experiments on organs and their controlling mechanisms, blood circulation, and lung function, as well as monitoring numerous processes.



Robotics Technology Experiment

A set of stimulus and measurement instruments will be used to examine human physiology in microgravity: blood sample collection kit, urine monitoring system, high-speed centrifuge, respiratory monitoring system, ergometer, peripheral blood measurement system, manual blood pressure measurement system, limb volume measurement device, electrode contact impedance meter, and ultrasound monitoring system. Most of these instruments are contained in a double rack; the bicycle ergometer is installed on the floor of the module.

Cardiovascular Regulation. Intravenous saline solutions will be added to the fluid shifts caused by microgravity to study the cardiovascular response to severe redistribution of body fluids. Before and after the flight, magnetic resonance imaging will measure changes in myocardial and skeletal muscle mass, and adrenergic function will be characterized by human versus lab experiments.

Central Venous Pressure (CVP). The CVP of two crew members will be measured while they are seated in the launch position awaiting lift-off, at the onset of microgravity, and early in the adaptation period. Shifts in blood volume caused by weightlessness are thought to increase CVP, but it has never been measured in people during launch or long-term weightlessness. Scientists want to see if the body starts adapting even before launch.

Leg Fluid Distribution. The bodily effects of microgravity include fluid shifts toward the upper body and dehydration, which may alter autonomic response patterns. Dehydration and disuse reduce volume, especially in the legs. This test will measure changes in skin texture, musculature, and blood vessels.

Segmental Fluid Content and Perfusion. Lack of hydrostatic pressure in space causes a cephalic fluid shift that reduces total body fluid. Through this experiment, scientists hope to determine how the new body fluid distribution pattern affects different body segments and how the cardiovascular system adapts to muscular underloading and changes in autonomic control patterns.

Left Ventricular Function. This experiment studies the mechanisms by which the cardiovascular system, especially the heart, adapts to weightlessness and then readapts to gravity on Earth.

Hemodynamic Adaptation During Rest/Exercise and Lower Body Negative Pressure. Standard stimuli will be applied to crew members and responses in cardiovascular reflexes will be recorded during rest and isometric/dynamic exercise. Cardiac output, arterial blood pressure, and subcutaneous blood flow in the forearm will be measured during the experiments, which take place both on Earth and in space. Measurements of subcutaneous blood flow will enable scientists to calculate the changes in both total peripheral resistance and vascular resistance as a function of cardiovascular regulation.

Intraocular Pressure. Fluid shifts to the upper body increase intraocular pressure. The peak pressure is thought to occur just after launch but has never been measured because the crew is strapped in. Now a new tonometer has been devised that allows self-measurement for the crew's convenience.

Tissue Thickness and Compliance Along Body Axis. This experiment will study the salt-water balance of people under extreme conditions with a new method that measures fluid shifts in superficial tissues along the body axis and the ability of the tissues to distend.

Changes in the Rate of Whole-Body Nitrogen Turnover, Protein Synthesis, and Protein Breakdown. Fluid shifts from the legs toward the gut are accompanied by negative fluid and nitrogen balance. The lack of nitrogen causes loss of muscle tone, muscle fatigue, and muscle atrophy. This study will measure the rates of whole-body nitrogen flux, protein synthesis, and protein breakdown in three astronauts before, during, and after the mission in hopes of discovering the mechanism responsible for negative nitrogen balance.

Regulation of Volume Homeostasis. Scientists hope to gain a better understanding of volume homeostasis in microgravity by studying the role of hormonal systems in the human body's adaptation to weightlessness. Changes in plasma levels, the atrial natriuretic factor, urodilatin, and cyclic GMP will be measured because they are important regulators of volume homeostasis, which is greatly altered by weightlessness.

Glucose Tolerance. Investigators suspect that microgravity causes an abnormal glucose/insulin relation and impairs glucose tolerance. Metabolic imbalance may increase with mission duration.

The results of this experiment may be useful for both the assessment of metabolic response to weightlessness and clinical medicine on Earth.

Endocrine and Renal Elements of Volume Homeostasis. Crew members will be tested for lack of hydrostatic endocrine and renal elements of volume homeostasis. Investigators think that microgravity increases renal excretion of electrolytes and water, causing the mechanisms of volume homeostasis to undergo a new state of adaptation.

Pituitary-Gonad-Adrenal Functions. The circadian rhythm of hormonal secretion may be disrupted by the work and sleep schedules of space missions, which could erode the crew's sense of well-being, capacity for work, and reproductive and sexual equilibrium. By checking the crew's blood, urine, and saliva for signs of disturbance in the adrenal or reproductive glands, investigators hope to design better work/rest rhythms for subsequent space flights.

Adapting to Microgravity and Readapting to Earth. This experiment will observe the renin-angiotensin-aidosterone system, which is a key factor in regulating salt balance and blood pressure.

Pulmonary Stratification and Compartment Analysis. Microgravity offers a unique opportunity to study the effect of gravity on ventilation distribution in the human lung. The main thrust of this test is to see whether the onset of weightlessness lessens inhomogeneity in the distribution of the ventilation-volume ratio.

Pulmonary Perfusion and Ventilation During Rest and Exercise. Scientists think that gravity is the most important influence on the distribution of both ventilation and blood perfusion in the lung. While both processes seem to occur mainly in the lower part of the lung, the degree of unevenness differs on Earth: The upper parts are overventilated, with respect to perfusion, and the lower parts are overperfused, with respect to ventilation. The following experiment will yield evidence to prove or disprove this hypothesis.

Ventilation Distribution. The components and pattern of ventilation in the lungs will be examined under microgravity conditions by measuring lung blood flow, capillary volume, liquid content, and changes in breathing patterns.

Dynamics of Gas Exchange, Ventilation, and Heart Rate. Before, during, and after the mission, crew members will exercise at pseudorandom levels between 20 and 80 W on the cycle ergometer while investigators study the kinetics of oxygen consumption, carbon dioxide output, ventilation, blood pressure, and heart rate. Among other things, scientists want to know whether carbon dioxide kinetics is a valid indicator of physical endurance during a space mission.

Cardiovascular Response to LBNP and Fluid Loading. This experiment will study the cardiovascular mechanisms thought to cause rapid, effective adaptation to microgravity as well as cardiovascular and neurohumoral dysfunction upon return to Earth. Subjects will be monitored during exercise and rest and will be subjected to rapid intravenous saline loading and lower body negative pressure. One resting test will attempt to validate 24-hour, 5-degree head-down bed rest as a model for studies of acute cardiovascular response to microgravity.

Biolabor

This research facility for biotechnology and life sciences was developed by Germany for performing research in cell electrofusion and cultivation, botany, and zoology on shuttle Spacelab missions. It is equipped with a workbench and microscope for cell electrofusion, a cell electrofusion control unit, two incubators for cell cultivation, a cooler, and two middeck-mounted cooling boxes. The workbench accommodates individual test chambers for electrofusion of various plant protoplasts and animal cells. The crew uses the microscope to observe the experiments inside the test chambers, and experimenters on Earth also observe and participate via downlinked video.

Vestibulo-ocular Reflexes in Amphibia and Fishes. This experiment examines the effect of short-term microgravity exposure on the development of the vestibular system of lower vertebrates in very early periods of life. Vestibulo-ocular reflexes are of particular interest because they are a good indicator of changes in the efficiency of the developing vestibular system. After this mission, these fragile tadpoles and perch fry will be placed in a specially constructed closed living system so that the degree of change in their reflexes can be determined and monitored throughout their lives until metamorphosis.

Structural Development and Function of the Gravity-Perceiving Organ. For the first time, the development of two different aquatic vertebrates—tadpoles and perch—that have been exposed to the same conditions in space will be compared. The experiment focuses on morphological differentiation of vestibular organs in microgravity and analysis of loop swimming behavior after variations in gravity.

Structure- and Function-Related Neuronal Plasticity of the CNS of Aquatic Vertebrates During Early Ontogenetic Development. Early ontogenetic development of perch and tadpoles will be examined after nine days of microgravity. Light and electron microscopes, along with biochemical analyses to differentiate gravity-related integration centers in the nervous system, are the tools of investigation.

Immunoelectron Microscopic Investigation of Cerebellar Development. This experiment studies the influence of microgravity on the structure and function of the cerebellum of fish and toad larvae. Polyclonal and monoclonal antibodies will be used against specific cell adhesion molecules.

Gravisensitivity of Cress Roots. Cress roots will be cultivated on a 1-g centrifuge in microgravity, and a threshold value for gravisensing will be determined. The structural characteristic of the gravity-perceiving cells will be correlated with the threshold value through electron microscopy on Earth. Finally, the threshold value will again be correlated with cell structure to obtain the first information ever on a plant's memory of the stimulus of gravity.

Cell Polarity and Gravity. The following experiments will discover whether gravity is a polarizing factor in higher plant cells and, if so, how it ranks among other polarizing factors.

The ultrastructure of fruiting bodies grown in microgravity and Earth's gravity will be studied to learn more about the mechanisms of graviperception and the effects of weightlessness on fungal morphogenesis.

To investigate how gravity and calcium metabolism influence metabolite production, growth, and regeneration capacity in cell cultures, scientists will conduct simulation experiments on Earth with a clinostat and centrifuge specifically adapted to cell cultures. Additional experiments with calcium chelators, calcium ionophores, and calmodulin antagonists are also planned.

Expression and Stability of Genetic Information in Bacteria. The growth rate and biomass of bacteria grown on previous space missions differ from those of Earth-grown bacteria. The study continues on this flight with measurements of specific product yields, stability of genetic information, and readaptation to growth at 1 g.

Connective Tissue Biosynthesis. Cultured mesenchymal cells, which actively produce connective tissue proteins, will be studied in microgravity to characterize the composition, number, and structure of synthesized proteins, most of which are collagens. Control cultures incubated at 1 g and hypergravity will be similarly studied. The results will confirm or deny the assumption that astronauts suffer severe bone degeneration after long space missions because microgravity decreases connective tissue biosynthesis in bone-forming cells.

Antigen-Specific Activation of Regulatory T-Lymphocytes and Increased Lymphokine Production. Undisturbed antigen-mediated cluster formation between responsive T-cells is expected in microgravity, which may increase the levels of secreted lymphokines. This experiment will determine the number of lymphokines produced in microgravity for comparison to similar 1-g tests. Investigators hope these measurements will offer new insight into the relationship between T-cells and accessory cells.

Enhanced Hybridoma Production. Promising results from past experiments on sounding rockets led to this joint experiment by Germany and the United States to produce new cells with curative properties. Through electrofusion, the use of electric current to join cells with different characteristics, investigators hope to produce a new hybrid cell. Specifically, human blood cells called lymphocytes will be joined with tumor cells that afflict bone marrow. The new cells, called hybridoma, may produce very specific antibodies that could be used to kill cancerous cells. Ground control experiments will be conducted in parallel with flight experiments in a laboratory at the Kennedy Space Center.

Culture and Electrofusion of Plant Cell Protoplasts. Plant cell protoplasts of different origin (leaf tissue, cell cultures) and the products formed from them by electrofusion will be cultured for 10 days at 1 g for comparison to identical samples kept at 1 g both in orbit (lab centrifuge) and on the ground. To monitor possible morphological and physiological/metabolic deviations, the crew will metabolically quench sample specimens at preset intervals. Analysis will entail microscopy, determination of cellular pool sizes in energy intermediates, carbohydrate metabolism, and protein characterization.

Yeast Experiment To Investigate Metabolism. In an attempt to improve the properties of yeast through durable, fixed genetic mutation, experimenters will expose fluid and solid cultures to cosmic radiation and microgravity—a first in space. The genome of HB-L29 yeast used in the experiment has two more chromosomes than cultures investigated to date.

Cosmic Radiation Experiments

These experiments are part of a radiobiological research program that encompasses projects in space and on Earth. The program is designed to collect information about the effect, importance, and hazards to people and biological specimens from particles of high atomic number and cosmic radiation. Such energy may affect experiments and pose health risks for crews of future long-term space missions. Once the effects are known, experiments and future spacecraft, like the space station, can be designed to eliminate risk. Therefore, on this mission, radiation detectors will be placed throughout the Spacelab near biological experiments and on the crew members.

Biological HZE-Particle Dosimetry With Biostack. Biostacks are layers of trays containing small biological specimens, such as plant seeds, insect eggs, and bacterial spores. Previous findings from biostack experiments indicate significant amounts of high-energy particles, but more detailed information is needed. On this mission, the trays will also contain radiation detectors that will contribute to assessments of the biological effects of specific cosmic radiation.

Personal Dosimetry—Crew Exposure to Ionizing Radiation. Various components of the cosmic radiation field will be measured with individual detectors, each specially designed to register heavy ions, nuclear disintegration of stars, or sparsely ionizing background radiation (electrons, protons, and rays). Groups of these detectors will be attached to the crew members' bodies in the vicinity of vital organs to establish a record of exposure to cosmic radiation.

Spacelab Internal Locations With Different Shielding Against Cosmic Radiation. Containers of different kinds of detectors will be placed in Spacelab locations whose shielding against cosmic radiation differs. The information obtained, which will be compared with theoretical predictions, will become baseline data for establishing protection guidelines and standards for people and radiation-sensitive experiments and materials.

Chromosome Aberration. The peripheral lymphocytes of the crew will be analyzed for chromosomal aberrations, micronuclei, and sister-chromated exchanges. The crew will be tested shortly before and after the mission and at intervals of four weeks, six months, and one year thereafter. The tests will serve as a biological dosimeter for exposure to ionizing radiation.

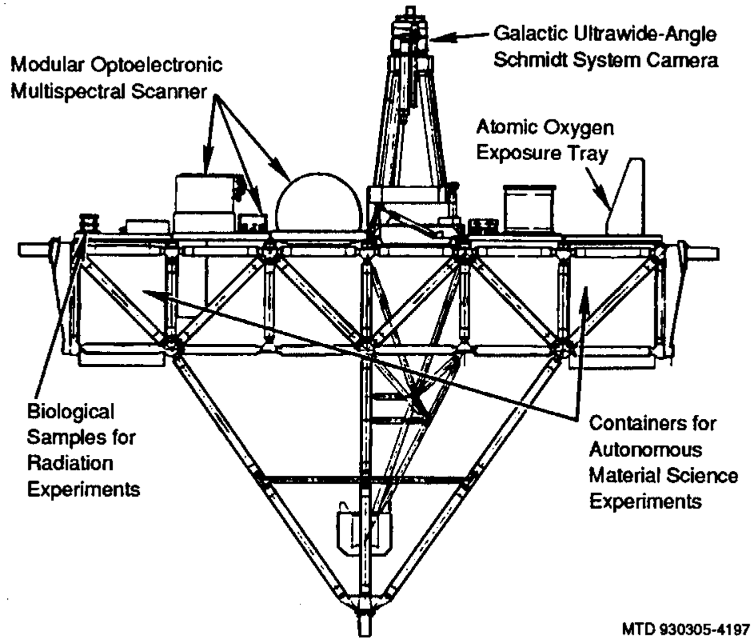
Biological Response to Extraterrestrial Solar UV Radiation and Space Vacuum. Spores of *bacillus subtilis* and DNA extracted from hemophilus influenzas will be exposed to space vacuum and selected intensities and wavelengths of extraterrestrial solar UV radiation. The samples, which will be placed on two exposure trays mounted on the unique support structure, will be studied for their photobiological and photobiochemical response.

Unique Support Structure (USS) Payloads

The USS supports four experiments that require exposure to space. The structure is located in the shuttle's cargo bay behind the Spacelab module.

Material Science Autonomous Payload (MAUS). MAUS consists of experiments that will investigate the diffusion phenomena of gas bubbles in salt melts and complex boiling processes. The first experiment will determine the diffusion coefficient in a soda-lime-silica melt through observation of the shrinking of a single oxygen bubble. The second experiment will attempt to confirm that pool boiling is quasi independent of gravity.

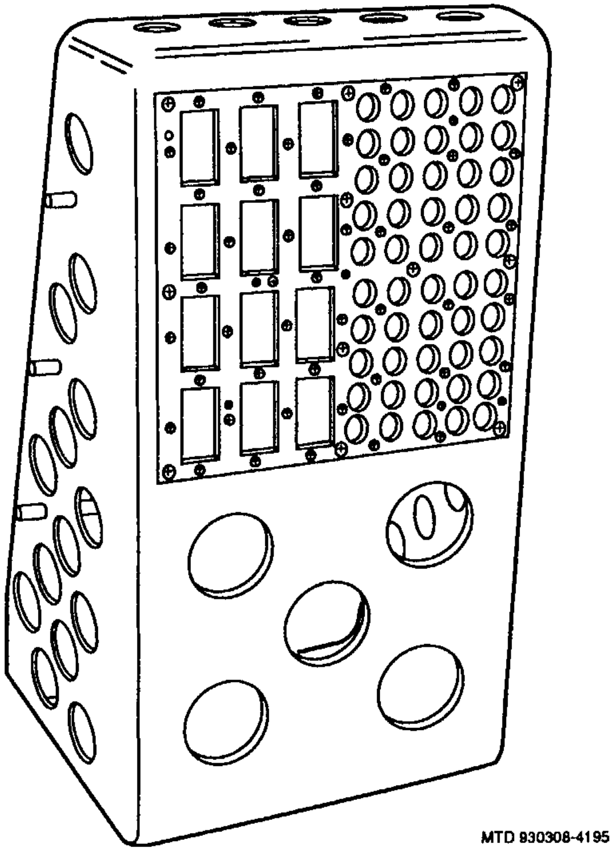
Atomic Oxygen Exposure Tray (AOET). The AOET will expose over 200 samples of different materials to examine how polymers, compounds, and organic films react to atomic oxygen in low Earth orbit. This information is vital to those who will build the space station, which must be able to remain in low Earth orbit for up to 30 years.



Unique Support Structure and Experiments

Galactic Ultrawide-Angle Schmidt System (GAUSS) Camera. Photographs of the Milky Way taken by this ultraviolet camera will increase our knowledge of our galaxy. The camera will also record images of the Earth's upper atmosphere when the shuttle's payload bay is turned toward Earth. About 100 photographs will be taken.

Modular Optoelectronic Multispectral Scanner (MOMS). MOMS-02 is an advanced Earth observation camera that is expected to produce breakthroughs in cartography, land use, ecology, and geology. The camera's long-track, high-performance stereo capabilities and digital images of higher geometric resolution and accuracy



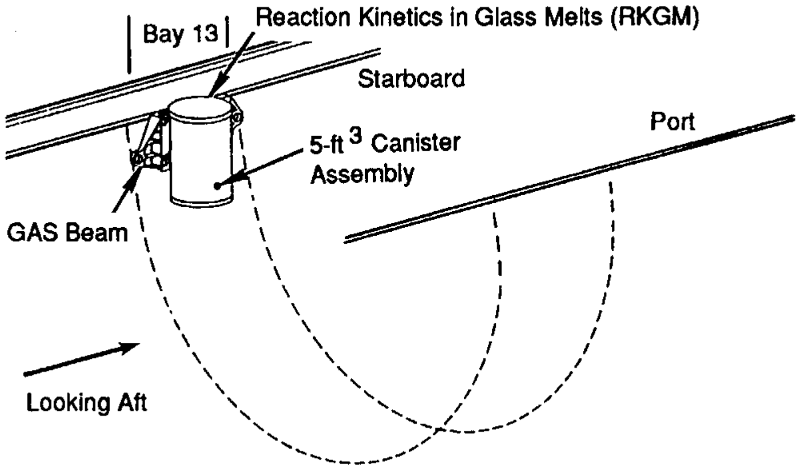
Atomic Oxygen Exposure Tray

will enable digital terrain models with a precision of better than 5 meters to be obtained.

Reaction Kinetics in Glass Melts (RKGM)

Two types of experiments will be conducted to determine the diffusion coefficients of glass melts and verify the mathematical models that describe mass transport in the melts. Four separate furnaces will process 16 samples.

The RKGM experiments are part of the Complex Autonomous Shuttle Payloads (CAP) program. They are contained in a getaway special canister mounted on the side of the payload bay near the USS.



Complex Autonomous Payload Installed in Orbiter Bay

Crew Telesupport Experiment (CTE)

This experiment will demonstrate real-time communication between the shuttle crew and the ground via a computer-based multimedia documentation file that includes text, graphics, and photos. For the CTE, the crew will use an interactive Hypermedia documentation file stored on an optical disk and a Macintosh portable computer equipped with a pen-activated, interactive graphics tablet. Crew telesupport is expected to improve the effectiveness of on-orbit payload operations, returns from scientific investigations, crew interaction with the ground, and contingency maintenance tasks for systems and payloads.

SHUTTLE AMATEUR RADIO EXPERIMENT II

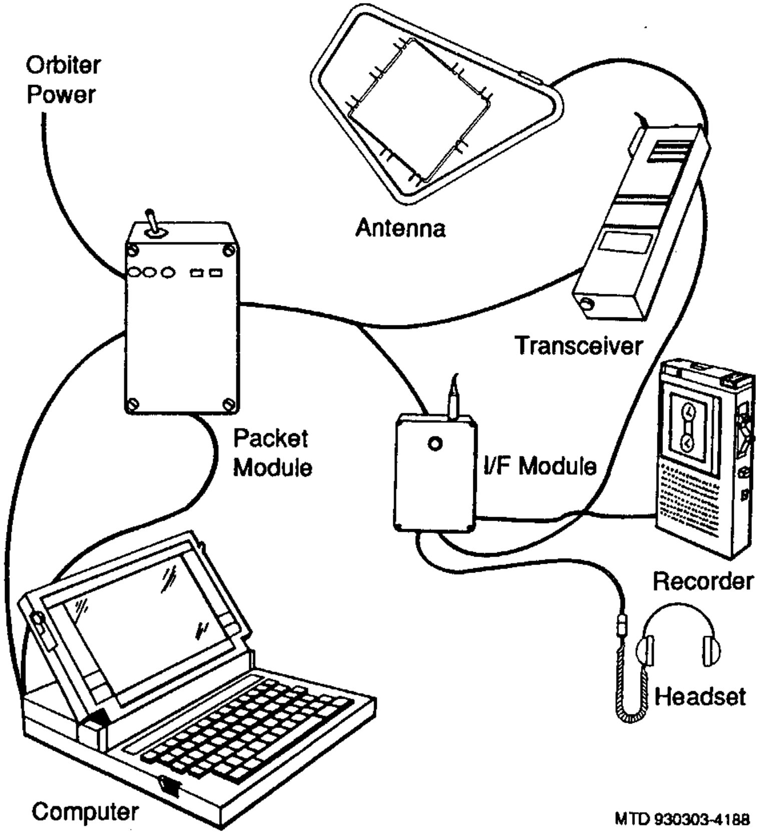
The Shuttle Amateur Radio Experiment (SAREX) was established by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club to encourage public participation in the space program through a program to demonstrate the effectiveness of conducting shortwave radio transmissions between the shuttle and ground-based amateur radio operators at low-cost ground stations with amateur and digital techniques. SAREX also is an educational opportunity for students around the world to learn about space firsthand by speaking directly to astronauts aboard the shuttle via ham radio. Contacts with certain schools are included in the planning for the mission.

SAREX has been flown on missions STS-9, -51F, -35, -37, -45, -50, and -47 in different configurations. A modified configuration C will be flown on STS-55. The equipment complement is stowed in one and one-half middeck lockers.

SAREX communicates with amateur stations within Columbia's line of sight in one of four transmission modes: voice, slow-scan TV (SSTV), data, or fast-scan TV (FSTV, uplink only). The voice transmissions are operated in the attended mode, while the SSTV, data, and FSTV transmissions can be operated in either the attended or unattended mode.

During the mission, SAREX-II will be operated at the discretion of four crew members who are licensed amateur radio operators: commander Steve Nagel (call sign N5RAW), pilot Jerry Ross (N5SCW), and payload specialists Hans Schlegel (DG1KIH) and Ulrich Walter (DG1KIM).

SAREX-II will be operated during periods when the crew members are not scheduled for orbiter or other payload activities. The



SAREX-II Configuration

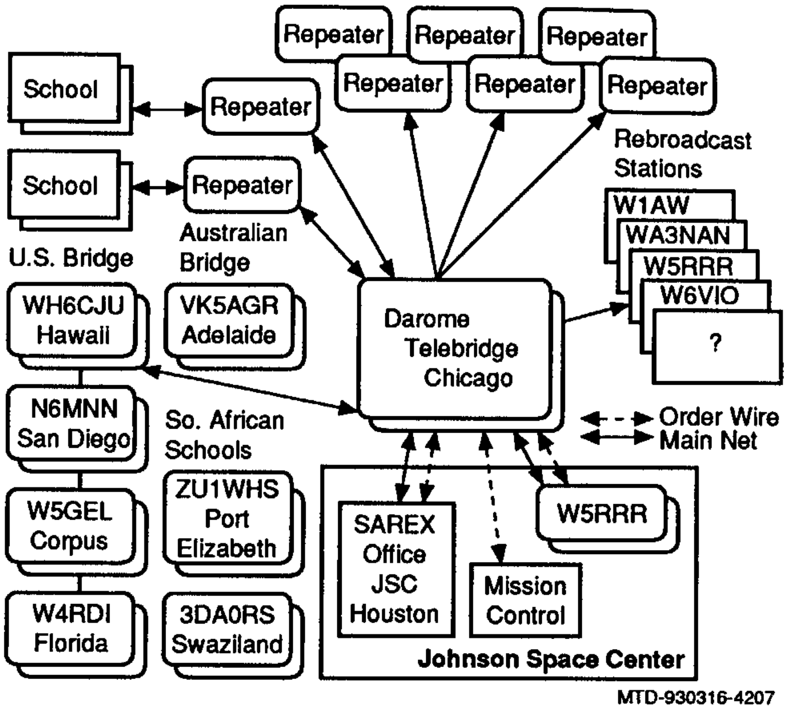
antenna's window location does not affect communications and therefore does not require a specific orbiter attitude for operations.

Ham operators may communicate with the shuttle by using 2-meter digital packet and VHF FM voice transmissions, a mode that makes contact widely available without the purchase of more expensive equipment.

The primary frequencies intended for use during the mission are 145.55 MHz for downlink from Columbia and 144.91, 144.93, 144.95, 144.97, and 144.99 MHz for uplink. A spacing of 600 kHz was deliberately chosen for this primary pair to accommodate those whose split-frequency capability is limited to the customary repeater offset. Digital packet will operate on 145.55 MHz for downlink transmission and 144.49 MHz for uplink transmission.

Students in the following U.S. schools will have the opportunity to talk directly with orbiting astronauts for approximately four to eight minutes:

- Meadow Village Elementary, San Antonio, Texas (WA5FRF)
- Fairmont Elementary, Deer Park, Texas (N5NBM)
- John F. Ward Elementary, Houston, Texas (N5EOS)
- Cumberland Junior High, Sunnyvale, Calif. (W2GN)
- Mudge Elementary, Fort Knox, Ky. (KE4NS)
- Seven Hills School and Lotspeich Elementary, Cincinnati, Ohio (KF8YA)
- St. Martin's Episcopal, Metairie, La. (N4MDC)
- Trumansburg Middle School, Trumansburg, N.Y. (N2PNA)
- The U.S. Air Force Academy, Colo. (KOMIC)

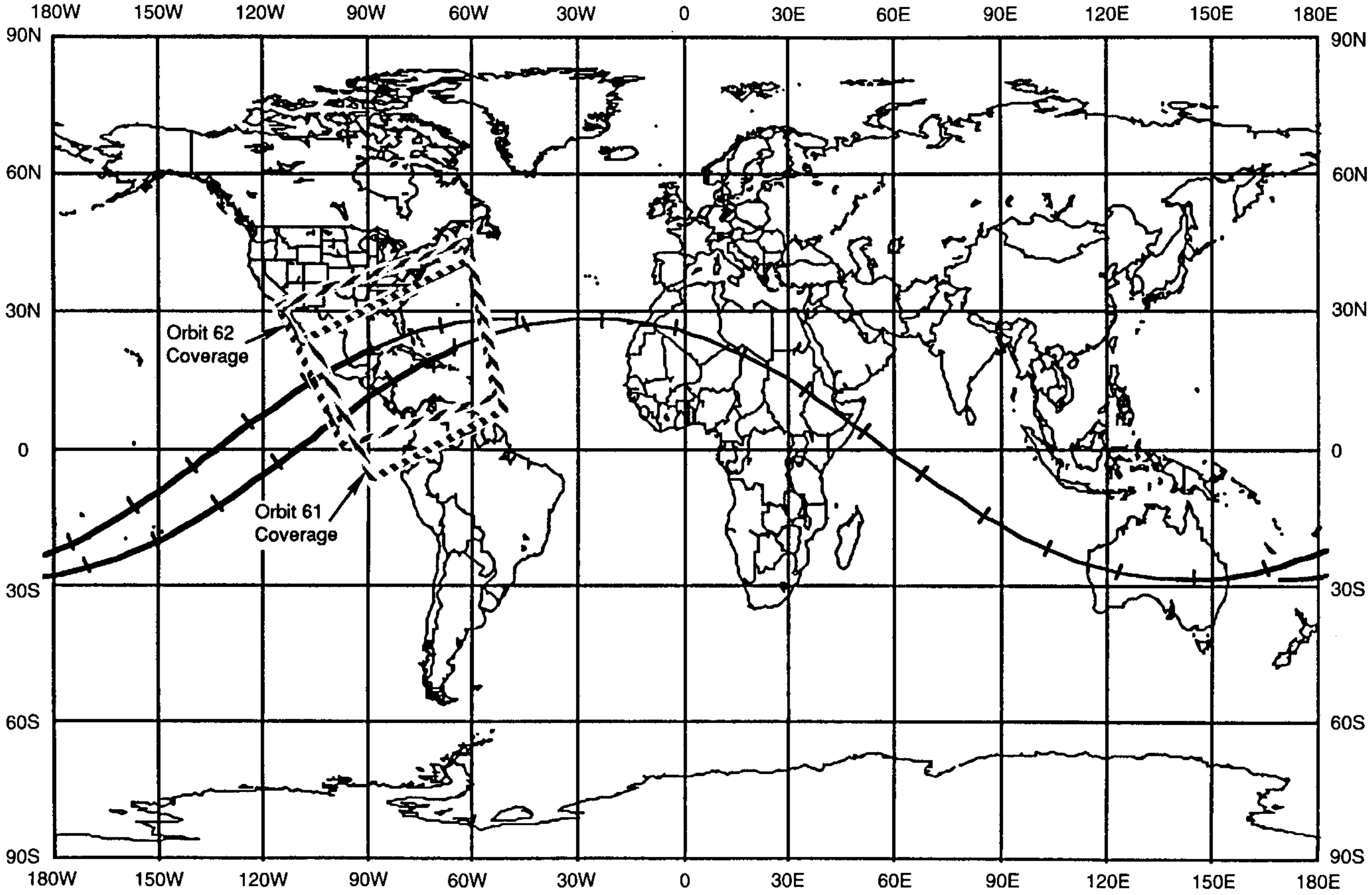


SAREX Bridge Network

International schools that will communicate with the crew are

- Westering High School, Port Elizabeth, South Africa (ZU1WHS)
- Sisekelo High School, Swaziland, South Africa (3DAORS)
- Tamworth High School, New South Wales, Australia
- Gladstone State High School, Gladstone, Queensland, Australia
- French Air Force Academy, Salon de Prov, France

An antenna test that will be conducted on orbits 61 and 62 will involve many amateur radio stations in the southern United States.



MTD 930316-4208

SAREX Antenna Test Track

The stations will measure the exact time of acquisition and loss of signal as well as other data. This data will be taken for two antennas, one in the orbiter window and a whip antenna protruding from Spacelab. The results will be tabulated and analyzed by the Motorola Amateur Radio Club in Ft. Lauderdale, Fla. The test will measure the pattern of both antennas and will aid in the design of future amateur radio antennas for spacecraft.

Information about orbital elements, contact times, frequencies, and crew operating schedules will be available during the mission from NASA, ARRL and AMSAT.

The ham radio club at JSC (W5RRR) will be operating on amateur shortwave frequencies, and the ARRL station (W1AW) will include SAREX information in its regular voice and teletype bulletins.

SAREX information may be obtained during the mission from the sponsoring groups, NASA JSC's Public Affairs Office, and amateur radio clubs at other NASA centers. SAREX information may also be obtained from the Johnson Space Center computer bulletin board (JSC BBS), 8 N1 1200 baud, by dialing (713) 483-2500 and then typing 62511.

The amateur radio station at the Goddard Space Flight Center (WA3NAN) will operate around the clock during the mission, providing information and restransmitting live shuttle air-to-ground audio.

SAREX Insignia

Another amateur radio experiment, SAFEX, will be operated by the licensed German payload specialists. SAFEX uses an external dual-band 2-meter/70-centimeter antenna mounted on the exterior of Spacelab, and the SAREX antenna is mounted on a window in the shuttle's cockpit.

DEVELOPMENT TEST OBJECTIVES

Ascent aerodynamic distributed loads verification (DTO 236). This DTO will collect data on wing aerodynamic distributed loads to allow verification of the aerodynamic data base.

Entry aerodynamic control surfaces test (part 6) (DTO 251). This DTO will perform programmed test input (PTI) maneuvers and one body flap maneuver during entry and terminal area energy management (TAEM) to obtain aerodynamic response data for use in evaluating the effectivity of aerodynamic control surfaces. Analysis may enhance vehicle performance and safety. This DTO uses the alternate forward elevon schedule and contains six parts.

Ascent wing structural capability evaluation (DTO 301D). The purpose of this DTO is to collect data to expand the data base of ascent dynamics for various weights.

Entry structural capability evaluation (DTO 307D). This DTO will collect structure load data for different payload weights and configurations to expand the data base of flight loads during entry.

ET TPS performance (DTO 312). This DTO will photograph the external tank after separation to determine thermal protection system (TPS) charring patterns, identify regions of TPS material spallation, and evaluate the overall performance of the TPS.

Orbiter drag chute system (DTO 521). This DTO will evaluate the orbiter drag chute system's performance through a series of landings with increasing deployment speeds. The DTO will be performed on vehicles equipped to measure drag forces imposed by the drag chute system. This DTO has two phases. Phase I consisted of two flights. The first drag chute deployment was at nose gear touchdown (STS-49) and the second was at the initiation of derotation. Phase II consists of seven additional flights, each flight gradually increasing in speed from initiation at derotation of 185 knots equivalent airspeed (KEAS) to initiation at 205 KEAS. Concrete runways will be used whenever possible during Phase II. On this flight, the chute will be deployed with the orbiter's nose in the air after derotation initiation and touchdown. A crosswind of less than 5 knots is required.

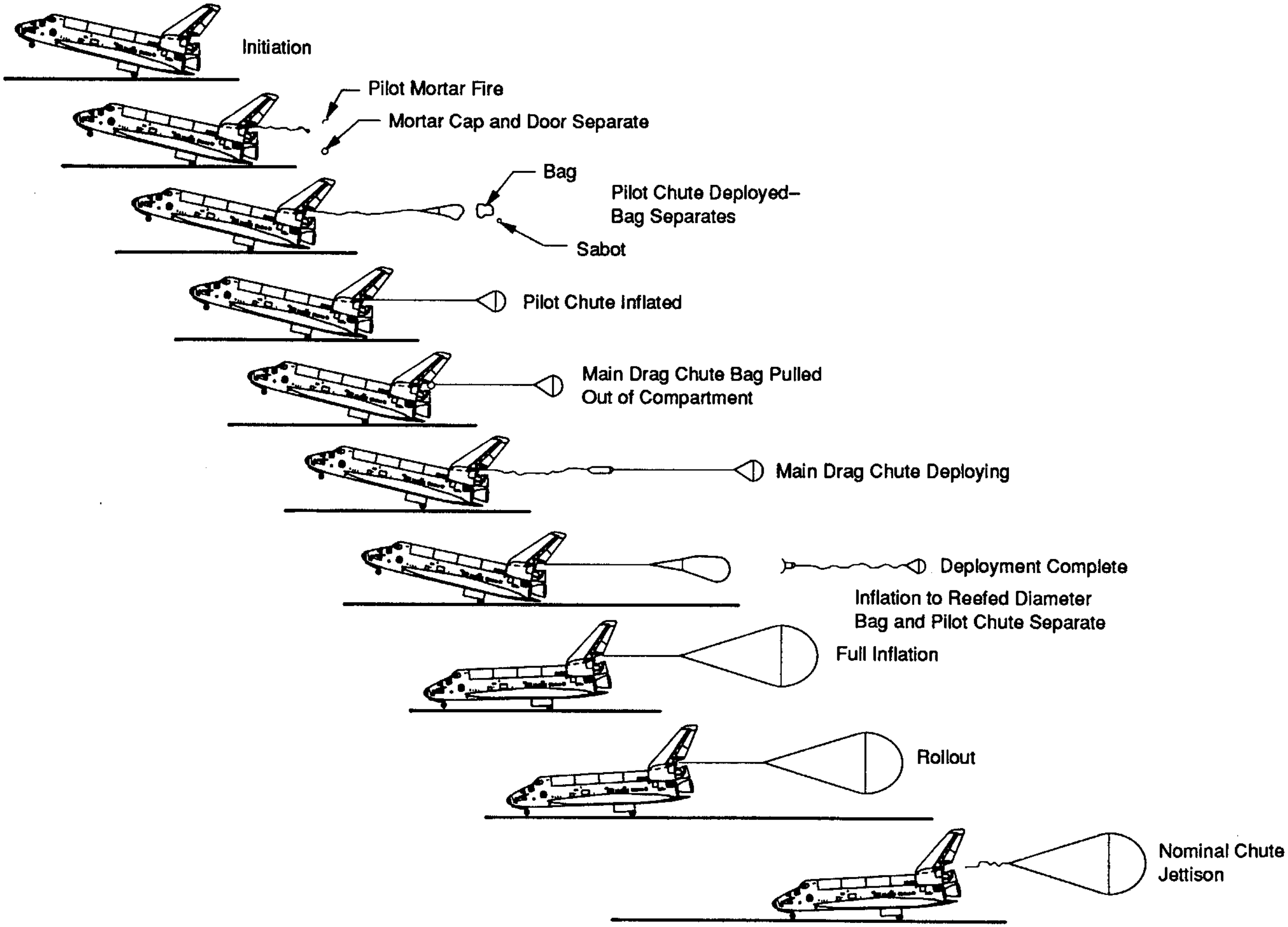
Cabin air monitoring (DTO 623). This DTO will use the solid sorbent sampler to continuously sample the orbiter's atmosphere throughout the flight. The solid sorbent sampler is to be flown on all Spacelab manned module flights.

Thermal impulse printer system demonstration (DTO 660). This DTO will evaluate the operational capability of the TIPS to uplink text and graphics via the orbiter voice/Ku-band communication link. This printer will be evaluated as an alternative to the onboard text and graphics system hard copier and teleprinter. The evaluation consists of uplinking various test patterns and messages to the TIPS printer in the S-band and Ku-band modes.

Acoustical noise dosimeter (DTO 663). This DTO will measure and record decibel levels in the middeck, the sleep stations, and the Spacelab module. Additionally, crew members will complete a questionnaire during the flight regarding noise levels.

Acoustical noise sound level data (DTO 665). This DTO will use a sound level meter to obtain baseline data of octave-band acoustical noise levels in the middeck, flight deck, sleep stations, and Spacelab module during routine orbiter and experiment operations.

Crosswind landing performance (DTO 805). This DTO will continue to gather data on manually controlling landing with a crosswind.



MTD 930301-4166

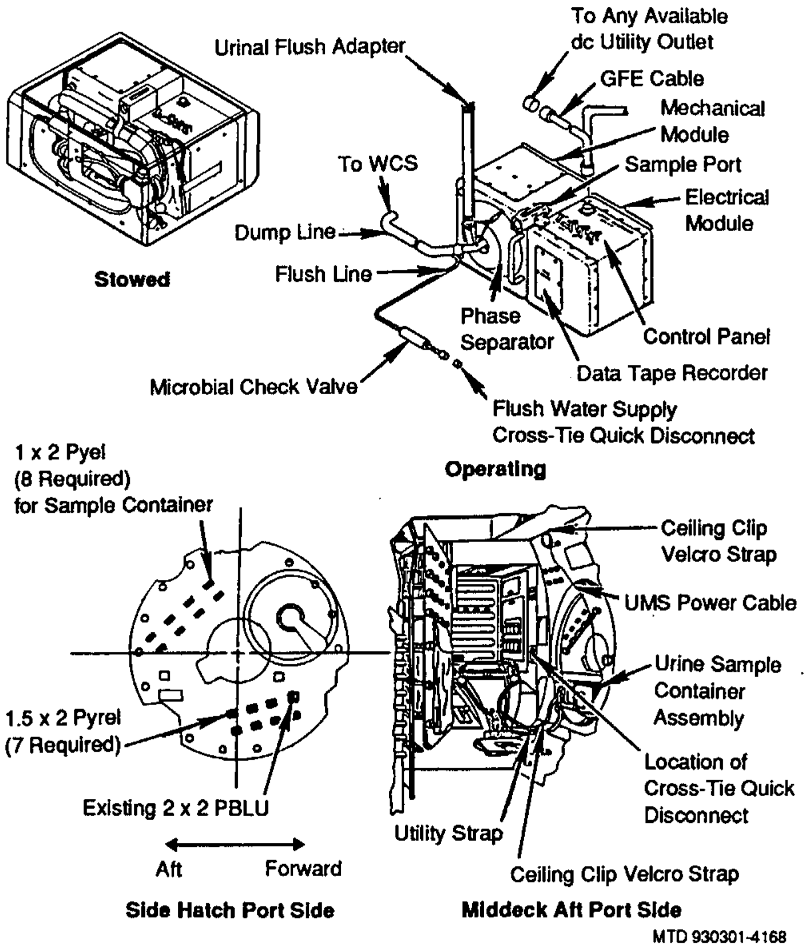
Nominal Sequence of Drag Chute Deployment, Inflation, and Jettison

Urine monitoring system evaluation (DSO 323). The purpose of this DSO is to determine if the in-flight dilution of samples collected from the UMS is different from the dilution that occurs in ground testing. In-flight volume measurements will also be checked to determine if middeck atmospheric pressure changes affect the measurements differently than in ground testing.

Physical examination in space (DSO 486). This DSO will implement the use of a standardized examination to identify normal physiological adaptations to the microgravity environment and to provide a baseline for differentiation of normal changes from pathologic changes. Differences in the examinations will be analyzed for their physiological and statistical significance.

Orthostatic function during entry, landing, and egress (DSO 603B*). Heart rate and rhythm, blood pressure, cardiac output, and peripheral resistance of crew members will be monitored during entry, landing, seat egress, and orbiter egress in order to develop and assess countermeasures designed to improve orthostatic tolerance upon return to Earth. This data will be used to determine whether precautions and countermeasures are needed to protect crew members if they have to leave the orbiter in an emergency. It will also be used to determine the effectiveness of proposed in-flight countermeasures. Crew members will don equipment before putting on their launch and entry suits during deorbit preparation. The equipment consists of a blood pressure monitor, accelerometers, an impedance cardiograph, and transcranial Doppler hardware. The crew members wear the equipment and record verbal comments throughout entry. This will be flown as a DSO of opportunity.

Evaluation of functional skeletal muscle performance following space flight (DSO 617*). The purpose of this DSO is to



Urine Monitoring System (UMS) Installation in a Middeck Locker and Operating Configuration

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*Indicates EDO buildup medical evaluation DSO determine the physiological effect of long-duration space flight on skeletal muscle strength, endurance, and power. Specific objectives are (1) to evaluate the concentric and eccentric functional changes before and after flight for the trunk and upper and lower limbs and (2) to determine the etiology of neuromuscular dysfunction as measured by EMG. The rationale for the DSO is that altered motor function and control resulting from the muscular deconditioning associated with adaptation to weightlessness could have negative implications for effective completion of many operational tasks, including landing and egress. Isokinetic testing and different velocities are used to assess skeletal muscle integrity at different rates of tension and functional speeds. Velocity spectrum testing can provide a valuable means of identifying functional deficits in the musculoskeletal system. It will also provide knowledge necessary to support the development of future countermeasure prescriptions essential for nominal performance. On-orbit activities consist of maintaining an exercise log.

Effects of intense exercise during space flight on aerobic capacity and orthostatic functions. (DSO 618*). The purpose of this DSO is to evaluate the effects of intense cycle ergometer exercise performed 18 to 24 hours before landing on postflight orthostatic function and on aerobic responses to maximum cycle exercise performed immediately after flight to quantify the degree of inflight aerobic deconditioning that occurs over the duration of the flight by comparing responses on flight day 3 and the last flight day to exercise.

Measurement of blood volume before and after space flight (DSO 625*). Blood volumes are not routinely measured before and after space shuttle missions, but they are thought to influence postflight crew performance.

Educational activities (DSO 802). The first objective of this DSO is to produce educational products that will capture the interest of students and motivate them to pursue careers in science, engineering, and mathematics. These products will include 20-minute video lessons featuring scenes recorded both on orbit and on the ground. The on-orbit video will be approximately one third of the finished video product. This DSO will support the videotaping of on-orbit educational activities performed by the flight crew as well as other educational activities that are deemed appropriate by the Educational Working Group and the flight crew. The second objective of this DSO is to support the live TV downlink of educational activities by the flight crew. Typically, these activities will be limited to one or two 30-minute live transmissions.

Documentary television (DSO 901). This purpose of DSO 901 is to provide live television transmission or video tape recorder (VTR) dumps of crew activities and spacecraft functions, including payload bay views, shuttle and payload crew activities, VTR downlink of crew activities, in-flight crew press conference, and unscheduled TV activities. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. The broadcast is accomplished using operational air-to-ground and/or operational intercom audio. Video tape recording may be used when live television is not possible.

Documentary motion picture photography (DSO 902). This DSO requires documentary and public affairs motion picture photography of significant activities that best depict the basic capabilities of the space shuttle and key flight objectives. This DSO includes photography of scheduled activities in the Spacelab, flight deck, and middeck and also unscheduled activities. This photography provides a historical record of the flight as well as material for release to the news media, independent publishers, and film producers.

Documentary still photography (DSO 903). This DSO requires still photography of crew activities in the orbiter and Space-

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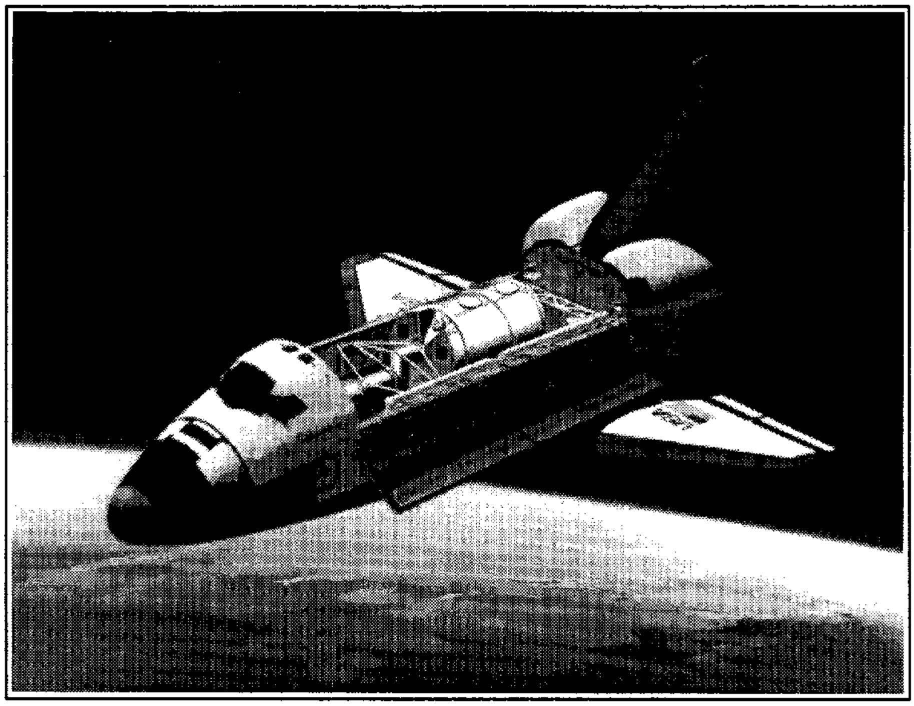
*Indicates EDO buildup medical evaluation DSO lab and mission-related scenes of general public and historical interest. Photographs of exterior and interior scenes will be taken in 70mm and 35mm formats, respectively.



STS-55

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

March 1993

Rockwell International
Space Systems Division

Office of External Communications &
Media Relations

CONTENTS

MISSION OVERVIEW

This is the 14th flight of Columbia and the 54th for the space shuttle.

The flight crew for the nine-day STS-55 mission is commander Steven (Steve) R. Nagel; pilot Terrence (Tom) T. Henricks; payload commander Jerry L. Ross; mission specialists Bernard A. Harris, Jr. and Charles (Charlie) J. Precourt; and payload specialists Hans Schlegel and Ulrich Walter of Germany. The crew will be divided into a blue team, consisting of Nagel, Henricks, Ross, and Walter; and a red team, comprised of Precourt, Harris and Schlegel. Each team will work consecutive 12-hour shifts, providing for around-the-clock operations.

STS-55's primary mission objective is to successfully launch, operate, and return the German Spacelab D-2, a German sponsored (DLR) payload that is designed to conduct research in a microgravity environment. The payload is composed of the Spacelab long module with transfer tunnel, a unique support structure (USS) for mounting experiments outside the module, and a complex autonomous shuttle payload: the Reaction Kinetic in Glass Melts (RKGM) Get-Away Special (GAS). Module experiments will investigate materials and life sciences, space technology, and automation and robotics. USS experiments will complete Earth and stellar observations.

Spacelab D-2 is the second German Spacelab mission (Spacelab D1 flew aboard STS-61A in October/November 1985). It is under German mission management, and Germany is responsible for its operation. In addition to continuing research areas and scientific experiments from Spacelab D-1, Spacelab D-2 will investigate and qualify technical and operational techniques and procedures in preparation for the operation of Space Station Freedom.

Specific areas of investigation include the following:

Materials Science--The material science experiments fall into the areas of fluid physics, nucleation and solidification. The fluid physics experiments include the study of capillarity and instability; change of phases; and heat transfer and diffusion. The nucleation and solidification experiments will study nucleation, dynamics of the solidification boundary, and production of monocrystals. The Holographics Optics Laboratory (HL) will investigate transient heat transfer, mass transfer, surface convection, and particle motion in optical transparent media via holographic methods. HL encompasses four different experiments: Interferences par Diffusion de Liquides dans L'Espace (IDILE), Interfussion in Salt Melts (ISIS), Marangoni Convection in a Square Cavity (MAC)), and Nucleation and Growth in Binary Mixtures With Miscibility Gap (NUGO). The Werkstofflabor (WL) consists of seven separate experiment facilities. Experiments within these facilities study several areas of metal processing, crystal growth for electronics applications, fluid boundary surfaces, and transport phenomena. The Material Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA) accommodates three separate experiment facilities: High Precision Thermostat (HPT), Gradient Furnace with Quenching (GFQ), and Ellipsoidspiegelofen (Elli). Material science and physical chemistry experiments will be carried out in the areas of critical point phenomena, direction solidification of metallic crystals, and long term crystallization. Radiation Detectors (RD) is a set of four experiments in which different types of material and biological probes will be exposed to different environmental conditions. The results of these tests will be used in the development of radiation protection in space.

Biological Sciences--The biological science experiments will study the electrofusion of cells, cell functions, reaction to gravity, development processes, and radiation and behaviorial physiology. Human aphysiology experiments will be performed in the areas of cardiovascular systems, pulmonary functions and hormonal adaptation. Biolabor (BB) studies the effects of the absence of gravity on plants and animal organisms, and on single cells (gravitational biology-GB). BB also studies cultivation methods of different cells and electrocell fusion of plant and animal cells (Biological Methods-BV). Anthrorack (AR) measures cardiac, pulmonary, and metabolic function in resting conditions and during challenges that are imposed to change the cardiopulmonary function. This experiment will investigate fluid shifts, the hormonal system, lung circulation and ventilation, deconditioning of the cardiovascular system, and the body's reaction to different physical states. Baroreflex (BA) will investigate changes in the baroreceptor reflex that play a major role in the development of conditions responsible for the fall of blood pressure (orthostatic hypotension) after space flight. The Urine Monitoring System (UMS) is used to collect urine samples from each crewmember. The urine sample will be analyzed for protein metabolism, fluid electrolyte regulation, and pathophysiology of mineral loss during space flight.

Technology--Technology areas of study will include automation and robotics, and transfer functions. In the Robotics Experiment (Rotex), a robotic arm located in an enclosed workcell will be operated from both within the module and from the ground. Rotex will employ teleprogramming and artificial intelligence to look at the design, verification and operation of advanced autonomous systems. Microgravity Measurement Assembly (MMA) will measure structural transfer functions at various locations, thus providing information about experiment environmental conditions for future Spacelab flights. The Crew Telesupport Experiment (CTE) will demonstrate communication between onboard and ground computer-based documentation files (text), graphics, photos) combined with real-time graphical inputs by the crewmember and the ground. The CTE is intended to enhance the effectiveness of payload operations, maintenance, and scientific return.

Earth Observation--The Modular Optoelectronic Multispectral Stereo Scanner (MOMS), an Earth observing instrument located on the USS platform, is an imaging and sensing instrument that will provide photogrammetic mapping and telemetic mapping applications.

Astronomy--The Galactic Ultrawide Angle Schmidt System (GAUSS) camera, located on the USS, will be used to study the Milky Way.

Atmospheric Physics--Various materials will be exposed to the atmosphere and the effects will be observed. The Atomic Oxygen Exposure Tray (AOET) will obtain in-situ reaction-rate measurements for various materials interacting with atomic oxygen.

RKGM--The Reaction Kinetic in Glass Melts (RKGM) Get-away Special will study the processes involved in the formation of a glass melt, specifically the process of mass transport by diffusion. Mass transfer is controlled by either diffusion or buoyancy convection. Once on-orbit, the crew enables and activates the RKGM payload. Once activated, experiment electronics run an automatic experiment control sequence.

The shuttle orbiter Columbia plays the role of "mother ship" to the Spacelab D-2 payload, serving as a stable and reliable platform for microgravity investigations, and providing a stable attitude, power, and cooling needs.

STS-55's secondary objective is to perform the operations of the Shuttle Amateur Radio Experiment (SAREX) II payload. SAREX, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, will establish crew voice communication with amateur radio stations within the line of sight of the orbiter. The SAREX will be operated at the discretion of the licensed crewmembers. Crewmembers are licensed radio operators for STS-55. SAREX will fly a modified configuration C on STS-55. Configuration C has the capability of operating in either voice or data mode in communications with amateur stations within line of sight of the orbiter. Configuration C can also be operated in the attended mode for voice communication and either attended or automatic mode for data communications.

Eleven development test objectives and 10 detailed supplementary objectives are scheduled to be flown on STS-55.

MISSION STATISTICS

Vehicle: Columbia (OV-102), 14th flight

Launch Date/Time:

3/21/93 9:52 a.m., EST
8:52 a.m., CST
6:52 a.m., PST

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

Launch Window: 2 hours, 30 minutes

Mission Duration: 8 days, 22 hours, 5 minutes. A highly desirable additional day cannot be guaranteed due to consumables, but potentially could be achieved real time. Planning will accommodate the longer duration wherever appropriate. The capability exists for two additional days for contingency operations and weather avoidance.

Landing: Nominal end-of-mission landing on orbit 143

3/30/93 7:57 a.m., EST
6:57 a.m., CST
4:57 a.m., PST

Runway: Nominal end-of-mission landing on concrete runway 15, Kennedy Space Center (KSC), Fla. Weather alternates are Edwards Air Force Base (EAFB), Calif., and Northrup Strip (NOR), White Sands, N. M.

Transatlantic Abort Landing: Banjul, The Gambia; alternates: Moron, Spain; Ben Guerir, Morocco

Return to Launch Site: KSC

Abort-Once-Around: EAFB; alternates: KSC, NOR

Inclination: 28.45 degrees

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

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

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

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2030
No. 2 position: Engine 2034
No. 3 position: Engine 2011

External Tank: ET-56

Solid Rocket Boosters: BI-057

Mobile Launcher Platform: 3

Editor's Note: The following weight data are current as of March 16, 1993.

Total Lift-off Weight: Approximately 4,518,784 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 255,252 pounds

Orbiter (Columbia) Empty and 3 SSMEs: Approximately 180,895 pounds

Payload Weight Up: Approximately 26,864 pounds

Payload Weight Down: Approximately 26,864 pounds

Orbiter Weight at Landing: Approximately 227,203 pounds

Payloads--Payload Bay (* denotes primary payload): Spacelab D-2 with long module, unique support structure (USS), and Reaction Kinetic in Glass Melts (RKGM) Get-Away Special

Payloads--Middeck: Shuttle Amateur Radio Experiment (SAREX) II

Flight Crew Members:

Red Team:

Mission Specialist 2: Charles (Charlie) J. Precourt, first space shuttle flight
Mission Specialist 3: Bernard A. Harris, Jr., first space shuttle flight
Payload Specialist 2: Hans Schlegel, Germany, first space shuttle flight

Blue Team:

Commander: Steven (Steve) R. Nagel, fourth space shuttle flight
Pilot: Terrence (Tom) T. Henricks, second space shuttle flight
Payload Commander (Mission Specialist 1): Jerry L. Ross, fourth space shuttle flight
Payload Specialist 1: Ulrich Walter, Germany, first space shuttle flight

Nagel, Henricks, and Precourt make up the orbiter crew, which operates the shuttle and Spacelab systems monitored by the Mission Control Center at NASA's Johnson Space Center, Houston, Texas. Harris, Schlegel, Ross, and Walter form the science crew, which will operate the Spacelab D-2 experiments monitored by the German Space Operations Center (GSOC) in Oberpfaffenhofen, Germany.

Ascent Seating:

Flight deck, front left seat, commander Steven R. Nagel
Flight deck, front right seat, pilot Terrence T. Henricks
Flight deck, aft center seat, mission specialist Charles J. Precourt
Flight deck, aft right seat, mission specialist Bernard A. Harris, Jr.
Middeck, payload specialist Hans Schlegel
Middeck, payload specialist Ulrich Walter
Middeck, mission specialist Jerry L. Ross

Entry Seating:

Flight deck, front left seat, commander Steven R. Nagel
Flight deck, front right seat, pilot Terrence T. Henricks
Flight deck, aft center seat, mission specialist Charles J. Precourt
Flight deck, aft right seat, mission specialist Jerry L. Ross
Middeck, mission specialist Bernard A. Harris, Jr.
Middeck, payload specialist Hans Schlegel
Middeck, payload specialist Ulrich Walter

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: mission specialist Jerry L. Ross
EV-2: mission specialist Charles J. Precourt

Intravehicular Astronaut: pilot Terrence T. Henricks

STS-55 Flight Directors:

Ascent/Entry/Orbit 1: Wayne Hale
Orbit 2 Team/Lead: Gary Coen
Orbit 3 Team: Milt Heflin

Entry: Automatic mode until subsonic, then control stick steering

Notes:

- The remote manipulator system is not installed in Columbia's payload bay for this mission.

- The shuttle orbiter repackaged galley is installed in Columbia's middeck.

MISSION OBJECTIVES

- Primary objective
  - Spacelab D-2 operations
- Secondary objective
  - Middeck
    - Shuttle Amateur Radio Experiment (SAREX) II
- 11 development test objectives/10 detailed supplementary objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Payload bay doors open
Spacelab D-2 activation
Payload activation
Priority Group B powerdown
Unstow cabin

Flight Day 2

Spacelab operations

Flight Day 3

Spacelab operations

Flight Day 4

Spacelab operations

Flight Day 5

Spacelab operations

Flight Day 6

Spacelab operations

Flight Day 7

Spacelab operations

Flight Day 8

Spacelab operations

Flight Day 9

Spacelab operations
FCS checkout
RCS hot fire

Flight Day 10

Spacelab deactivation
Priority Group B powerup
Cabin stow
Deorbit preparation
Deorbit burn
Landing

Note:

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

CREW ASSIGNMENTS

Commander: (Steven R. Nagel)

Overall mission decisions
Orbiter--IFM (Spacelab systems)
Payload--MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
DTOs/DSOs--DTOs 251, 623, 660, 663, 665, 805; DSOs 323, 617, 618

Pilot: (Terrence T. Henricks)

Orbiter--IFM
Payload--IFM (Spacelab systems), MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
DTOs/DSOs--DTOs 251, 623, 660, 663, 665; DSOs 323, 603, 617, 618, 625
Other--Earth observations

Payload Commander (Mission Specialist 1): (Jerry L. Ross)

Payload--IFM (Spacelab systems), IFM (Spacelab experiments), Spacelab module experiments, Baroreflex, UMS
DTOs/DSOs--DTO 312; DSO 603
Other--EV1, medic

Mission Specialist 2: (Charles J. Precourt)

Orbiter--IFM
Payload--IFM (Spacelab systems), MOMS, GAUSS, RKGM, CTE, Baroreflex, UMS
DTOs/DSOs--DTOs 623, 660, 663, 665; DSOs 323, 486, 603, 617, 618
Other--IV, photo/TV

Mission Specialist 3: (Bernard A. Harris, Jr.)

Payload--Spacelab module experiments, IFM (Spacelab systems), IFM (Spacelab experiments), Baroreflex, UMS
DTOs/DSOs--DSO 486
Other--EV2, medic

Payload Specialist 1: (Ulrich Walter)

Payload--Spacelab module experiments, Baroreflex, UMS, IFM (Spacelab experiments)

Payload Specialist 2: (Hans Schlegel)

Payload--Spacelab module experiments, Baroreflex, UMS, IFM (Spacelab experiments)

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

. Ascent aerodynamic distributed loads verification (DTO 236)
. Entry aerodynamic control surfaces test (Part 6) (DTO 251)
. Ascent structural capability evaluation (DTO 301D)
. Entry structural capability evaluation (DTO 307D)
. ET TPS performance, methods 1 and 2 (DTO 312)
. Orbiter drag chute system (DTO 521)
. Cabin air monitoring (DTO 623)
. Thermal impulse printer system demonstration (DTO 660)
. Acoustical noise dosimeter (DTO 663)
. Acoustical noise sound level data (DTO 665)
. Crosswind landing performance (DTO 805)

DSOs

. Urine monitoring system evaluation (DSO 323)
. Physical examination in space (DSO 486)
. Orthostatic function during entry, landing, and egress (DSO 603B*)
. Evaluation of functional skeletal muscle performance following space flight (DSO 617*)
. Effects of intense exercise during space flight on aerobic capacity and orthostatic functions (DSO 618*)
. Measurement of blood volume before and after space flight (DSO 625*)
. Educational activities (objective 1 and 2) (DSO 802)
. Documentary television (DSO 901)
. Documentary motion picture photography (DSO 902)
. Documentary still photography (DSO 903)

* EDO buildup medical evaluation

STS-55 PRELAUNCH COUNTDOWN

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

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
03:20:00	The main propulsion system (MPS) helium tanks begin filling from 2,000 psi to their full pressure of 4,500 psi.
03:15:00	Liquid hydrogen stable replenishment begins and continues until just minutes prior to T minus zero.
03:10:00	Liquid oxygen stable replenishment begins and continues until just minutes prior to T minus zero.
03:00:00	The MILA antenna alignment is completed.
03:00:00	The orbiter closeout crew goes to the launch pad and prepares the orbiter crew compartment for flight crew ingress.
03:00:00 Holding	Begin 2-hour planned hold. An inspection team examines the ET for ice or frost formation on the launch pad during this hold.
03:00:00 Counting	Two-hour planned hold ends.
02:55:00	Flight crew departs Operations and Checkout (O&C) Building for launch pad.
02:25:00	Flight crew orbiter and seat ingress occurs.
02:10:00	Post ingress software reconfiguration occurs.
02:00:00	Checking of the launch commit criteria starts at this time.
02:00:00	The ground launch sequencer (GLS) software is initialized.
01:50:00	The solid rocket boosters' (SRBs') hydraulic pumping units' gas generator heaters are turned on and the SRBs' aft skirt gaseous nitrogen purge starts.
01:50:00	The SRB rate gyro assemblies (RGAs) are turned on. The RGAs are used by the orbiter's navigation system to determine rates of motion of the SRBs during first-stage flight.
01:35:00	The orbiter accelerometer assemblies (AAs) are powered up.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
01:35:00	The orbiter reaction control system (RCS) control drivers are powered up.
01:35:00	The flight crew starts the communications checks.
01:25:00	The SRB RGA torque test begins.
01:20:00	Orbiter side hatch is closed.
01:10:00	Orbiter side hatch seal and cabin leak checks are performed.
01:01:00	IMU preflight align begins. Flight crew functions from this point on will be initiated by a call from the orbiter test conductor (OTC) to proceed. The flight crew will report back to the OTC after completion.
01:00:00	The orbiter RGAs and AAs are tested.
00:50:00	The flight crew starts the orbiter hydraulic auxiliary power units' (APUs') water boilers preactivation.
00:45:00	Cabin vent redundancy check is performed.
00:45:00	The GLS mainline activation is performed.
00:40:00	The eastern test range (ETR) shuttle range safety system (SRSS) terminal count closed-loop test is accomplished.
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.
00:30:00	The gaseous nitrogen system for the orbital maneuvering system (OMS) engines is pressurized for launch. Crew compartment vent valves are opened.
00:26:00	The ground pyro initiator controllers (PICs) are powered up. They are used to fire the SRB hold-down posts, liquid oxygen and liquid hydrogen tail service mast (TSM), and ET vent arm system pyros at lift-off and the SSME hydrogen gas burn system prior to SSME ignition.
00:25:00	Simultaneous air-to-ground voice communications are checked. Weather aircraft are launched.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:22:00	The primary avionics software system (PASS) is transferred to the BFS computer in order for both systems to have the same data. In case of a PASS computer system failure, the BFS computer will take over control of the shuttle vehicle during flight.
00:21:00	The crew compartment cabin vent valves are closed.
00:20:00	A 10-minute planned hold starts.
Hold 10 Minutes	All computer programs in the firing room are verified to ensure that the proper programs are available for the final countdown. The test team is briefed on the recycle options in case of an unplanned hold. The landing convoy status is again verified and the landing sites are verified ready for launch. The IMU preflight alignment is verified complete. Preparations are made to transition the orbiter onboard computers to Major Mode (MM)-101 upon coming out of the hold. This configures the computer memory to a terminal countdown configuration.
00:20:00	The 10-minute hold ends.
Counting	Transition to MM-101. The PASS onboard computers are dumped and compared to verify the proper onboard computer configuration for launch.
00:19:00	The flight crew configures the backup computer to MM-101 and the test team verifies the BFS computer is tracking the PASS computer systems. The flight crew members configure their instruments for launch.
00:18:00	The Mission Control Center-Houston (MCC-H) now loads the onboard computers with the proper guidance parameters based on the prestated lift-off time.
00:16:00	The MPS helium system is reconfigured by the flight crew for launch.
00:15:00	The OMS/RCS crossfeed valves are configured for launch. All test support team members verify they are "go for launch."

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:12:00	Emergency aircraft and personnel are verified on station.
00:10:00	All orbiter aerosurfaces and actuators are verified to be in the proper configuration for hydraulic pressure application. The NASA test director gets a "go for launch" verification from the launch team.
00:09:00	A planned 10-minute hold starts.
Hold 10 Minutes	NASA and contractor project managers will be formally polled by the deputy director of NASA, Space Shuttle Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records. All test support team members verify that they are "go for launch." Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins. From this point, the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the onboard orbiter PASS redundant-set computers.
00:09:00	Operations recorders are on. MCC-H, Johnson Space Center, sends a command to turn these recorders on. They record shuttle system performance during ascent and are dumped to the ground once orbit is achieved.
00:08:00	Payload and stored prelaunch commands proceed.
00:07:30	The orbiter access arm (OAA) connecting the access tower and the orbiter side hatch is retracted. If an emergency arises requiring flight crew activation, the arm can be extended either manually or by GLS computer control in approximately 30 seconds or less.
00:06:00	APU prestart occurs.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:05:00	Orbiter APUs start. The orbiter APUs provide pressure to the three orbiter hydraulic systems. These systems are used to move the SSME engine nozzles and aerosurfaces.
00:05:00	ET/SRB range safety system (RSS) is armed. At this point, the firing circuit for SRB ignition and destruct devices is mechanically enabled by a motor-driven switch called a safe and arm device (S&A).
00:04:30	As a preparation for engine start, the SSME main fuel valve heaters are turned off.
00:04:00	The final helium purge sequence, purge sequence 4, on the SSMEs is started in preparation for engine start.
00:03:55	At this point, all of the elevons, body flap, speed brake, and rudder are moved through a preprogrammed pattern. This is to ensure that they will be ready for use in flight.
00:03:30	Transfer to internal power is done. Up to this point, power to the space vehicle has been shared between ground power supplies and the onboard fuel cells. The ground power is disconnected and the vehicle goes on internal power at this time. It will remain on internal power through the rest of the mission.
00:03:25	The SSMEs' nozzles are moved (gimbaled) through a preprogrammed pattern to ensure that they will be ready for ascent flight control. At completion of the gimbal profile, the SSMEs' nozzles are in the start position.
00:02:55	ET liquid oxygen prepressurization is started. At this point, the liquid oxygen tank vent valve is closed and the ET liquid oxygen tank is pressurized to its flight pressure of 21 psi.
00:02:50	The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted.
00:02:35	Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the onboard tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:02:30	The caution/warning memory is cleared.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.
00:00:47	The liquid oxygen and liquid hydrogen outboard fill and drain valves are closed.
00:00:40	The external tank bipod heaters are turned off.
00:00:38	The onboard computers position the orbiter vent doors to allow payload bay venting upon lift-off and ascent in the payload bay at SSME ignition.
	The SRB forward MDM is locked out.
00:00:37	The gaseous oxygen ET arm retract is confirmed.
00:00:31	The GLS sends "go for redundant set launch sequence start." At this point, the four PASS computers take over main control of the terminal count. Only one further command is needed from the ground, "go for main engine start," at approximately T minus 9.7 seconds. The GLS in the integration console in the launch control center still continues to monitor several hundred launch commit criteria and can issue a cutoff if a discrepancy is observed. The GLS also sequences ground equipment and sends selected vehicle commands in the last 31 seconds.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:00:28	Two hydraulic power units in each SRB are started by the GLS. These provide hydraulic power for SRB nozzle gimbaling for ascent first-stage flight control.
	The orbiter vent door sequence starts.
00:00:21	The SRB gimbal profile is complete. As soon as SRB hydraulic power is applied, the SRB engine nozzles are commanded through a preprogrammed pattern to assure that they will be ready for ascent flight control during first stage.
00:00:21	The liquid hydrogen high-point bleed valve is closed.
	The SRB gimbal test begins.
00:00:18	The onboard computers arm the explosive devices, the pyrotechnic initiator controllers, that will separate the T-0 umbilicals, the SRB hold-down posts, and SRB ignition, which is the final electrical connection between the ground and the shuttle vehicle.
00:00:16	The sound suppression system water is activated.
00:00:15	If the SRB pyro initiator controller (PIC) voltage in the redundant-set launch sequencer (RSLS) is not within limits in 3 seconds, SSME start commands are not issued and the onboard computers proceed to a countdown hold.
00:00:13	The aft SRB MDM units are locked out. This is to protect against electrical interference during flight. The electronic lock requires an unlock command before it will accept any other command.
	SRB SRSS inhibits are removed. The SRB destruct system is now live.
00:00:12	The MPS helium fill is terminated. The MPS helium system flows to the pneumatic control system at each SSME inlet to control various essential functions.
00:00:10	LPS issues a "go" for SSME start. This is the last required ground command. The ground computers inform the orbiter onboard computers that they have a "go" for SSME start. The GLS retains hold capability until just prior to SRB ignition.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:00:09.7	Liquid hydrogen recirculation pumps are turned off. The recirculation pumps provide for flow of fuel through the SSMEs during the terminal count. These are supplied by ground power and are powered in preparation for SSME start.
00:00:09.7	In preparation for SSME ignition, flares are ignited under the SSMEs. This burns away any free gaseous hydrogen that may have collected under the SSMEs during prestart operations. The orbiter goes on internal cooling at this time; the ground coolant units remain powered on until lift-off as a contingency for an aborted launch. The orbiter will redistribute heat within the orbiter until approximately 125 seconds after lift-off, when the orbiter flash evaporators will be turned on.
00:00:09.5	The SSME engine chill-down sequence is complete and the onboard computers command the three MPS liquid hydrogen prevalves to open. (The MPSs three liquid oxygen prevalves were opened during ET tank loading to permit engine chill-down.) These valves allow liquid hydrogen and oxygen flow to the SSME turbopumps.
00:00:09.5	Command decoders are powered off. The command decoders are units that allow ground control of some onboard components. These units are not needed during flight.
00:00:06.6	The main fuel and oxidizer valves in each engine are commanded open by the onboard computers, permitting fuel and oxidizer flow into each SSME for SSME start. All three SSMEs are started at 120-millisecond intervals (SSME 3, 2, then 1) and throttle up to 100-percent thrust levels in 3 seconds under control of the SSME controller on each SSME.
00:00:04.6	All three SSMEs are verified to be at 100-percent thrust and the SSMEs are gimbaled to the lift-off position. If one or more of the three SSMEs does not reach 100-percent thrust at this time, all SSMEs are shut down, the SRBs are not ignited, and an RSLS pad abort occurs. The GLS RSLS will perform shuttle and ground systems safing. Vehicle bending loads caused by SSME thrust buildup are allowed to initialize before SRB ignition. The vehicle moves towards ET including ET approximately 25.5 inches.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:00:00	The two SRBs are ignited under command of the four onboard PASS computers, the four hold-down explosive bolts on each SRB are initiated (each bolt is 28 inches long and 3.5 inches in diameter), and the two T-0 umbilicals on each side of the spacecraft are retracted. The onboard timers are started and the ground launch sequence is terminated. All three SSMEs are at 104-percent thrust. Boost guidance in attitude hold.
00:00	Lift-off.

STS-55 MISSION HIGHLIGHTS TIMELINE

Editor's Note: This timeline lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-55 Flight Plan, Ascent Checklist, Post Insertion Checklist, Deorbit Prep Checklist, and Entry Checklist.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY ZERO	
0/00:00:07	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:10	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down, wings level.
0/00:00:19	Roll maneuver ends.
0/00:00:27	All three SSMEs throttle down from 100 to 70 percent for maximum aerodynamic load (max q).
0/00:00:56	All three SSMEs throttle to 104 percent.
0/00:01:01	Max q occurs.
0/00:02:05	SRBs separate. When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:03:58	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:07:02	Single engine press to main engine cutoff (MECO).
0/00:08:26	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:29	MECO occurs at approximate velocity 25,877 feet per second, 36 by 158 nautical miles (41 by 182 statute miles).
0/00:08:36	Zero thrust.
0/00:08:47	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs.
	--Remaining residual propellants are vented to space vacuum, inerting the MPS.
	--Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads.
	--MPS vacuum inerting terminates.
0/00:40	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 19 seconds in duration, at 221 fps, 162 by 160 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:59	MS configures aft flight station.
0/01:00	MS unstows, sets up, and activates PGSC.
0/01:04	Pilot activates payload bus (panel R1).
0/01:08	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive Y velocity vector attitude.
0/01:17	Commander activates radiators.
0/01:18	If go for payload bay door operations, MS configures for payload bay door operations.
0/01:28	MS opens payload bay doors.
0/01:33	Commander switches star tracker power 2 (panel 06) to ON.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	Commander and pilot seat egress.
0/01:38	Commander and pilot clothing configuration.
0/01:39	MS/PS clothing configuration.
0/01:50	Pilot initiates fuel cell auto purge.
0/01:51	MS activates teleprinter (if flown).
0/01:53	Commander begins post-payload bay door operations and radiator configuration.
0/01:55	MS/PS remove and stow seats.
0/01:56	Commander starts ST self-test and opens door.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:57	MS configures middeck.
0/01:59	Pilot closes main B supply water dump isolation circuit breaker, panel ML86B, opens supply water dump isolation valve, panel R12L.
0/02:01	Pilot activates auxiliary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:07	Mission Control Center tells crew to "go for Spacelab activation."
0/02:08	Spacelab D-2 activation.
0/02:09	Ku-band antenna deployment.
0/02:10	Commander configures vernier controls.
0/02:12	Commander, pilot configure controls for on-orbit.
0/02:15	Initiate Spacelab activation.
0/02:15	Commander manuevers to IMU alignment attitude.
0/02:19	Ku-band antenna activation.
0/02:21	MS enables hydraulic thermal conditioning.
0/02:25	IMU alignment: ST.
0/02:26	MS resets caution/warning (C/W).
0/02:28	Pilot plots fuel cell performance.
0/02:30	Red team begins presleep activities.
0/03:30	Ingress Spacelab.
0/03:30	Red team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/04:05	DTO 623.
0/04:15	RKGM activation.
0/04:40	Payload activation.
0/04:45	Priority Group B powerdown.
0/05:05	Biolabor
0/06:55	DSO 323 UMS setup.
0/08:55	Blue team begins presleep activities.
0/09:30	Red team begins postsleep activities.
0/10:00	Blue team handover to red team.
0/11:05	Blue team begins sleep period.
0/11:43	MOMS.
0/14:50	Biolabor.
0/18:40	DSO 486 operations.
0/19:05	Blue team begins postsleep activities.
0/20:13	RKGM deactivation.
0/20:35	Red team handover to blue team.
0/21:05	Biolabor.
0/21:42	Baro reflex.
0/22:30	Red team begins presleep activities.

MET DAY ONE

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:15	DSO 323.
1/00:30	Red team begins sleep period.
1/00:55	SAREX setup.
1/01:45	DTO 660--TIPS activation.
1/06:05	SAREX operations (U.S. school).
1/06:30	DSO 323.
1/07:45	SAREX operations (U.S. school).
1/08:30	Red team begins postsleep activities.
1/08:30	DTO 663.
1/09:00	DTO 623.
1/09:35	Blue team handover to red team.
1/09:45	Blue team begins presleep activities.
1/10:35	DSO 618.
1/11:00	Baro reflex.
1/11:45	Blue team begins sleep period.
1/12:30	DSO 323.
1/12:40	Biolabor.
1/18:46	SAREX operations (Australia).
1/19:15	Blue team begins postsleep activities.
1/20:15	SAREX operations (personal contact).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/21:00	Red team handover to blue team.
1/21:30	Red team begins presleep activities.
1/21:40	DSO 618.
1/22:25	DTO 663.
1/23:25	SAREX operations (personal contact).
1/23:30	Red team begins sleep period.
MET DAY TWO	
2/00:06	SAREX operations (U.S. school).
2/00:30	AR land.
2/03:15	SAREX operations (U.S. school).
2/03:45	DSO 323.
2/05:00	Biolabor.
2/05:35	Crew press conference.
2/06:15	SAREX operations (U.S. school).
2/07:30	Red team begins postsleep activities.
2/08:00	DTO 663.
2/08:30	Blue team handover to red team.
2/08:45	Blue team begins presleep activities.
2/10:10	Biolabor.
2/10:45	Blue team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/11:55	Rotex.
2/13:30	DTO 623.
2/14:15	DSO 323.
2/17:25	DSO 486.
2/18:13	MOMS.
2/18:45	Blue team begins postsleep activities.
2/20:30	Crew press conference.
2/20:45	Red team handover to blue team.
2/21:00	Red team begins presleep activities.
2/21:30	Baro reflex.
2/22:10	DTO 663.
2/22:40	SAREX operations (U.S. school).
2/22:45	Red team begins sleep period.

MET DAY THREE

3/00:00	Biolabor.
3/00:15	SAREX operations (U.S. school).
3/01:40	CTE operations.
3/04:00	SAREX operations (Africa).
3/05:00	DSO 323.
3/06:45	Red team begins postsleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/07:15	DTO 663.
3/08:30	Blue team handover to red team.
3/08:45	Blue team begins presleep activities.
3/09:15	Baro reflex.
3/10:30	Biolabor.
3/10:45	Blue team begins sleep period.
3/11:25	Crew press conference.
3/15:30	DSO 323.
3/16:48	MOMS.
3/18:10	SAREX operations (SAREX antenna test).
3/18:30	DTO 623.
3/18:45	Blue team begins postsleep activities.
3/19:45	SAREX operations (SAREX antenna test).
3/20:30	Red team handover to blue team.
3/20:45	Red team begins presleep activities.
3/21:45	Biolabor.
3/22:45	Red team begins sleep activities.
3/22:45	DTO 663.

MET DAY FOUR

4/02:00	DTO 663.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/02:30	SAREX operations (Africa).
4/04:10	DSO 323.
4/04:55	SAREX operations (U.S. school).
4/06:45	Red team begins postsleep activities.
4/07:45	DTO 663.
4/08:30	Blue team handover to red team.
4/08:45	Blue team begins presleep activities.
4/08:45	AR saline.
4/10:45	Blue team begins sleep period.
4/13:25	Biolabor.
4/15:18	MOMS.
4/16:32	DSO 486.
4/18:45	Blue team begins postsleep activities.
4/20:30	Red team handover to blue team.
4/20:45	Red team begins presleep activities.
4/21:50	DTO 665.
4/22:10	SAREX operations (personal contact).
4/22:25	DTO 663.
4/22:40	SAREX operations (U.S. school).
4/22:45	Red team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/22:45	DSO 323.
4/23:45	Baro reflex.
MET DAY FIVE	
5/00:20	DTO 623.
5/02:05	MOMS.
5/02:30	Biolabor.
5/04:15	U.S. crew conference.
5/04:25	DTO 665.
5/06:00	DSO 323.
5/06:00	DTO 665.
5/06:15	Red team begins postsleep activities.
5/06:15	DTO 665.
5/07:00	DTO 663.
5/08:00	Blue team handover to red team.
5/08:15	Blue team begins presleep activities.
5/08:15	AR saline.
5/10:15	Blue team begins sleep period.
5/12:12	Baro reflex.
5/15:25	MOMS.
5/16:00	SAREX operations (Australia).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/17:45	DSO 323.
5/18:15	Blue team begins postsleep activities.
5/20:00	Red team handover to blue team.
5/20:15	AR saline.
5/20:30	Red team begins presleep activities.
5/21:20	DTO 663.
5/22:30	Red team begins sleep period.

MET DAY SIX

6/00:33	MOMS.
6/01:55	Biolab.
6/04:30	CTE stow.
6/05:30	DSO 323.
6/06:00	DTO 623.
6/06:30	Red team begins postsleep activities.
6/07:00	DTO 663.
6/08:05	Blue team handover to red team.
6/08:20	Blue team begins presleep activities.
6/09:45	Rotex.
6/10:15	Blue team begins sleep period.
6/12:31	MOMS.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/15:25	DSO 486.
6/16:45	DSO 323.
6/17:30	Blue team begins postsleep activities.
6/19:15	Red team handover to blue team.
6/19:30	Crew press conference.
6/20:30	Baro reflex.
6/20:45	Red team begins presleep activities.
6/22:25	SAREX operations (personal contact).
6/22:45	Red team begins sleep period.
6/22:50	DTO 663.
MET DAY SEVEN	
7/00:15	Biolabor.
7/01:45	AR tissues.
7/03:15	DSO 323.
7/04:00	MOMS.
7/05:30	DSO 323.
7/06:00	Red team begins postsleep activities.
7/06:30	DTO 663.
7/07:05	Blue team handover to red team.
7/07:20	Blue team begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/07:55	DSO 618.
7/09:15	Blue team begins sleep period.
7/11:05	DTO 623.
7/11:45	UMS stow.
7/14:05	MOMS.
7/16:30	Baro reflex.
7/17:15	Blue team begins postsleep activities.
7/18:15	Red team handover to blue team.
7/19:30	SAREX stow.
7/20:05	AR tissues.
7/21:00	DSO 618.
7/21:05	Biolabor.
7/21:50	DSO 486/802.
7/22:05	Red team begins presleep activities.
7/22:10	FCS checkout.
7/23:30	RCS hot fire.

MET DAY EIGHT

8/00:00	Cabin stow.
8/00:05	Red team begins sleep period.
8/03:45	Baro end.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/04:08	MOMS.
8/04:52	Biolabor deactivation.
8/07:10	Blue team begins presleep activities.
8/08:05	Red team begins postsleep activities.
8/08:30	Blue team handover to red team.
8/09:15	Blue team begins sleep period.
8/11:05	WL crystal.
8/13:10	Payload deactivation.
8/13:15	DTO 623.
8/13:40	Spacelab deactivation.
8/14:35	Spacelab egress.
8/15:15	Blue team begins postsleep activities.
8/15:40	Priority Group B powerup.
8/17:05	Begin deorbit preparation.
8/17:07	CRT timer setup.
8/17:12	Commander initiates coldsoak.
8/17:21	Stow radiators, if required.
8/17:39	Commander configures DPS for deorbit preparation.
8/17:42	Mission Control Center updates IMU star pad, if required.
8/17:51	MS configures for payload bay door closure.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/18:00	Ku-band antenna stow.
8/18:02	MCC-H gives "go/no-go" command for payload bay door closure.
8/18:05	Maneuver vehicle to IMU alignment attitude.
8/18:20	IMU alignment/payload bay door operations.
8/18:28	MCC gives the crew the go for OPS 3.
8/18:35	Pilot starts repressurization of SSME systems.
8/18:39	Commander and pilot perform DPS entry configuration.
8/18:48	MS deactivates ST and closes ST doors.
8/18:50	All crew members verify entry payload switch list.
8/19:05	All crew members perform entry review.
8/19:07	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
8/19:20	Commander and pilot configure clothing.
8/19:35	MS/PS configure clothing.
8/19:46	Commander and pilot seat ingress.
8/19:48	Commander and pilot set up heads-up display (HUD).
8/19:50	Commander and pilot adjust seat, exercise brake pedals.
8/19:58	Final entry deorbit update/uplink.
8/20:04	OMS thrust vector control gimbal check is performed.
8/20:05	APU prestart.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/20:20	Close vent doors.
8/20:24	MCC-H gives "go" for deorbit burn period.
8/20:30	Maneuver vehicle to deorbit burn attitude.
8/20:33	MS/PS ingress seats.
8/20:42	First APU is activated.
8/20:45	Deorbit burn.
8/20:48	Initiate post-deorbit burn period attitude.
8/20:52	Terminate post-deorbit burn attitude.
8/21:00	Dump forward RCS, if required.
8/21:08	Activate remaining APUs.
8/21:33	Entry interface, 400,000 feet altitude.
8/21:38	Automatically deactivate RCS roll thrusters.
8/21:45	Automatically deactivate RCS pitch thrusters.
8/21:50	Initiate first roll reversal.
8/21:54	Initiate second roll reversal.
8/21:55	TACAN acquisition.
8/21:57	Initiate air data system (ADS) probe deploy.
8/21:58	Initiate third roll reversal.
8/21:59	Begin entry/terminal area energy management (TAEM).
8/21:59	Initiate payload bay venting.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/22:00	Automatically deactivate RCS yaw thrusters.
8/22:04	Begin TAEM/approach/landing (A/L) interface.
8/22:04	Initiate landing gear deployment.
8/22:05	Vehicle has weight on main landing gear.
8/22:05	Vehicle has weight on nose landing gear.
8/22:05	Initiate main landing gear braking.
8/22:06	Wheel stop.

GLOSSARY

A/G	air-to-ground
AG	airglow
AA	accelerometer assembly
ACS	active cooling system
ADS	air data system
AFB	Air Force base
A/L	approach and landing
AOS	acquisition of signal
APC	autonomous payload controller
APCS	autonomous payload control system
APU	auxiliary power unit
ASE	airborne support equipment
BFS	backup flight control system
CCD	charge-coupled device
CCDS	Center for the Commercial Development of Space
CDMS	command and data management subsystem
COAS	crewman optical alignment sight
CRT	cathode ray tube
C/W	caution/warning
DACA	data acquisition and control assembly
DA	detector assembly
DC	detector controller
DAP	digital autopilot
DOD	Department of Defense
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
EDO	extended duration orbiter
EDOMP	extended duration orbiter medical project
EHF	extremely high frequency
ELV	expendable launch vehicle
EMP	enhanced multiplexer/demultiplexer pallet
EMU	extravehicular mobility unit
EOM	end of mission

EPS	electrical power system
ESC	electronic still camera
ESA	European Space Agency
ESS	equipment support section
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FCP	fuel cell power plant
FCS	flight control system
FDF	flight data file
FES	flash evaporator system
FPA	fluid processing apparatus
FPS	feet per second
FRCS	forward reaction control system
GAP	group activation pack
GAS	getaway special experiment
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GSFC	Goddard Space Flight Center
HAINS	high accuracy inertial navigation system
HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
I/O	input/output
IR	infrared
IUS	inertial upper stage
IV	intravehicular
JSC	Johnson Space Center
KEAS	knots equivalent air speed
KSC	Kennedy Space Center
LBNP	lower body negative pressure
LCD	liquid crystal display
LES	launch escape system

LPS	launch processing system
LRU	line replaceable unit
MCC-H	Mission Control Center--Houston
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merritt Island
MLP	mobile launcher platform
MM	major mode
MPM	manipulator positioning mechanism
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NCC	corrective combination maneuver
NH	differential height adjustment
NMI	nautical miles
NOR	Northrup Strip
NPC	plane change maneuver
NSR	coelliptic maneuver
O&C	operations and checkout
OAA	orbiter access arm
OCP	Office of Commercial Programs
OG	orbiter glow
OMS	orbital maneuvering system
OPF	orbiter processing facility
OTC	orbiter test conductor
PAO	public affairs officer
PASS	primary avionics software system
PC	proportional counter
PCMMU	pulse code modulation master unit
PCS	pressure control system
PDU	playback/downlink unit
PGSC	payload and general support computer
PI	payload interrogator
PIC	pyro initiator controller
POCC	Payload Operations Control Center
PRCS	primary reaction control system
PRD	payload retention device
PRLA	payload retention latch assembly
PRSD	power reactant storage and distribution

PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV
RAAN	right ascension of the ascending node
RCRS	regenerable carbon dioxide removal system
RCS	reaction control system
RF	radio frequency
RGA	rate gyro assembly
RMS	remote manipulator system
ROEU	remotely operated electrical umbilical
RPM	revolutions per minute
RSLS	redundant-set launch sequencer
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SA	solar array
SAF	Secretary of the Air Force
SHF	superhigh frequency
SM	statute miles
SPASP	small payload accommodations switch panel
SPOC	shuttle payload of opportunity carrier
SRB	solid rocket booster
SRM	solid rocket motor
SRSS	shuttle range safety system
SSCE	solid surface combustion experiment
SSME	space shuttle main engine
SSP	standard switch panel
SSPP	Shuttle Small Payload Project
SSPP	solar/stellar pointing platform
ST	star tracker
STA	structural test article
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	tracking and data relay satellite
TDRSS	tracking and data relay satellite system
TFL	telemetry format load
TI	thermal phase initiation

TIG	time of ignition
TPS	thermal protection system
TSM	tail service mast
TT&C	telemetry, tracking, and communications
TV	television
TVC	thrust vector control
UHF	ultrahigh frequency
VRCS	vernier reaction control system
VTR	videotape recorder
WCCS	wireless crew communication system
WCS	waste collection system

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