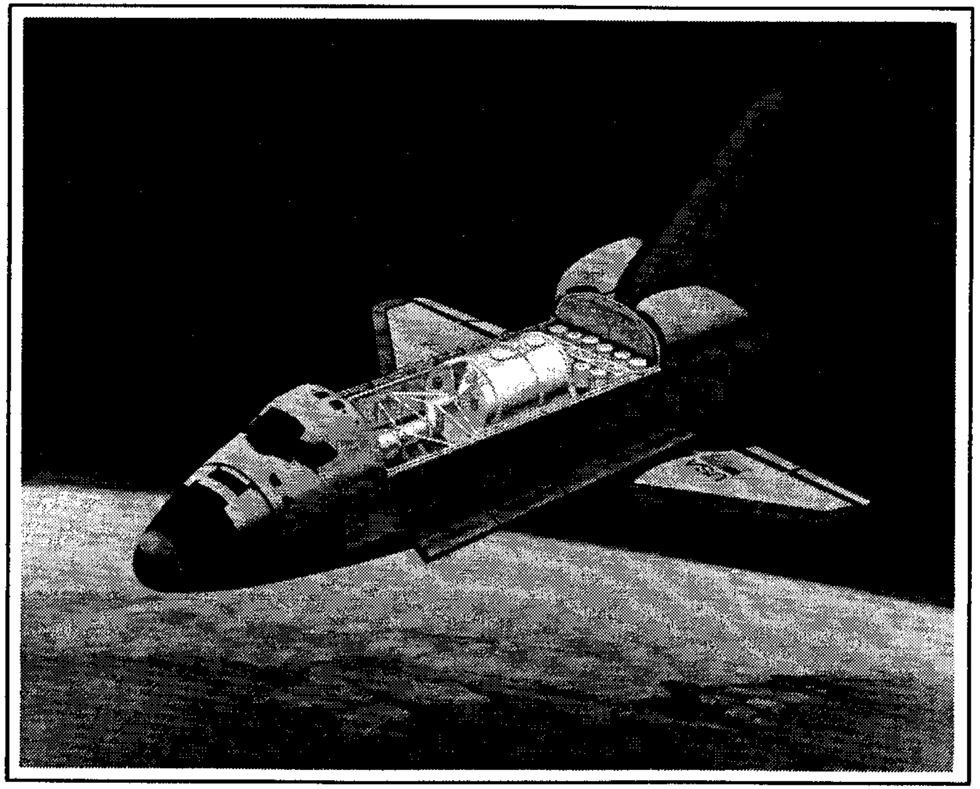


STS-47

PRESS INFORMATION

September 1992

Rockwell International
Space Systems Division

Office of External Communications &
Media Relations

PUB 3546-V Rev 9-92

CONTENTS

MISSION OVERVIEW

This is the second flight of Endeavour and the 50th for the space shuttle.

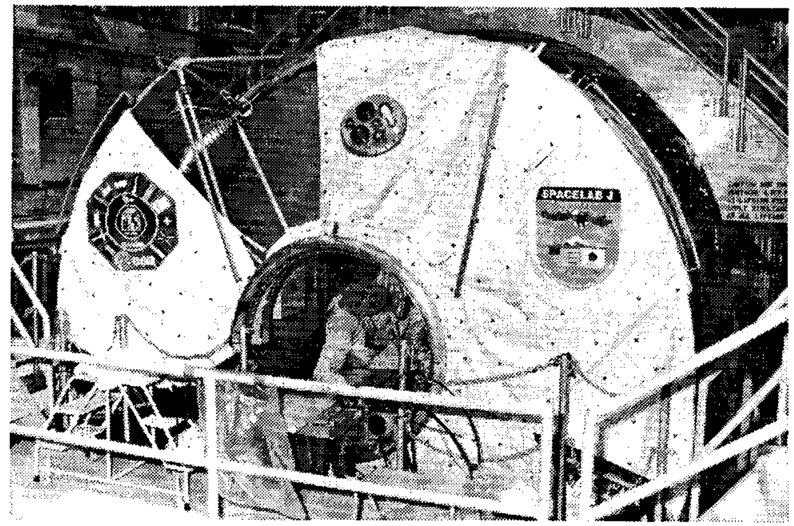
The flight crew for the seven-day STS-47 mission is commander Robert L. "Hoot" Gibson; pilot Curtis (Curt) L. Brown, Jr.; payload commander (lead mission specialist) Mark C. Lee; mission specialists N. Jan Davis, Dr. Mae C. Jemison, and Jerome (Jay) Apt; and Japanese payload specialist Mamoru Mohri. Jemison is the first African American woman to fly in space, and Mohri is the first Japanese to fly aboard a NASA spacecraft. The crew will be divided into a blue team, consisting of Apt, Davis, and Jemison, and a red team, comprised of Brown, Lee, and Mohri. Gibson is not assigned to a team and is free to adjust his hours real time as necessary. Each team will work consecutive 12-hour shifts, providing around-the-clock operations.

STS-47's primary objective is to successfully perform the planned operations of the Spacelab Japan laboratory, a joint venture between NASA and the National Space Development Agency (NASDA) of Japan.

Spacelab-J consists of 24 materials science and 19 life science investigations involving government, industry, and university sponsors in Japan and the U.S. The materials science experiments will study various materials and processes in microgravity, including protein crystals, electronic materials, fluids, glasses and ceramics, metals, and alloys. The life sciences experiments include cell separation, cell biology, developmental biology, animal and human physiology and behavior, space radiation, and biological rhythms. Thirty-four of the Spacelab-J experiments are from Japan, seven are from the U.S., and two are collaborative efforts of the two countries.

STS-47 secondary objectives include nine getaway special (GAS) experiments, the Israel Space Agency Investigation About

KSC-92PC-900



Experiment Racks and Floor of Spacelab-J Payload Are Installed in Spacelab Module in Operations and Checkout Building at KSC

Hornets (ISAIAH), Shuttle Amateur Radio Experiment (SAREX), and the Solid Surface Combustion Experiment (SSCE).

The nine GAS experiments mounted on the GAS bridge assembly are as follows:

- G-102, sponsored by TRW's Defense and Space Systems Group, will investigate capillary pumping, cosmic rays, crystal growth, emulsion formation, fluid drop mechanics, floppy disks, and fiber optics.

- G-255, sponsored the Kansas University Space Program, will investigate crystal growth, formation of cell membranes, and seed germination rates and health.

- G-300, sponsored by MATRA/Laboratoire de Génie Électrique de Paris, will investigate thermal conductivity of distilled water and silicon oils.

- G-330, sponsored by the Swedish Space Corporation, will investigate the boundary of a melted and resolidified material.

- G-482, sponsored by Telesat Canada, will investigate the behavior of bread yeast in the absence of gravity.

- G-520, sponsored by Independent Television News of London, will investigate growth mechanisms of a chemical garden.

- G-521, sponsored by the National Research Council of Canada, Space Division, will investigate material melting and directional resolidification.

- G-534, sponsored by NASA's Lewis Research Center, will investigate the interrelationships between heat transfer, heat rate, buoyancy, momentum, and surface tension in microgravity.

- G-613, sponsored by the University of Washington, will investigate fluid dyamics and heat pipe characteristics.

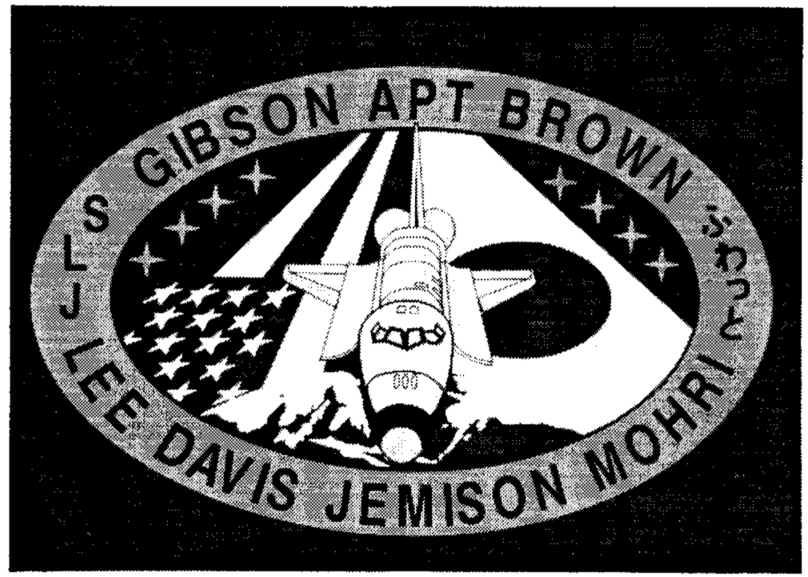
ISAIAH will test the unique ability of oriental hornets to build combs in the direction of gravity when subjected to a microgravity environment in order to gain greater insight into this phenomenon.

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 primary objective of SSCE is to supply information on flame spread over solid fuel surfaces in the reduced-gravity environment of space. The experiment will measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds in low gravity. The data obtained will be used to validate flame spread models to improve fire safety during space flight. For this flight, ashless filter paper mounted in a pressurized chamber will serve as the fuel source.

Fourteen detailed test objectives and 15 detailed supplementary objectives are scheduled to be flown on STS-47.

S47-(S)-001



Crew Insignia

MISSION STATISTICS

Vehicle: Endeavour (OV-105), second flight

Launch Date/Time:

9/12/92	10:23 a.m., EDT
	9:23 a.m., CDT
	7:23 a.m., PDT

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

Launch Window: 2 hours, 30 minutes (crew-on-back constraint)

Launch Period: 3 hours, 54 minutes

Mission Duration: 6 days, 20 hours, 36 minutes

Landing: Nominal end-of-mission landing on orbit 110

9/19/92	6:59 a.m., EDT
	5:59 a.m., CDT
	3:59 a.m., PDT

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: Zaragoza, Spain; alternates: Ben Guerir, Morocco, and Moron, Spain

Return to Launch Site: KSC

Abort-Once-Around: NOR

Inclination: 57 degrees

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

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

Altitude: 163 nautical miles (188 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2026
No. 2 position: Engine 2022
No. 3 position: Engine 2029

External Tank: ET-45

Solid Rocket Boosters: BI-053

Editor's Note: The following weight data are current as of September 2,1992.

Total Lift-off Weight: Approximately 4,506,649 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 244,413 pounds

Orbiter (Endeavour) Empty and 3 SSMEs: Approximately 172,781 pounds

Payload Weight Up: Approximately 28,158 pounds

Payload Weight Down: Approximately 28,158 pounds

Orbiter Weight at Landing: Approximately 219,327 pounds

Payloads—Payload Bay (* denotes primary payload): Spacelab-J,* nine getaway special (GAS) canister experiments

Payloads—Middeck: Israel Space Agency Investigation About Hornets (ISAIAH), Shuttle Amateur Radio Experiment (SAREX) II, Solid Surface Combustion Experiment (SSCE)

Flight Crew Members:

Commander: Robert L. "Hoot" Gibson, fourth space shuttle flight

Red Team:

Pilot: Curtis (Curt) L. Brown, Jr., first space shuttle flight
Mission Specialist 1: Mark. C. Lee, second space shuttle flight
Payload Specialist 1: Mamoru Mohri, Japan, first space shuttle flight

Blue Team:

Mission Specialist 2: Jerome (Jay) Apt, second space shuttle flight
Mission Specialist 3: N. Jan Davis, first space shuttle flight
Mission Specialist 4: Dr. Mae C. Jemison, first space shuttle flight

Ascent Seating:

Flight deck, front left seat, commander Robert L. "Hoot" Gibson
Flight deck, front right seat, pilot Curtis (Curt) L. Brown, Jr.
Flight deck, aft center seat, mission specialist Jerome (Jay) Apt
Flight deck, aft right seat, mission specialist Mark C. Lee
Middeck, mission specialist N. Jan Davis
Middeck, mission specialist Dr. Mae C. Jemison
Middeck, payload specialist Mamoru Mohri

Descent Seating:

Flight deck, front left seat, commander Robert L. "Hoot" Gibson
Flight deck, front right seat, pilot Curtis (Curt) L. Brown, Jr.
Flight deck, aft center seat, mission specialist Jerome (Jay) Apt
Flight deck, aft right seat, mission specialist N. Jan Davis
Middeck, mission specialist Mark C. Lee
Middeck, mission specialist Dr. Mae C. Jemison
Middeck, payload specialist Mamoru Mohri

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: Jerome (Jay) Apt
EV-2: N. Jan Davis

Intravehicular Astronaut: Curtis (Curt) L. Brown, Jr.

STS-47 Flight Directors:

Ascent, Entry: Wayne Hale
Orbit 1 Team: Al Pennington
Orbit 2 Team/Lead: Milt Heflin

Orbit 3 Team: Linda Ham

Entry: Automatic mode until subsonic, then control stick steering

Notes:

- The remote manipulator system is installed in Endeavour's payload bay for this mission.
- The galley is installed in Endeavour's middeck.

S47-(S)-002

STS-47 crew members are (front row, left) mission specialist Jay Apt and pilot Curtis Brown and (back row, from left) mission specialist N. Jan Davis, payload commander Mark Lee, commander Robert Gibson, mission specialist Mae Jemison, and payload specialist Mamoru Mohri.

MISSION OBJECTIVES

- Primary objective
  - — Spacelab-J operations
- Secondary objectives
  - — Middeck
    - Israel Space Agency Investigation About Hornets (ISAIAH)
    - Shuttle Amateur Radio Experiment (SAREX) II
    - Solid Surface Combustion Experiment (SSCE)
  - — Payload bay
    - Nine getaway special (GAS) experiments
- Development test objectives/detailed supplementary objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Unstow cabin
Spacelab activation
Payload activation

Flight Days 2–7

Spacelab operations

Flight Day 7

RCS hot-fire test
FCS checkout

Flight Day 8

Cabin stow
Spacelab deactivation
Deorbit preparation
Deorbit burn
Landing

Notes:

- 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.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

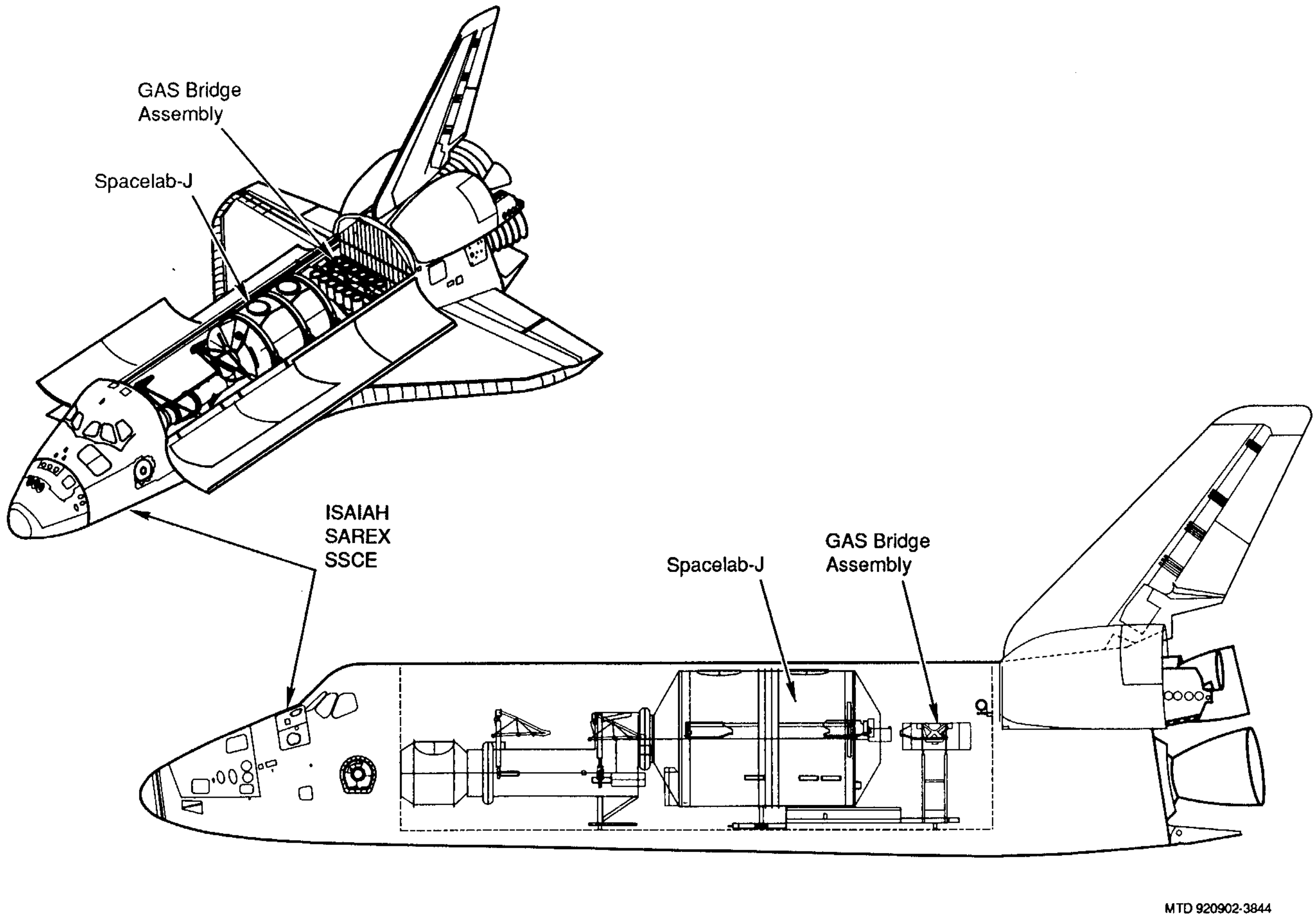
- Entry aerodynamic control surfaces test—alternate elevon schedule, Part 3 (DTO 251)
- Ascent structural capability evaluation (DTO 301D)
- Ascent compartment venting evaluation (DTO 305D)
- Descent compartment venting evaluation (DTO 306D)
- Entry structural capability evaluation (DTO 307D)
- ET TPS performance (Methods 1 and 2) (DTO 312)
- Orbiter drag chute system (Test 2—deployed with nose gear up, first time) (DTO 521)
- Cabin air monitoring (DTO 623)
- Water separator filter performance evaluation (DTO 647)
- Cycle ergometer hardware evaluation (DTO 651)
- Foot restraint evaluation (DTO 655)
- Acoustical noise dosimeter data (DTO 663)
- Acoustical noise sound level data (DTO 665)
- Crosswind landing performance (DTO 805)

DSOs

- Collection of shuttle humidity condensate for analytical evaluation (DSO 317)
- Evaluation of samples obtained from the urine monitoring system (DSO 323)
- In-flight radiation dose distribution (TEPC only) (DSO 469)
- Assessment of circadian shifting by bright light in astronauts (DSO 484)
- Orthostatic function during entry, landing, and egress (DSO 603B)
- Air monitoring instrument evaluation and atmospheric characterization (DSO 611)
- Energy utilization (DSO 612)
- Changes in the endocrine regulation of orthostatic tolerance during space flight (DSO 613)
- The effect of prolonged space flight on head and gaze stability during locomotion (DSO 614)
- Pre-/postflight measurement of cardiorespiratory response to submaximal exercise (DSO 624)
- Educational activities (DSO 802)
- Documentary television (DSO 901)

- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)
- Assessment of human factors (DSO 904)

PAYLOAD CONFIGURATION



SPACELAB JAPAN

Spacelab Japan, also known as Spacelab-J, is a joint science mission sponsored by the Japanese National Space Development Agency (NASDA) and NASA. This mission consists of 24 materials science and 19 life science investigations with government, industry, and university sponsors in Japan and the United States. The Japanese are sponsoring 34 of the experiments (First Materials Processing Test) and collaborating with NASA on two others. The rest are sponsored by NASA.

The materials science investigations include materials processing, crystal growth, and fluid physics experiments. The life science experiments will investigate human physiology, cell development, the effects of radiation, sample separation, and enzyme crystal growth.

Spacelab-J is housed in the European Space Agency's Spacelab, a pressurized module carried in Endeavour's payload bay that provides astronauts a shirt-sleeve environment for conducting experiments. Spacelab elements include a long Spacelab transfer tunnel and a long module made up of a core segment and an experiment segment. The experiments will be operated by the payload specialist and mission specialists and will be monitored at the Payload Operations Control Center at the Marshall Space Flight Center in Huntsville, Ala.

JAPANESE EXPERIMENTS

New Materials

About a third of the Japanese experiments are devoted to investigations of processes for producing crystals and other materials that are difficult to make on Earth or are imperfect when produced on Earth because of gravitational effects. In the low-gravity environment of Spacelab, researchers will attempt to create a variety of

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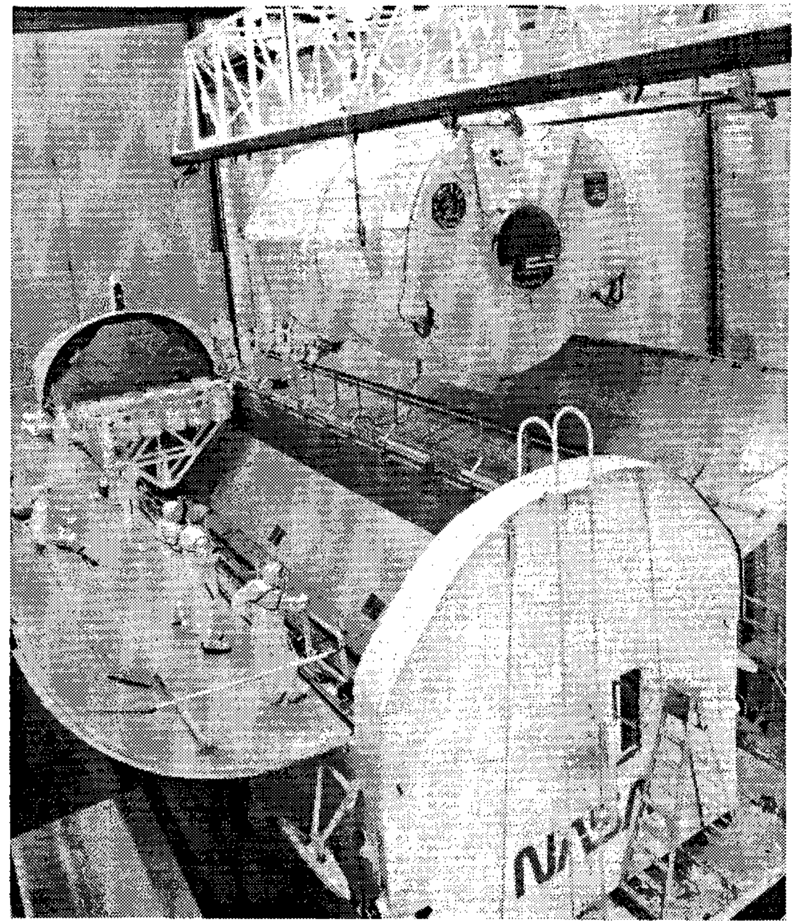
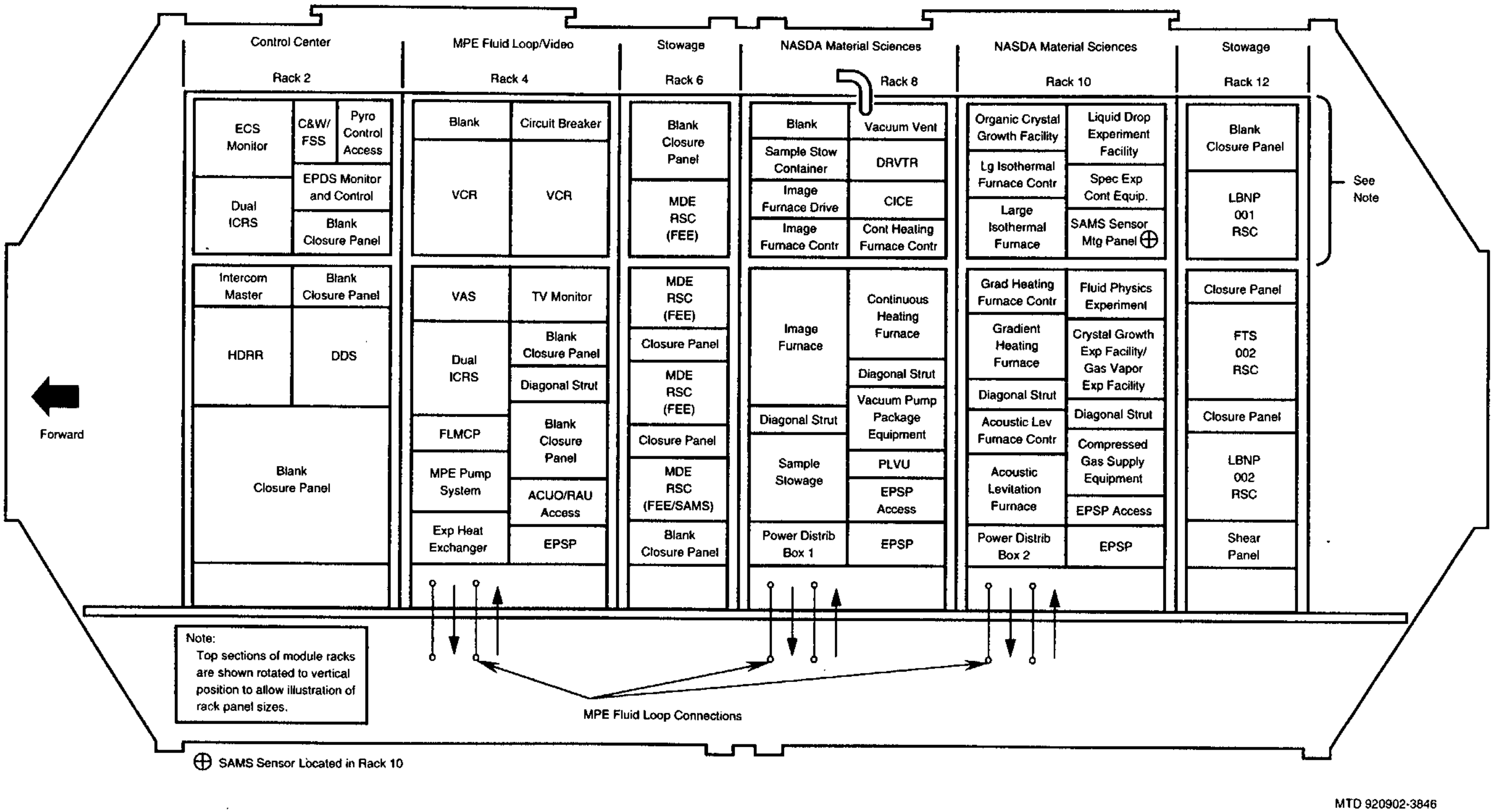
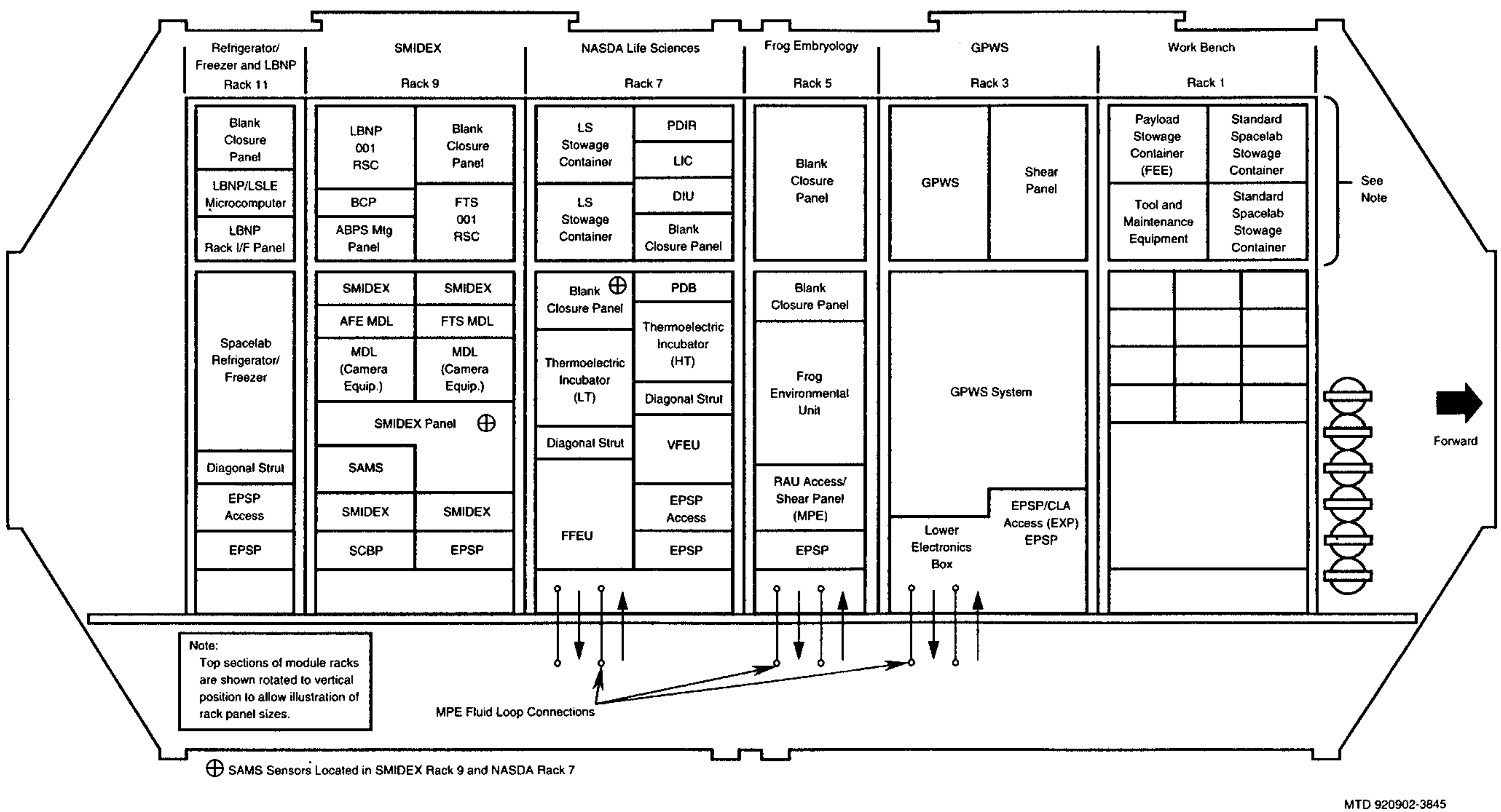


MTD 920826-3841

Workers Install Spacelab-J Laboratory Module in Canister/Transporter. A Getaway Special Bridge Holding 12 GAS Canisters Containing Experiments Is Already Installed at the Rear of the Canister/Transporter. The Two Payloads Were Installed in the Cargo Bay of the Shuttle Orbiter Endeavour in the Orbiter Processing Facility at KSC.

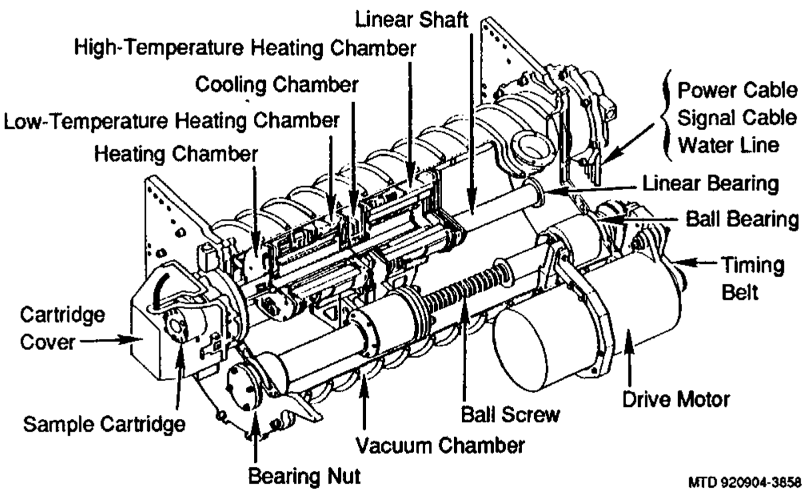


Spacelab-J Module Configuration (Starboard Side)



Spacelab-J Module Configuration (Port Side) semiconductor crystals with possible applications in electronics, a superconducting wire, and high-strength metal alloys.

Growth Experiment of Narrow Band-Gap Semiconductor Pb-Sn-Te Single Crystals in Space (M01). This experiment's objective is to produce homogeneous crystalline ingots of lead-tin-tellurium (Pb-Sn-Te). Because Pb-Sn-Te semiconductor materials can detect a wide range of infrared radiation frequencies, they are desirable for use in electronics products such as fire and security systems and space-based imaging systems.



Gradient Heating Furnace

The ingot will be grown in a boron-nitride crucible from a Pb-Sn-Te seed and polycrystalline ingot. A special heating element in the gradient heating furnace passing over the sample permits the metallic crystal to grow directionally.

Growth of Pb-Sn-Te Single Crystal by Traveling Zone Method in Low Gravity (M02). Researchers hope to use the absence of gravitational sedimentation in space to grow a single homogeneous crystal of Pb-Sn-Te using the float zone and traveling zone methods in the image furnace. The payload specialist will place an encapsulated sample on the lower end of the shaft in the image furnace and will establish the melting zone by adjusting the power of the heating lamp. Once a proper melt has been established, the furnace will automatically conduct the experiment.

The effectiveness of this process will be evaluated after the mission.

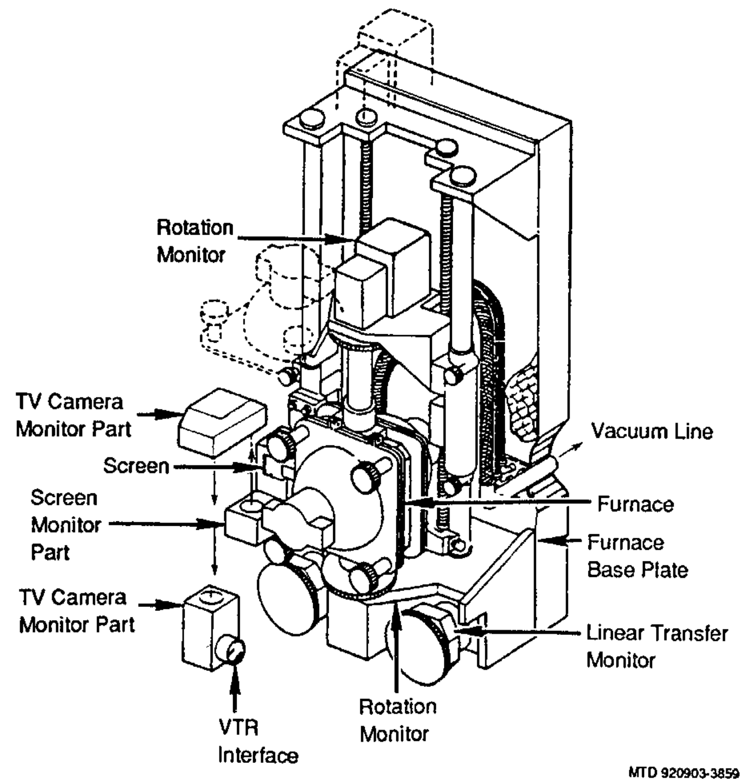


Image Furnace

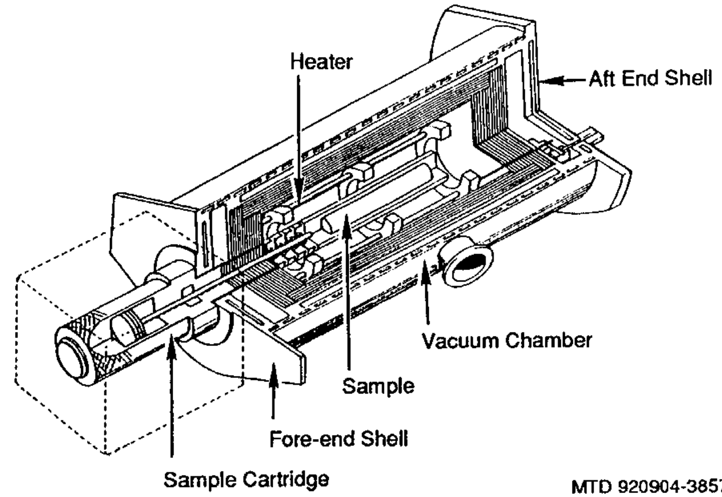
Growth of Semiconductor Compound Single Crystal by Floating Zone Method (M03). Researchers will determine the feasibility of using the float zone technique for growing high-density, low-surface-tension crystals of indium-antimonide (In-Sb) in space. The payload specialist will insert two rodlike samples of In-Sb in the image furnace, one above the other. The upper sample is a polycrystal; the bottom is a single crystal. As the tips of the crystals melt, the two samples will merge and melt into a large single crystal. When the growth process is complete, the rods will be separated for postflight evaluation on Earth.

Casting of Superconducting Filamentary Composite Materials (M04). Producing superconducting compounds in microgravity enables more uniform alloy composites to be achieved, which should allow researchers to produce superconducting wire materials with improved characteristics and bring these materials closer to everyday use. On this mission, two types of superconducting compounds will be studied. In one series, alloys of aluminum, lead, and bismuth will be produced. In the other, alloys of silver and copper; silver, yttrium, barium, and copper; and silver, ytterbium, barium, and copper will be produced. The alloys will be subjected to resistance testing at various temperatures.

Three samples of each compound will be heated in the continuous heating furnace at 1,300°C for 17 minutes. The samples will be cooled in vacuum for a minute and then in helium until their temperatures reach room level.

Preparation of Nickel Base Dispersion-Strengthened Alloys (M06). This experiment will investigate the feasibility of using the conventional (and economical) melting process to produce particle dispersion alloys in microgravity. These alloys are stronger and more durable at high temperatures than conventional alloys, but they cannot be produced on Earth because the recipient metal and the powdered metal particles that are added are not uniformly dispersed in the liquid state. The most widely used alternative process, powder metallurgy, is costly and complicated and has other problems that detract from its desirability for use in large-volume production.

Samples of nickel-molybdenum with particles of titanium-carbon added will be processed in this experiment. After the flight,



Large Isothermal Furnace

scientists will study the structure and quality of the alloy produced to determine the feasibility of processing these types of alloys in space.

Fabrication of Very Low Density, High-Stiffness Carbon Fiber/Aluminum Hybridized Composites (M11). This experiment will investigate a process for producing lightweight, high-strength composites that avoids the use of conventional foaming methods, which are difficult to perform even in microgravity. These composites are ideal for space construction but also have applications on Earth.

Before the flight, carbon fibers will be coated with an aluminum alloy by vacuum evaporation, cut into 1-mm or shorter lengths, and encapsulated. On orbit, the samples will be processed in the continuous heating furnace and stored for a postflight analysis of the composite materials produced.

Fabrication of Si-As-Te:Ni Ternary Amorphous Semiconductor in Microgravity (M13). Scientists will investigate the feasibility of producing silicon-arsenic-tellurium:nickel (Si-As-Te:Ni) semiconductors in microgravity. Semiconductors made of this material could potentially be used in a wide variety of applications in amorphous and opto-electronics devices and in the investigation of the compositional dependence of atomic and electronic properties in the random network of solids, but they are difficult to fabricate in Earth's gravity.

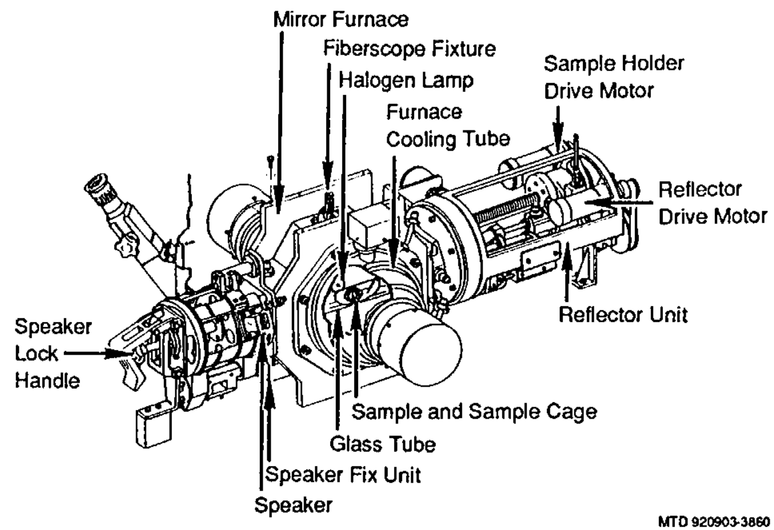
In this experiment, nickel will be mixed with silicon-arsenic-tellurium to allow researchers to exam the controllability of electron valence. The Si-As-Te:Ni samples will be heated in the continuous heating furnace at 1,300°C for an hour. The samples will then be placed in a helium chamber for 10 minutes, which cools them to 45°C.

A postflight structural and electronic analysis of the samples will be performed to determine the feasibility of using this method to produce Si-As-Te:Ni semiconductors.

Preparation of Optical Materials Used in Nonvisible Regions (M17). The objective of this experiment is to produce a nonsilicon-based glass with superior transmission properties in the infrared wavelength using a containerless processing technique. Containerless processing avoids the contamination of the liquid sample that occurs during processing in containers on Earth.

While twin ellipsoidal mirrors in the acoustic levitation furnace levitate samples of oxides of calcium, gallium, and germanium, two halogen lamps will heat the samples, producing glass.

Growth of Samarskite Crystal in Microgravity (M20). Researchers will use the traveling solvent float zone method to produce a single crystal of the mineral samarskite in the image furnace so that they can study its system phase relationships during controlled cooling to learn more about samarskite's structure and formation. Samarskite is a complex oxide of rare earths, uranium, iron, lead, thorium, niobium, tantalum, titanium, and tin. Scientists have not been able to determine its precise structure because alpha par-



Acoustic Levitation Furnace

ticles emitted by uranium tend to destroy samarskite's original structure without altering its chemical composition and external form.

Growth Experiment of Organic Metal Crystal in Microgravity (M21). This experiment will produce two large single crystals of the organic metal tetramethyltetrathiafulvalenium tetracyanoquinodimethanide (TMTT-TCNQ). Because of the effects of gravity, crystals of organic metals produced on Earth are small and imperfect, which makes them difficult to study. Scientists hope that in the microgravity environment they will be able to produce larger, more homogeneous crystals so that they can better study the electrical conductivity of the crystals. Because of their conductivity, organic metals may have important applications in electronics in the future.

The crystals will be grown in two chambers of the organic crystal growth experiment facility. One will be grown in the smaller cell, and its growth will be recorded for eight hours by a still camera. The other will be grown in the larger cell for five days.

Crystal Growth of Compound Semiconductors in a Low-Gravity Environment (M22). In this experiment, scientists will investigate the diffusion method of growing crystals and its effect on the properties of bulk-grown indium-gallium-arsenic (In-Ga-As) semiconductor crystals. Under the influence of Earth's gravity, the growth of these crystals is hampered by mass transfer, which is caused by convective flow. But in microgravity, convective flow should be greatly reduced or eliminated.

In the gradient heating furnace, a polycrystal sample of In-Ga-As will be heated to 1,070°C in the higher zone and 500°C in the lower zone. A temperature differential between the two zones of 60°C per centimeter will move over the sample at 4 centimeters per hour for 7-1/2 hours, causing the crystal to grow.

Scientists will compare the sample grown in space to crystals produced on Earth to determine the effects of microgravity on the growth process.

Microgravity Manufacturing Technology

The following experiments are designed to determine whether certain manufacturing processes work better in the absence of gravity and to better understand the phenomena that occur during material processing in space.

Formulation Mechanism of Deoxidation Products in Iron Ingot Deoxidized With Two or Three Elements (M05). This experiment will study the effects of microgravity, particularly the absence of convection and buoyancy, on the deoxidation of iron. Deoxidation is an essential part of the manufacture of iron and its alloys that removes oxygen from the metal. Researchers would like to determine whether deoxidized iron can be produced more efficiently in microgravity.

In this experiment, iron and iron-nickel samples containing the deoxidation agents silicon, manganese, aluminum, and mixtures of the three will be processed in the large isothermal furnace. After the mission, investigators will compare the structure, form, composition, and distribution of the deoxidation products of the iron processed in space and the samples produced on Earth.

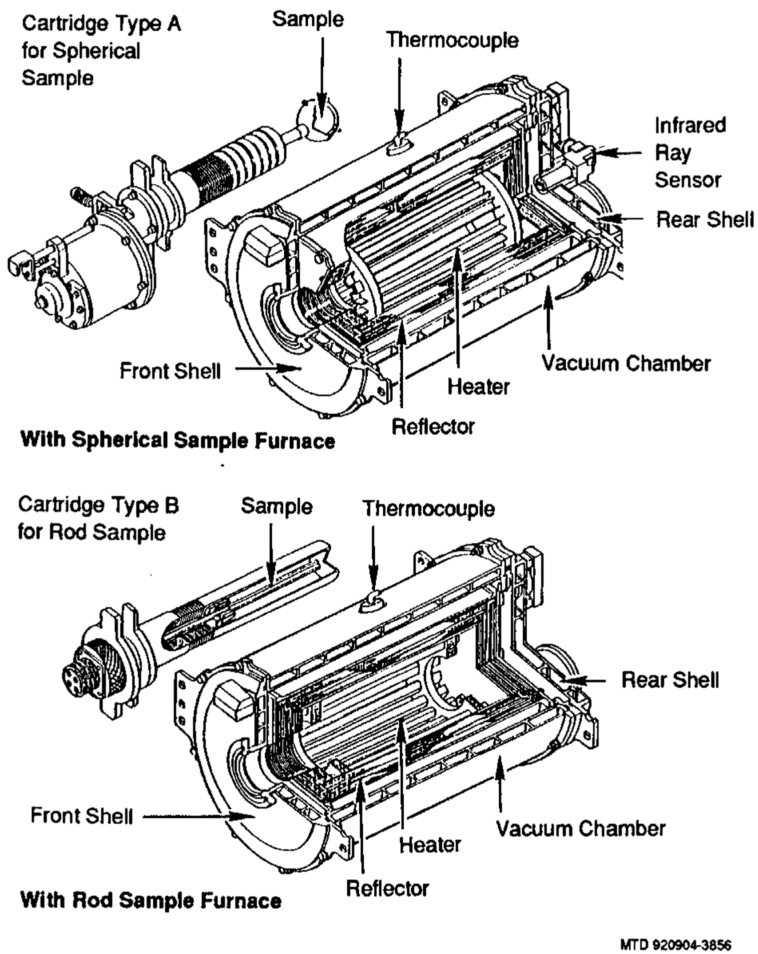
High-Temperature Behavior of Glass (M08). This experiment will investigate flow in a viscous glass sphere in microgravity to attempt to verify volume-temperature findings obtained on Earth. A glass sample containing small gold flakes will be melted in the image furnace and form a sphere. Flow in the melted glass will be detected by the movement of the gold flakes. Researchers will also measure properties of the glass, such as the glass-transition temperature and its expansion coefficient at high temperatures.

Growth of Silicon Spherical Crystals and Surface Oxidation (M09). The objective of this experiment is to grow a single spherical crystal of silicon so that researchers can study the crystal's growth behavior, electronic properties, and surface oxidation in different directions within the sphere, which may lead to advances in silicon semiconductor substrates.

A spherical sample of silicon will be melted in the crystal growth experiment facility, and a single crystal will be grown and cooled. It is expected that surface tension in the microgravity environment will produce a spherical crystal, which would make it anisotropic, that is, the crystal would have different physical properties in different directions.

Study of the Mechanisms of Liquid Phase Sintering (M12). This experiment will investigate the feasibility of using the sintering process to form alloys in microgravity. In the sintering process, metals are joined without melting.

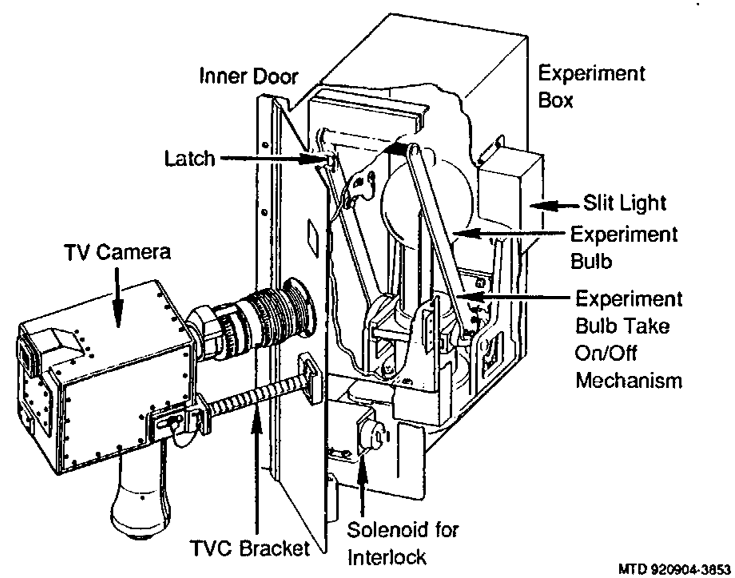
In this experiment, scientists will study the growth behavior of solid particles when one metal is melted. On Earth, this process is



Crystal Growth Facility Experiment

not feasible because sedimentation causes the solid particles to segregate, which reduces the strength and corrosion resistance of the alloy. The samples used for this experiment consist of compacted tungsten and nickel powder. Five samples will be heated in the large isothermal furnace at 1,550°C for one hour and another five samples will be heated for three hours. The alloys will be examined with a metallographic microscope after the flight.

Gas Evaporation in Low-Gravity Field: Congelation Mechanism of Metal Vapors (M14). This experiment will attempt to form fine metallic particles in a gas atmosphere. This investigation has been largely ineffectual on Earth because gravity-caused convection distorts particle uniformity; however, it may be possible to achieve even dispersion of the particles in the low gravity of space. Uniform, submicron-size particles could be used as coatings on high-density magnetic and optical recording media, electrodes, and fine fluorescence screens.



Gas Evaporation Facility Experiment

The experiment hardware consists of several glass chambers filled with helium or xenon at different pressures. Metal samples placed in the center of the chambers will be vaporized by heating filaments. The process will be videotaped and the results measured.

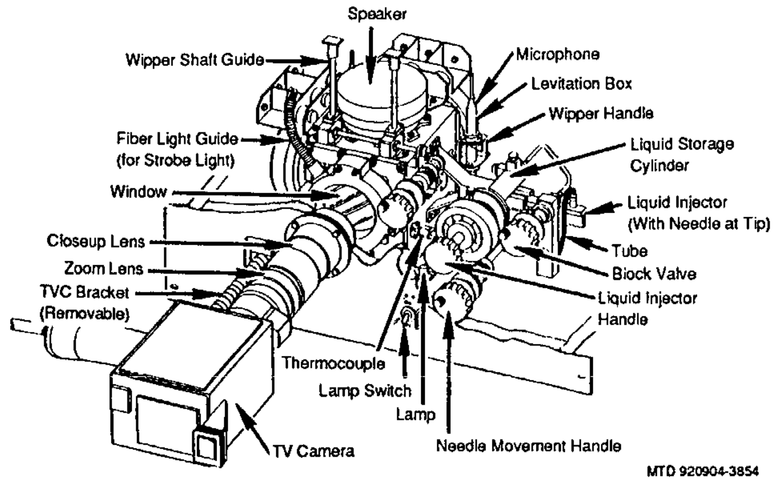
Diffusion in Liquid State and Solidification of Binary System (M07). Researchers hope to improve their understanding of the structure of liquid metals and how to control atom diffusion within them. Silver and gold rods that have been joined together and encapsulated will be heated in the continuous heating furnace and cooled at different rates. After the mission, they will be studied with an electron probe microscope. If the researchers are correct, microgravity will minimize gravitational forces that affect movement within liquid metals and enable them to measure the diffusion of the constituent atoms.

Study on Solidification of Immiscible Alloy (M10). Researchers have successfully created new alloys by combining immiscible metals in microgravity, but the components of those alloys have exhibited uneven mixtures. It is hoped that this experiment will help explain the uneven mixture.

Four indium-aluminum samples with varying aluminum contents and one copper-lead sample encapsulated in a tantalum cartridge will be melted at 955°C in the gradient heating furnace. The temperature will be maintained at 955°C for 56 minutes, and during this period, an ultrasonic vibrator will be applied to the samples for 10 minutes. The temperature of the furnace will then be reduced to 639°C and maintained for 30 minutes. Finally, the furnace's helium purge will cool the samples. After the mission, scientists will use metallurgical microscopes to examine the samples and seek the answers to their questions about the structure and other properties of the alloy.

Drop Dynamics in Space and Interference With Acoustic Field (M15). Data on the behavior of drops obtained from this experiment will be used to develop containerless processing.

Drops of mineral oil will be levitated in an acoustic field in the liquid drop experiment facility and examined to determine stable

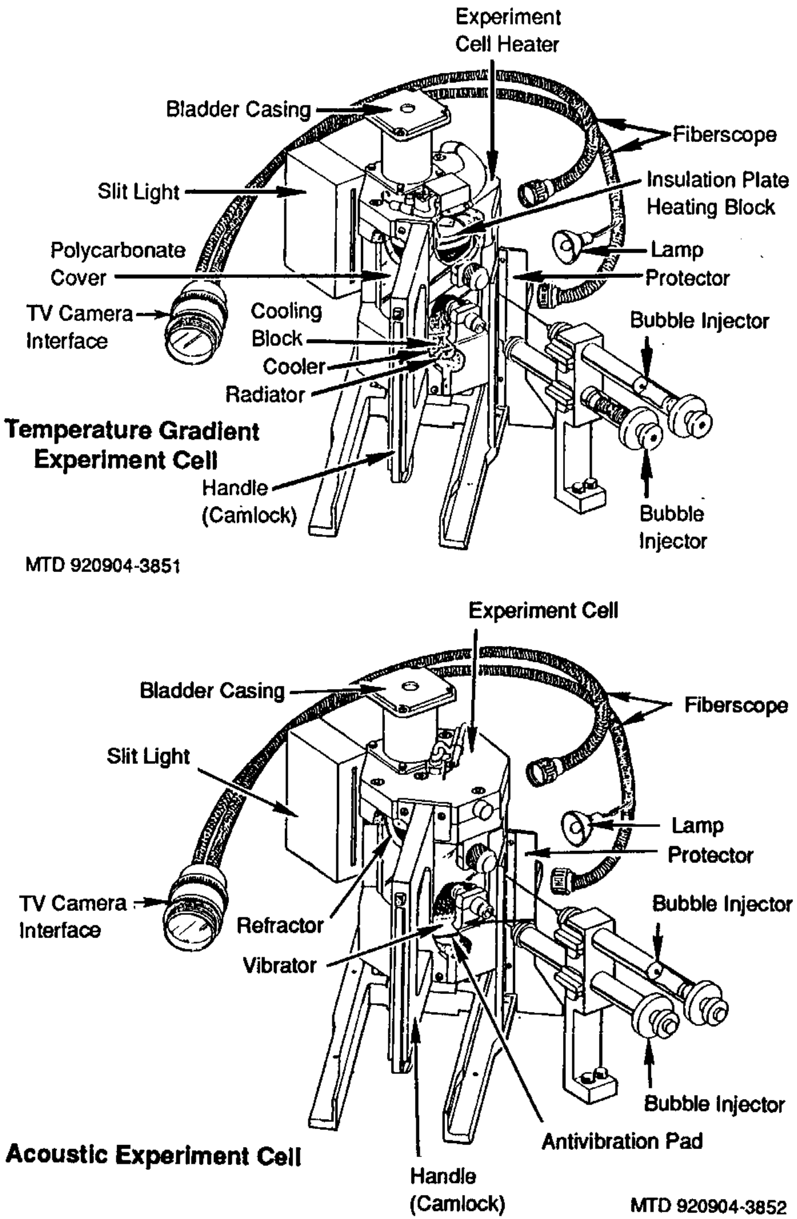


Liquid Drop Facility Experiment

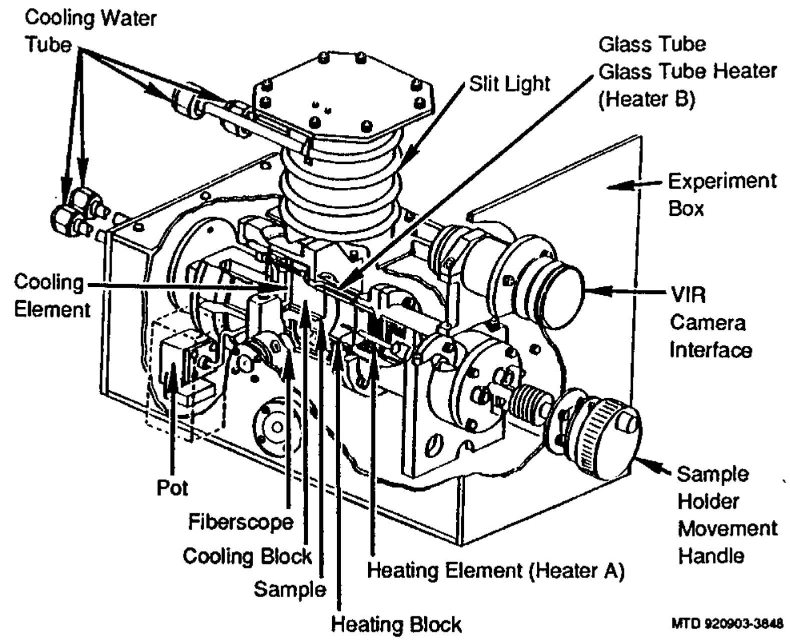
positioning, rotation, and capillary wave excitation in the drops. A videotape camera will record the drops' behavior as sound phases change in the chamber.

Study of Bubble Behavior (M16). Since bubbles do not rise to the surface of liquids in microgravity, researchers are investigating the use of sonic pressure to remove bubbles from liquid or molten metal processed in space. This experiment will examine the speed at which bubbles migrate over a range of Marangoni (or surface-tension-driven) convection, the speed of sound in a bubble, and hydrodynamic and thermal interaction among bubbles. The individual and collective behavior of bubbles in a stationary sonic wave will also be observed. The experiment will be videotaped for postflight study.

Marangoni-Induced Convection in Materials Processing in Microgravity (M18). This experiment will investigate the phenomenon of Marangoni convection in paraffin. The paraffin, enclosed in a cylinder, will be placed just below the top wall of the Marangoni convection experiment unit, and the temperature gradient between the cold top wall and hot bottom wall will be varied to increase and



Fluid Physics Facility Experiment and Bubble Behavior Experiment



FPF Marangoni Convection Unit Experiment

decrease the Marangoni convection. The results will be videotaped, allowing researchers to measure the speed of particles in the paraffin.

Solidification of Eutectic System Alloys in Space (M19). Eutectic structure formation, including the relationship between primary crystal migration and the eutectic grain structure, remains a mystery to scientists. It is hoped that this experiment, conducted in the microgravity environment free from the thermal convection that has plagued tests on Earth, will shed new light on the solidification process.

Four samples of hypoeutectic aluminum and two samples of hypereutectic aluminum and copper alloys will be processed in the continuous heating furnace for five minutes each at 700°C. Postprocessing comparison will be facilitated by the unidirectionally solidified structures of the original samples, which should also result in the creation of valuable new data on the solidification mechanisms involved.

Separation and Refinery Technology in Living Matter

In these biological experiments, scientists will assess the use of electrical separation to obtain high-purity cells in microgravity. They will also attempt to grow high-quality protein cystals for further study.

Separation of Biogenic Materials by Electrophoresis Under Zero Gravity (FFEU). The objective of this experiment is to quantify the effects of microgravity on the separation of biological materials by electrophoresis. Free-flow electrophoresis is used to process large quantities of materials, but high-purity separation is difficult to achieve on Earth because of gravity-induced convection currents and sedimentation. Previous experiments in microgravity have demonstrated that low gravity increases the efficiency of the separation process.

In this experiment, a sample of mixed proteins will be separated in the free-flow electrophoresis unit during several runs. A postflight examination of the sample will quantify the effects of microgravity on the process.

Crystal Growth of Enzymes in Low Gravity (ENZYME). This experiment represents an important step toward the goal of producing proteins with specific functions, which could revolutionize nutrition and medicine. Researchers will use the unique advantages microgravity offers over Earth-bound processing to grow high-quality protein crystals for postflight structural analysis. A solution containing a functional protein will be mixed with another solution containing crystallization-inducing agents. When crystals begin to form, the mixture will be stored in an incubator at 20°C to minimize fluid movement.

Studies on the Effects of Microgravity on the Ultrastructure and Function of Cultured Mammalian Cells (KIDNEY CELLS). The purpose of this experiment is to study the arrangement of intermediate and microfilaments, which influence mitosis and other cell functions, in kidney cells. Nutrient consumption and the production levels of urokinase, which is an enzyme that dissolves blood clots, also will be examined.

On orbit, four cultures of monkey kidney epithelial cells will be grown in a thermoelectric incubator. Two of the cultures will be treated with trypsin, an enzyme that separates cells from each other and the culture chamber walls. One of the cultures will be fixed immediately after being treated; the second, 24 hours after treatment. Both will be stored at 4°C. In the third culture, the cells will be grown in a medium that contains no serum for 48 hours and then frozen. The cells grown in the fourth medium will be observed for the effects of microgravity.

Separation of Animal Cells and Cellular Organella by Means of Free-Flow Electrophoresis (FFEU). One objective of this experiment is to determine if microgravity offers a better environment for separating cells than Earth. Scientists' efforts to separate cells that have acceptable purity on Earth have been hindered by the effects of gravity.

The researchers will produce relatively pure spores of the aspergillus fungus for use in this experiment. The experiment will also demonstrate the effectiveness of a new thick chamber in the free-flow electrophoresis unit. Among the advantages this innovation is expected to offer are larger volume and reduced wall effects in processing.

How Living Organisms Adapt to Space

Researchers have planned a number of experiments to study the effects of microgravity and radiation on human physiology. They hope their results will help them find answers to some of the risks astronauts will face on prolonged space missions and lead to improvements of life on Earth.

Endocrine and Metabolic Changes in Payload Specialist (UMS). This experiment will evaluate the effects of stress reactions on the human body as it undergoes changes in chemistry during space flight. The results will help scientists minimize the health risks of future extended-duration space missions.

After the flight, researchers will examine blood and urine samples taken during the mission from Dr. Mamoru Mohri, the Japanese payload specialist. By comparing the results of this analysis with Dr. Mohri's record of fluid intake during the flight, they may be able to detect the presence and levels of stress hormones in his body, which will enable them to quantify stress reactions. Researchers also hope the test results will help them clarify the relationship between the upward shift of body fluids and water-electrolyte metabolism during space flight and the associated regulatory hormones, better understand the circadian rhythm of hormone secretion, and find the relationship between bone-muscle atrophy and anabolic and catabolic hormone secretion.

Neurophysiological Study on Visual-Vestibular Control of Posture and Movement in Fish During Adaptation to Weightlessness (FISH). This experiment will attempt to corroborate a theory that explains why astronauts exhibit symptoms of space adaptation syndrome during the first one or two days in space. These symptoms include disorientation, loss of appetite, nausea, and vomiting. The theory is that SAS is caused by a disparity between the signals that the eyes and inner ear send to the brain.

To test this theory, the brain waves of two carp in special tanks will be measured and their movements videotaped twice a day as the fish are stimulated by pulses of light entering their tanks alternately from the top and side. Brain waves will be measured by an electrode implanted in the brain of each fish. The otolith, which is a gravity-sensing organ in the inner ear, has been removed from one of the carp so that researchers can compare its behavior to that of the other fish. The human otolith is very similar to the fish's organ.

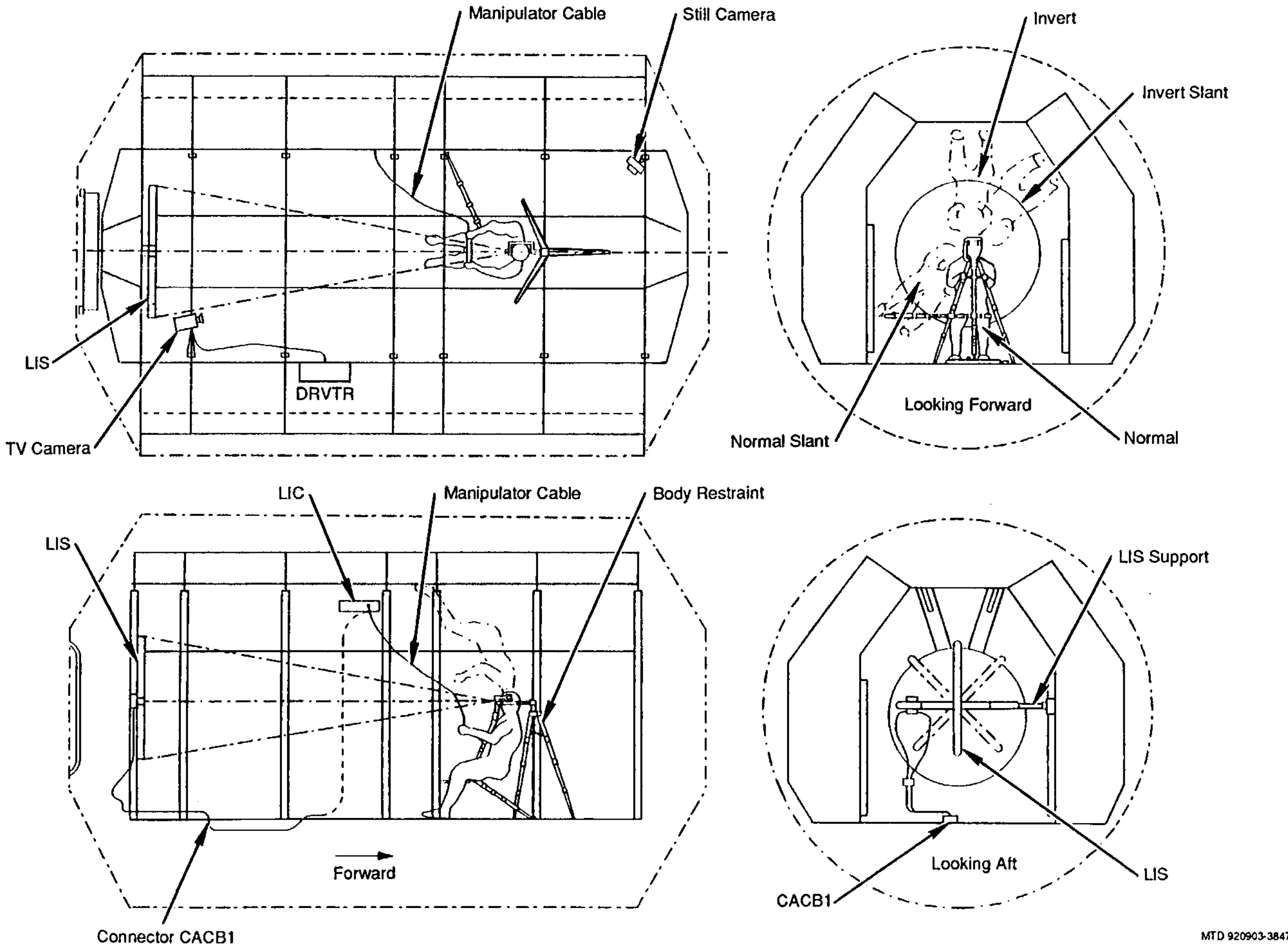
Researchers will use the data gathered to evaluate space adaptation mechanisms and the extent to which sensory conflict is a factor in SAS.

Comparative Measurement of Visual Stability in Earth and Cosmic Space (VISUAL STABILITY). Dr. Mohri is the subject of this experiment, which will investigate the lack of eye, head, and body coordination as a possible contributor to space adaptation syndrome. Electrodes attached to the payload specialist will record his eye movements and neck tension as he tracks a flickering light while he is rightside up, upside down, and at different 45-degree angles. A camera monitoring Dr. Mohri will enable the principal investigator to change the procedure during the experiment if necessary.

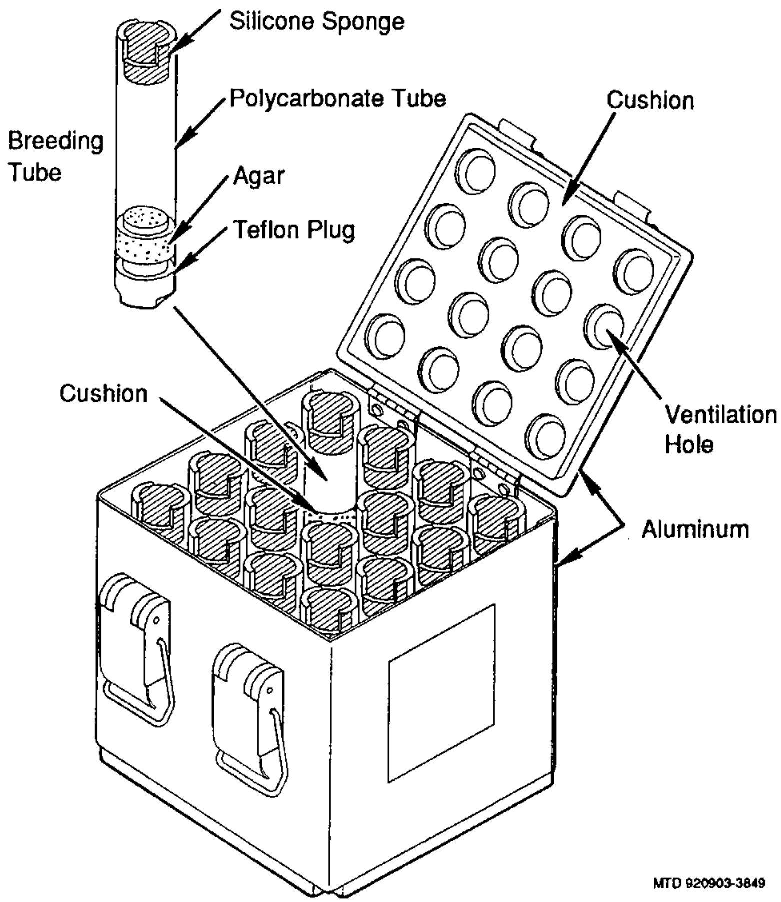
The Effect of Low Gravity on Calcium Metabolism and Bone Formation (EGG). Researchers will use chicks to study one of the greatest obstacles to prolonged space missions: bone calcium loss and the consequent loss of bone density. Scientists have established a direct relationship between calcium loss and the duration of space flight. Although they do not know the exact cause, evidence points to a decrease in bone formation as a probable cause.

Two groups of 30 fertilized chicken eggs will be used in this study. One group will be flown into space; the other group will remain on Earth as a control. The eggs in each group will be zero, two, seven, and 11 days old. After the mission, researchers will examine the embryos from a fixed number of eggs from both groups for cartilage growth, bone formation, calcium, and other factors. The other eggs will be allowed to hatch and the chickens to grow so that scientists can determine the long-term effects of weightlessness on their development.

Genetic Effects of HZE and Cosmic Radiation (FLY RAD). This experiment will investigate the effects on cells of exposure to high-charge and high-energy galactic rays (HZE) and other cosmic



Light Impulse Stimulation Experiment Hardware



Fly Container

radiation in space. Outside of Earth's protective atmosphere, astronauts have no protection from harmful radiation, which could cause cell mutations, malignant tumors, and even death over extended periods of exposure. The resolution of this problem will become more critical as the U.S. space station Freedom is completed and other permanent structures in space follow.

The subject of this investigation is the fruit fly *Drosophila melanogaster* because mutations are easily recognizable in this species. Scientists will study the extent of mutation in the flies' wings in response to different levels of radiation.

Space Research on Perceptual-Motor Functions Under Zero Gravity (VISUAL STABILITY). This experiment will assess certain human functions and performance in tracking objects in microgravity. The findings from this experiment may be useful in determining what types of automation and the amount of automation that will be needed to control future spacecraft.

This investigation will measure the eye movements and neck muscle tension of the payload specialist as he uses a joystick to duplicate the movements of a flickering light. Researchers will assess operator characteristics, tracking performance, and hand movement effectiveness based on the payload specialist's responses.

Study of the Biological Effects of Cosmic Radiation and the Development of Radiation Protection Technology (HZE RAD). The purpose of this experiment is to learn more about the nature of high-energy cosmic radiation and the effects of exposure to HZE. The radiation monitoring container device and passive dosimeters will measure the amount and type of high-energy radiation entering the Spacelab module. The RMCD contains layers of track detectors and specimens of maize seeds, shrimp eggs, and bacterial spores. After the flight, researchers will analyze the detectors and specimens to determine the path of the radiation particles and the effect of the particles on the biological materials at different stages of their development, which will enable them to pinpoint the effects of exposure over time.

Circadian Rhythm of Conidiation in Nerurospora Crassa ***(FUNGI).*** This experiment will evaluate the effect of microgravity on the circadian rhythm (or 24-hour cycle of activities) of the fungus Neurospora crassa. The fungi will be exposed to constant light at 20°C for one day and then deprived of light for five days. After the flight, researchers will examine the fungi to determine how much their spore formation cycles deviated from those of fungi on Earth. The findings may be applicable to future space missions since humans also have a circadian rhythm, which includes sleeping and waking cycles.

U.S. EXPERIMENTS

Effects of Weightlessness on the Development of Amphibian Eggs Fertilized in Space (FEE)

This experiment will investigate how microgravity affects the fertilization and development of frog eggs. During the mission, eggs will be fertilized on board Spacelab-J and allowed to develop. The development of some of the eggs will be stopped before they hatch, but the others will be allowed to develop into tadpoles and frogs.

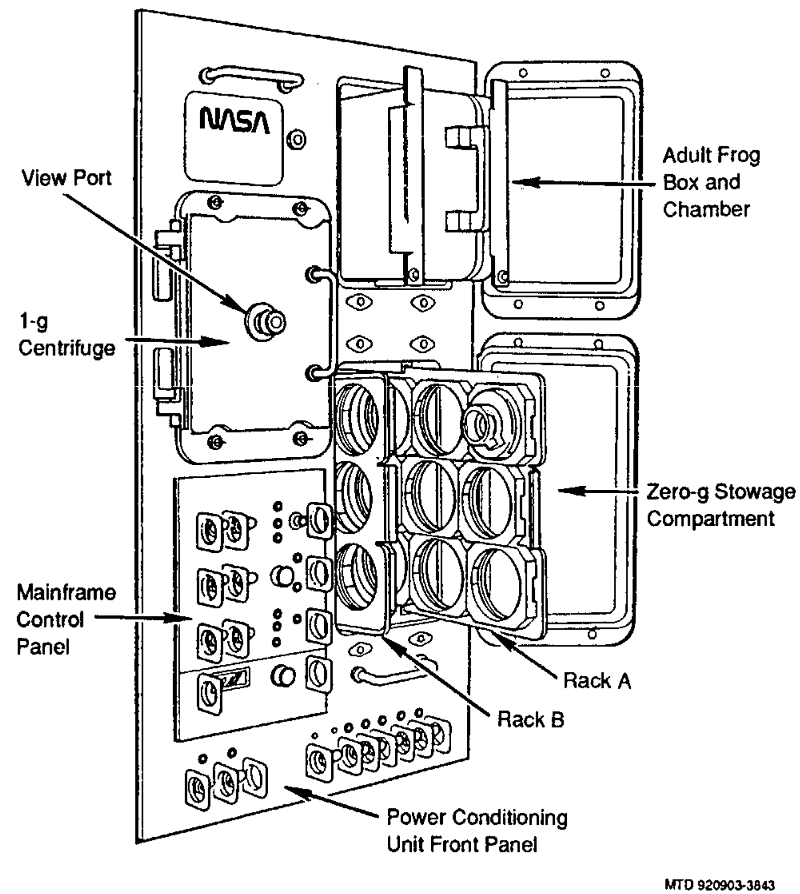
Autogenic Feedback Training Equipment (AFTE)

The objective of this experiment is to teach astronauts to use biofeedback rather than drugs to combat nausea and other effects of space motion sickness. Two crew members will participate in this experiment. One of the two participants will use the biofeedback technique to control unconscious or involuntary processes of the body; the other crew member, who is a control subject, will not use the technique. During waking hours, their physical responses will be monitored by sensors attached to a special suit they will wear.

The information collected in this experiment may also enable NASA to identify astronauts who may be susceptible to space motion sickness.

Lower Body Negative Pressure (LBNP)

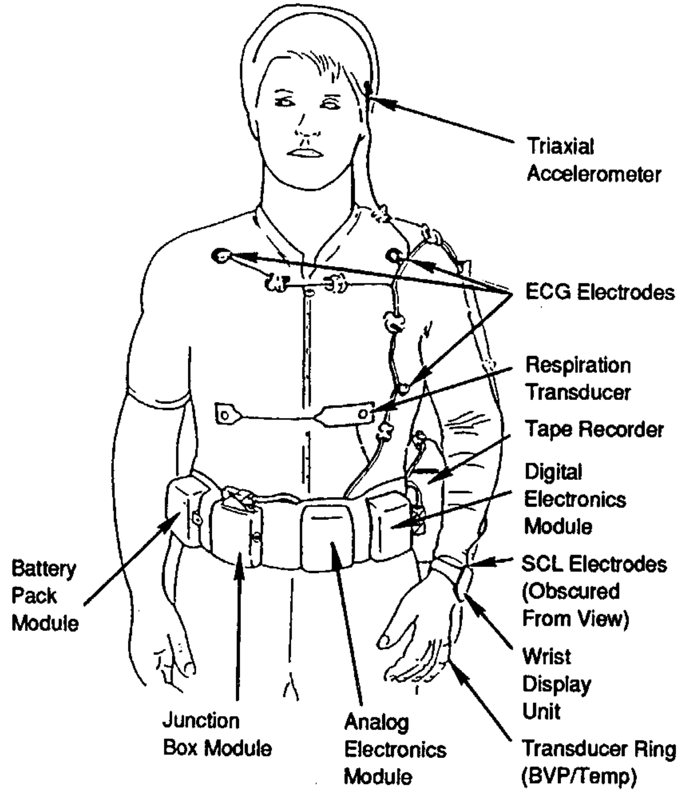
This experiment will study the shift in fluids from the lower body to the head, which has caused some astronauts to experience light-headedness and fainting spells when they return to Earth. Investigators want to see if negative pressure on the lower body,



Frog Environmental Unit

applied by a vacuum within a shroud that seals around the waist, can redistribute the fluids and mitigate the downstream effects. During this treatment, pressure will be automatically increased and reduced, heart functions and blood pressure will be recorded, and leg volume will be measured before and after each sequence.

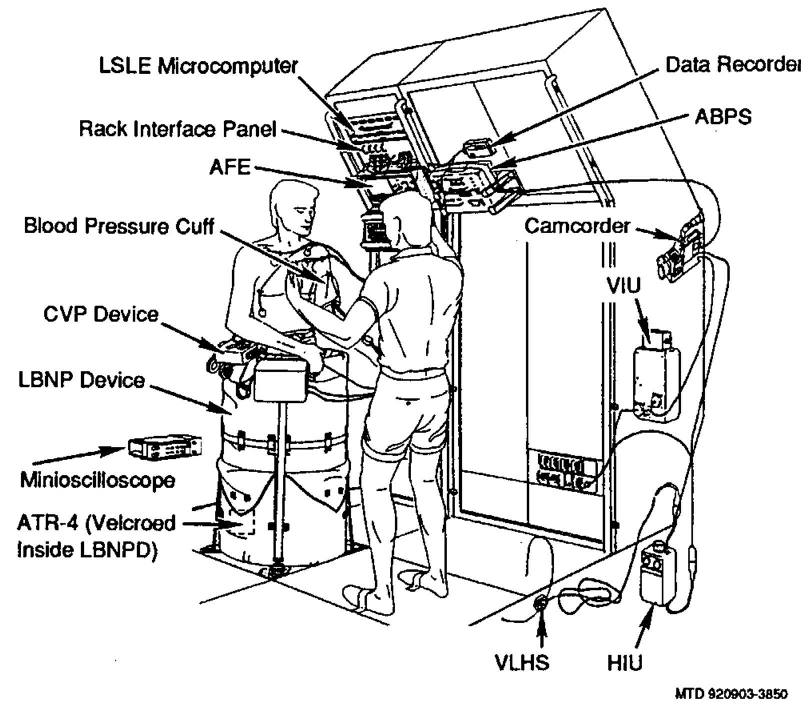
The effectiveness of fluid loading during LBNP in reversing cardiovascular changes induced by zero-g will be evaluated.



Autogenic Feedback System Instrumentation

Magnetic Resonance Imaging (MRI) After Exposure to Microgravity

Researchers will use MRI to determine what causes space travelers to lose muscle mass. They will examine MRI images of the calf and thigh muscles of some crew members produced before and after the mission to look for changes in muscle mass and in spinal bone marrow and vertebrae as well. Researchers will use MRI because it produces a much better image than X-rays and is not known to have health hazards.



LBNP Hardware Configuration (Soak Protocol)

Fluid Therapy System

This experiment will examine the effect of low gravity on the administration of intravenous fluids in space. Since gravity assists the delivery and flow of IV fluids on Earth, researchers want to determine what problems the absence of gravity would cause if an IV had to be administered to an astronaut in space.

Part of this experiment is a test of a new device that converts contaminated water into a sterile solution that can be used in IVs.

Protein Crystal Growth (PCG)

Proteins are complex amino acid compounds present in all life forms. They perform numerous critical roles in biochemical processes. If scientists can determine how proteins work, new and improved medicines may be developed.

Scientists want to know what specific proteins do and how their structures determine their function. But the protein crystals grown on Earth that are large enough to study are too flawed to be useful. The Protein Crystal Growth experiment, a veteran of previous shuttle missions, grows crystals at constant temperatures over long periods of time in microgravity to produce larger, more uniformly structured crystals that are much better suited to X-ray diffraction analysis. The experiment also evaluates the kinetics of the growth and the defects created by fluid disturbances.

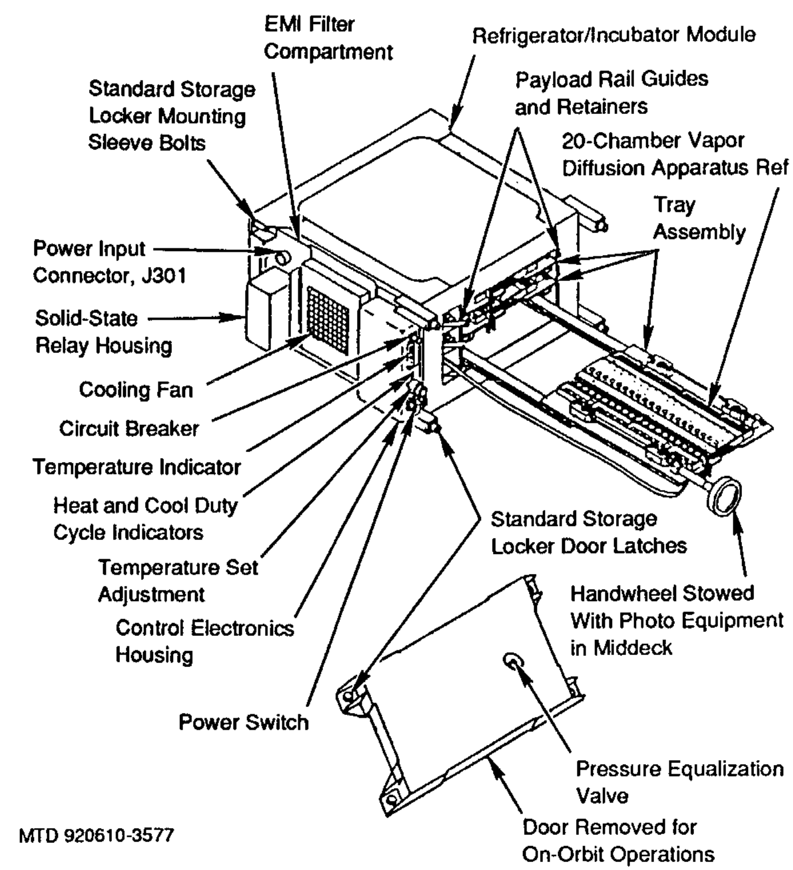
Investigators also want to assess the growth rates of proteins under various conditions to find the optimum process for space-grown crystals so that they can further their protein studies and produce some of the more difficult-to-grow specimens.

If these proteins reveal their secrets, we will know more about biological processes (e.g., what enables viruses like influenza and AIDS to spread and replicate), nutritional content of foods, crop improvement, and drug effectiveness.

Protein crystals on STS-47 will be grown in two scientific instruments, each relying on a different technique to promote crystallization: vapor diffusion and liquid/liquid diffusion.

Space Acceleration Measurement System (SAMS)

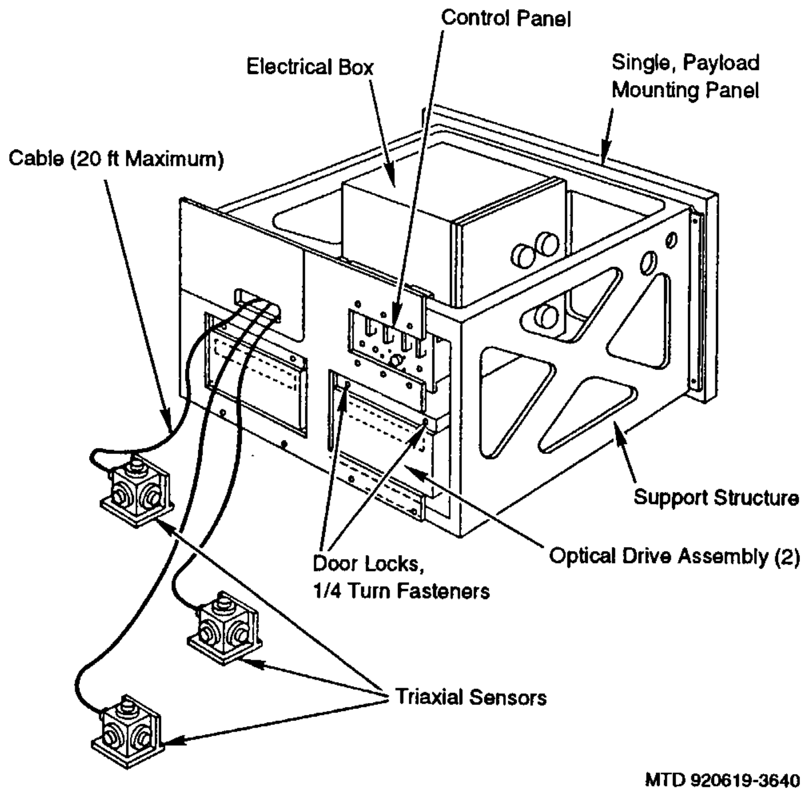
Microgravity, which allows unique experiments in the Spacelab environment, is not the total absence of gravity. Investigators need to know to what extent the momentary vibrations of crew movement, equipment operation, and spacecraft maneuvers act like gravitational forces on their experiments. They also want to measure the quasi-steady accelerations caused by the constant drag and rotation of the orbiting shuttle.



Protein Crystal Growth Flight Hardware

The three sensor heads of the SAMS unit measure accelerations at different locations in the Spacelab module. Three inertial sensors on each sensor head monitor both positive and negative accelerations in a preset frequency range. Each head, which also measures local temperature, filters and amplifies the signals from the sensors.

Data taken at each location will be sent to a central unit for conversion and storage on optical disks. Analysis of these various accelerations will enhance the understanding of other experiment results



SAMS Hardware

and enable designers to improve future experiments and space structures.

COLLABORATIVE EXPERIMENTS

Plant Culture Research (PCR)

This experiment investigates the development of plant embryos at the cellular level in microgravity. Carrot cell cultures will be flown in the cell culture kit.

Bone Cell Growth and Mineralization in Microgravity (BCR)

This experiment compares the activity of isolated bone cells exposed to a microgravity environment with controls treated similarly on the ground.

Spacelab-J Assignments and Responsibilities

<table>
<tr><th>Tasks</th><th>Crew Member</th><th>Tasks</th><th>Crew Member</th></tr>
<tr><td>Payload commander
• Overall crew responsibility
• MSFC interface
• Training plan/coordinator
• Time line/PCAP
• Meetings
• Documentation
• Hardware/software changes</td><td>Mark Lee</td><td rowspan="2">U.S. experiments/equipment lead*
• FEE
• LBNP
• FTS
• MRI
• AFTE
• SAMS
• PCG
• Refrigerator and R/IM
• UMS
• PMS
• USL-6</td><td rowspan="2">Mae Jemison

Mae Jemison/Jan Davis
Mae Jemison/Mark Lee
Mae Jemison/Jan Davis
Mae Jemison
Mae Jemison/Jan Davis
Jan Davis/Mark Lee
Mae Jemison/Mark Lee
Mae Jemison/Mark Lee
Mae Jemison/Mamoru Mohri
Mae Jemison/Mamoru Mohri
Mae Jemison/Mark Lee</td></tr>
<tr><td>Science mission specialist/ Investigator's Working Group interface</td><td>Mae Jemison</td></tr>
<tr><td>Spacelab
• Flight data file systems in-flight maintenance
• Activation
• Deactivation
• General-purpose workstation</td><td>
Mark Lee/Jan Davis

Mark Lee
Jan Davis/Mae Jemison
Mae Jemison/Mark Lee</td><td rowspan="2">Miscellaneous
• Medical officer
• Extravehicular activity
• PCTC
• KSC processing
• Human Research Policy and Procedures Committee
• Japanese payload specialist contact
• Backup payload specialist contact
• Getaway special beam</td><td rowspan="2">
Mae Jemison
Mark Lee/Jan Davis
Mae Jemison
Mae Jemison/Mark Lee
Mae Jemison

Mark Lee

Mae Jemison

Mark Lee</td></tr>
<tr><td>First Materials Processing Test lead*
• MEL
• LS
• Common item</td><td>Mamoru Mohri

Jan Davis/Mark Lee
Mark Lee/Jan Davis
Jan Davis/Mark Lee</td></tr>
<tr><td colspan="4">*First Materials Processing Test and U.S. experiments include several areas; the primary ones are listed below. For those areas that overlap and require coordination, a lead is designated in parentheses.
Equipment—hardware/software
Flight data file (Lee)
Stowage (Jemison)
Photo/TV (Davis)
Safety (Davis)</td></tr>
</table>

SPACELAB

On Sept. 24, 1973, a memorandum of understanding was signed between the European Space Agency, formerly known as the European Space Research Organization, and NASA with NASA's George C. Marshall Space Flight Center as lead center for ESA to design and develop Spacelab, 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-47.

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.

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-47 crew will work two 12-hour shifts.

PRESSURIZED MODULE

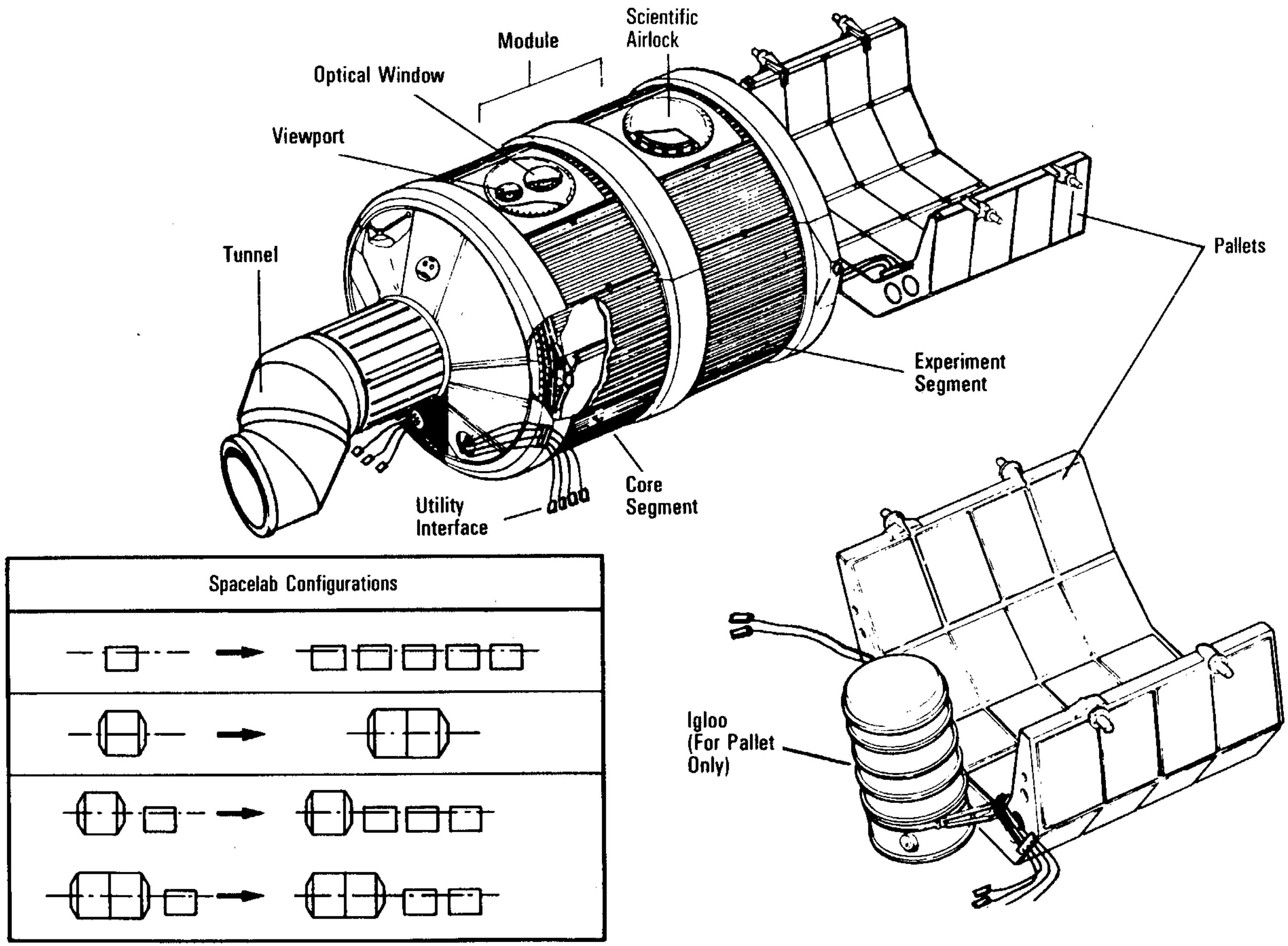
The pressurized module, or laboratory, is available in two segments. One, called the core segment, contains supporting systems, such as data processing equipment and utilities for the pressurized modules and pallets (if pallets are used in conjunction with the pressurized modules). The laboratory has 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.

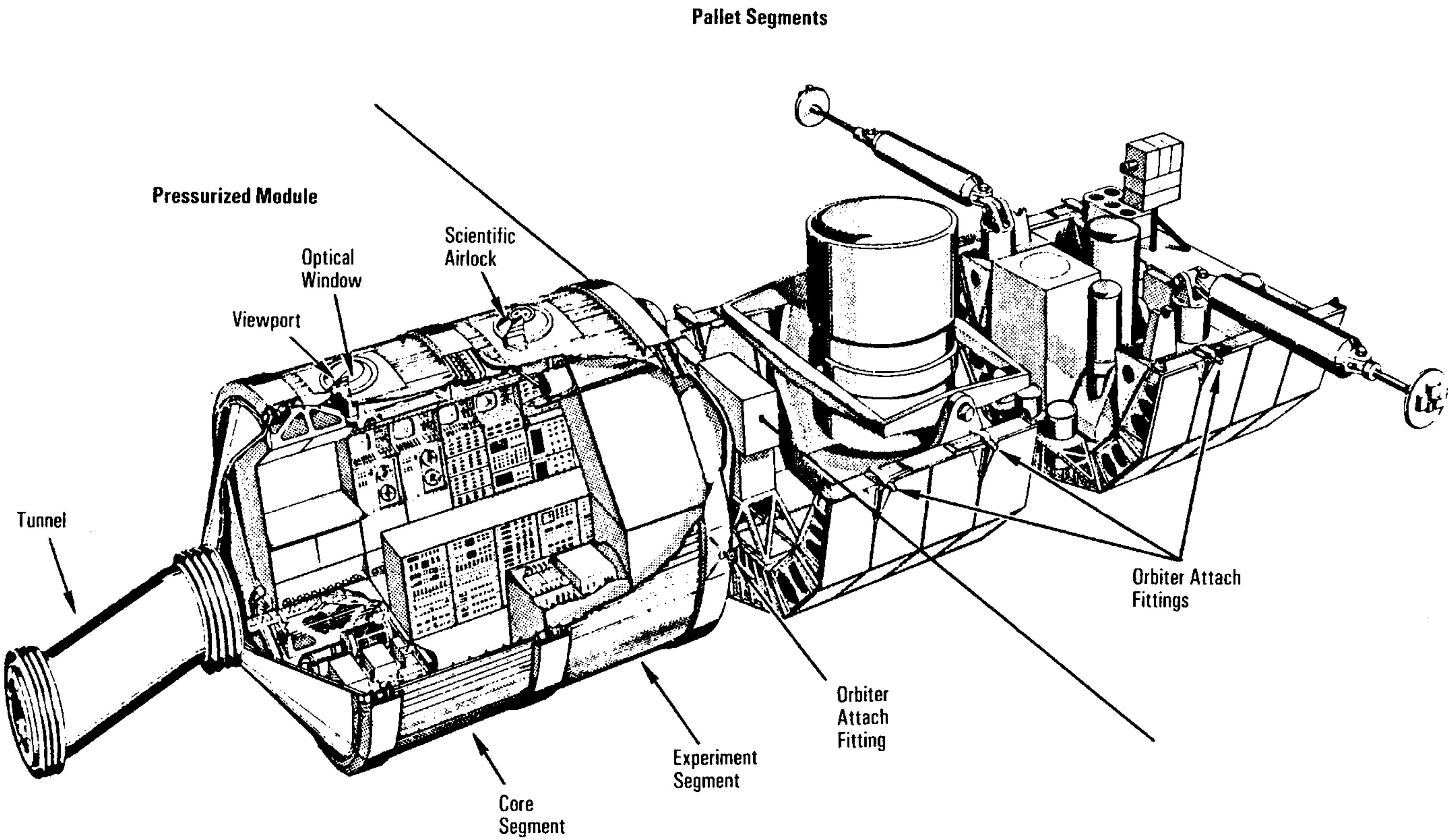
The ceiling skin panel of each segment contains a 51.2-inch-diameter opening for mounting a viewport adapter assembly, a Spacelab window adapter assembly, or scientific airlock; if none of these items are used, the openings are closed with cover plates that are bolted in place. The module shell is made 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.

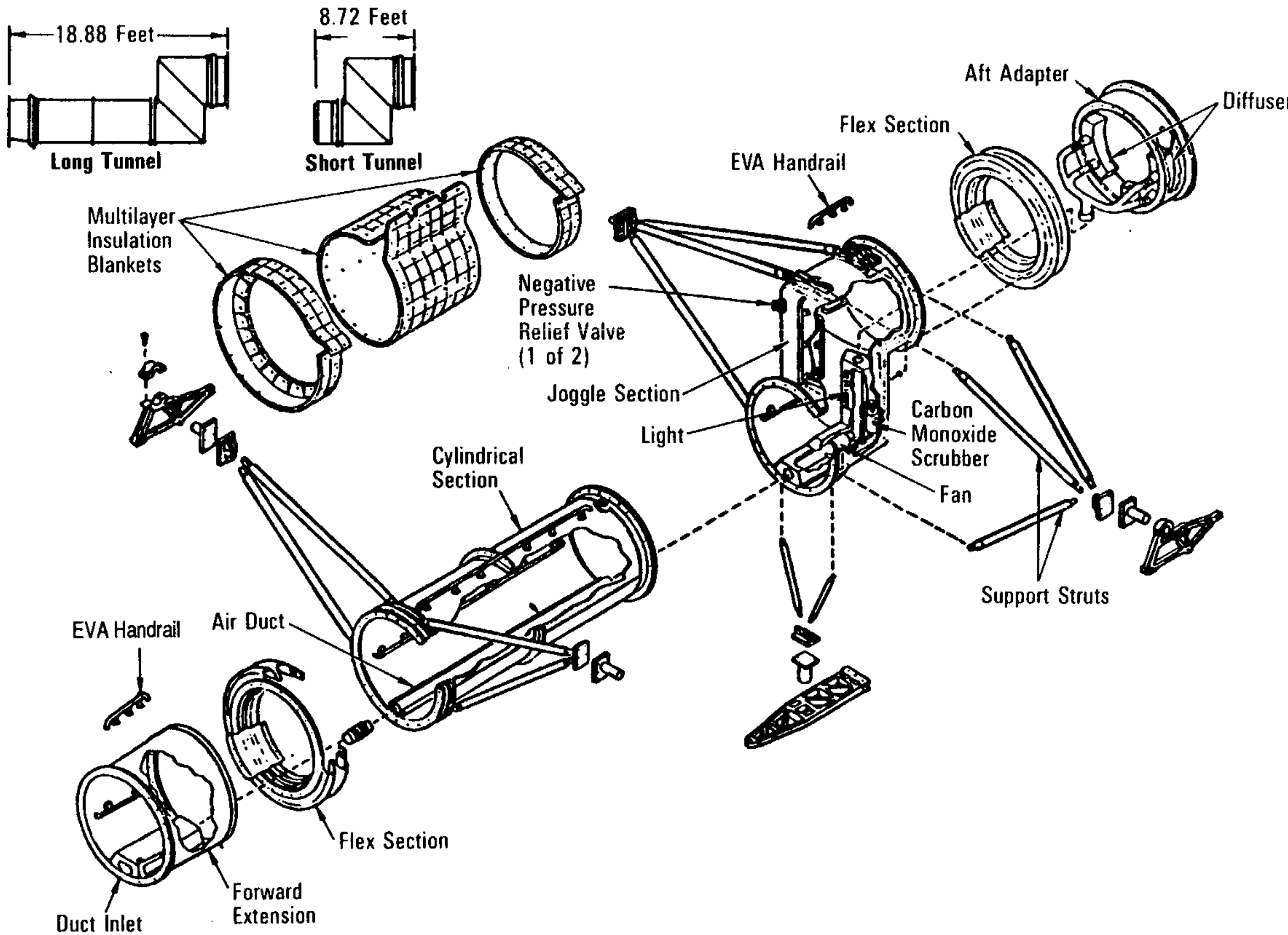
Because of the orbiter's center-of-gravity conditions, the Spacelab pressurized modules cannot be installed at the forward end of the payload bay. Therefore, a pressurized tunnel is provided for equipment and crew transfer between the orbiter's pressurized crew compartment and the Spacelab pressurized 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



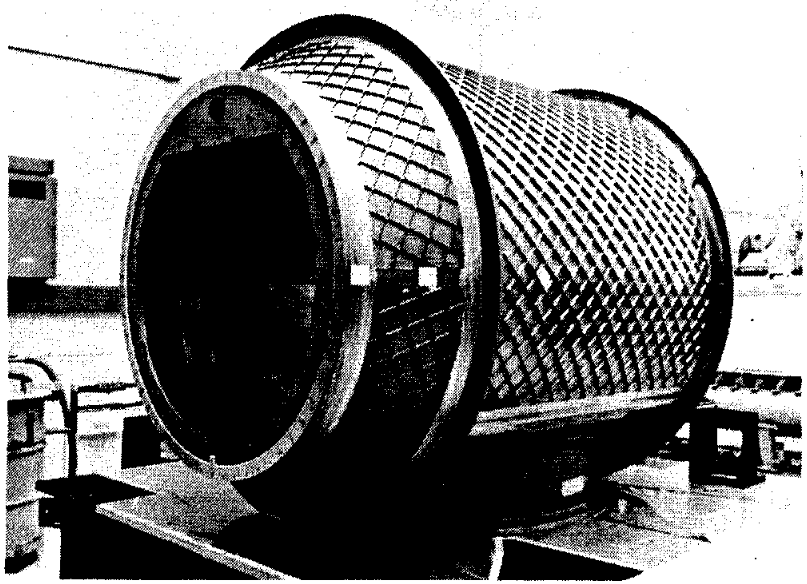
Spacelab External Design Features



European Space Agency's Spacelab



Spacelab Transfer Tunnel



Tunnel Adapter

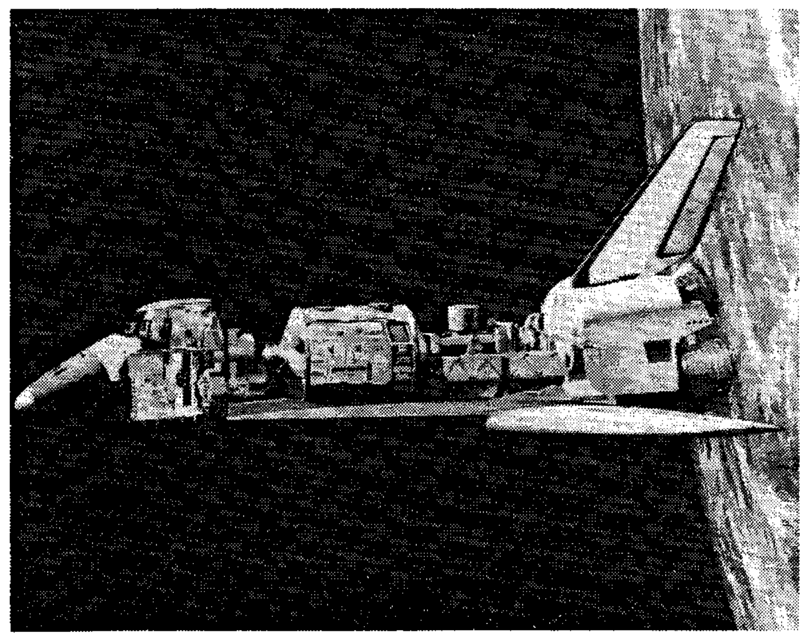
built by McDonnell Douglas Astronautics Company, Huntington Beach, Calif.

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,

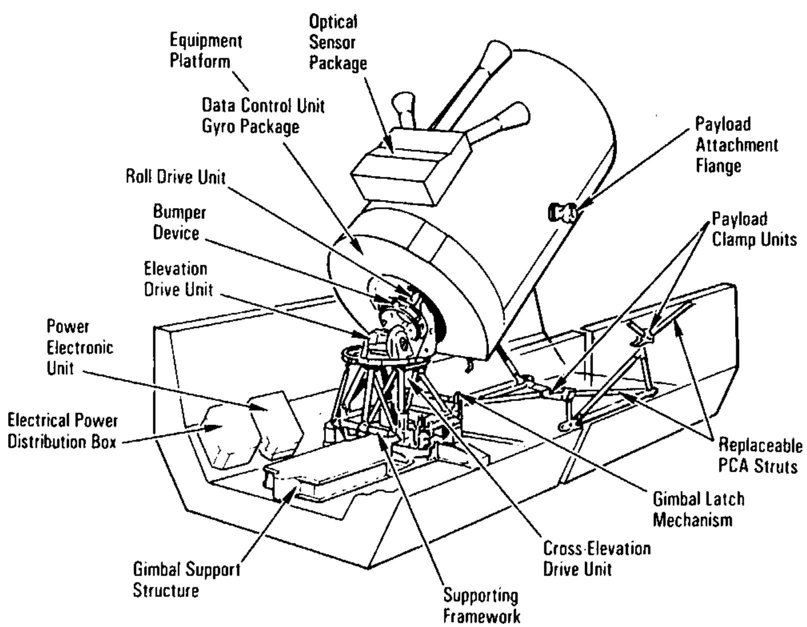


Spacelab

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.

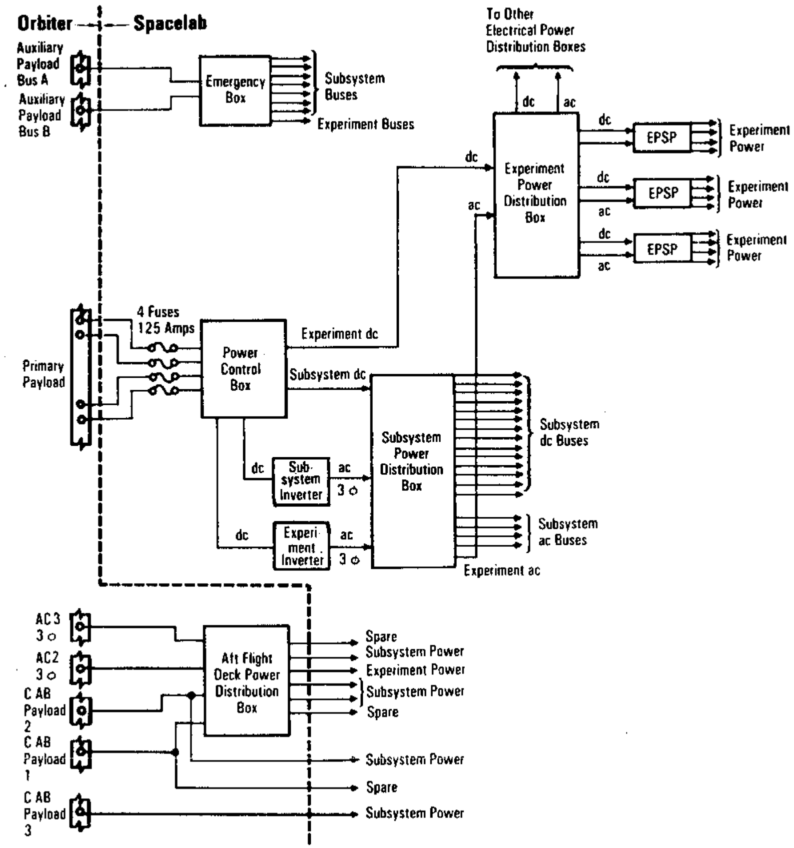
Cable ducts and cable support trays can be bolted to the forward and aft frame of each pallet to support and route electrical cables to and from the experiments and subsystem equipment mounted on the pallet. All ducts mounted on the right side of the pallet are used to route subsystem cables, and all 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.

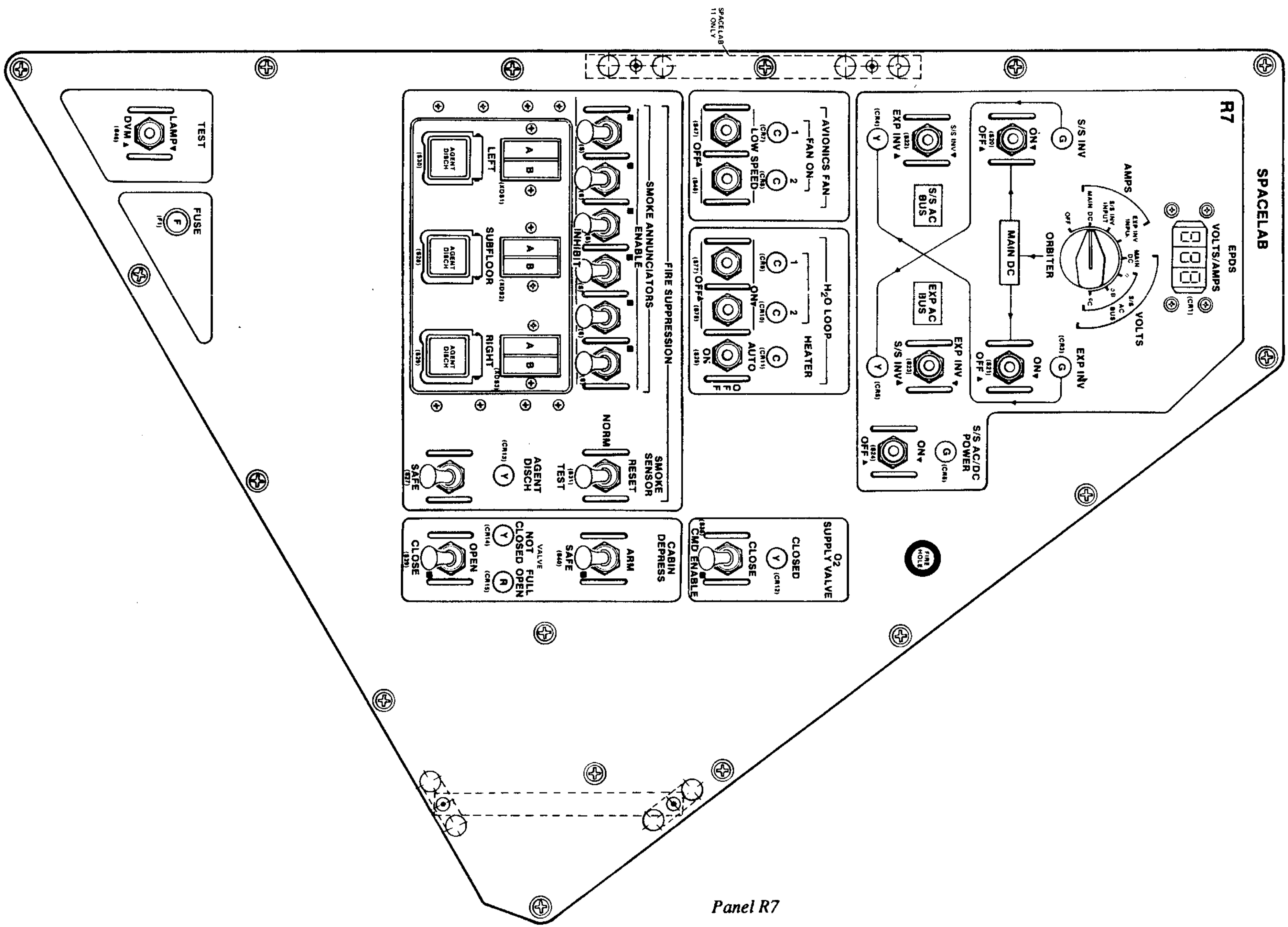
ELECTRICAL POWER

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


SPACELAB
11 ONLY
R7
SPACELAB
EPDS
VOLTS/AMPS
S/S INV
ON
OFF
AMPS
VOLTS
ORBITER
MAIN DC
S/S AC BUS
EXP AC BUS
EXP INV
S/S INV
EXP INV
S/S AC/DC POWER
AVIONICS FAN
FAN ON
LOW SPEED
OFF
H_2O LOOP
HEATER
AUTO
ON
OFF
FIRE SUPPRESSION
SMOKE ANNUNCIATORS
ENABLE
INHIBIT
LEFT
SUBFLOOR
RIGHT
AGENT DISCH
SMOKE SENSOR
RESET
NORM
TEST
AGENT DISCH
SAFE
CABIN DEPRESS
ARM
SAFE
VALVE
NOT CLOSED
FULL OPEN
OPEN
CLOSE
O2 SUPPLY VALVE
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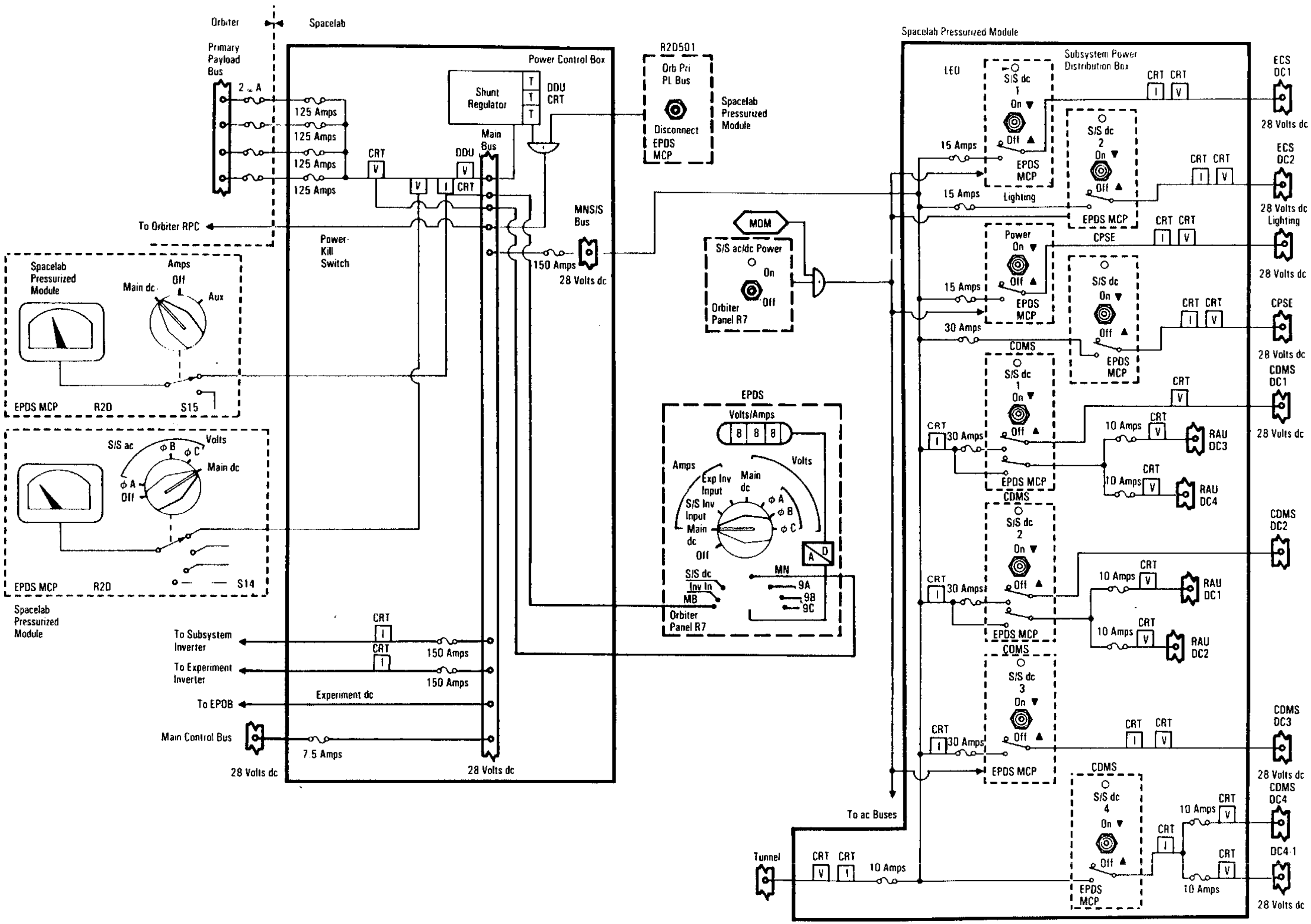
CMD ENABLE
FIRE HOLE
TEST
LAMP
DVM
FUSE

Panel R7



Orbiter-to-Spacelab Electrical Power Distribution—Subsystem dc Power Distribution and a worst-case minimum of 23 volts. The four redundant power feeders from the orbiter supply the Spacelab power control box with power through 125-amp fuses. Spacelab main bus voltage and current readings are available on orbiter CRT Spacelab displays. For the igloo/pallet configuration, the main bus dc voltage and amperage are also available to the flight crew from the EPDS *volts/amps* digital meter and rotary switch on panel R7 at the orbiter crew compartment aft flight deck mission specialist station. The Spacelab power control box is installed in the subfloor of the Spacelab pressurized core segment and in the igloo of the pallet-only configuration.

In the Spacelab pressurized module configuration, the main dc voltage and amperage are available in the pressurized module on the control center rack EPDS monitoring and control panel. The voltage reading is obtained by setting the *volts* rotary switch on the EPDS MCP to the *main dc* position, and the amperage reading is obtained by setting the amps rotary switch to the *main dc* position. The meters on the EPDS MCP panel have only colored zones to indicate nominal (green) or off-nominal (red) readings. The amp readout for main dc power has an additional color field (yellow) to indicate a peak power loading condition.

In the pressurized module configuration, the EPDS MCP provides a manually operated *orb PRI PL bus* disconnect switch, which acts as a kill-power switch for the main dc power to the module. When this switch is positioned momentarily to the *disconnect* position, all Spacelab subsystem functions supplied by normal dc and ac power cease to operate, and the Spacelab water pump, Freon pump, and avionics delta pressure caution channels are activated.

The Spacelab subsystem power distribution box distributes the subsystem dc bus and ac bus power into subsystem-dedicated feeders. In the pressurized module configuration, all outputs except the tunnel and environmental control subsystem ac and experiment ac outputs are remotely switched by latching relays. Power protection circuits and command activation are controlled by the remote amplification and advisory box. In the subsystem power distribution box, the dc power line feeds several subsystem power buses controlled by switches on the electrical power distribution subsystem monitoring and control panel. In the pallet-only configuration, all outputs are remotely switched by latching relays.

Various Spacelab systems' operations are controlled on orbit from panel R7 in the orbiter crew compartment aft flight station. In either the pallet-only or pressurized module configuration, Spacelab power protection circuits and command activation are controlled from the remote amplification and advisory box. The subsystem power distribution box is controlled by the *S/S ac/dc power on/off* switch on the orbiter aft flight deck panel R7 or by an item command on several orbiter CRT Spacelab displays. The status of this switch on panel R7 is displayed on the orbiter CRT and indicated by a green LED above the manual switch on panel R7. The voltages and currents of the various Spacelab subsystem buses are also available to the flight crew on the orbiter CRT Spacelab subsystem power display.

The dc power in the Spacelab power control box is directed through two parallel 150-amp fuses, one to the Spacelab subsystem dc/ac inverter and the other to a Spacelab experiment dc/ac inverter. Normally, only the subsystem inverter is used to power both subsystem and experiment ac requirements, and the experiment inverter is used as a backup. Each inverter generates three-phase ac power at 117/203 volts, 400 hertz. It is possible to connect the ac experiment bus to the subsystem inverter and, conversely, the subsystem ac bus to the experiment inverter.

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

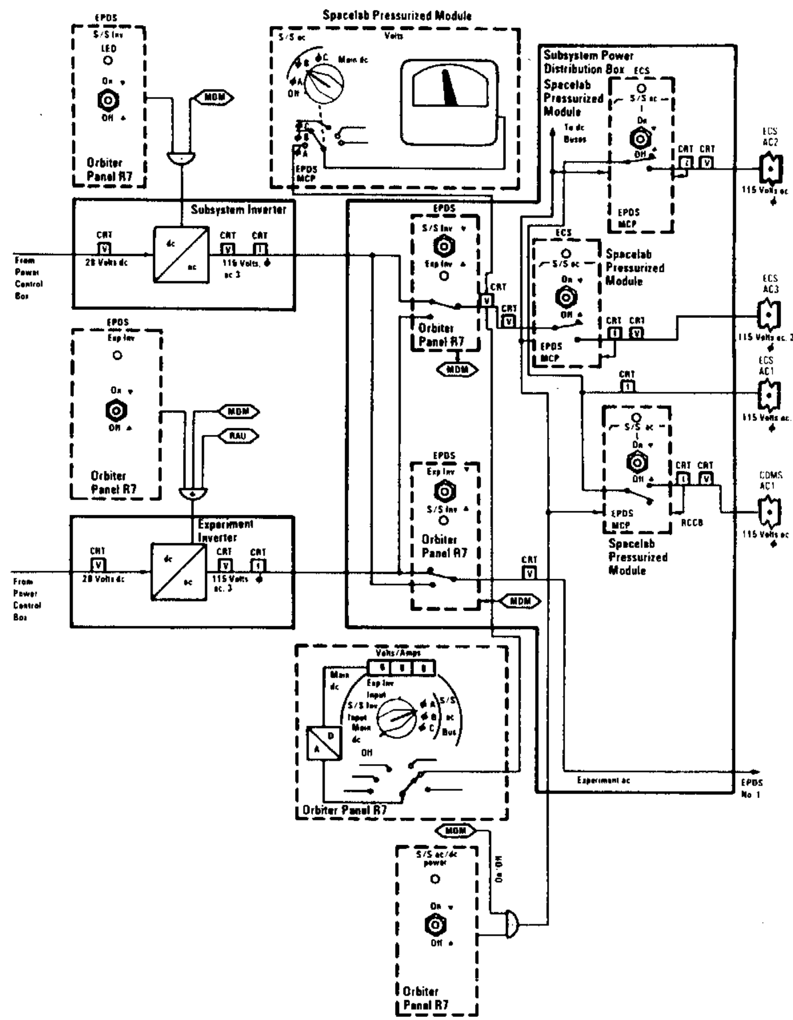
The Spacelab subsystem inverter is activated by the *S/S inv on/off* switch on panel R7 or by orbiter Spacelab CRT command. Positioning the switch to *on* activates the subsystem inverter, and a green LED above the switch on panel R7 is illuminated, indicating the inverter is operating. Positioning the 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

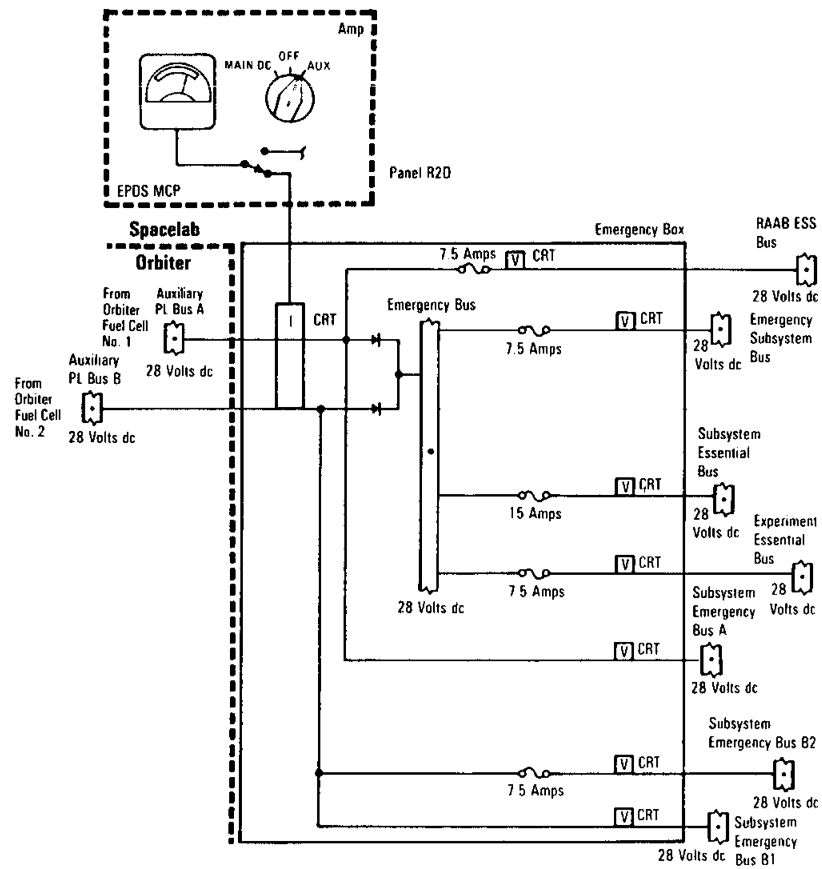
power on/off switch on orbiter panel R7 or by item commands from the orbiter CRT Spacelab displays. The status of the commanded relays is available via orbiter CRT Spacelab displays and indicated by the green LED light above the respective switch on panel R7.

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.

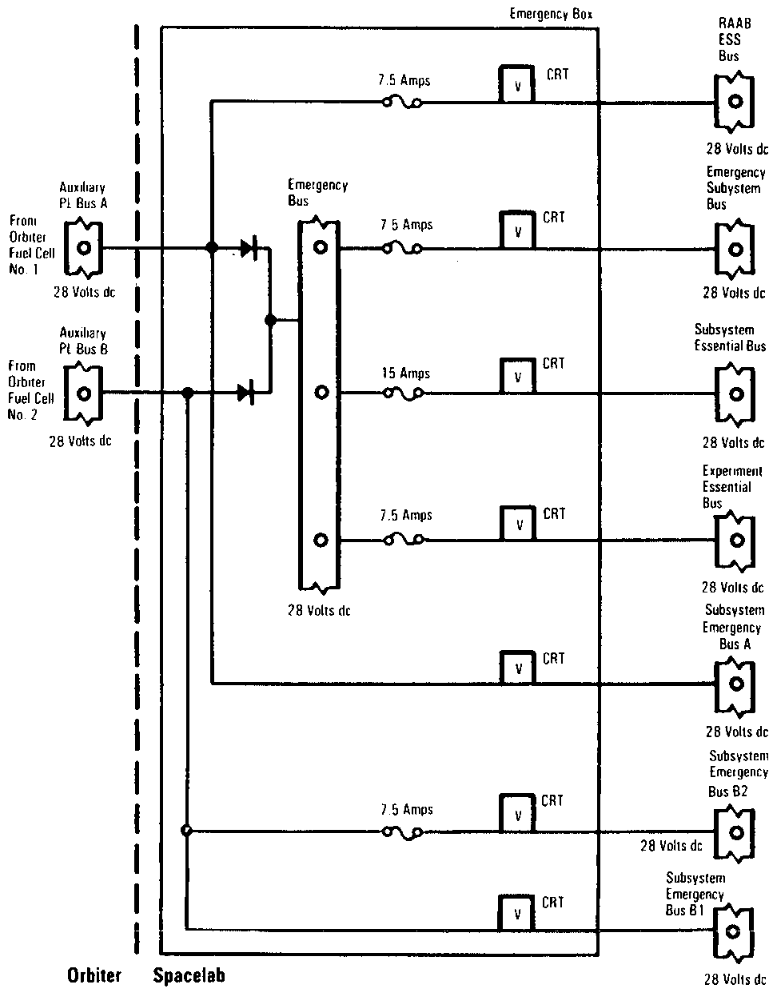
In the Spacelab pressurized module configuration, experiment power distribution boxes provide distribution, control, and monitoring facilities for the experiment electrical power distribution system, which consists of a nominal redundant 28-volt experiment main dc supply and a 115-volt, 400-hertz ac 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,



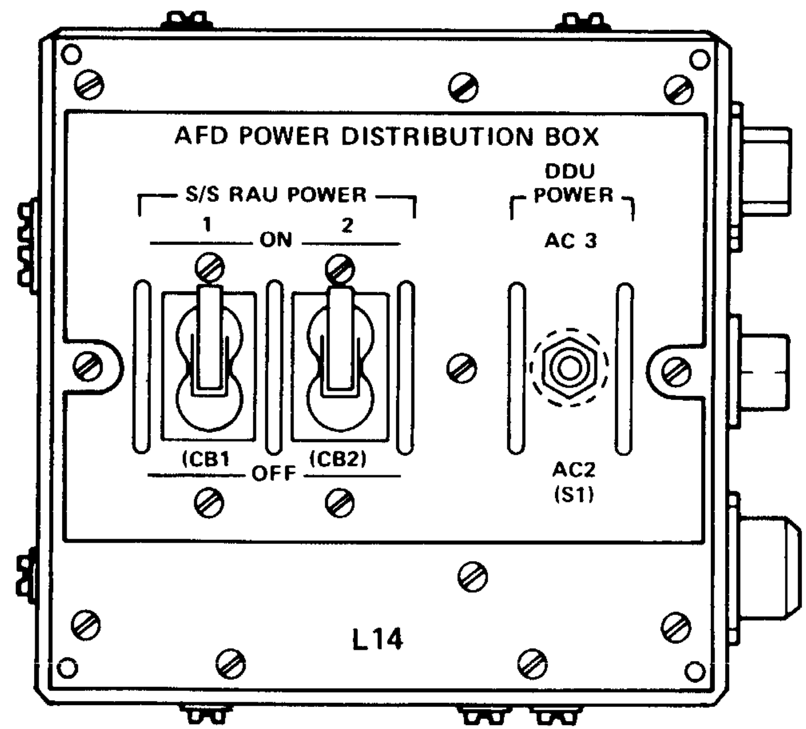
Spacelab Pressurized Module Emergency and Essential Power Distribution the experiment power distribution box is mounted with other assemblies with an adapter plate on a cold plate that is fitted on a support structure and attached to the pallet.

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.

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



Spacelab Pallet Emergency and Essential Power Distribution



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.

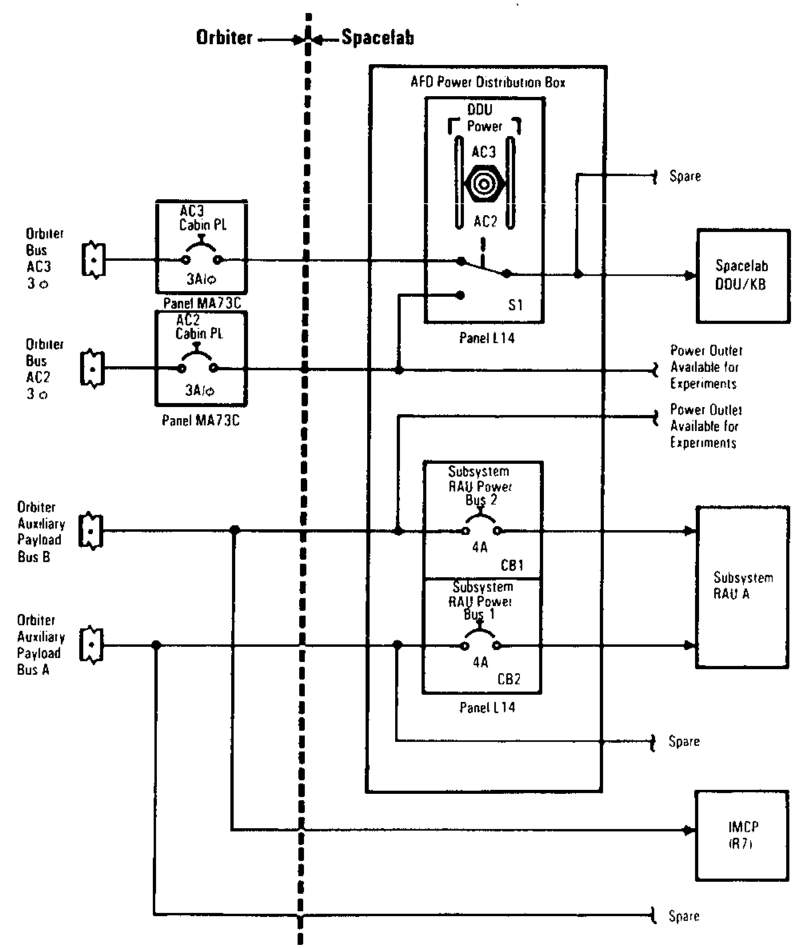
The Spacelab power distribution box at the orbiter aft flight deck payload station distributes dc and ac power to the Spacelab subsystem remote acquisition unit and the Spacelab data display system (a data display unit and keyboard). When a Spacelab data display system is installed at the mission station,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



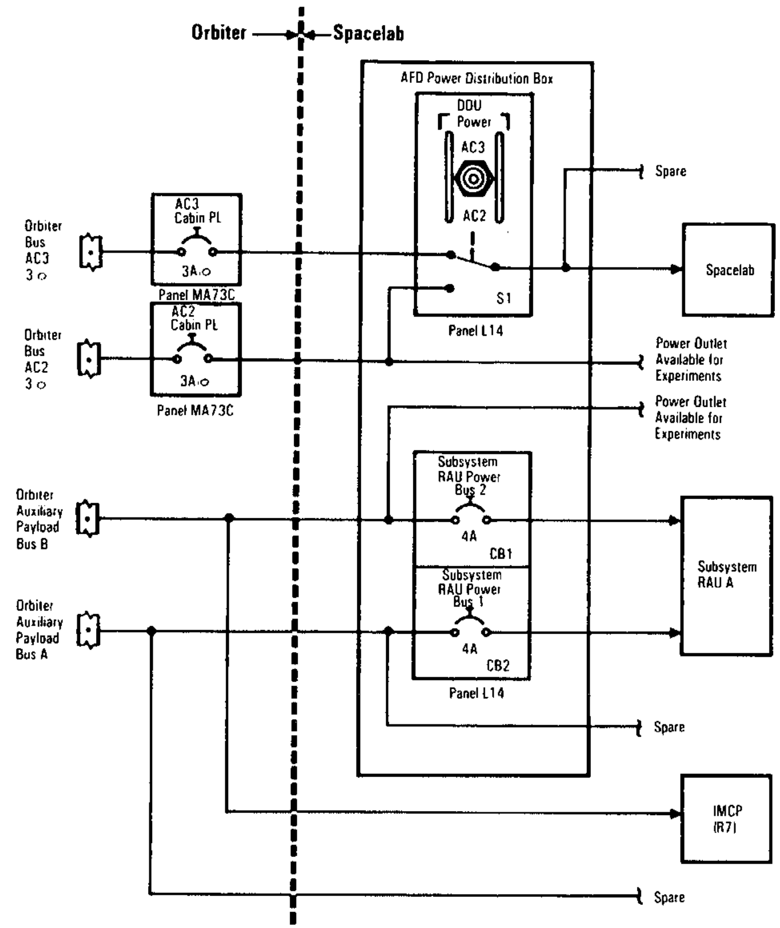
Pressurized Module Configuration—Orbiter Aft Flight Deck Power Distribution

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.

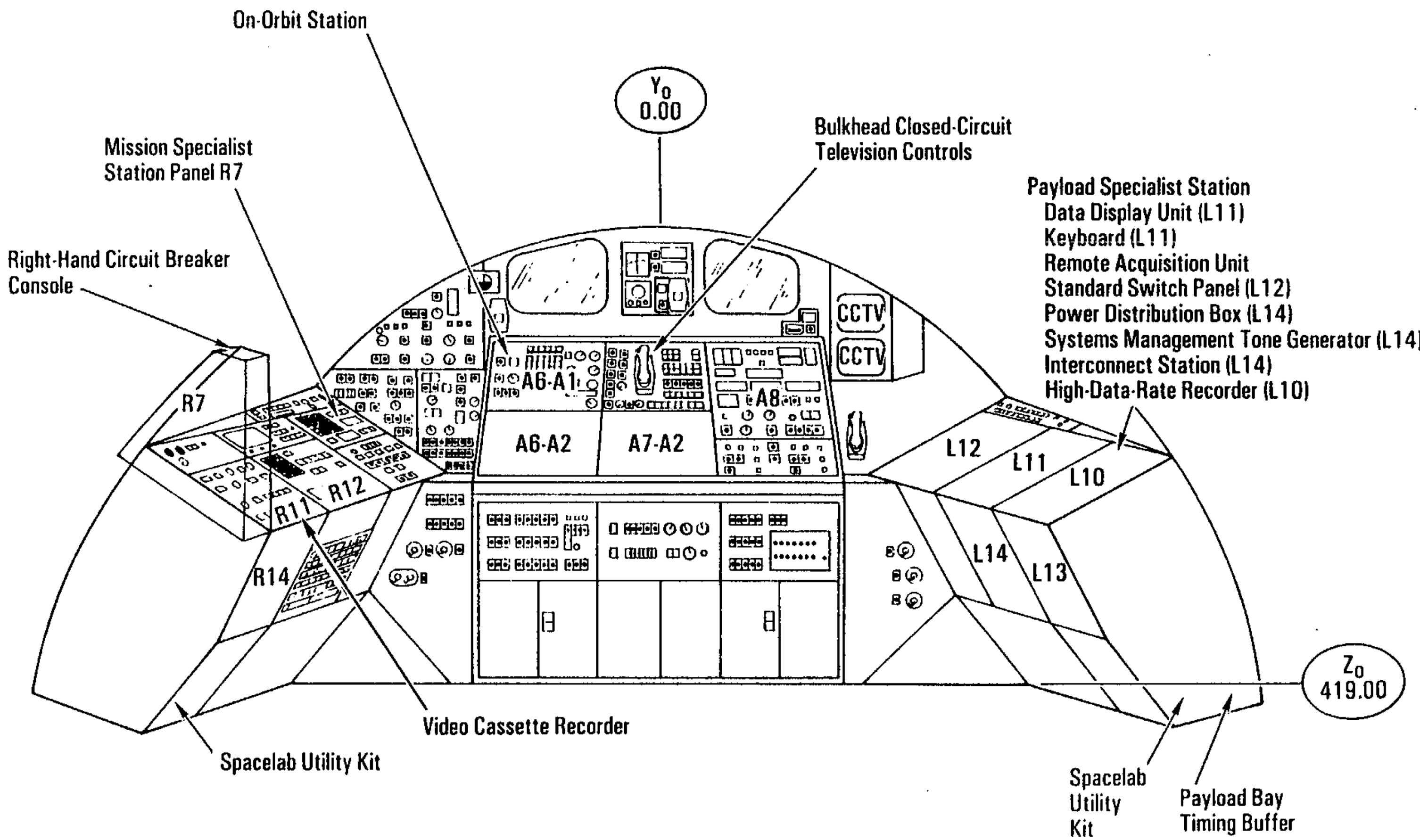
COMMAND AND DATA MANAGEMENT SYSTEM

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.

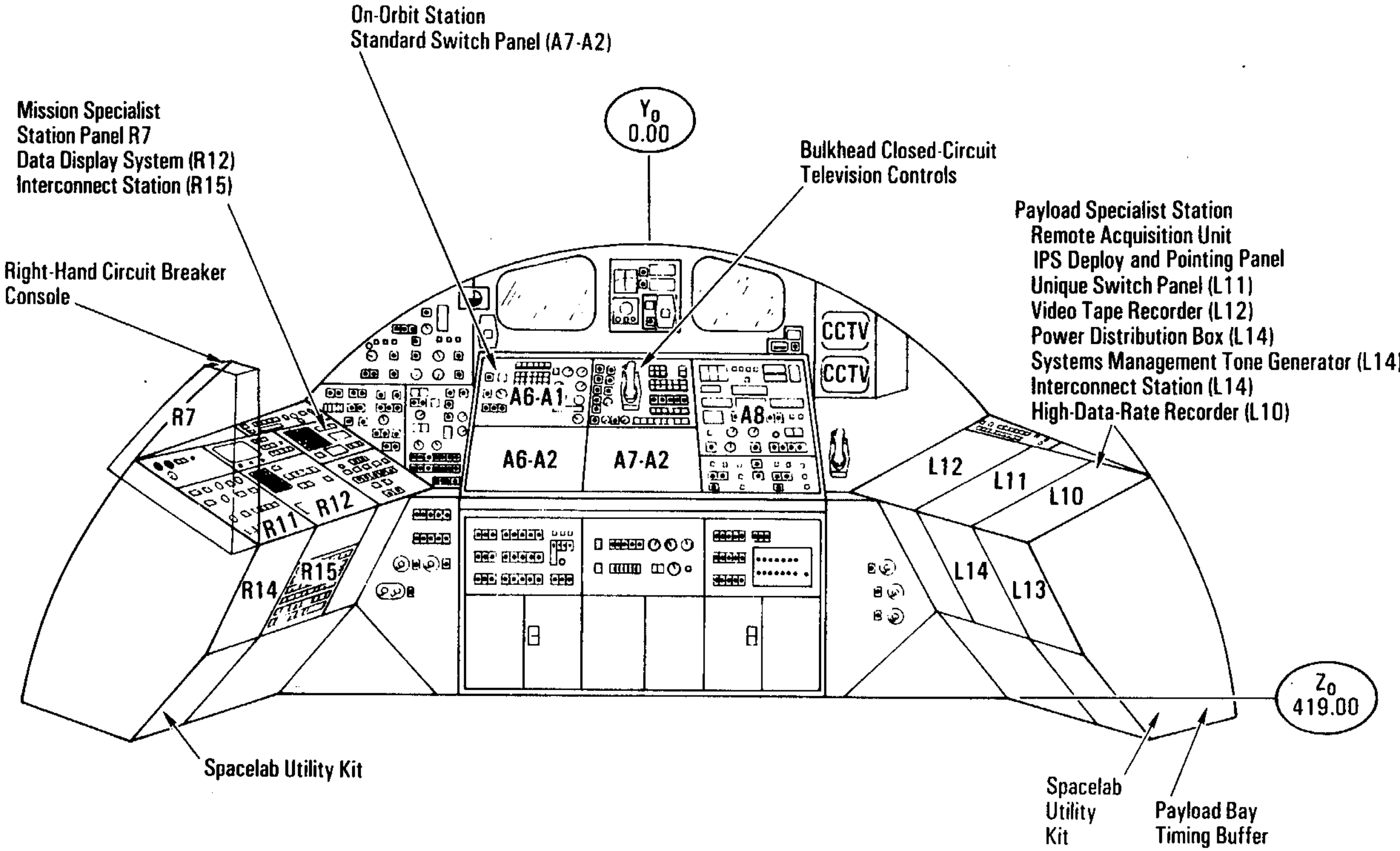


Pallet-Only Configuration—Orbiter Aft Flight Deck Power Distribution

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-



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.

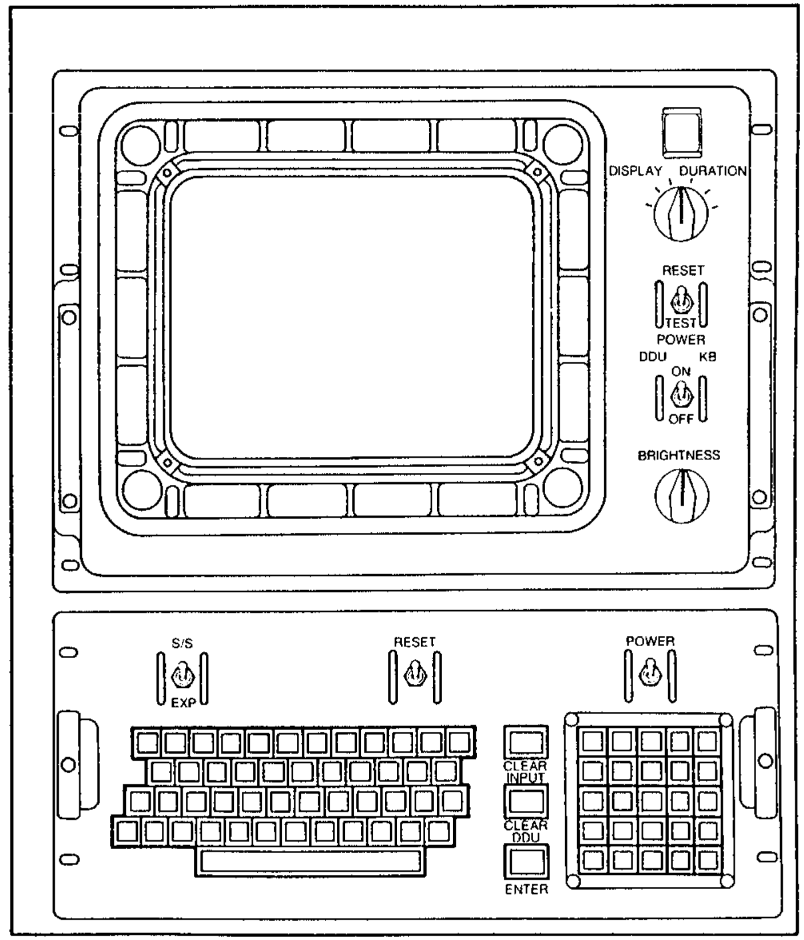
Mass Memory Unit

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.

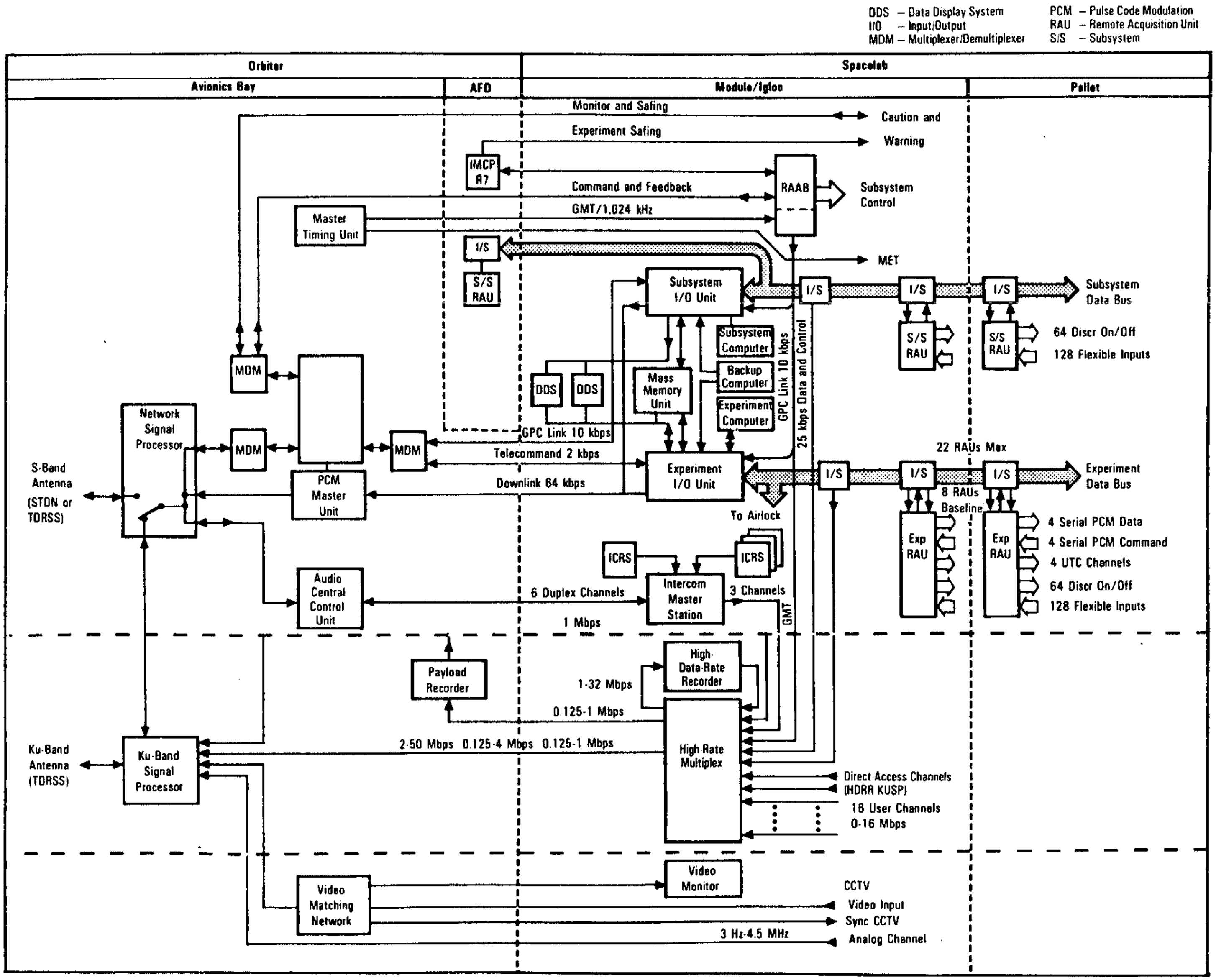
The subsystem computer functions mainly to monitor and control other Spacelab subsystems and equipment, such as the electrical power distribution subsystem and the environmental control subsystem. These functions are performed by the subsystem computer operating software.

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.

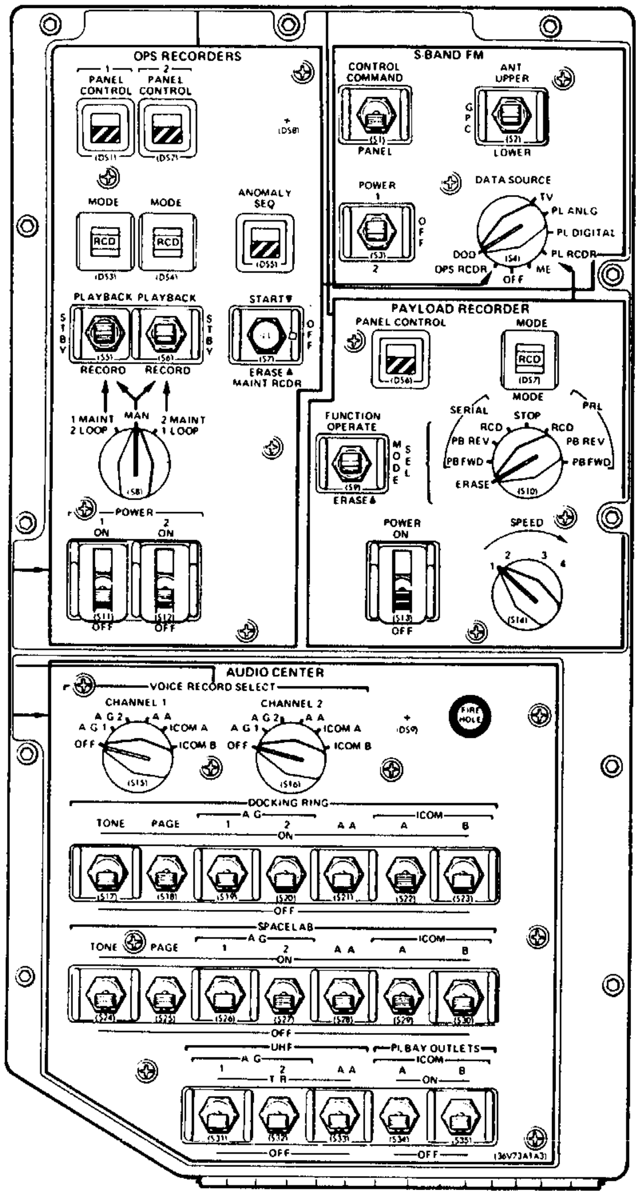
The Spacelab experiment computer interfaces with two telemetry systems. The orbiter PCMMU allows the orbiter to acquire data for on-board monitoring of systems and provides the Mission Control Center in Houston with system performance data for real-time display and recording through the orbiter network 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



Spacelab Command and Data Management System Interfaces With the Orbiter



Panel AIA3

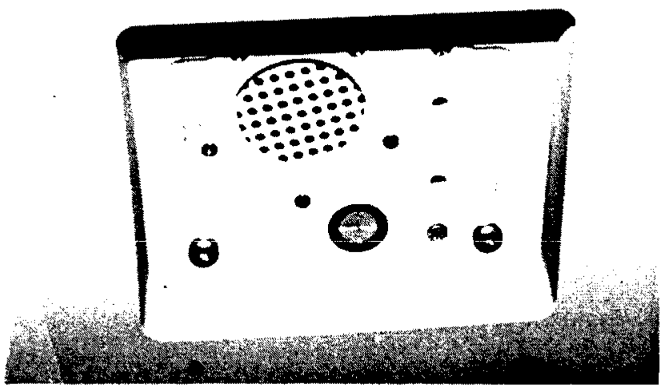
periods with no downlink capability or degraded downlink capability for playback when the capability is available. The HDRR dumps in reverse order at 2, 4, 8, 12, 16, 24, or 32 Mbps. At a rate of 32 Mbps, a tape runs for 20 minutes. The recorder can be changed manually by the flight crew; however, no 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.

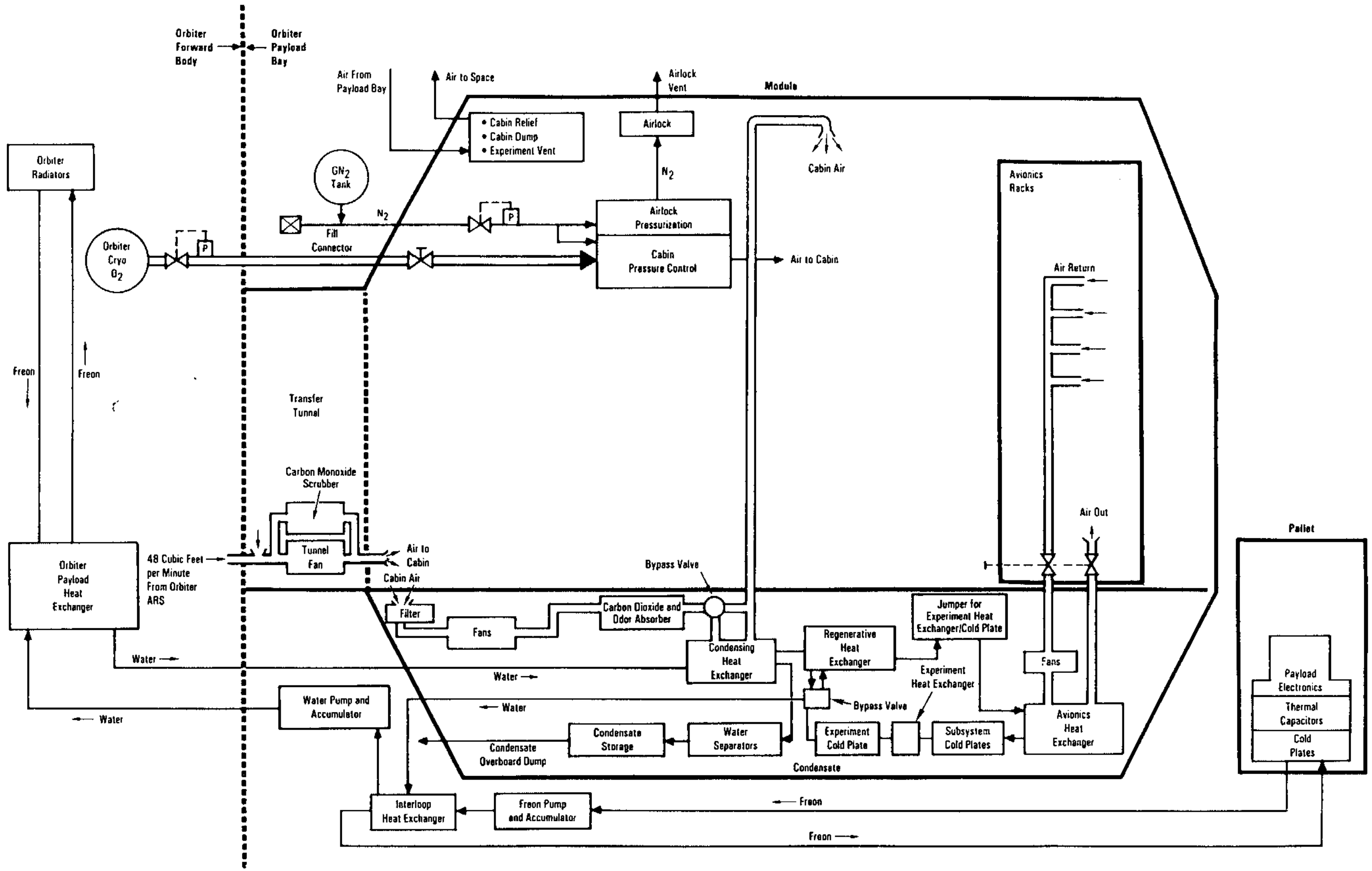
PRESSURIZED MODULE ENVIRONMENTAL CONTROL SUBSYSTEM AND LIFE SUPPORT

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

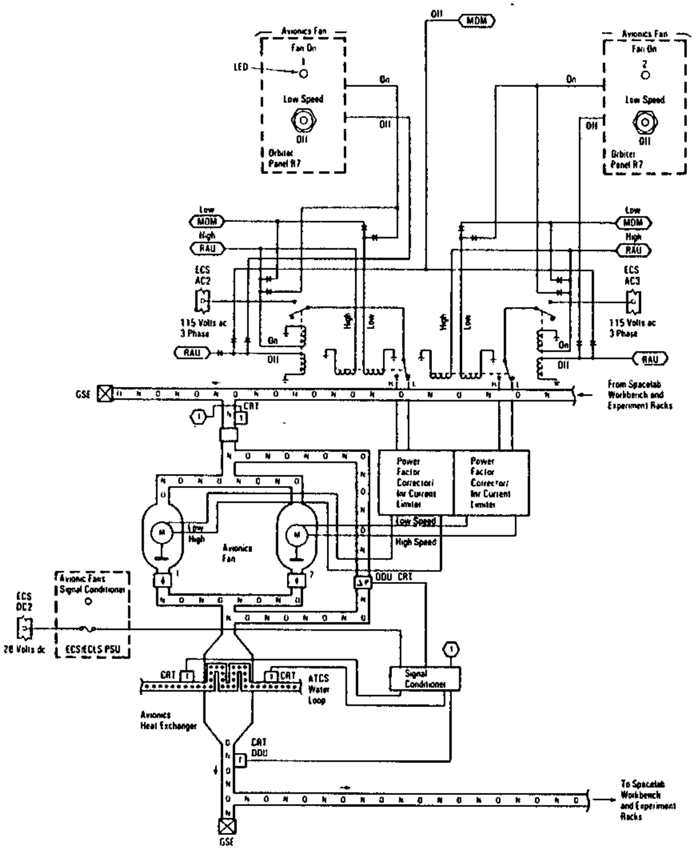
The atmosphere storage and control subsystem receives gaseous oxygen from the orbiter power reactant storage and distribution system and gaseous nitrogen from a tank located on the Spacelab module's exterior. The Spacelab ASCS regulates the gaseous oxygen and nitrogen pressure and flow rates to provide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

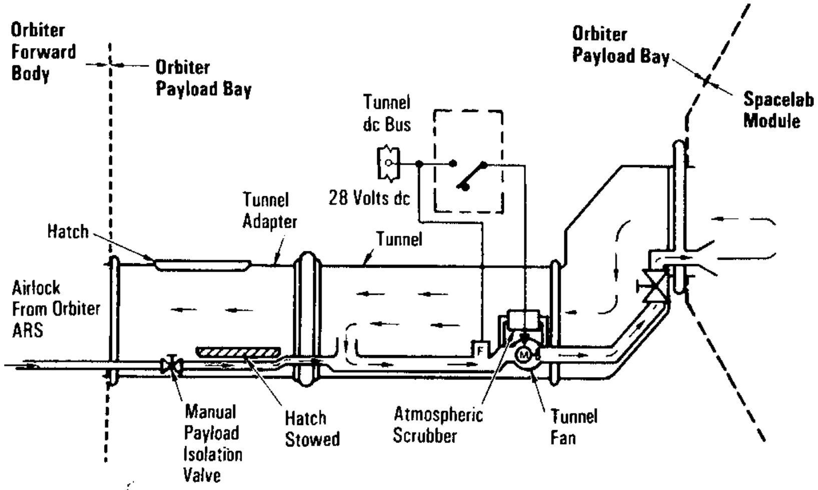
The fans are designed to switch from four-pole to eight-pole operation. The air flow through one fan is reduced from 1,923 to 639 pounds per hour, and the power is reduced from 643 to 110 watts. The two fans, powered by separate 115-volt ac buses, are activated and deactivated at low speed (eight-pole) 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.

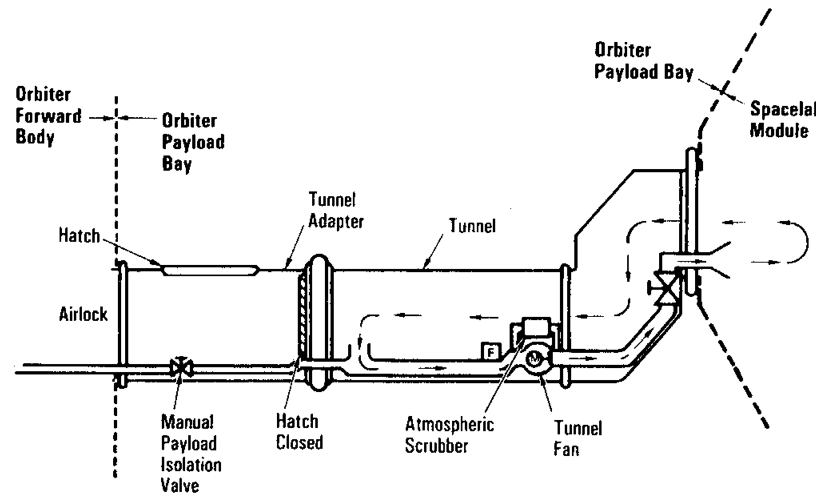
Pressurized Module/Tunnel Air Loop

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.

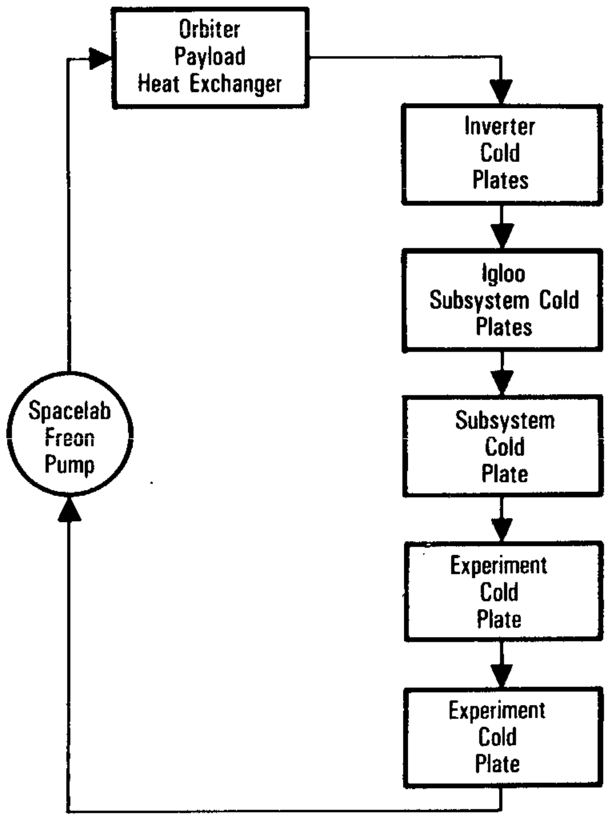
Two methods are provided for extinguishing a fire in the Spacelab module: discharging a fire suppressant into the affected area or dumping the Spacelab cabin atmosphere, when appropriate. The fire suppressant discharge consists of 15 orbiter-common fire suppression modules, each filled with the Freon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

ISRAEL SPACE AGENCY INVESTIGATION ABOUT HORNETS

Investigations have shown that the oriental hornet has the unique ability to build combs in the direction of gravity. When centrifugal force is used to simulate different directions of gravity, it becomes apparent that these forces are the only factor on Earth that determines the direction a comb is built. The ISAIAH experiment will research this phenomenon by testing the hornets' ability to orient their combs without the influence of gravity.

ISAIAH is stowed in one middeck locker and consists of two compartments. The front compartment contains electronics, a blower, two tape recorders, and front panel controls for the experiment. The back compartment contains 18 test chambers of various shapes and a metronome. The nine top chambers have lamps to simulate day and night, audio sensors, and food and water containers. The bottom chambers will remain in constant darkness when the experiment is inside the locker. Two lexan windows, one on the top and one on the bottom, will allow the crew to view, photograph, and videotape the experiment.

ISAIAH is sponsored by the Israel Space Agency. The hardware was developed by Israel Aircraft Industries International, Inc.

SOLID SURFACE COMBUSTION EXPERIMENT

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

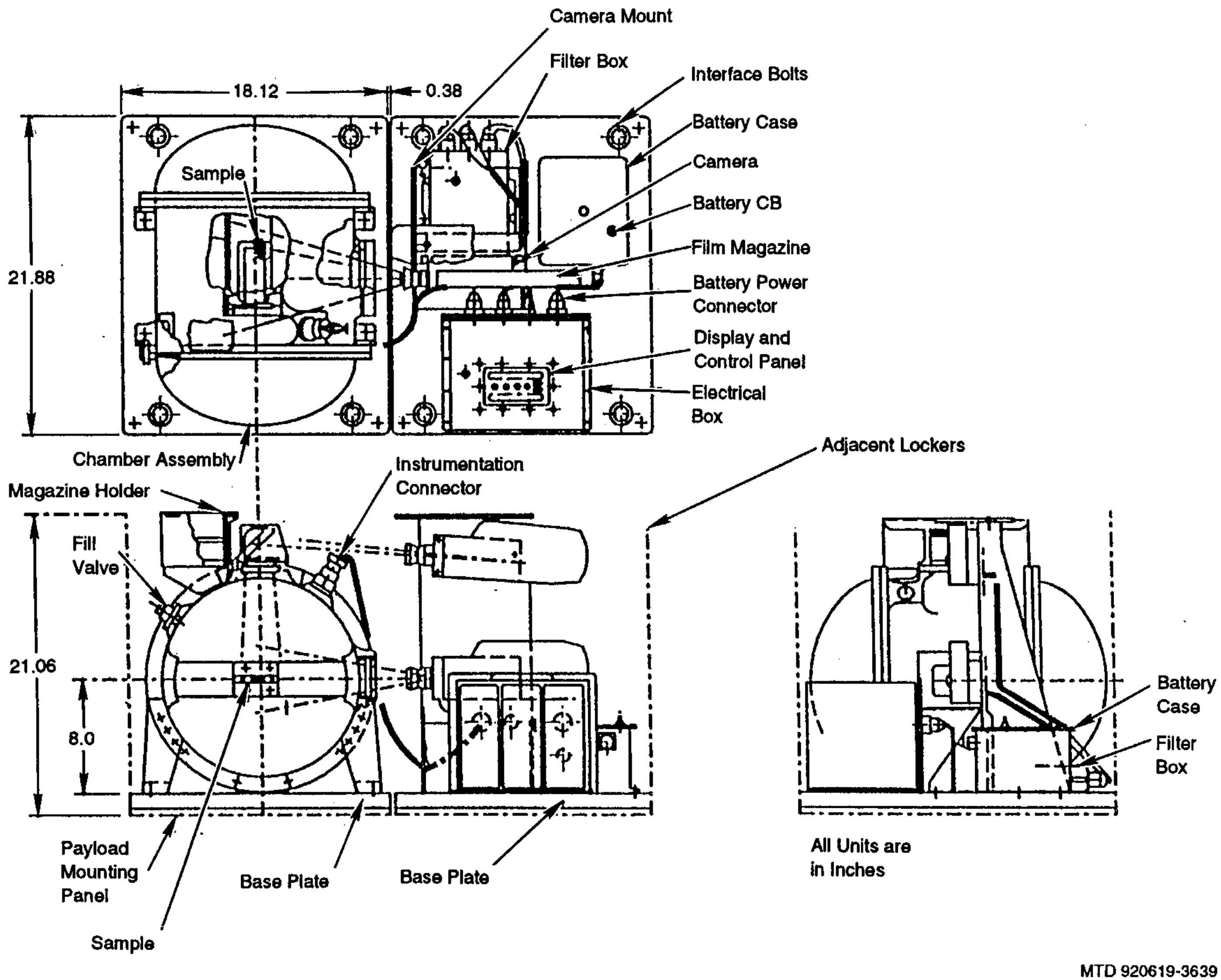
For this flight, ashless filter paper, internally mounted in a pressurized chamber, has been selected as the "thin" fuel source. Polymethyl-methacrylate will be used on later flights of SSCE to test "thick" fuel flame spread. These materials were chosen because extensive data bases already exist on their combustion in Earth's gravity, thereby permitting ready comparison of Earth and space combustion processes.

Scientists will test how flames spread along an instrumented filter paper sample in a test chamber containing 35-percent oxygen and 65-percent nitrogen at 1.5 atmospheric pressure. The four previous flights of SSCE used different levels of oxygen and pressure.

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

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

This is the fifth of eight planned SSCE flights. SSCE is managed by NASA's Lewis Research Center.



SSCE Configuration

GETAWAY SPECIAL PROGRAM

NASA's Getaway Special program, officially known as the Small, Self-Contained Payloads program, offers interested individuals or groups opportunities to fly small experiments aboard the space shuttle. To assure that diverse groups have access to space, NASA rotates payload assignments among three major categories of users: educational, foreign and commercial, and U.S. government.

Since the program was first announced in the fall of 1976, payloads have been reserved by foreign governments and individuals; U.S. industrialists, foundations, high schools, colleges and universities; professional societies; service clubs; and many others. Although persons and groups involved in space research have obtained many of the reservations, a large number of spaces have been reserved by persons and organizations outside the space community.

To date, 78 GAS cans have been flown on 18 missions. The GAS program began in 1982 and is managed by the Goddard Space Flight Center, Greenbelt, Md.

There are no stringent requirements to qualify for space flight. However, each payload must meet specific safety criteria and be screened for its propriety as well as its educational, scientific, or technological objectives. These guidelines preclude commemorative items, such as medallions, that are intended for sale as objects that have flown in space.

GAS requests must first be approved at NASA Headquarters in Washington, D.C., by the director of the Transportation Services Office. At that point NASA screens the propriety objectives of each request. To complete the reservation process for GAS payloads, each request must be accompanied or preceded by the payment of $500 earnest money.

Approved requests are assigned an identification number and referred to the GAS team at the Goddard Space Flight Center, the designated lead center for the project. The GAS team screens the proposals for safety and provides advice and consultation on payload design. It certifies that proposed payloads are safe and will not harm or interfere with the operations of the space shuttle, its crew, or other experiments on the flight. The costs of any physical testing required to answer safety questions before launch are borne by the GAS customer.

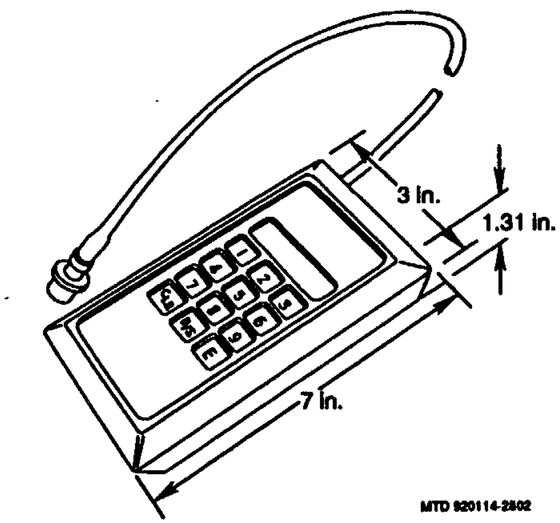
NASA's space shuttle program has specific standards and conditions relating to GAS payloads. Payloads must fit NASA standard containers and weigh no more than 200 pounds. However, two or more experiments may be included in a single container if they fit in it and do not exceed weight limitations. The payload must be self-powered and not draw on the shuttle orbiter's electricity. In addition, payload designs should consider that the crew's involvement with GAS payloads will be limited to six simple activities (such as turning on and off up to three payload switches) because crew activity schedules do not provide opportunities to either monitor or service GAS payloads in flight.

The cost of this unique service depends on the size and weight of the experiment. Getaway specials of 200 pounds and 5 cubic feet cost $10,000; 100 pounds and 2.5 cubic feet, $5,000; and 60 pounds and 2.5 cubic feet, $3,000. The weight of the GAS container, experiment mounting plate and its attachment screws, and all hardware regularly supplied by NASA is not charged to the experimenter's weight allowance.

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

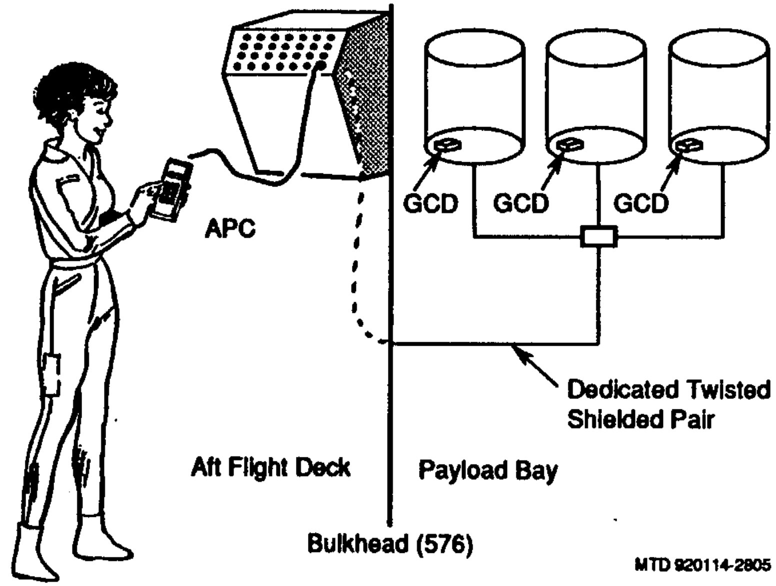
The GAS container is made of aluminum, and the circular end plates are 0.625-inch-thick aluminum. The bottom 3 inches of the container are reserved for NASA interface equipment, such as command decoders and pressure regulating systems. The container is a pressure vessel that can be evacuated before or during launch or on orbit and can be repressurized during reentry or on orbit, as required by the experimenter.

The getaway bridge, which is capable of holding 12 canisters, made its maiden flight on STS 61-C. The aluminum bridge fits across the payload bay of the orbiter and offers a convenient and economical way of flying several GAS canisters.



GAS Autonomous Payload Controller

For additional information about NASA's Getaway Special program contact the program manager, Code MC, NASA Headquarters, Washington, D.C. 20546. The primary contact for payload users is the technical liaison, Code 740, NASA Goddard Space Flight Center, Greenbelt, Md. 20771.



Getaway Special Control Concept

GETAWAY SPECIAL EXPERIMENTS

Nine getaway special payloads will be flown on this mission, including experiments from Sweden, France, Canada, England, and the United States. Ten GAS payloads were originally scheduled to fly on STS-47; however, one was cancelled due to technical difficulties. GAS ballast payloads will be used in its place and in the other two unused GAS canisters in the GAS bridge.

The seven experiments of payload G-102 were selected from 38 proposals that were submitted by Boy Scout Explorer posts. The experiments and their sponsors are as follows:

- Capillary pumping, developed by Explorer Post 9005 and sponsored by McDonnell Douglas Corp. of St. Louis, Mo.
- Cosmic ray, developed by Explorer Ship 101 and sponsored by the American Legion of Bridgeport, Conn.
- Crystal growth, developed by Post 310 and sponsored by Chesebrough Pond's Research Laboratory, Trumbull, Conn.
- Emulsions, developed by Post 475 and sponsored by Chesebrough Pond's Research Laboratory, Trumbull, Conn.
- Fiber optics, developed by Post 475 and sponsored by the Naval Avionics Center, Indianapolis, Ind.
- Floppy disk, developed by Post 1022 and sponsored by the Church of Jesus Christ of Latter Day Saints, Columbia, Md.
- Fluid droplets, developed by Post 822 and sponsored by Martin Marietta, Littleton, Colo.
- Command, power, and mechanical systems, designed by Post 1275 and sponsored by the Goddard Explorer Club of NASA's Goddard Space Flight Center, Greenbelt, Md.

Payload G-255, sponsored by the Kansas University Space Program, consists of three experiments. In the first experiment, enzymes will be crystalized. The second will study cell formations. The third will investigate the effects of space on the germination rates of seeds.

The G-300 GAS payload will study the thermal conductivity of fluids in space. The experiment will measure the conductivity of distilled water, which is used as a standard, and two silicone oils. The experiment hardware consists of a modified "hot plate" and a simplified guard ring to reduce heat loss.

This experiment is sponsored by Matra Marconi Space/ Laboratorie de Genie Electrique de Paris. It is the first French-sponsored experiment in the GAS program.

Payload G-330 will study the breakdown of a planar solid/liquid interface when the rate of growth goes from stable to unstable. A crystal will be grown from a sample of germanium doped with gallium in a gradient furnace, which controls the growth rate along the crystal.

The Swedish Space Corporation is the sponsor of this experiment.

The behavior of bread yeast in microgravity and normal atmospheric conditions will be compared in the G-482 experiment, which is sponsored by Spar Aerospace Ltd. of Canada. In this experiment, bread will be made from "scratch." After yeast is mixed with flour and water, the dough will be allowed to rise and will be baked.

Payload G-520 consists of two experiments designed by students at the Ashford School, Kent, England. The experiments won first place in a competition sponsored by a British television network.

In the first experiment, a few grams of cobalt nitrate crystals will be dropped into a solution of sodium silicate while a camera records the reaction for later study. In the other experiment, a chemical solution will be deposited on a gel made from a different compound, and a camera will record crystal growth over four days.

The G-521 payload (called the Queen's University Experiment on the Shuttle Transportation System, or QUESTS) consists of two types of furnaces. Twelve constant-temperature furnaces will be used to study diffusion in metals in the liquid state. Three other furnaces will be used to grow crystals by applying a uniform temperature gradient along the samples.

This payload is sponsored by the Canadian Space Agency.

Payload G-534 will attempt to learn more about the fundamental mechanisms of nucleate pool boiling. This NASA Lewis Research Center experiment will study heat transfer and vapor bubble dynamics that accompanies nucleation, bubble growth and collapse, and subsequent motion.

Payload G-613 will test an experimental cooling system designed by engineering students at the University of Washington. A device resembling a shower head will direct drops of water into a spinning bowl, which will collect the water for reuse. A micro heat pipe is also included in this payload as a smaller experiment.

SHUTTLE AMATEUR RADIO EXPERIMENT II

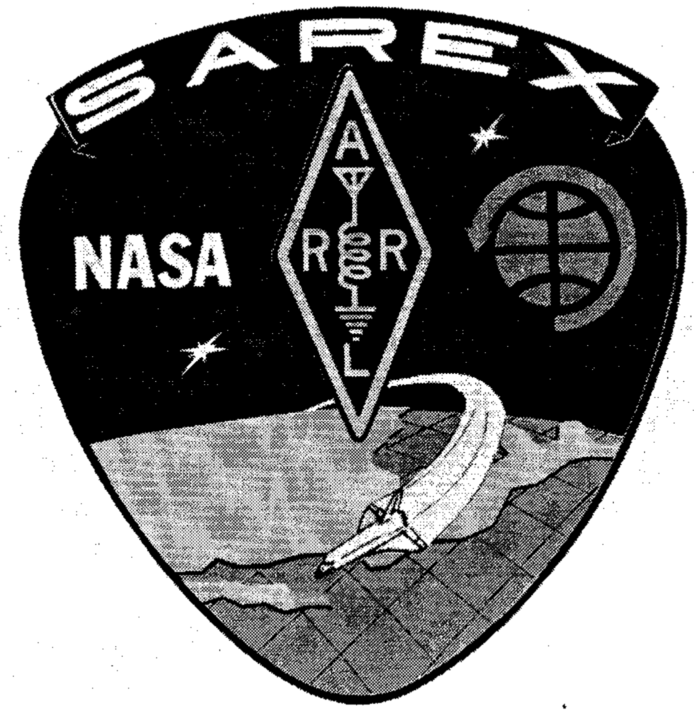
The Shuttle Amateur Radio Experiment (SAREX) was established by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club to encourage public participation in the space program through a program to demonstrate the effectiveness of conducting 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, and -50 in different configurations. STS-47 SAREX hardware consists of a low-power hand-held FM transceiver, a spare battery set, an interface module, a headset assembly, an equipment assembly cabinet, and an antenna that will be mounted in a forward flight deck side window. The equipment complement is stowed in one and one-half middeck lockers.

SAREX communicates with amateur stations within Endeavour'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 two licensed amateur radio operators who are members of the STS-47 crew: mission specialist Jay Apt (call sign N5QWL) and payload specialist Mamoru Mohri (call sign 7L2NJY).

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



SAREX Insignia

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 digital packet and VHF FM voice transmissions, a mode that makes contact widely available without the purchase of more expensive equipment. Several selected ground stations will also be able to send standard television to the crew via SAREX. The television uplink will be used to send video of the crew's families and the launch.

The primary frequencies intended for use during the missions are 145.55 MHz for downlink from Endeavour and 144.95 MHz, 144.91 MHz, and 144.97 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 144.70 MHz for uplink transmission.

STS-47 SAREX Operating Frequencies (MHz)

Location	Shuttle Transmission	Shuttle Reception
U.S., Africa	145.55	144.95
South America	145.55	144.97
and Asia	145.55	144.91
Europe	145.55	144.80 144.75 144.70
Goddard Amateur Radio Club operations*	3.860 14.295	7.185 21.395 28.395

*SAREX information and shuttle audio broadcasts

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 obrtained from the Johnson Space Center computer bulletin board (JSC BBS), 8 N1 1200 baud, by dialing (713) 483-2500 and then typing 62511.

Entry aerodynamic control surfaces test—alternate elevon schedule, Part 3 (DTO 251). The purpose of this DTO is to perform PTI maneuvers and one body flap maneuver during entry and TAEM. Aerodynamic response data will be used to evaluate 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.

Ascent compartment venting evaluation (DTO 305D). This DTO is intended solely to collect data to expand the data base for vent model verification.

Descent compartment venting evaluation (DTO 306D). The purpose of this DTO is to expand the data base to verify vent models.

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 (Methods 1 and 2) (DTO 312). This DTO will photograph the external tank after separation to determine TPS charring patterns, identify regions of TPS material spallation, and evaluate overall TPS performance.

Orbiter drag chute system (Test 2—deployed with nose gear up, first time) (DTO 521). This DTO will evaluate the orbiter drag chute system 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 will consist of three flights, with the first-flight drag chute deployment at or subsequent to nose gear touchdown, second-flight deployment at nose gear touchdown (incorporating delayed load relief), and third-flight deployment initiation at derotation. Upon completion of Phase I, the deceleration parachute will be operational for all vehicles. Phase II will consist of seven additional flights gradually increasing in speed from initiation at derotation of 185 knots equivalent air speed (KEAS) to initiation at 205 KEAS.

Cabin air monitoring (DTO 623). This DTO will use the solid sorbent sampler to sample the orbiter atmosphere continuously throughout the flight. The sampler collects trace levels of volatile contaminants, which are used to determine spacecraft air quality and the effectiveness of the ECLSS in removing these compounds from the air.

Water separator filter performance evaluation (DTO 647). This DTO will record for postflight evaluation the in-flight performance of a water separator filter currently being designed.

Cycle ergometer hardware evaluation (DTO 651). This DTO will evaluate the cycle ergometer as an alternative to the shuttle treadmill. Treadmill use has raised concerns about noise, vibration, subject discomfort, and inability to quantify work load. These concerns warrant evaluation of alternate in-flight exercise hardware. Vibration and physical discomfort will be documented, and biomedical analysis will be performed in conjunction with various protocols/work loads. Heart rate will be recorded for evaluation of the resistive work load settings in zero-g.

Foot restraint evaluation (DTO 655). The purpose of this DTO is to evaluate a new conceptual design for foot restraints. The crew will comment on ease of ingress/egress, pitch requirements, foot loop size and space, fit and comfort, and base plate size. The foot restraints will be used in the Spacelab module during experiment operations.

Acoustical noise dosimeter data (DTO 663). This DTO will gather baseline data with an audio dosimeter on the time-averaged acoustical noise levels for the middeck during day and night operation. Noise levels affect crew operations, performance, and health. Data is sought on middeck payloads, intermittent equipment noises, voice/communications, the new RCRS, the WCS, manned laboratory (when laboratories are flown), the three- or four-tier sleep station, and on the middeck during sleep periods when no "hard" sleep station is flown. This data will provide information to help determine new specification levels for intermittent noises as well as a maximum 24-hour exposure level.

Acoustical noise sound level data (DTO 665). This DTO will obtain baseline data of octave-band acoustical noise levels for the middeck and flight deck, exercise equipment, inside the four-tier sleep station, on the new regenerable carbon dioxide removal system, new galley, new waste collection system, and manned laboratory when labs are flown. A Spacelab analog sound level meter will be used.

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

Collection of shuttle humidity condensate for analytical evaluation (DSO 317). This DSO will characterize the content of the shuttle's humidity condensate both in quantity and composition. Condensate will be collected in a modified beverage container on four separate flight days and analyzed after the flight.

Evaluation of samples obtained from the urine monitoring system (DSO 323). The purpose of this DSO is to determine if in-flight dilution of urine samples differs from postflight ground dilution. It will also determine if middeck pressure changes affect volume measurements differently from those experienced in ground testing.

In-flight radiation dose distribution (TEPC only) (DSO 469). This DSO will measure the radiation at a thinly shielded region of the orbiter. The crew will attach devices to the right middeck wall soon after attaining orbit and stow the hardware as late as possible. The objective is to evaluate and verify methods for assessing and managing health risks from space radiation exposure.

Assessment of circadian shifting in astronauts by bright light (DSO 484). This DSO will determine the efficacy of bright light in facilitating preflight circadian shifting in astronauts who require atypical work-rest cycles during space flight. A total of 12 crew members from varying flights will be tested. The activity is scheduled before and after flights; there is no in-flight activity.

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 to develop and assess countermeasures that improve orthostatic tolerance upon return to Earth. This data will be used to determine whether precautions and countermeasures are needed to protect crew members in the event of an emergency egress. It will also be used to determine the effectiveness of proposed in-flight countermeasures. Crew members will don equipment prior to donning the LES during deorbit preparation. Equipment consists of a blood pressure monitor, accelerometers, an impedance cardiograph, and transcranial Doppler hardware. The crew member wears the equipment and records verbal comments throughout entry.

Air monitoring instrument evaluation and atmospheric characterization (DSO 611). DSO 611 is designed to evaluate and verify air monitoring equipment. The microbial air sampler (MAS) will be used to collect data on the contaminants that affect crew health and safety. Samples will be collected on an early, mid, and late flight day in the middeck and flight deck.

Energy utilization (DSO 612). DSO 612 will be used to develop, verify, and optimize appropriate countermeasures for maintaining crew entry, landing, and egress capabilities after extended-duration flights. This requires prevention of muscle atrophy, weight loss, and reduced nitrogen and potassium levels. Crew members will collect urine, saliva, blood, and ketone samples immediately upon wakeup for five flight days. A log of all exercise, food, and fluid intake will also be maintained.

Changes in the endocrine regulation of orthostatic tolerance following space flight (DSO 613). This DSO will characterize the extent and pattern of changes in plasma volume during space flights of up to 16 days. It will also determine whether resting levels of catecholamines (hormones such as adrenalin that provide a surge of energy to cope with emergency situations) are elevated immediately after flight and whether catecholamine release in response to varying degrees of orthostatic and cardiovascular stresses is impaired after space flight. There are no on-orbit activities for this DSO.

The effect of prolonged space flight on head and gaze stability during locomotion (DSO 614). The purpose of this DSO is to characterize preflight and postflight head and body movement along with gaze stability during walking, running, and jumping, all of which are relevant to egress from the shuttle. Changes in these parameters caused by the microgravity environment could impair a crew member's ability to perform an emergency egress from the vehicle. There are no on-orbit activities for this DSO.

Pre-/postflight measurement of cardiorespiratory response to submaximal exercise (DSO 624). DSO 624 will evaluate changes in aerobic capacity through submaximal exercise testing before and after the flight. These evaluations will help develop optimal exercise prescriptions to prevent decrements in nominal cardiorespiratory response. On orbit, crew members will don their heart watches during exercise and log exercise.

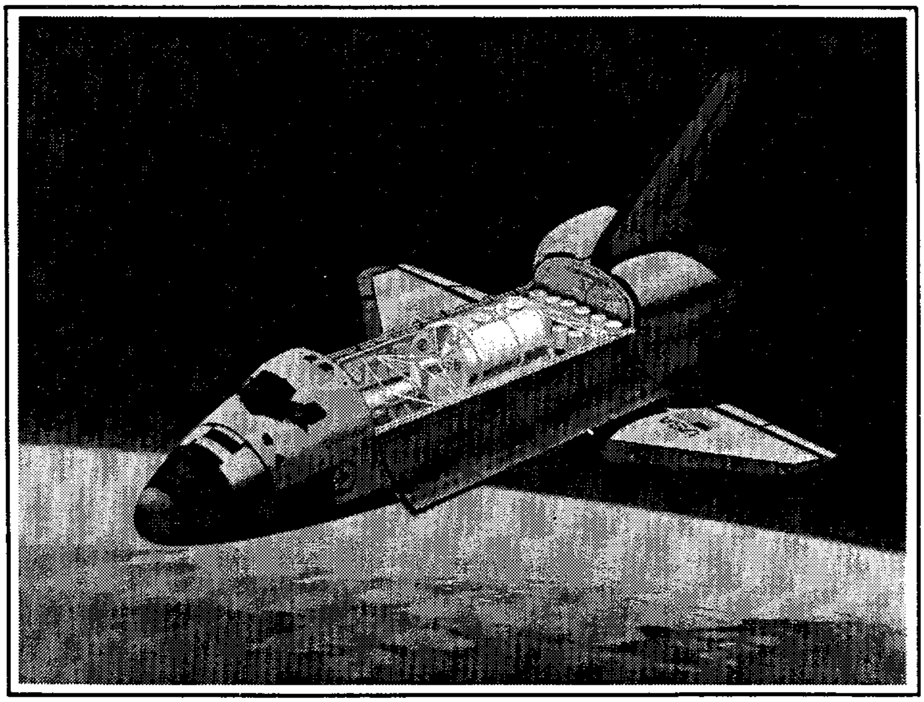
Educational activities (DSO 802). The purpose of this DSO is to use the attraction of space flight to capture the interest of students and motivate them toward careers in science, engineering, and mathematics. The DSO requires motion picture photography of crew presentations in the Spacelab module, the middeck, and/or the flight deck. Lesson topics include demonstration of microgravity characteristics as well as material and life science experiments.

Documentary television (DSO 901). This purpose of DSO 901 is to provide live television transmission or VTR dumps of crew activities and spacecraft functions: payload bay views, STS and payload bay activities, VTR downlink of crew activities, in-flight crew press conference, and unscheduled TV activities.

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 motion picture photography of Spacelab module activities, flight deck activities, middeck activities, and any unscheduled motion picture photography. This photography will provide 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 Spacelab as well as mission-related scenes of general public and historical interest. A 70mm format for exterior photography and 35mm format for interior photography will be used.

Assessment of human factors (DSO 904). This DSO will examine human factors during equipment transfer to and from the Spacelab module. Video will be obtained while the crew is moving through the Spacelab tunnel on flight days 1 and 8. Crew members will also complete a questionnaire during the mission.



STS-47

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

September 1992

Rockwell International
Space Systems Division

Office of External Communications &
Media Relations

CONTENTS

MISSION OVERVIEW

This is the 2nd flight of Endeavour and the 50th for the space shuttle.

The flight crew for the 7-day STS-47 mission is commander Robert L. "Hoot" Gibson; pilot Curtis (Curt) L. Brown, Jr.; payload commander (lead mission specialist) Mark C. Lee; mission specialists N. Jan Davis, Dr. Mae C. Jemison, and Jerome (Jay) Apt; and Japanese payload specialist Mamoru Mohri. Jemison is the first African American woman to fly in space, while Mohri is the first Japanese to fly aboard a NASA spacecraft. The crew will be divided into a blue team, consisting of Apt, Davis, and Jemison, and a red team, comprised of Brown, Lee, and Mohri. Gibson is not assigned to a team and is free to adjust his hours real-time as necessary. Each team will work consecutive 12-hour shifts, providing for around-the-clock operations.

STS-47's primary objective is to successfully perform the planned operations of the Spacelab J (Japan) laboratory; a joint venture between NASA and the National Space Development Agency (NASDA) of Japan.

Spacelab-J consists of 24 materials science and 19 life science investigations involving government, industry, and university sponsors in Japan and the U.S. The materials science experiments will study various materials and processes in microgravity, including protein crystals, electronic materials, fluids, glasses and ceramics, metals, and alloys. The life sciences experiments include cell separation, cell biology, developmental biology, animal and human physiology and behavior, space radiation, and biological rhythms. Thirty-four of the Spacelab J experiments are from Japan, seven are from the U.S., and two are conducted jointly between the two countries.

STS-47 secondary objectives include nine Getaway Special (GAS) experiments, the Israel Space Agency Investigation About Hornets (ISAIAH), Shuttle Amateur Radio Experiment (SAREX), and the Solid Surface Combustion Experiment (SSCE).

The nine GAS experiments mounted on the GAS bridge assembly include the following:

. G-102, sponsored by TRW's Defense and Space Systems Group, will investigate capillary pumping, cosmic rays, crystal growth, emulsion formation, fluid drop mechanics, floppy disks, and fiber optics.

. G-255, sponsored the the Kansas University Space Program, will investigate crystal growth, formation of cell membranes, and seed germination rates and health.

. G-300, sponsored by MATRA/General Electric Laboratory of Paris, will investigate thermal conductivity of distilled water and silicon oils.

. G-330, sponsored by the Swedish Space Corporation, will investigate the boundary of a melted, then re-solidified material.

. G-482, sponsored by Telesat Canada, will investigate the behavior of bread yeast in the absence of gravity.

. G-520, sponsored by Independent Television News of London, will investigate growth mechanisms of a chemical garden.

. G-521, sponsored by the National Research Council of Canada, Space Division, will investigate material melting and directional resolidification.

. G-534, sponsored by NASA's Lewis Research Center, will investigate the interrelationships between heat transfer, heat rate, buoyancy, momentum, and surface tension in microgravity

. G-613, sponsored by the University of Washington, will investigate fluid dyamics and heat pipe characteristics.

ISAIAH will test the unique ability of Oriental Hornets to build combs in the direction of gravity when subjected to a microgravity environment in order to gain greater insight into this phenomenon.

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 primary objective of SSCE is to supply information on flame spread over solid fuel surfaces in the reduced gravity environment of space. The experiment will measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds in low gravity. The data obtained will be used to validate flame spread models to improve fire safety during space flight. For this flight, ashless filter paper will serve as the fuel source. The samples are mounted in a pressurized chamber.

Fourteen detailed test objectives and fifteen detailed supplementary objectives are scheduled to be flown on STS-47.

MISSION STATISTICS

Vehicle: Endeavour (OV-105), 2nd flight

Launch Date/Time:

9/12/92 10:23 a.m., EDT
9:23 a.m., CDT
7:23 a.m., PDT

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

Launch Window: 2 hours, 30 minutes (crew-on-back constraint)

Launch Period: 3 hours, 54 minutes

Mission Duration: 6 days, 20 hours, 36 minutes

Landing: Nominal end-of-mission landing on orbit 110

9/19/92 6:59 a.m., EDT
5:59 a.m., CDT
3:59 a.m., PDT

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

Transatlantic Abort Landing: Zaragoza, Spain; alternates: Ben Guerir, Morocco; Moron, Spain

Return to Launch Site: KSC

Abort-Once-Around: NOR

Inclination: 57 degrees

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

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

Altitude: 163 nautical miles (188 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 100 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2026
No. 2 position: Engine 2022
No. 3 position: Engine 2029

External Tank: ET-45

Solid Rocket Boosters: BI-053

Editor's Note: The following weight data are current as of September 2, 1992.

Total Lift-off Weight: Approximately 4,506,649 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 244,413 pounds

Orbiter (Endeavour) Empty, and 3 SSMEs: Approximately 172,781 pounds

Payload Weight Up: Approximately 28,158 pounds

Payload Weight Down: Approximately 28,158 pounds

Orbiter Weight at Landing: Approximately 219,327 pounds

Payloads--Payload Bay (* denotes primary payload): Spacelab J*, nine Getaway Special (GAS) canister experiments

Payloads--Middeck: Israel Space Agency Investigation About Hornets (ISAIAH), Shuttle Amateur Radio Experiment (SAREX) II, Solid Surface Combustion Experiment (SSCE)

Flight Crew Members:

Commander: Robert L. "Hoot" Gibson, fourth space shuttle flight

Red Team:

Pilot: Curtis (Curt) L. Brown, Jr., first space shuttle flight
Mission Specialist 1: Mark. C. Lee, second space shuttle flight
Payload Specialist 1: Mamoru Mohri, Japan, first space shuttle flight

Blue Team:

Mission Specialist 2: Jerome (Jay) Apt, second space shuttle flight
Mission Specialist 3: N. Jan Davis, first space shuttle flight
Mission Specialist 4: Dr. Mae C. Jemison, first space shuttle flight

Ascent Seating:

Flight deck, front left seat, commander Robert L. "Hoot" Gibson
Flight deck, front right seat, pilot Curtis (Curt) L. Brown, Jr.
Flight deck, aft center seat, mission specialist Jerome (Jay) Apt
Flight deck, aft right seat, mission specialist Mark C. Lee
Middeck, mission specialist N. Jan Davis
Middeck, mission specialist Dr. Mae C. Jemison
Middeck, payload specialist Mamoru Mohri

Descent Seating:

Flight deck, front left seat, commander Robert L. "Hoot" Gibson
Flight deck, front right seat, pilot Curtis (Curt) L. Brown, Jr.
Flight deck, aft center seat, mission specialist Jerome (Jay) Apt
Flight deck, aft right seat, mission specialist N. Jan Davis
Middeck, mission specialist Mark C. Lee
Middeck, mission specialist Dr. Mae C. Jemison
Middeck, payload specialist Mamoru Mohri

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: Jerome (Jay) Apt
EV-2: N. Jan Davis

Intravehicular Astronaut: Curtis (Curt) L. Brown, Jr.

STS-47 Flight Directors:

Ascent, Entry: Wayne Hale
Orbit 1 Team: Al Pennington
Orbit 2 Team/Lead: Milt Heflin
Orbit 3 Team: Linda Ham

Entry: Automatic mode until subsonic, then control stick steering

Notes:

. The remote manipulator system is installed in Endeavour's payload bay for this mission

. The galley is installed in Endeavour's middeck

MISSION OBJECTIVES

. Primary Objective
  - Spacelab J operations
. Secondary Objectives
  - Middeck
    . Israel Space Agency Investigation About Hornets (ISAIAH)
    . Shuttle Amateur Radio Experiment (SAREX) II
    . Solid Surface Combustion Experiment (SSCE)
  - Payload Bay
    . Nine Getaway Special (GAS) Experiments
. Development Test Objectives/Detailed Supplementary Objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Unstow cabin
Spacelab activation
Payload activation

Flight Days 2-7

Spacelab operations

Flight Day 7

RCS hot-fire test
FCS checkout

Flight Day 8

Cabin stow
Spacelab deactivation
Deorbit preparation
Deorbit burn
Landing

Notes:

. 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.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

. Entry aerodynamic control surfaces test -- alternate elevon schedule, part 3 (DTO 251)
. Ascent structural capability evaluation (DTO 301D)
. Ascent compartment venting evaluation (DTO 305D)
. Descent compartment venting evaluation (DTO 306D)
. Entry structural capability evaluation (DTO 307D)
. ET TPS performance (method 1 & 2) (DTO 312)
. Orbiter drag chute system (test 2--deployed with nose gear up-first time) (DTO 521)
. Cabin air monitoring (DTO 623)
. Water separator filter performance evaluation (DTO 647)
. Cycle ergometer hardware evaluation (DTO 651)
. Foot restraint evaluation (DTO 655)
. Acoustical noise dosimeter data (DTO 663)
. Acoustical noise sound level data (DTO 665)
. Crosswind landing performance (DTO 805)

DSOs

. Collection of shuttle humidity condensate for analytical evaluation (DSO 317)
. Evaluation of samples obtained from the urine monitoring system (DSO 323)
. In-flight radiation dose distribution (TEPC only) (DSO 469)
. Assessment of circadian shifting by bright light in astronauts (DSO 484)
. Orthostatic function during entry, landing, and egress (DSO 603B)
. Air monitoring instrument evaluation and atmospheric characterization (DSO DSO 611)
. Energy utilization (DSO 612)
. Changes in the endocrine regulation of orthostatic tolerance during space flight (DSO 613)
. The effect of prolonged space flight on head and gaze stability during locomotion (DSO 614)
. Pre-postflight measurement of cardiorespiratoryu response to submaximal exercise (DSO 624)
. Educational activities (DSO 802)
. Documentary television (DSO 901)
. Documentary motion picture photography (DSO 902)
. Documentary still photography (DSO 903)
. Assessment of human factors (DSO 904)

STS-47 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-47 MISSION HIGHLIGHTS TIMELINE

Editor's Note: The following timeline lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-47 Flight Plan, Ascent Checklist, Post Insertion Checklist, Deorbit Prep Checklist, and Entry Checklist.

Spacelab-J experiments are listed by either acronym or experiment number. Please refer to the Glossary (page 49) for titles.

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 (astronauts), wings level.
0/00:00:19	Roll maneuver ends.
0/00:00:28	All three SSMEs throttle down from 100 to 67 percent for maximum aerodynamic load (max q).
0/00:01:00	All three SSMEs throttle to 104 percent.
0/00:01:05	Max q occurs.
0/00:02:04	SRBs separate.
	When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration.

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.
0/00:04:05	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.
0/00:08:34	MECO occurs at approximate velocity 25,830 feet per second, 16 by 158 nautical miles (18 by 182 statute miles).
0/00:08:52	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.
0/00:36	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 42 seconds in duration, at 264 fps, 163 by 163 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS)/payload specialist (PS) 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.
0/01:19	If go for payload bay door operations, MS configures for payload bay door operations.
0/01:27	Orbit 2 begins.
0/01:28	MS opens payload bay doors.
0/01:33	Commander switches star tracker (ST) 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.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:54	ISAIAH activation.
0/01:55	MS/PS remove and stow seats.
0/01:56	Commander starts ST self-test and opens door.
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 informs crew to "go for Spacelab activation."
0/02:12	Commander, pilot configure controls for on-orbit.
0/02:15	MS, PS begin Spacelab activation.
0/02:20	MS performs on-orbit initialization.
0/02:21	MS enables hydraulic thermal conditioning.
0/02:26	MS resets caution/warning (C/W).
0/02:28	Pilot plots fuel cell performance.
0/02:30	Blue team begins presleep activities.
0/02:50	Priority Group B powerdown.
0/02:57	Orbit 3 begins.
0/03:12	Spacelab ingress.
0/03:30	Blue team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:40	IMU alignment: ST.
0/03:40	Red Team begins Spacelab Flight Day 1 activities (M23, L7, PCG, M12, FEE, L5, L12, L11, LBNP, L1, L6, PMS, BCR, M21, SAMS).
0/03:45	COAS calibration.
0/03:50	Maneuver vehicle to -ZLV, -YVV attitude.
0/04:15	DSO 469--radiation dose distribution.
0/04:28	Orbit 4 begins.
0/04:40	DTO 665--acoustical noise sound level data.
0/04:45	Payload activation.
0/05:30	COAS calibration--forward station.
0/05:35	Maneuver orbiter to Spacelab J attitude: -XLV, +YVV.
0/05:58	Orbit 5 begins.
0/07:28	Orbit 6 begins.
0/08:20	DTO 623--cabin air monitoring.
0/08:50	DSO 611--air monitoring instrument evaluation.
0/08:58	Orbit 7 begins.
0/09:15	Red team begins presleep activities.
0/10:00	Blue team begins postsleep activities.
0/10:15	Red team handover to blue team.
0/10:30	Orbit 8 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/11:00	Red team begins sleep period.
0/11:00	Blue team begins Spacelab Flight Day 2 activities (AFTE, M12, M11, M19, L7, M27, M01, L9, LBNP, M14, FEE).
0/12:00	Orbit 9 begins.
0/13:00	Group A Getaway Special Experiments.
0/13:30	Group B Getaway Special Experiments.
0/13:31	Orbit 10 begins.
0/14:15	SAREX setup.
0/14:45	SAREX packet operations.
0/15:01	Orbit 11 begins.
0/15:40	Group C Getaway Special experiments.
0/16:32	Orbit 12 begins.
0/18:02	Orbit 13 begins.
0/19:00	Red team begins postsleep activities.
0/19:33	Orbit 14 begins.
0/20:00	Red team begins Spacelab Flight Day 2 activities (L1, PMS, L4, L10, L2, BCR, PCG, SAMS, M18, FEE, L7, L6, L9, L12).
0/20:20	SAREX operations--Launceston, Australia.
0/21:04	Orbit 15 begins.
0/21:30	Blue team handover to red team.
0/21:45	SAREX operations--South Perth, Australia.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/21:50	IMU alignment: ST.
0/22:00	SAREX operations.
0/22:00	Blue team begins presleep activities.
0/22:30	ISAIAH observations.
0/22:34	Orbit 16 begins.

MET DAY ONE

1/00:05	Orbit 17 begins.
1/00:30	Blue team begins sleep period.
1/01:35	Orbit 18 begins.
1/03:05	Orbit 19 begins.
1/03:10	SAREX operations--Scotts Valley, California.
1/04:36	Orbit 20 begins.
1/06:00	Begin waste dump.
1/06:07	Orbit 21 begins.
1/07:15	DTO 623--cabin air monitoring.
1/07:30	Terminate waste dump.
1/07:37	Orbit 22 begins.
1/07:45	DTO 663 setup--acoustic dosimeter.
1/08:30	Blue team begins postsleep activities.
1/08:30	DSO 612--energy utilization.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/09:07	Orbit 23 begins.
1/09:45	Red team handover to blue team.
1/10:15	Red team begins presleep activities.
1/10:15	Blue team begins Spacelab J Flight Day 3 activities (AFTE, M01, M04, FEE, M13, SAMS, L7, LBNP, M25, L9).
1/10:38	Orbit 24 begins.
1/11:45	IMU alignment: ST.
1/11:45	Red team begins sleep period.
1/12:08	Orbit 25 begins.
1/12:30	DSO 612--energy utilization.
1/13:00	SAREX operations.
1/13:38	Orbit 26 begins.
1/14:30	Group D Getaway Specials.
1/15:09	Orbit 27 begins.
1/16:40	Orbit 28 begins.
1/18:10	Orbit 29 begins.
1/19:41	Orbit 30 begins.
1/19:45	DSO 612--energy utilization.
1/19:45	Red team begins postsleep activities.
1/20:30	SAREX operations--Adelaide, Australia.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/21:12	Orbit 31 begins.
1/21:15	Blue team handover to red team.
1/21:30	Blue team begins presleep activities.
1/22:00	IMU alignment: ST.
1/22:10	DTO 651--exercise.
1/22:15	DTO 663--acoustic dosimeter.
1.22:40	DTO 651--exercise.
1/22:42	Orbit 32 begins.
1/23:00	Red team begins Spacelab Flight Day 3 activities (M21, L2, L0, L1, M02, PCG, SAMS, FEE, L7, L9, M22, L6).
1/23:45	DSO 612--energy utilization.
1/23:30	Blue team begins sleep period.

MET DAY TWO

2/00:13	Orbit 33 begins.
2/00:30	ISAIAH observations.
2/01:00	DSO 317--humidity separation collection.
2/01:43	Orbit 34 begins.
2/02:00	DSO 317 operations.
2/02:50	DSO 317 operations.
2/03:13	Orbit 35 begins.
2/04:00	DSO 317 operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/04:44	Orbit 36 begins.
2/05:00	DSO 317 stow.
2/05:45	DTO 647--filter installation.
2/06:14	Orbit 37 begins.
2/06:55	DTO 623--cabin air monitoring.
2/07:05	DTO 663--acoustic dosimeter.
2/07:20	DTO 647 performance evaluation.
2/07:30	Blue team begins postsleep activities.
2/07:30	DSO 612--energy utilization.
2/07:45	Orbit 38 begins.
2/08:05	DTO 647 performance evaluation.
2/08:50	DTO 647 performance evaluation.
2/09:00	Red team handover to blue team.
2/09:15	Red team begins presleep activities.
2/09:15	Blue team begins Spacelab Flight Day 4 activities (AFTE, L8, M15, LBNP, L9, SAMS, M22, L7, FEE).
2/09:15	Orbit 39 begins.
2/10:46	Orbit 40 begins.
2/11:30	Red team begins sleep period.
2/11:40	IMU alignment: ST.
2/12:00	SAREX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/12:17	Orbit 41 begins.
2/13:47	Orbit 42 begins.
2/15:17	Orbit 43 begins.
2/16:47	Orbit 44 begins.
2/17:30	Group E Getaway Specials.
2/18:18	Orbit 45 begins.
2/19:15	SAREX operations--Launceston, Australia backup.
2/19:30	Red team begins postsleep activities.
2/19:30	DSO 612--energy utilization.
2/19:45	DTO 651--exercise.
2/19:49	Orbit 46 begins.
2/20:45	Blue team begins presleep activities.
2/21:00	Blue team handover to red team.
2/21:19	Orbit 47 begins.
2/21:30	Red team begins Spacelab Flight Day 4 activities (BCR, L0, M17, L4, L10, L2, L5, SAMS, M12, L7, L6).
2/22:05	DTO 663--acoustic dosimeter.
2/22:50	Orbit 48 begins.
2/23:15	DTO 647--water separator filter performance evaluation.
2/23:30	Blue team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/23:40	IMU alignment: ST.

MET DAY THREE

3/00:20	Orbit 49 begins.
3/00:30	ISAIAH observations.
3/01:15	DSO 611--MAS.
3/01:51	Orbit 50 begins.
3/01:55	DTO 663--acoustic dosimeter.
3/03:21	Orbit 51 begins.
3/04:52	Orbit 52 begins.
3/06:22	Orbit 53 begins.
3/06:40	DTO 623--cabin air monitoring.
3/06:50	DTO 663--acoustical noise dosimeter.
3/07:10	DTO 647--water separator filter performance evaluation.
3/07:30	Blue team begins postsleep activities.
3/07:30	DSO 612--energy utilization.
3/07:53	Orbit 54 begins.
3/08:00	Red team begins presleep activities.
3/08:30	Red team handover to blue team.
3/09:15	Blue team begins Spacelab Flight Day 5 activities (LBNP, M12, M05, BCR, M06, L7, L9).
3/09:23	Orbit 55 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/10:00	DTO 665--SLM.
3/10:30	SAREX operations.
3/10:30	Red team begins sleep period.
3/10:53	Orbit 56 begins.
3/11:55	IMU alignment: ST.
3/12:00	DTO 665--SLM.
3/12:24	Orbit 57 begins.
3/12:50	SAREX operations--Honolulu, Hawaii.
3/13:00	DTO 665--SLM.
3/13:54	Orbit 58 begins.
3/15:25	Orbit 59 begins.
3/16:55	Orbit 60 begins.
3/17:50	SAREX operations.
3/18:26	Orbit 61 begins.
3/18:30	DSO 612--energy utilization.
3/18:30	Red team begins postsleep activities.
3/19:56	Orbit 62 begins.
3/20:00	Blue team handover to red team.
3/20:15	Blue team begins presleep activities.
3/20:30	Red team begins Spacelab Flight Day 5 activities (M09, SAMS, M32, L2, FEE, M20, L7, L5, L6).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/21:27	Orbit 63 begins.
3/21:45	DTO 663--acoustic dosimeter.
3/22:05	DTO 665--SLM.
3/22:30	Blue team begins sleep period.
3/22:40	IMU alignment: ST.
3/22:57	Orbit 64 begins.
3/23:00	SAREX operations--Cary, North Carolina.
3/23:35	DTO 647--water separator filter performance evaluation.

MET DAY FOUR

4/00:28	Orbit 65 begins.
4/00:30	ISAIAH observations.
4/01:30	DSO 317--humidity separation collection.
4/01:58	Orbit 66 begins.
4/02:00	SAREX operations--Scotts Valley, California.
4/02:45	DSO 317 observations.
4/03:29	Orbit 67 begins.
4/03:45	DSO 317 observations.
4/04:00	Waste dump initiation.
4/04:10	Manual fuel cell purge.
4/04:45	DSO 317 observations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/04:59	Orbit 68 begins.
4/05:15	DTO 623--cabin air monitoring.
4/05:30	Waste dump termination.
4/05:45	DSO 317 stow.
4/06:00	DTO 647--water separator filter performance evaluation.
4/06:15	DTO 663--acoustic dosimeter.
4/06:30	Orbit 69 begins.
4/06:30	Blue team begins postsleep activities.
4/06:30	DSO 612--energy utilization.
4/06:45	Red team begins presleep activities.
4/07:30	Red team handover to blue team.
4/08:00	Orbit 70 begins.
4/08:30	Blue team begins Spacelab Flight Day 6 activities (M10, M20, LBNP, SAMS, L7, L9, M08).
4/08:45	SSCE activation.
4/09:15	Red team begins sleep period.
4/09:31	Orbit 71 begins.
4/10:25	SAREX operations.
4/10:40	IMU alignment: ST.
4/11:02	Orbit 72 begins.
4/12:32	Orbit 73 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/13:00	SAREX operations--Honolulu, Hawaii.
4/14:02	Orbit 74 begins.
4/15:33	Orbit 75 begins.
4/16:45	Group F Getaway Specials.
4/17:03	Orbit 76 begins.
4/17:15	Red team begins postsleep activities.
4/17:15	DSO 612--energy utilization.
4/18:33	Orbit 77 begins.
4/19:10	Red team begins Spacelab Flight Day 6 activities (L0, L2, SAMS, M08, M03, M16, L5, L7, L6).
4/19:15	SAREX operations.
4/19:25	SAREX operations--Adelalide, Australia.
4/19:40	Blue team handover to red team.
4/19:55	Crew press conference.
4/20:05	Orbit 78 begins.
4/20:15	Blue team begins presleep activities.
4/21:15	DTO 663--acoustic dosimeter.
4/21:35	Orbit 79 begins.
4/22:30	Blue team begins sleep period.
4/22:35	IMU alignment: ST.
4/23:05	Orbit 80 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/23:10	SAREX operations--Cary, North Carolina.
4/23:30	DTO 647--water separator filter performance evaluation.
4/23:45	DSO 317--humidity separation.

MET DAY FIVE

5/00:36	Orbit 81 begins.
5/01:00	DSO 317 observations.
5/01:30	ISAIAH observations.
5/02:00	DSO 317 observations.
5/02:07	Orbit 82 begins.
5/03:00	DSO 317 observations.
5/03:15	DTO 663--acoustical noise dosimeter.
5/03:37	Orbit 83 begins.
5/03:50	DSO 317 stow.
5/04:00	DTO 647 filter removal.
5/05:00	Red team begins presleep activities.
5/05:05	DTO 623--cabin air monitoring.
5/05:07	Orbit 84 begins.
5/06:30	Blue team begins postsleep activities.
5/06:30	DSO 612--energy utilization.
5/06:38	Orbit 85 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/07:00	Red team handover to blue team.
5/07:45	Red team begins sleep period.
5/08:08	Orbit 86 begins.
5/08:15	Blue team begins Spacelab Flight Day 7 activities (M26, LBNP, M07, SAMS, FTS, M07, L7, L9, BCR).
5/09:15	IMU alignment: ST.
5/09:38	Orbit 87 begins.
5/11:09	Orbit 88 begins.
5/12:00	SAREX operations.
5/12:39	Orbit 89 begins.
5/14:10	Orbit 90 begins.
5/15:40	Orbit 91 begins.
5/15:45	Red team begins postsleep activities.
5/15:45	DSO 612--energy utilization.
5/16:45	Red team begins Spacelab Flight Day 7 activities (BCR, L0, L1, M17, L2, L4, L10, PCG, SAMS, L12, L9, L11, M23, L5, L6).
5/17:11	Orbit 92 begins.
5/17:50	SAREX operations--Sydney, Australia.
5/18:00	DTO 663--acoustic dosimeter.
5/18:30	Blue team handover to red team.
5/18:41	Orbit 93 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/18:45	FCS checkout.
5/20:10	SAREX packet operations.
5/20:12	Orbit 94 begins.
5/20:15	Blue team begins presleep activities.
5/21:10	IMU alignment: ST.
5/21:42	Orbit 95 begins.
5/22:30	Blue team begins sleep period.
5/23:13	Orbit 96 begins.

MET DAY SIX

6/00:00	DSO 317--humidity separator collection.
6/00:43	Orbit 97 begins.
6/01:00	DSO 317 observations.
6/01:20	Group G Getaway Specials.
6/02:00	DSO 317 observations.
6/02:13	Orbit 98 begins.
6/02:30	DTO 663--acoustic dosimeter.
6/02:40	DSO 611--MAS.
6/03:00	DSO 317 observations.
6/03:30	ISAIAH observations.
6/03:43	Orbit 99 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/04:00	DSO 317 stow.
6/04:20	DTO 623--cabin air monitoring.
6/05:15	Orbit 100 begins.
6/05:45	TEPC stow (DSO 469--radiation).
6/06:00	Red team begins presleep activities.
6/06:30	Blue team begins postsleep activities.
6/06:45	Orbit 101 begins.
6/07:00	Red team handover to blue team.
6/07:45	Red team begins sleep period.
6/08:15	Orbit 102 begins.
6/08:15	Blue team begins Spacelab Flight Day 8 operations (L7, FEE, L0, SAMS, M21, L1).
6/08:45	SAREX powerdown.
6/08:50	SAREX stow.
6/09:30	IMU alignment: ST.
6/09:30	Cabin stow.
6/09:46	Orbit 103 begins.
6/11:15	Priority Group B powerup.
6/11:16	Orbit 104 begins.
6/12:30	Spacelab deactivation.
6/12:47	Orbit 105 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/13:25	Spacelab egress.
6/13:45	Red team begins postsleep activities.
6/14:00	Maneuver vehicle to -XSI attitude.
6/14:17	Orbit 106 begins.
6/14:50	DSO 603B entry preparation--orthostatic function.
6/15:20	RCS hot fire.
6/15:36	Begin deorbit preparation.
6/15:41	CRT timer setup.
6/15:41	Commander initiates coldsoak.
6/15:47	Orbit 107 begins.
6/15:50	Stow radiators, if required.
6/16:08	Commander configures DPS for deorbit preparation.
6/16:11	Mission Control Center updates IMU star pad, if required.
6/16:20	MS configures for payload bay door closure.
6/16:29	Ku-band antenna stow.
6/16:42	MCC-H gives "go/no-go" command for payload bay door closure.
6/16:48	Maneuver vehicle to IMU alignment attitude.
6/16:56	IMU alignment/payload bay door operations.
6/17:17	Orbit 108 begins.
6/17:19	MCC gives the crew the go for OPS 3.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/17:26	Pilot starts repressurization of SSME systems.
6/17:30	Commander and pilot perform DPS entry configuration.
6/17:39	MS deactivates ST and closes ST doors.
6/17:41	All crew members verify entry payload switch list.
6/17:56	All crew members perform entry review.
6/17:58	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
6/18:11	Commander and pilot configure clothing.
6/18:26	MS/PS configure clothing.
6/18:36	Commander and pilot seat ingress.
6/18:38	Commander and pilot set up heads-up display (HUD).
6/18:40	Commander and pilot adjust seat, exercise brake pedals.
6/18:48	Orbit 109 begins.
6/18:48	Final entry deorbit update/uplink.
6/18:54	OMS thrust vector control gimbal check is performed.
6/18:56	APU prestart.
6/19:11	Close vent doors.
6/19:17	MCC-H gives "go" for deorbit burn period.
6/19:21	Maneuver vehicle to deorbit burn attitude.
6/19:22	MS/PS ingress seats.
6/19:31	First APU is activated.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/19:36	Deorbit burn.
6/19:40	Initiate post-deorbit burn period attitude.
6/19:44	Terminate post-deorbit burn attitude.
6/19:52	Dump forward RCS, if required.
6/20:00	Activate remaining APUs.
6/20:04	Entry interface, 400,000 feet altitude.
6/20:08	Enter communication blackout.
6/20:09	Automatically deactivate RCS roll thrusters.
6/20:16	Automatically deactivate RCS pitch thrusters.
6/20:19	Orbit 110 begins.
6/20:20	Initiate PTIs.
6/20:25	Initiate first roll reversal.
6/20:26	Exit communications blackout.
6/20:27	Initiate second roll reversal.
6/20:28	Initiate air data system (ADS) probe deploy.
6/20:28	Terminate PTIs.
6/20:29	Initiate third roll reversal.
6/20:29	Begin entry/terminal area energy management (TAEM).
6/20:30	Initiate payload bay venting.
6/20:32	Automatically deactivate RCS yaw thrusters.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/20:35	Begin TAEM/approach/landing (A/L) interface.
6/20:35	Initiate landing gear deployment.
6/20:36	Vehicle has weight on main landing gear.
6/20:36	Vehicle has weight on nose landing gear.
6/20:36	Initiate main landing gear braking.
6/20:37	Wheel stop.

GLOSSARY

A/G	air-to-ground
AA	accelerometer assembly
ACS	active cooling system
ADS	air data system
AFB	Air Force base
AFTE	autogenic feedback training equipment: a preventative method for space motion sickness: autogenic feedback training for vestibular symptomology (SL-J)
A/L	approach and landing
AMS	acceleration measurement system
AOCS	attitude and orbit control subsystem
AOS	acquisition of signal
APC	autonomous payload controller
APCS	autonomous payload control system
APU	auxiliary power unit
ASE	airborne support equipment
BCR	bone cell growth and mineralization in microgravity (SL-J)
BFS	backup flight control system
CCD	charge-coupled device
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
DAP	digital autopilot
DCORE	deployer core equipment
DHS	data handling subsystem
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
ESA	European Space Agency
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FCS	flight control system
FDF	flight data file
FEE	affects of weightlessness in the development of amphibian eggs fertilized in space (SL-J)
FES	flash evaporator system
FMPT	first materials processing test (SL-J)
FPS	feet per second
FRCS	forward reaction control system
FSTV	fast-scan TV
FTS	fluid therapy system: inflight demonstration of the Space Station (SL-J)
GAPC	GAS autonomous payload controller
GAS	getaway special experiment
GCD	GAS control decoders
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
HZE	high-energy galactic rays

IFM	in-flight maintenance
IMU	inertial measurement unit
I/O	input/output
IPS	instrument pointing system
IR	infrared
ISAIAH	Israel Space Agency Investigation About Hornets
IV	intravehicular
JSC	Johnson Space Center
KEAS	knots equivalent air speed
KSC	Kennedy Space Center
L-0	PMS health monitoring (SL-J)
L-1	endocrine and metabolic changes in payload specialist (SL-J)
L-2	neurophysiological study on visuo-vestibular control of posture and movement in fish during adaptation to weightlessness (SL-J)
L-4	comparative measurement of visual stability in Earth and cosmic space (SL-J)
L-5	crystal growth of enzymes in low gravity (SL-J)
L-6	studies on the effects of microgravity on the ultrastructure and functions of cultured mammalian cells (SL-J)
L-7	the effect of low gravity on calcium metabolism and bone formation (SL-J)
L-8	separation of the animal cells and cellular organella by means of free flow electrophoresis (SL-J)
L-9	genetic effects of HZE and cosmic radiation (SL-J)
L-10	space research on perceptual motor functions under the zero gravity condition (SL-J)
L-11	study on the biological effect of cosmic radiation and the development of radiation protection technology (SL-J)
L-12	circadian rhythm of conidiation in Neurospora Crassa (SL-J)
LBNP	lower body negative pressure: countermeasure for reducing postflight orthostatic intolerance (SL-J)
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit

M-01	growth experiment of narrow band-gap semiconductor Pb-Sn-Te single crystals in space (SL-J)
M-02	growth of Pb-Sn-Te single crystal by traveling zone method in low gravity (SL-J)
M-03	growth of semiconductor compound single crystal by floating zone method (SL-J)
M-04	casting of superconducting filamentary composite materials (SL-J)
M-05	formation mechanism of deoxidation products in iron ingot deoxidized with two or three elements (SL-J)
M-06	preparation of nickel base dispersion strengthened alloys (SL-J)
M-07	diffusion in liquid state and solidification of binary system (SL-J)
M-08	high-temperature behavior of glass (SL-J)
M-09	growth of silicon spherical crystals and surface oxidation (SL-J)
M-10	study on solidification of immiscible alloy (SL-J)
M-11	fabrication of very-low-density, high-stiffness carbon fiber/aluminum hybridized composites (SL-J)
M-12	study on the mechanisms of liquid phase sintering (SL-J)
M-13	fabrication of SI-As-Te:Ni ternary amorphous semiconductor in microgravity environment (SL-J)
M-14	gas evaporation in low gravity field: congelation mechanism of metal vapors (SL-J)
M-15	drop dynamics in space and interference with acoustic field (SL-J)
M-16	study of bubble behavior (SL-J)
M-17	preparation of optical materials used in non-visible region (SL-J)
M-18	Marangoni induced convection in materials processing under microgravity (SL-J)
M-19	solidification of eutectic system alloys in space (SL-J)
M-20	growth of Samarskite crystal in microgravity (SL-J)
M-21	growth experiment of organic metal crystal in low gravity (SL-J)
M-22	crystal growth of compound semiconductors in a low gravity environment (SL-J)
MAS	microbial air sampler
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
MPESS	mission-peculiar equipment support structure
MPM	manipulator positioning mechanism
MPS	main propulsion system
MRI	magnetic resonance imaging after exposure to microgravity (SL-J)
MS	mass spectrometer

MS	mission specialist
MSFC	Marshall Space Flight Center
NASDA	National Space Development Agency of Japan
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
OMS	orbital maneuvering system
OPF	orbiter processing facility
OST	on-station
OTA	orbital transfer assembly
OTC	orbiter test conductor
OTM	orbital transfer maneuver
PASS	primary avionics software system
PCMMU	pulse code modulation master unit
PCG	protein crystal growth (SL-J)
PCR	plant culture research (gravity, chromosomes, and organized development in aseptically cultured plant cells) (SL-J)
PCS	pressure control system
PGSC	payload and general support computer
PI	payload interrogator
PIC	pyro initiator controller
PMS	physiological monitoring system
POCC	Payload Operations Control Center
POM	proximity operations mode
PPC	payload power contactors
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
RMCD	radiation monitoring container device
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
SAM	sun acquisition mode
SAMS	space acceleration measurement system (SL-J)
SAREX	shuttle amateur radio experiment
SAS	space adaptation syndrome
SEU	single-event upset
SFMDM	smart flexible MDM
SGF	solution growth facility
SHF	superhigh frequency
SM	statute miles
SRB	solid rocket booster
SRL	satellite restraint latch
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
SSTV	slow-scan TV
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
TCU	thermal control unit
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
VTR	videotape recorder
WCS	waste collection system