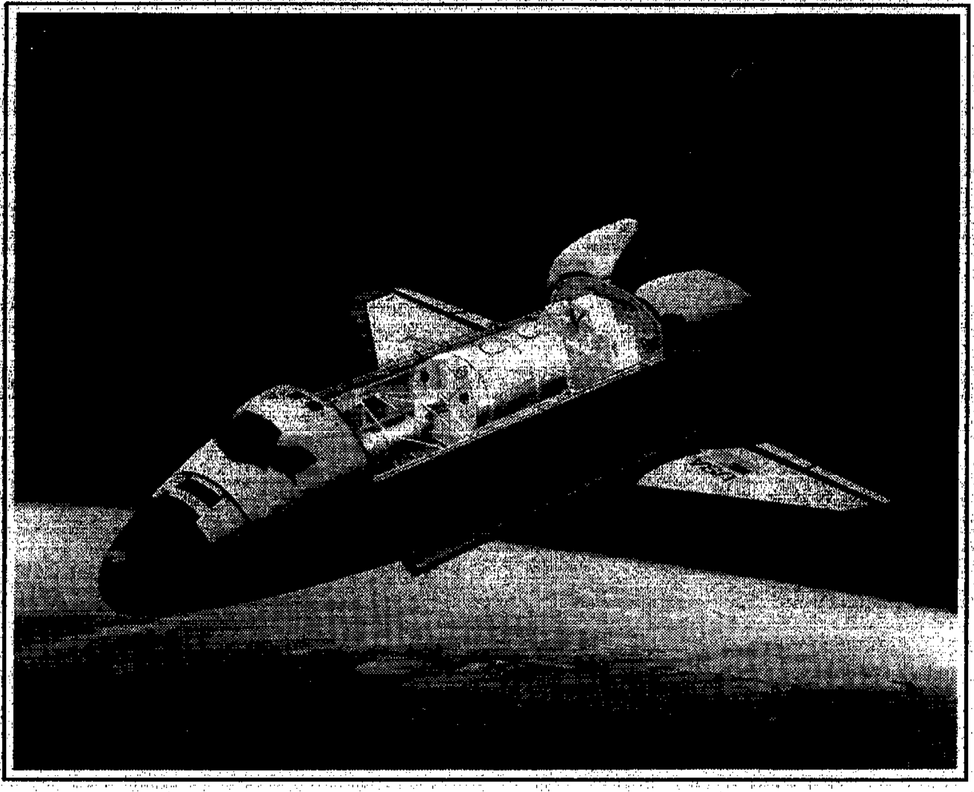


STS-58

PRESS INFORMATION AND MISSION TIME LINE

October 1993

Rockwell International

Space Systems Division

Office of Customer &
Media Relations

PUB 3546-V Rev 10-93

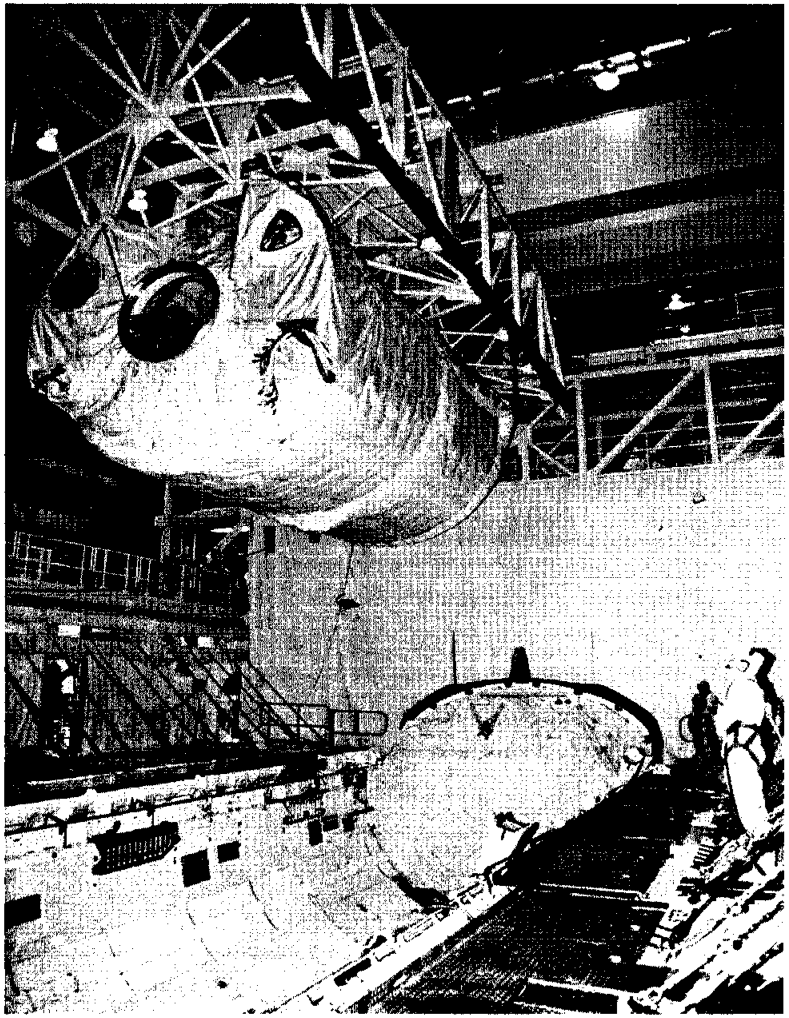
CONTENTS

MISSION OVERVIEW

This is the 15th flight of Columbia and the 58th for the space shuttle.

The flight crew for the STS-58 mission is commander John E. Blaha, Col., USAF; pilot Richard (Rick) A. Searfoss, Lt. Col., USAF; payload commander M. Rhea Seddon, M.D.; mission specialists Shannon W. Lucid, Ph.D., David A. Wolf, M.D., and William (Bill) S. McArthur, Jr., Lt. Col., USAF; and payload specialist Dr. Martin J. Fettman, D.V.M., Ph.D.

STS-58's primary mission objective is to successfully perform the planned operations of the Spacelab Life Sciences (SLS) 2 payload in Columbia's payload bay and the orbiter middeck. SLS-2 is the second Spacelab flight dedicated exclusively to life sciences research to determine the effects of microgravity on human and animal subjects. The mission will continue the life sciences investigations begun on SLS-1 (STS-40) in June 1991. Although many of the same investigations will be performed, the emphasis and scheduling of in-flight activities are significantly different. On SLS-1, data collection emphasized in-flight human cardiovascular and metabolic experiments, pre- and postflight human vestibular experiments (in-flight reserve), and pre- and postflight animal experiments. On SLS-2, data collection will emphasize additional subjects for in-flight human cardiovascular and metabolic experiments, in-flight human vestibular experiments, and in-flight animal hematology, vestibular, and bone and muscle experiments. SLS-2 is designed to help NASA answer critical questions about human physiological functions in space before people work for months aboard a space station or travel for years to Mars and other planets. The challenge for SLS-2 and future missions is to find out why these changes take place and learn how to prevent or control undesirable responses.



NASA Photo

Workers at Kennedy Space Center Install the Spacelab Module in Payload Bay of Columbia

Operating on an approximate nine-hour work shift, the SLS-2 crew will perform 14 scientific experiments (eight human and six rodent) covering four scientific disciplines: cardiovascular/cardiopulmonary, neuroscience, regulatory physiology (renal/endocrine and hematology), and musculoskeletal. Results from the experiments, when combined with data collected on SLS-1, will provide the most detailed and interrelated physiological measurements acquired in the space environment since the Skylab program in 1973-74, will aid NASA's efforts to fly longer missions, and will give researchers insight into medical problems experienced on Earth.

The Johnson Space Center is responsible for managing human (crew) experiments, and the Ames Research Center is responsible for managing nonhuman (rodent) experiments. Because of the success of the research animal holding facilities (RAHFs) on SLS-1, the hardware will be a valuable part of SLS-2. Two RAHFs will be flown to accommodate sufficient test populations. Having passed rigorous containment tests, the RAHFs on SLS-2 will allow in-flight handling of rodents. Activities will include tracer injections, blood sampling, rodent body mass measurement, and dissection.

Several other pieces of hardware will support experiments requiring rodent test subjects. They include a small mass measuring instrument (SMMI), refrigerator/incubator module (RMI), general-purpose workstation (GPWS), general-purpose transfer unit (GPTU), and two animal enclosure modules (AEMs).

The SLS-2 investigations are described below.

CARDIOVASCULAR/CARDIOPULMONARY

In-flight study of cardiovascular deconditioning (066) will determine the effects of zero gravity on circulatory and respiratory functions of resting and exercising subjects by means of gas analysis using a noninvasive rebreathing technique.

Pulmonary function during weightlessness (198) will observe human pulmonary function in zero gravity using noninvasive measurements of parameters related to pulmonary gas exchange. Results will be compared to those obtained in Earth's gravity.

Cardiovascular adaptation to zero gravity (294) will study cardiovascular function and dimensions using a variety of test methods on subjects at rest and during exercise.

NEUROSCIENCE

Vestibular experiments in Spacelab (072) will study human vestibular adaptation to weightlessness and the basis of space motion sickness. Otolith system measurements will be emphasized.

A study of the effects of space travel on mammalian gravity receptors (238) will study the biochemical and structural integrity of the otolith organs of the rat after flight to determine the chronic and/or progressive effects of spaceflight.

REGULATORY PHYSIOLOGY

Regulation of erythropoiesis in rats during spaceflight (012) will study the roles of nutritional status and hemoconcentration in rat blood cell production during spaceflight.

Regulation of blood volume during space flight (141) will evaluate the use of rats as models for humans in hematological studies.

Fluid electrolyte regulation during spaceflight (192) will analyze blood, urine, and saliva samples for parameters that indicate changes in the fluid, electrolyte, renal, and circulatory status of humans exposed to weightlessness.

Influence of spaceflight on erythrokinetics in man (261) will collect blood from crew members to determine whether the reduced red cell mass associated with microgravity is due to decreased production or increased hemolysis.

MUSCULOSKELETAL

Protein metabolism during spaceflight (120) will study human whole-body metabolism using isotope-labeled glycine as a tracer to determine whether nitrogen loss is caused by decreased uptake and production of protein or by increased mobilization and metabolism of muscle protein.

Effects of zero gravity on biochemical and metabolic properties of skeletal muscle in rats (127) will determine alterations in the functional capacity of rat skeletal muscles through preflight and postflight exercise tests and tissue analysis.

Bone, calcium, and spaceflight (194) will analyze rat wastes for tracer calcium added to the diet. Bone morphology examinations will characterize bone loss attributable to microgravity.

Electron microscopy, electromyography, and protease activity of rat hindlimb muscles (303) will determine morphological, biochemical, and histochemical changes in muscles attributable to launch and reentry stress, in-flight atrophy, and postflight repair through in-flight activity monitoring and postflight analysis of enzymes.

Pathophysiology of mineral loss during spaceflight (305) will administer dual stable isotopes of calcium to crew members (one orally and one intravenously) to determine whether elevated fecal calcium is caused by decreased gastrointestinal absorption or by active gastrointestinal excretion.

STS-58's secondary objective is to successfully operate the Shuttle Amateur Radio Experiment (SAREX) II. SAREX, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, is a middeck payload that will establish two-way communication with amateur radio stations within the line of sight of the orbiter. Configuration C is planned for this mission and is capable of operating in a robot mode and voice mode. It consists of a suite of amateur radio equipment, including a hand-held transceiver, window antenna, headset assembly, interface module, spare battery set, packet module and a personal tape recorder. SAREX-II will be operated in the robot mode most of the flight. Intermittent voice operations will be performed by crew members Rick Searfoss, Bill McArthur, Jr., and Martin Fettman as time permits.

STS-58 is the second dedicated extended-duration orbiter flight and, at just over 14 days, the longest planned flight to date. The longer flight is made possible by extended-duration orbiter provisions incorporated into Columbia under a 1988 NASA amendment to an existing Rockwell shuttle orbiter contract. Rockwell International Corporation's Space Systems Division (SSD) designed, developed, certified, and produced an extended-duration orbiter (EDO) mission kit that allows a shuttle to remain in orbit for up to 16 days, plus a two-day contingency capability. The EDO modification program is designed to reduce the number of flights required to accomplish tasks; lower risks, costs, and vehicle wear; and substantially increase the volume of data that can be collected on a mission.

Major 16-day EDO mission kit elements produced by Rockwell under the terms of the contract include a set of cryogenic liquid hydrogen and liquid oxygen tanks mounted on a special pallet in the payload bay that provide supplemental reactants for the shuttle's electrical generation system, a regenerating system for removing carbon dioxide from the crew cabin atmosphere, an improved waste collection system that compacts human wastes, additional nitrogen tanks for the crew cabin atmosphere, and the creation of more habitable volume and equipment storage space in the crew cabin. Rockwell modified Columbia for a 16-day EDO capability during a major modification period at Rockwell's Orbiter Assembly and Modification Facility in Palmdale, Calif., from August 1991 to February 1992.

Sixteen development test objectives and 20 detailed supplementary objectives are scheduled to be flown on STS-58.

STS-58 Crew Insignia

MISSION STATISTICS

Vehicle: Columbia (OV-102), 15th flight

Launch Date/Time:

10/14/93	10:53 a.m., EDT 9:53 a.m., CDT 7:53 a.m., PDT

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

Launch Window: 2 hours, 30 minutes (based on SLS-2 mandatory science requirements)

Mission Duration: 14 days, 23 minutes. The capability exists for two additional days for contingency operations and weather avoidance.

Landing: Nominal end-of-mission landing on orbit 225

10/28/93	11:16 a.m., EDT 10:16 a.m., CDT 8:16 a.m., PDT

Runway: Nominal end-of-mission landing on concrete runway 22, Edwards Air Force Base (EAFB), Calif. Alternates are KSC, and Northrup Strip (NOR), White Sands, N.M.

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

Return to Launch Site: KSC

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

Inclination: 39 degrees

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

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

Altitude: 153 nautical miles (176 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2024
No. 2 position: Engine 2109
No. 3 position: Engine 2018

External Tank: ET-57

Solid Rocket Boosters: BI-061

Mobile Launcher Platform: 1

Editor's Note: The following weight data are current as of Oct. 4, 1993.

Total Lift-off Weight: Approximately 4,519,968 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 256,007 pounds

Orbiter (Columbia) Empty and 3 SSMEs: Approximately 180,948 pounds

Payload Weight Up: Approximately 23,188 pounds

Payload Weight Down: Approximately 23,188 pounds

Orbiter Weight at Landing: Approximately 229,753 pounds

Payloads—Payload Bay (* denotes primary payload): Spacelab Life Sciences (SLS) 2 with long module*

Payloads—Middeck: Shuttle Amateur Radio Experiment (SAREX)

Flight Crew Members:

Commander: John E. Blaha, fourth space shuttle flight
Pilot: Richard (Rick) A. Searfoss, first space shuttle flight
Payload Commander (Mission Specialist 1): M. Rhea Seddon, third space shuttle flight
Mission Specialist 2: William (Bill) S. McArthur, Jr., first space shuttle flight
Mission Specialist 3: David A. Wolf, first space shuttle flight
Mission Specialist 4: Shannon W. Lucid, fourth space shuttle flight
Payload Specialist: Dr. Martin J. Fettman, first space shuttle flight

Ascent and Entry Seating:

Ascent:

Flight deck, front left seat, commander John E. Blaha
Flight deck, front right seat, pilot Richard A. Searfoss
Flight deck, aft center seat, mission specialist William S. McArthur, Jr.
Flight deck, aft right seat, payload commander M. Rhea Seddon
Middeck, mission specialist David A. Wolf
Middeck, mission specialist Shannon W. Lucid
Middeck, payload specialist Dr. Martin J. Fettman

Entry:

Flight deck, front left seat, commander John E. Blaha
Flight deck, front right seat, pilot Richard A. Searfoss
Flight deck, aft center seat, mission specialist William S. McArthur, Jr.
Flight deck, aft right seat, mission specialist David A. Wolf
Middeck, payload commander M. Rhea Seddon
Middeck, mission specialist Shannon W. Lucid
Middeck, payload specialist Dr. Martin J. Fettman

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: mission specialist Shannon W. Lucid
EV-2: mission specialist David A. Wolf

Intravehicular Astronaut: pilot Richard A. Searfoss

Entry: Automatic mode until subsonic; then control stick steering

Notes:

- The remote manipulator system is not installed in Columbia's payload bay for this mission.
- The shuttle orbiter repackaged galley is installed in Columbia's middeck.
- The EDO cryogenic pallet is installed in Columbia's payload bay.
- Because of Columbia's heavy nominal end-of-mission landing weight (heaviest to date), the landing is planned for Edwards Air Force Base, Calif.

MISSION OBJECTIVES

- Primary objective
  - Spacelab Life Sciences (SLS) 2 operations
- Secondary objective
  - Shuttle Amateur Radio Experiment (SAREX) II
- 16 development test objectives/20 detailed supplementary objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2 burn
Payload bay doors open
Unstow cabin
Spacelab activation
SLS-2 operations

Flight Days 2-13

SLS-2 operations

Flight Day 14

FCS checkout
RCS hot fire
Spacelab stow
Cabin stow
Spacelab deactivation—first half

Flight Day 15

Spacelab final deactivation
Deorbit
Entry
Landing

Note:

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

CREW ASSIGNMENTS

Commander: John E. Blaha

- Overall mission decisions
- Payload—Spacelab systems
- DTOs/DSOs—landing trainer

Pilot: Richard (Rick) A. Searfoss

- Payload—Spacelab systems,* SAREX*
- DTOs/DSOs—ET photo, acoustic noise, orbiter acceleration, LBNP
- Other—photography/TV, Earth observations, orbiter maintenance, IV

Payload Commander: M. Rhea Seddon

- Payload—SLS-2, Spacelab activation, Spacelab deactivation*
- Other—medic*

Mission Specialist 2: William (Bill) S. McArthur, Jr.

- Payload—SAREX
- DTOs/DSOs—cabin air
- Other—orbiter maintenance, photography/TV,* Earth observations,* Spacelab maintenance*

Mission Specialist 3: David A. Wolf

- Payload—Spacelab deactivation, SLS-2,* Spacelab activation*
- Other—Spacelab maintenance, medic, EV-2

Mission Specialist 4: Shannon W. Lucid

- Payload—SLS-2*
- DTOs/DSOs—human factors
- Other—EV-1

Payload Specialist: Dr. Martin J. Fettman

- Payload—SLS-2*
- DTOs/DSOs—seat egress/landing, education activities, human factors

---

*Backup responsibility

NASA photo

STS-58 CREW—Seven astronauts are assigned to this mission. In the front row, from the left, are mission specialists David A. Wolf and Shannon W. Lucid, payload commander Rhea Seddon, and pilot Richard A. Searfoss. In the second row are mission commander John E. Blaha, mission specialist William S. McArthur, Jr., and payload specialist Martin J. Fettman, DVM

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- Ascent aerodynamic distributed loads verification on Columbia (DTO 236)
- Forward RCS test—control surface effects (DTO 250)
- Elevon deflection load sensitivity verification for Columbia (DTO 253)
- Ascent structural capability evaluation (DTO 301D)
- Entry structural capability evaluation (DTO 307D)
- Payload bay acoustic evaluation (DTO 308D)
- ET TPS performance (methods 1, 2, and 3) (DTO 312)
- Orbiter/payload acceleration and acoustics environment data (DTO 319D)
- On-orbit PRSD cryogenic hydrogen boiloff (DTO 413)
- APU shutdown test (sequence A) (DTO 414)
- Orbiter drag chute system (DTO 521)
- Cabin air monitoring (DTO 623)
- Acoustical noise dosimeter (DTO 663)
- Acoustical noise sound level data (DTO 665)
- Portable in-flight landing operations trainer (DTO 667)
- OEX Orbital Acceleration Research Experiment (OARE) (DTO 910)

DSOs

- Columbia acceleration data collection (DSO 314)
- Dried blood method for in-flight stowage (protocols 1 and 2) (DSO 325)
- Window impact observation (DSO 326)
- Inter-Mars tissue equivalent proportional counter (ITEPC) (DSO 485)
- Immunological assessment of crew members (DSO 487)
- Orthostatic function during entry, landing, and egress (DSO 603B*)
- Visual-vestibular integration as a function of adaption (DSO 604 OI-1 and OI-3*)
- Postural equilibrium control during landing/egress (DSO 605*)

---

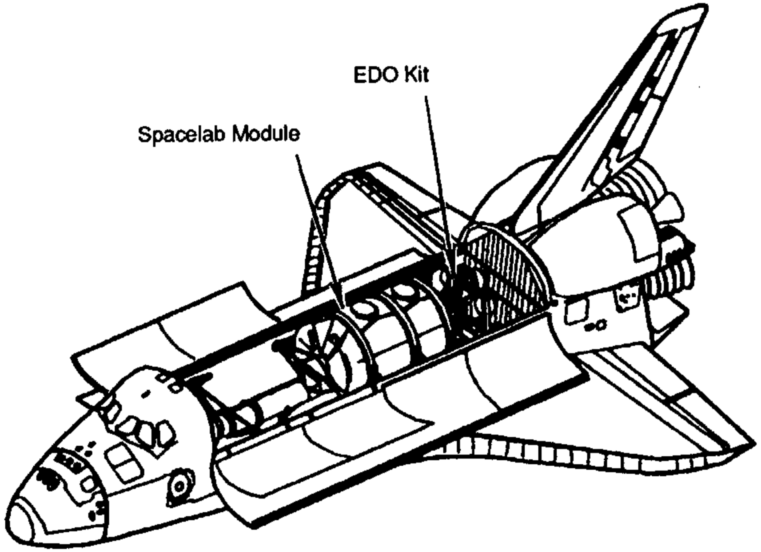
*EDO buildup medical evaluation

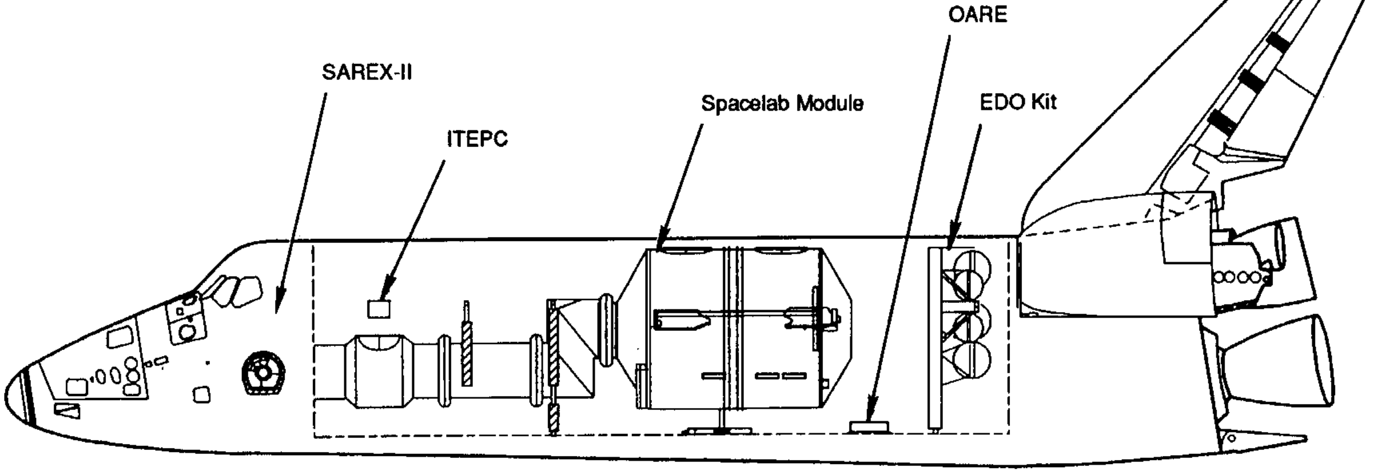
- Air monitoring instrument evaluation (microbial air sampler) (DSO 611*)
- Energy utilization (DSO 612*)
- The effect of prolonged spaceflight on head and gaze stability during locomotion (DSO 614*)
- Physiological evaluation of astronaut seat egress ability (DSO 620*)
- In-flight LBNP test of countermeasures and end-of-mission countermeasure trial (DSO 623*)
- Cardiorespiratory responses to submaximal exercise (DSO 624*)
- Cardiovascular and cerebrovascular responses to standing before and after spaceflight (DSO 626*)
- Educational activities (objective 1) (DSO 802)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)
- Assessment of human factors (configuration A) (DSO 904)

---

*EDO buildup medical evaluation

STS-58 PAYLOAD CONFIGURATION





MTD 930920-4539

SPACELAB LIFE SCIENCES 2

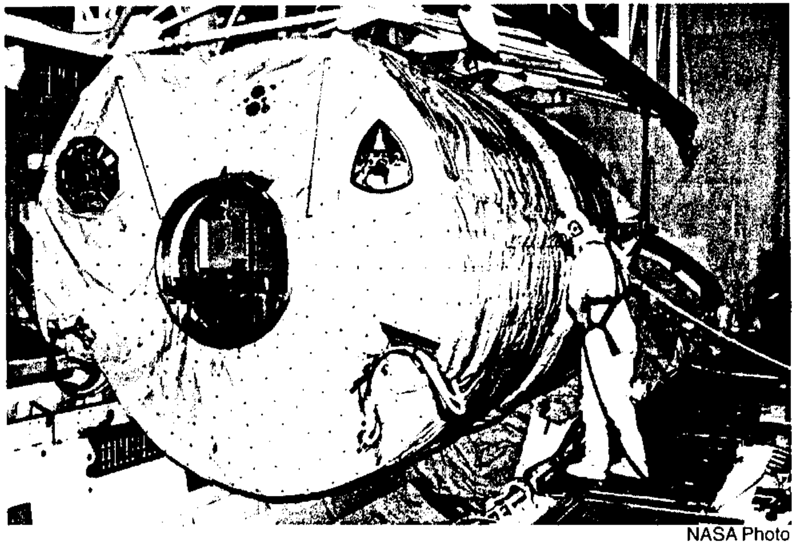
Long before American astronaut Alan Shepard and Soviet cosmonaut Yuri Gagarin made mankind's first journeys into space over 30 years ago, animals were sent as surrogates in an attempt to determine how human beings would respond to the space environment. Instruments monitored the animals' physiological responses as they experienced the stresses of launch and reentry and the weightless environment. These first space pioneers returned to Earth healthy, refuting predictions that some vital organs might not function in low gravity.

The short flights of America's Mercury astronauts soon led medical scientists to dismiss many of the concerns they had initially expressed about man's ability to live and work productively in space. However, during these flights, it became apparent that humans do undergo some physiological changes in space, such as weight loss and fluid redistribution.

Further life science studies helped to design the space suit and equipment needed for the first U.S. space walk during Gemini 4. Astronauts completed a more complex set of in-flight medical studies during the Gemini missions, which served as preludes to the Apollo lunar missions. While additional physiological changes were observed, no substantial health problems were discovered to prevent humans from traveling to the moon. The Apollo astronauts reported a few minor physiological problems, such as space motion sickness, but they were able to live and work productively in space.

Although scientists continued to learn more and more about human responses to microgravity, the Mercury, Gemini, and Apollo spacecraft were too small to house the precise research equipment needed to properly study the effects of living in weightlessness. Scientists were finally able to make more detailed measurements during three missions of America's first space station, Skylab, in 1973 and 1974. The Skylab missions, which lasted 28, 59, and 84 days, demonstrated that people could live and work in space for several months. The experiments gave scientists a basic picture of how individual parts of the body respond to weightlessness. Still, however, some responses went unexplained, and there was no complete picture of the interrelationship of reactions from different parts of the body.

During the years between the Skylab and space shuttle life science investigations, life scientists developed detailed plans for studying the entire body's response to spaceflight and examining how microgravity affects individual parts of the body. In response, NASA has dedicated a series of shuttle missions to examine how living and working in space affects the human body. The Spacelab Life Sciences 2 mission is the second of these missions designed to make interrelated physiological measurements in space. SLS-1, which flew in June 1991, provided scientists their first opportunity in


NASA Photo

Workers at Kennedy Space Center Install the Spacelab Module in Payload Bay of Columbia nearly 20 years to conduct comprehensive studies of changes in human physiology in microgravity.

THE SLS-2 MISSION

SLS-2's primary objective is to continue and extend the study initiated on SLS-1 of the mechanisms, magnitudes, and time courses of certain physiological changes that occur during spaceflight and to investigate the consequences of the body's adaptation to microgravity and readjustment to gravity. Operating on a nine-hour shift, the crew members will perform 14 experiments in four areas: cardiovascular/cardiopulmonary (heart, lungs, and blood vessels), regulatory (kidneys), musculoskeletal (muscles and bones), and neurovestibular (brain and nerves, eyes, and inner ear). Eleven of the experiments were also conducted on the first SLS mission.

Humans and rodents will be used as the subjects of the experiments on SLS-2. NASA's Ames Research Center is responsible for developing the rodent experiments, and the Johnson Space Center will develop the human experiments. JSC is also responsible for overall mission management.

Results from the research performed on SLS-2 also may help us more clearly understand the nature of certain medical disorders experienced on Earth. For example, the cardiovascular experiments may help scientists learn more about hypertension and heart failure, and the musculoskeletal investigations may increase our knowledge of bone diseases such as osteoporosis, muscle disorders, and the vital role of force and pressure on musculoskeletal structure and metabolism.

SPACE MEDICINE AND BIOLOGY

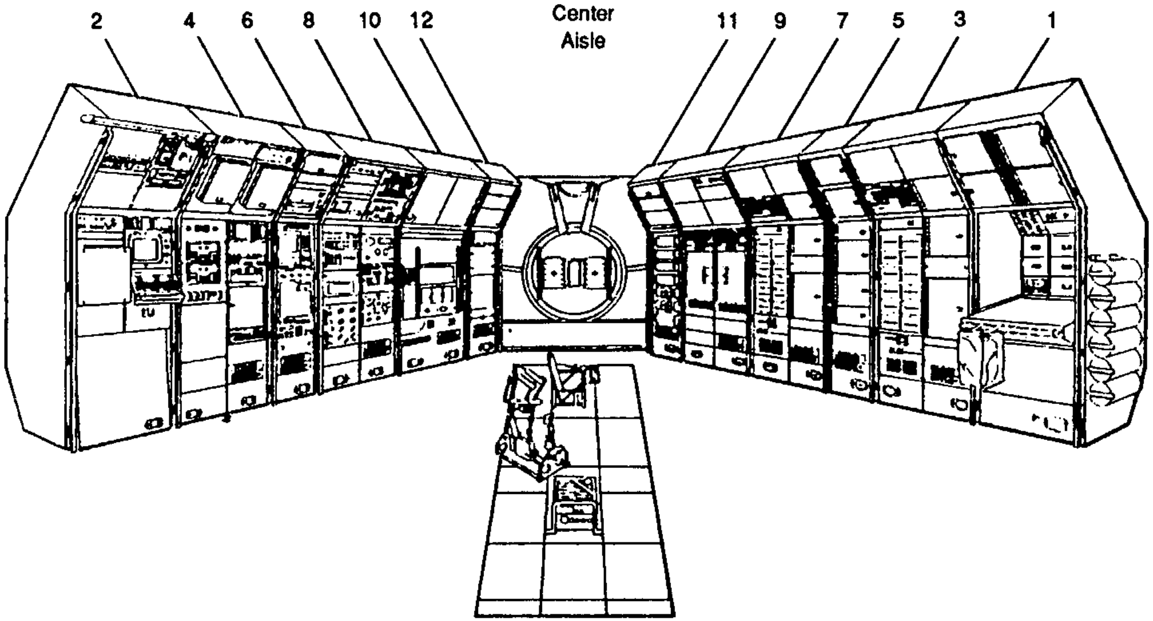
On Earth, the body normally operates in a steady state; blood pressure, fluid content, and other physiological conditions stabilize at particular set points. In space, the body adapts by establishing a new balance. On previous missions, the physiological changes associated with this adaptation have been identified: redistribution of body fluids, space sickness, and other responses to microgravity exposure among more slowly changing systems, such as muscle and bone.

Although these changes appear to be part of the body's natural adaptation to microgravity, they may not be harmless because the body must readjust to gravity upon return to Earth. Following a short period of readaptation to gravity, the changes appear to reverse. However, after flights of six months or more, the readaptation process may require a significant rehabilitation period, and people may even experience irreversible changes during repeated or longer exposures to space. If this is the case, ways must be found to prevent such adverse effects.

Current data suggest that physiological disturbances begin in the initial hours of spaceflight, when fluids are redistributed in the body. On Earth, blood tends to pool in the feet and legs, and passive physiological responses force blood back to the heart. Scientists believe that in space fluid no longer pools in the lower extremities and larger than normal amounts of fluid accumulate in the chest, neck, and head. In order to relieve the increased pressure caused by these fluid shifts, the organs that regulate body fluid volume (endocrine glands and kidneys) remove what appears to be excess fluid. The SLS-2 experiments will investigate how the heart and pulmonary system respond to the redistribution of body fluids.

Another disturbance that sometimes occurs and subsides in the first few days of a mission is space motion sickness, which has some symptoms similar to Earth motion sickness and has affected approximately half of all astronauts. SLS-2 investigations will attempt to discover its causes and counter its effects.

Muscle atrophy, bone deterioration, and cellular disturbances begin as soon as astronauts are exposed to microgravity and may continue indefinitely. SLS-2 investigations will study the



Starboard Racks	Center Aisle	Port Racks
Rack 2: Standard Spacelab Control Center Rack 4: Standard Spacelab Communications Systems, Gas Analyzer Mass Spectrometer Rack 6: Echocardiograph, Video Tape Recorder, ECDS Microcomputer System Rack 8: Gas Analyzer Mass Spectrometer, Gas Tank Assembly, LSLE Microcomputer Rack 10: General-Purpose Workstation Rack 12: LSLE Centrifuge, Stowage	Body Restraint System Floor Mount Bicycle Ergometer Body Mass Measurement Device	Rack 1: Standard Spacelab Workstation Rack 3: Rodent Research Animal Holding Facility Rack 5: Stowage Rack 7: Rodent Research Animal Holding Facility Rack 9: Life Sciences Laboratory Equipment Refrigerator/ Freezer (2) Rack 11: Standard Interface Rack

MTD 930920-4538

SLS-2 Spacelab Configuration

mechanisms of bone deterioration in the hope of finding countermeasures and will define the nature and progression of muscle degradation.

THE SLS-2 LABORATORY

Most of the SLS-2 experiments will be performed in the pressurized Spacelab module, a reusable laboratory carried in the

Spacelab Life Sciences 2 Logo

shuttle's payload bay. The module, a cylindrical room about the size of a bus, contains utilities, computers, work areas, and instrument racks for performing the experiments. Spacelab will be outfitted with instruments routinely found in biomedical research laboratories. The equipment is mounted in 12 racks that extend from the floor to the ceiling along the sides of the module, in 14 overhead lockers, and in the center aisle.

In addition to the racks of equipment, three items are mounted in the center aisle: the body mass measuring device, the bicycle ergometer, and the body restraint system.

CARDIOVASCULAR/CARDIOPULMONARY INVESTIGATIONS

During spaceflight, the cardiovascular system changes its operation. Scientists have hypothesized that weightlessness affects this system when blood and other fluids move to the upper body and cause the heart to enlarge to handle increased blood flow. Pressure in the arteries rises and triggers baroreceptors (nerve cells clustered in the heart, carotid artery in the neck, and the aorta), which signal the brain to adjust the heart rate to maintain a consistent blood pressure. Through mechanisms that are not well understood, the kidneys and the endocrine system reduce the quantity of fluids and electrolytes, leading to a reduction in total circulating blood volume.

The fluid shift appears to reach a maximum in 24 hours, and the heart reaches a new steady state of operation in three to five days. Previous experiments have detected some small changes that do not appear to impair cardiac function: decreased heart volume, increased blood volume in the upper body, head congestion, decreased blood volume in the lower body, decreased circulating blood volume, a small increase in resting heart rate, and a slight decrease in performance during strenuous exercise. None of these changes has affected crew productivity or impaired health.

After a mission, the cardiovascular system must readapt to Earth's gravity. When a person stands, gravity causes blood to pool in the lower extremeties. Before exposure to microgravity, the cardiovascular system can handle this without any problem, and blood pressure remains constant. After spaceflight, however, fluid shifts associated with standing present a challenge to the cardiovascular system: The heart beats rapidly, blood pressure often falls, and exercise capacity is reduced. These phenomena usually return to normal after a few days. However, scientists do not clearly understand the exact mechanisms that cause these changes or the results of prolonged exposure to microgravity.

Scientists are also investigating the effect of microgravity on the lungs. On Earth, gravity causes ventilation, blood flow, gas exchange, and pressure to vary in different regions of the lungs; scientists want to measure these parameters in microgravity. Scientists have speculated that small decreases in lung capacity described by astronauts may be related to increases in blood volume in the upper body, but they need more precise measurements to verify their observation.

The cardiovascular/cardiopulmonary system interacts with every organ in the body; thus, small changes in this system may affect the entire body. Three experiments, using astronauts as subjects, will measure heart size, blood pressure, heart rate, fluid shift, blood volume, blood flow patterns, blood vessel characteristics, and lung functions throughout the mission. After the mission, these measurements will be used to determine cardiovascular and cardiopulmonary adaptation to microgravity and readaptation to gravity.

Cardiovascular Adaptation to Microgravity

This experiment seeks to increase the understanding of microgravity-induced changes in the heart's structure and function in space. It will measure the mechanisms and time course of cardiovascular adaptation to weightlessness, focusing on the acute changes in cardiovascular function, heart dimension and function at rest, cardiovascular response to maximal exercise, and control mechanisms of the cardiovascular system.

Central venous pressure-measurement of changes in the blood pressure in the great veins near the heart-is one indicator of fluid changes in the upper body. To measure these pressure changes, catheters will be inserted in crew members before the flight. The catheters will be run through their arms and upper torso and placed just above their hearts. The catheters will be removed from the subjects after the first day or two of flight, by which time most of the fluid shifting should be complete and pressures stabilized. The catheters will be reinserted shortly after the astronauts land so that investigators can measure any changes in pressure related to readaptation to gravity.

The central venous pressure measurements from SLS-1 surprised the investigators. Instead of increasing under the influence of microgravity-induced fluid shifting, the subject's pressure decreased. Nevertheless, the astronaut's heart was larger than before the flight, and the heart's stroke volume and the amount of blood pumped with each heartbeat were also higher. These unexpected changes may indicate a general opening of blood vessels during spaceflight.

Another indicator of fluid shifting is blood flow in the legs. As body fluids shift from the lower to the upper body in microgravity, the volume of the lower extremities may decrease and the flow of blood in the legs may also decrease. Investigators will test this by measuring the circumference of an astronaut's leg at regular intervals.

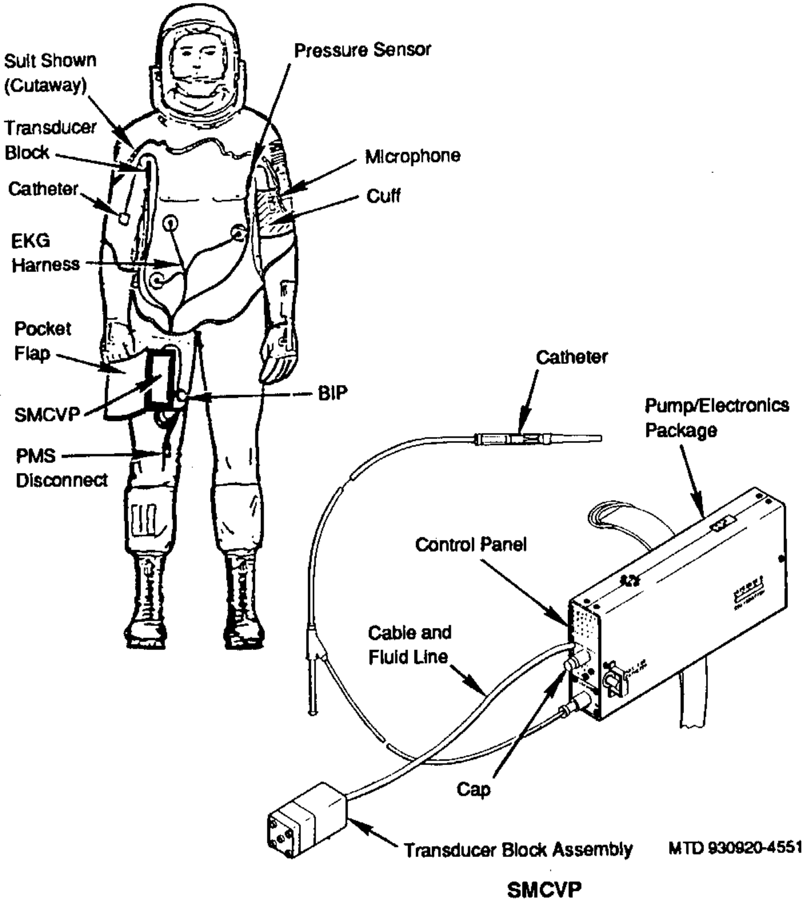
Echocardiographs of crew members' hearts will also be taken to see how their hearts adapt to weightlessness. The echocardiograph produces real-time images of the heart using high-frequency sound waves. An electrocardiogram will indicate the time when the echocardiograms are taken.

Investigators will observe the response of the astronauts' cardiovascular system to various levels of exercise while they ride the bicycle ergometer. They hope to learn whether the size and function of the heart are reduced in space and if reductions in heart performance are related to these changes.

The principal investigator for this experiment is C. Gunnar Blomqvist, M.D., of the University of Texas Southwestern Medical Center, Dallas.

In-flight Study of Cardiovascular Deconditioning

How physiological changes induced by microgravity affect the body's cardiovascular and cardiopulmonary systems is the focus of



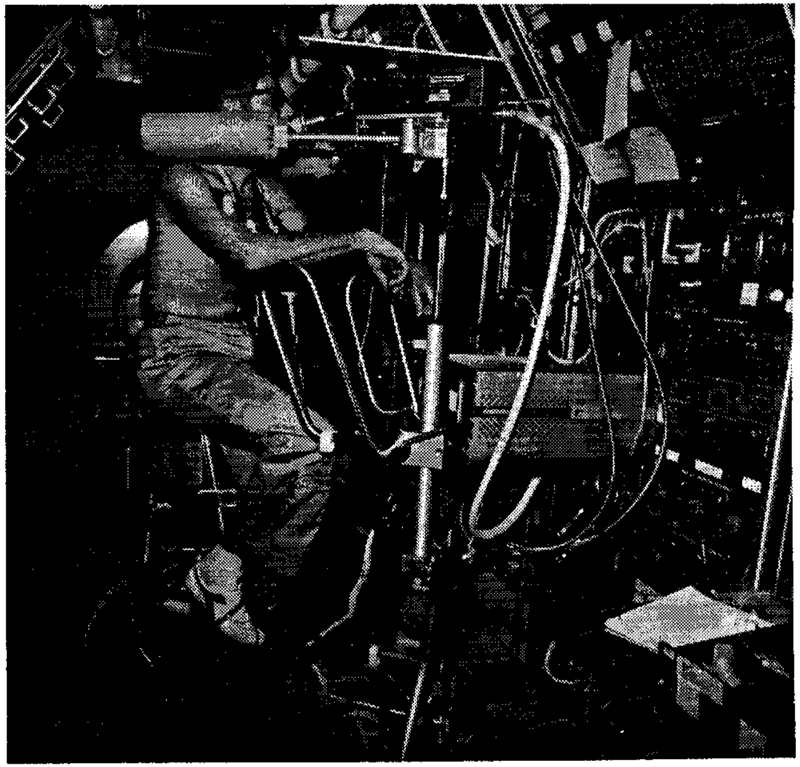
SMCVP Configuration

this experiment. Measurements of the astronauts' cardiac output, the amount of blood pumped with each heartbeat, will be taken while the crew members are resting and pedaling the exercise bicycle.

In this experiment, the astronauts breathe into the cardiopulmonary rebreathing unit, which measures their respiratory gas volumes and concentrations. This technique provides information on the amount of blood pumped out of the heart, oxygen usage and carbon dioxide released by the body, heart contractions, blood pressure, and lung function.

On SLS-1, investigators discovered that crew members seemed to have less capacity for exercise during and after the flight. Investigators will continue to study the extent and impact of this so-called deconditioning during this mission.

The investigators also found that cardiac output remained high during the SLS-1 mission but total peripheral resistance-the resistance of blood flow through the body-adapted to microgravity. They



NASA Photo

Astronaut Trains in Use of Cardiopulmonary Rebreathing Unit will be collecting data on this phenomenon early in the SLS-2 mission to enhance the earlier investigation's findings.

The principal investigator is Leon E. Farhi, M.D., of the State University of New York at Buffalo.

Pulmonary Function During Weightlessness

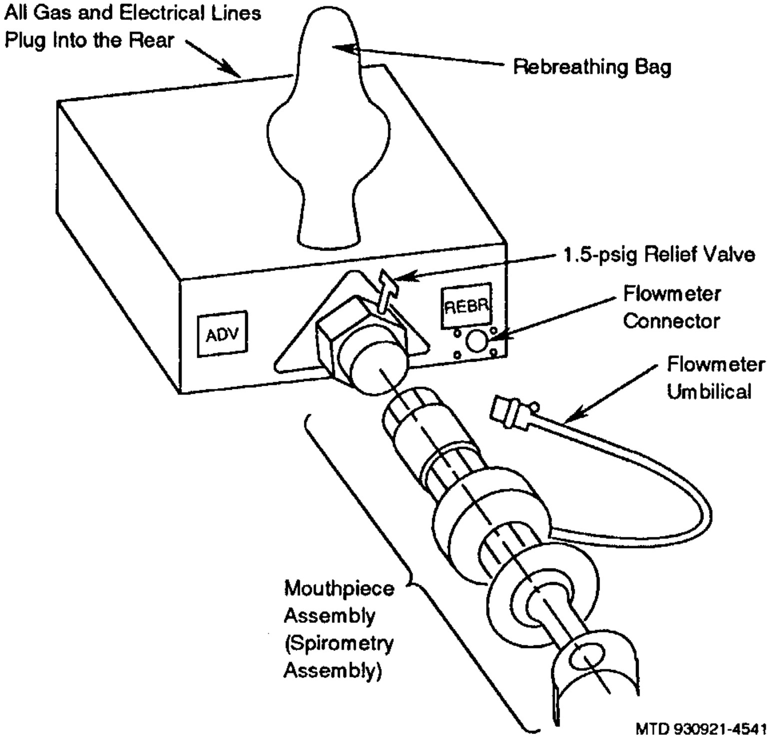
This experiment will investigate the distribution and movement of blood and gas in the pulmonary system under the influence of microgravity and will compare the results with normal respiration on Earth. The astronauts will conduct tests that measure their pulmonary blood flow, lung diffusing capacity, and other functions.

Scientists believe that microgravity causes changes in many pulmonary functions and that these functions will be temporarily impaired after astronauts return to Earth. Investigators will compare the results of the tests conducted on this mission with the results of tests performed on Earth to determine the changes that occur in pulmonary functions.

Scientists hope that their tests will help them isolate the mechanisms that caused an unexpected change in pulmonary function that they discovered during the first Spacelab life sciences mission. On SLS-1, they found that the astronauts' lung ventilation, which they expected to be much more even in space, showed only about half the improvement they expected.

This is a reserve experiment and will be conducted only if crew time and resources allow.

John B. West, M.D., Ph.D., is the principal investigator. He is affiliated with the University of California, San Diego.



Cardiopulmonary Rebreathing Unit

REGULATORY SYSTEM INVESTIGATIONS

Two of the bodies regulatory systems, renal/endocrine and blood, are the subject of these investigations.

The kidneys and hormones of the renal/endocrine system regulate the amount of fluids and the pressure inside veins and arteries, but gravity plays a role in the distribution of fluids in the body, pulling them down to the lower part of the body. When those fluids shift toward the upper body in space, however, the body perceives this as an increase in body fluids, which results in many physiologic changes in the regulatory systems and the cardiovascular system.

Scientists will use the data gathered from these experiments to study how the astronauts are affected by changes in blood pressure, heart rate, and overall heart performance caused by changes in fluids. This information may also help researchers find countermeasures for physical conditions experienced on Earth, such as low and high blood pressure and cardiac failure.

Several experiments on this mission will investigate the effect of spaceflight on the blood system. Scientists have observed decreases in the volume of astronauts' blood plasma and red blood cell count on previous missions. The loss of red blood cells, which distribute oxygen to the tissues, could pose a problem during space missions, particularly if astronauts become ill or suffer an injury.

Fluid-Electrolyte Regulation During Spaceflight

Astronauts' urine and blood samples taken before, during, and after the mission will be examined to determine the immediate and long-term changes in kidney function; alterations in the balance of water, salt, and minerals; shifts in body fluids from cells and tissues; changes in the levels of the hormones that affect kidney function and circulation. Data from this experiment will be compared to data from the cardiovascular experiments to study how the responses of the renal and cardiovascular systems to weightlessness are related.

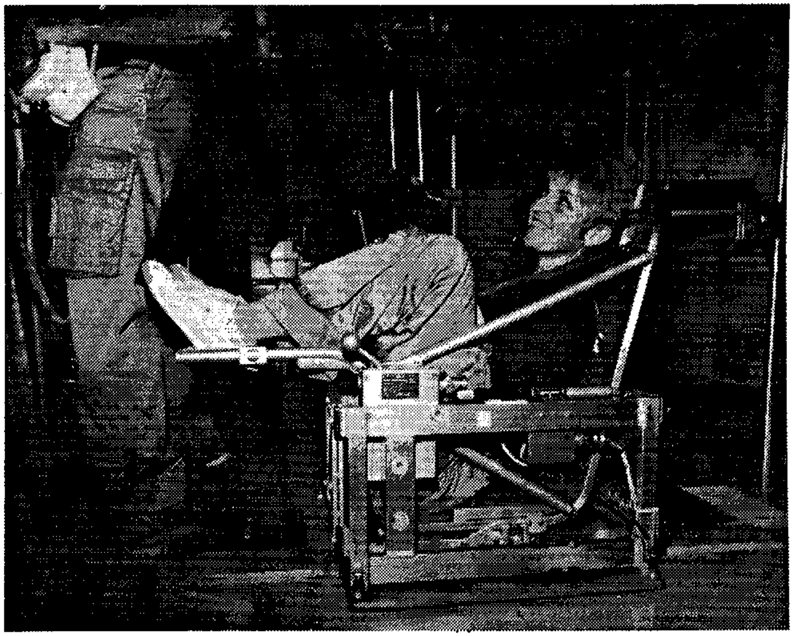
The crew members will drink water with a heavy isotope of oxygen and will take urine and blood samples, beginning as soon as possible after entering microgravity. The urine samples will be examined after the flight to determine the amount of body water each crew member loses and the rate of loss. The blood samples will be examined to determine the astronauts' plasma and extracellular fluid volume. The samples of blood and urine will also be studied for changes in hormones, especially those that regulate fluid and electrolyte levels.

The astronauts will weigh themselves each day and keep a record of the fluids and medications they consume. Twice during the mission, they will receive injections of chemical tracers, and the amount of tracers released into the urine during a specified amount of time will be determined to help scientists trace the shift of fluids and spot kidney function changes.

The principal investigator is Carolyn Leach, Ph.D., of the Johnson Space Center, Houston.

Regulation of Blood Volume During Spaceflight

In this experiment, rats will be used to study the volume of red blood cells and plasma, the length of time red blood cells survive, the number of red blood cells produced during spaceflight, and the



NASA Photo

Payload Specialist Millie Hughes-Fulford Trains in SLS-1 Body Mass Measurement Device number of red blood cells released into the blood. Samples of blood will be taken from the rats before, during, and after the flight to monitor changes.

Rats must be used in this experiment in order to closely control the experimental conditions and to permit researchers to examine sample tissues of the spleen, marrow, and liver.

The data gathered is expected to help researchers understand the role played by growth factors and hormones in the maturation and release of red blood cells. It has been demonstrated on previous spaceflights that the body produces red blood cells at a slower rate in microgravity than on Earth because there is less space to store blood in the body.

Erythropoietin, the hormone that regulates the formation and maturation of red blood cells, is used to treat anemia, but it is very expensive. The cost of this treatment could be reduced significantly if scientists can learn more about how it works.

The principal investigator is Clarence P. Alfrey, M.D., of the Baylor College of Medicine, Houston.

Regulation of Erythropoiesis in Rats During Spaceflight

This experiment, in conjunction with the other two hematology experiments, will attempt to determine the processes at work in the decrease in red blood cell mass observed in astronauts on previous spaceflights.

Scientists will study blood samples taken from rats during the flight and compare them with samples from crew members and control rats on Earth. After the flight, they will study bone marrow, spleens, and thymuses removed from the flight rats and control rats to obtain additional data about the effects of microgravity on the blood system.

The researchers will try to determine whether the hematological changes observed in the rats are similar to the changes in the human blood system that occur under the same conditions and whether rats are suitable models for studying changes in hemodynamic parameters in zero gravity.

Albert Ichiki, Ph.D., of the University of Tennessee Medical Center in Knoxville, is the principal investigator.

Influence of Spaceflight on Erythrokinetics in Man

The objective of this experiment is to verify the preliminary findings of the study. After SLS-1, researchers found that red blood cell mass, plasma volume, and erythropoietin decreased. The results indicated that the drop in red blood cell mass was caused by the suppression of red blood cell production during the flight.

While a reduction in red blood cell mass is not considered medically significant on Earth, it could increase the chances that astronauts might become ill or suffer injuries during spaceflight, especially on long flights. Reduced production of red blood cells decreases the blood's oxygen-carrying capacity, which may interfere with the astronauts' ability to function when they return to Earth.

Researchers will measure samples of blood drawn from crew members before, during, and after the mission and blood from a control group for erythropoietin, reticulytes (precursors of red blood cells), absorption of iron by red blood cells, red cell mass, and plasma volume.

Dr. Clarence Alfrey of the Baylor College of Medicine is the principal investigator.

NEUROVESTIBULAR INVESTIGATIONS

Human beings rely on several neural orientation sensors which send out nerve impulses that are integrated and interpreted by the brain. The neurovestibular system, which helps people orient their bodies, is very sensitive to gravity. For example, the otoliths, small vestibular organs in the inner ear, respond to the acceleration of an elevator. Nerves also constantly perceive gravity as muscles relax and contract and use this information to sense body position. The eyes see surroundings and sense the body's relationship to other objects.

In space, gravity no longer tugs at the otolith crystals, and the muscles no longer have to support the weight of the limbs. Theory suggests that, in microgravity, information sent to the brain from the inner ear and other sense organs conflicts with cues anticipated from past experience in Earth's gravity. This conflict can result in disorientation.

Neurosensory research in space has focused on space motion sickness because changes in neurovestibular activity may cause this ailment. Although the symptoms of space motion sickness—pallor, loss of appetite, nausea, and vomiting—are similar to Earth motion sickness symptoms, scientists are not sure if the stimulus is the same.

These investigations will attempt to identify the changes in the neurovestibular system that occur in space, study the processes involved, and determine remedies for space motion sickness. The knowledge gained can be used to treat neurovestibular disorders on Earth.

A Study of the Effects of Space Travel on Mammalian Gravity Receptors

After SLS-1, researchers found that the number, type, and groups of synapses, or gaps, between nerve cells had changed in the gravity sensors of adult rats exposed to microgravity. Gravity sensors are organs that contribute to the sense of equilibrium. This investigation will study the gravity sensors in rats' ears to determine how they adapt to the novel environment of microgravity and changes in the structure of the inner ear that may occur as the body attempts to adapt to weightlessness.

Scientists believe that the structure of gravity sensors changes in response to prolonged exposure to fluid shifts and metabolism changes during spaceflight. It is possible that these structural changes may affect the way the nerve cells send equilibrium signals to the brain.

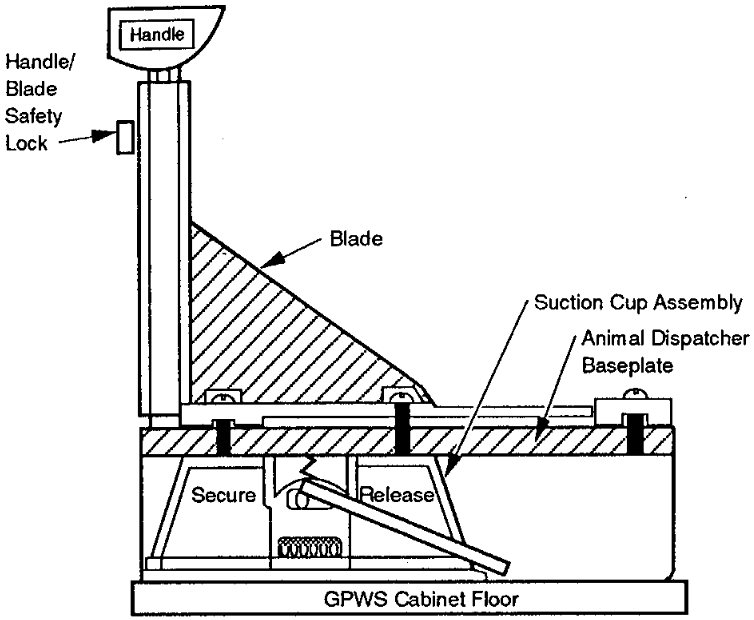
In order to learn how near-zero gravity affects gravity sensors and to what extent the sensors can recover, it is necessary to collect samples of inner ear tissue during the flight. The SLS-2 investigators will use the inner ear sensory hair cells of rats as the model for human sensors. This requires that the astronauts remove the temporal bones and cochlea from five rats and fix them for postflight study. To do this, it will be necessary to decapitate the rats with a device called the animal dispatcher, a small guillotinelike instrument.

After the flight, the researchers will use an electron microscope to obtain three-dimensional pictures of the gravity sensors. They will compare the images with electron microscope pictures of receptors taken before and after the flight to determine changes that occurred in space and how long it takes rats to recover.

The principal investigator is Muriel Ross, Ph.D. of the Ames Research Center, Moffett Field, Calif.

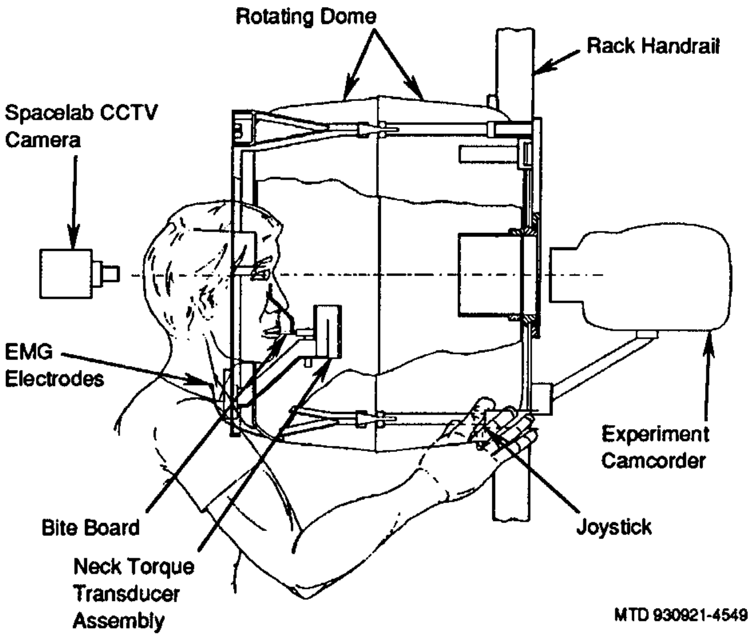
Vestibular Experiments in Spacelab

The astronauts will perform six tests to learn more about the human vestibular system's response to weightlessness and the causes of space motion sickness.



MTD 930920-4544

Animal Dispatcher



MTD 930921-4549

Rotating Dome Experiment Setup

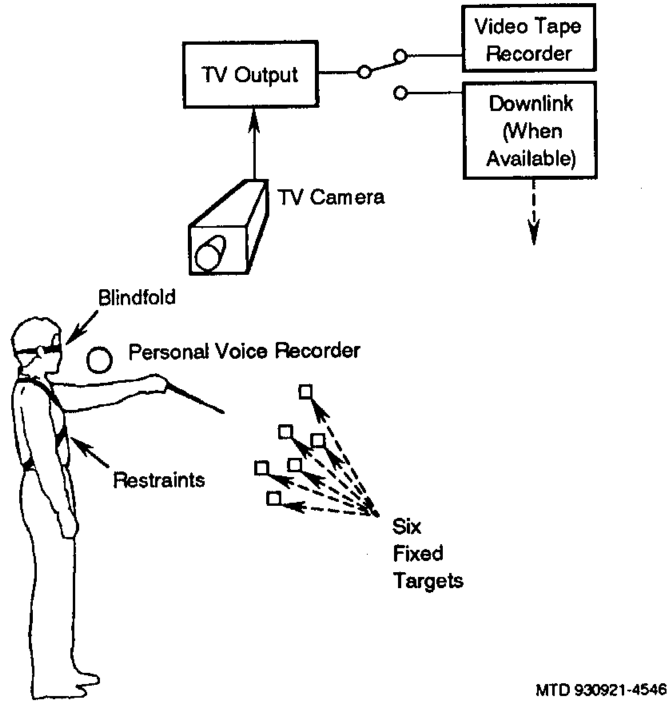
In one test, the crew members will sit in a rotating chair to test how involuntary eye movements are influenced by the otoliths and semicircular canals of the ears. In another test, the astronauts will use a joystick to indicate the perceived direction and velocity of rotation as they look at dot patterns inside a rotating dome.

One test will measure the astronauts' awareness of body position. After looking at targets on a screen, they will close their eyes and point at the targets with a light pointer. Investigators will compare the crew members' on-orbit performance to their performance on Earth to discern differences in how they perceive the relationship of their bodies to their environment in space and on Earth.

A "drop" experiment will be conducted to measure the relationship between the nervous system and muscles during simulated falls or stumbles in space. The falling sensation will be simulated by elastic bungee cords that will pull the astronaut subject toward the floor of the Spacelab module when a T handle, from which the astronaut is suspended, automatically releases him. During the falling movement, electrodes on the astronaut's legs will measure muscle activity.

An acceleration recording unit worn by the astronauts on their heads will record natural and exaggerated head movements to study space motion sickness. By comparing data from the accelerometers with the astronauts' own logs of space motion sickness symptoms they experience, the researchers hope to find if there is a relationship between head movements and periods of sickness.

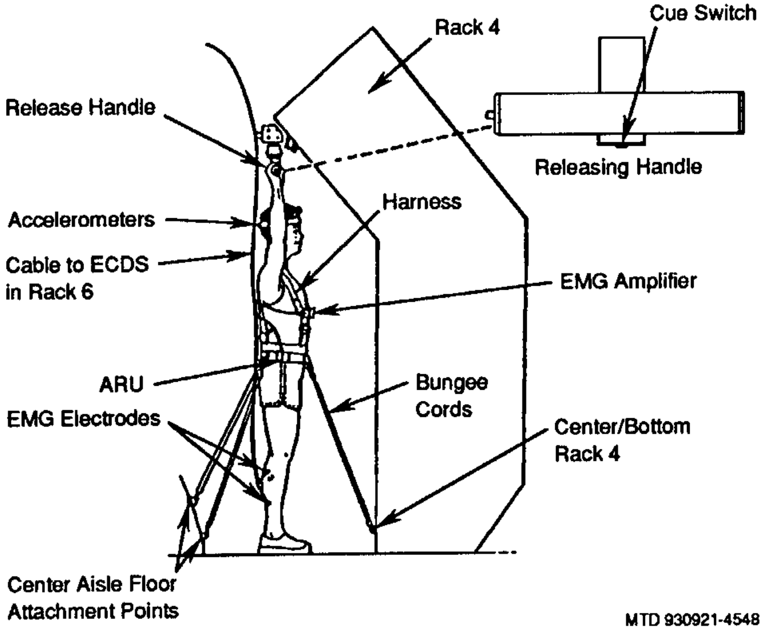
A new instrument that should help astronauts perform experiments in space more efficiently and improve the quality of the science is being flown on this mission to support the rotating dome



Position Awareness Experiment Setup

experiment. The astronaut science advisor, developed by NASA's Ames Research Center and the Massachusetts Institute of Technology, consists of a Macintosh PowerBook computer that uses commercial and NASA-developed software.

The major functions of the astronaut science advisor are to diagnose and troubleshoot equipment, collect data, manage protocols, and detect data of interest. The ASA replaces the Earth-bound scientist, who was limited in his ability to correct problems and follow new leads as experiments were conducted in space. The ASA can comment on the quality and importance of data being collected and create protocols that could improve experiments.



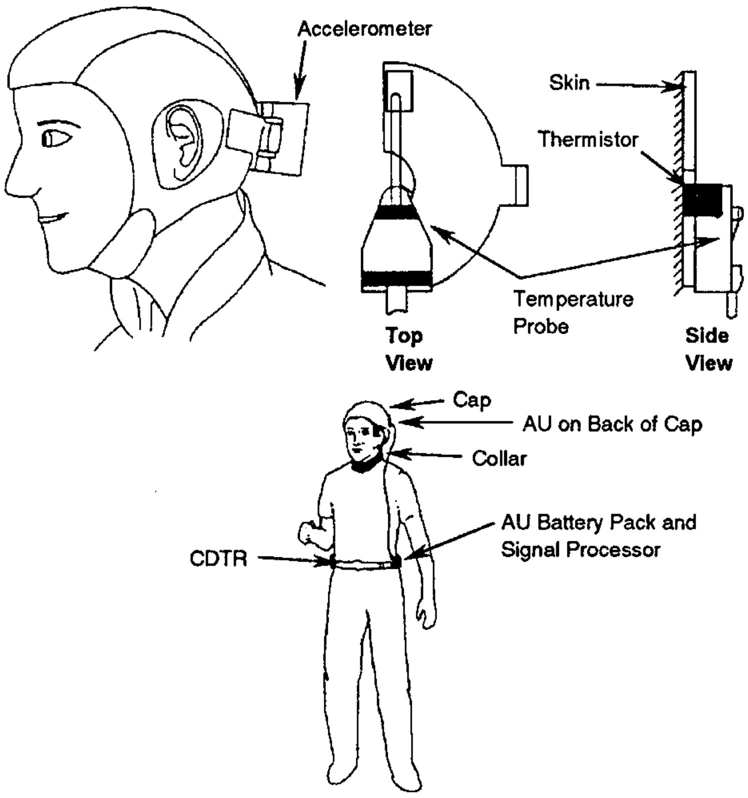
Drop Assembly Test Subject Configuration

The principal investigator is Laurence R. Young, Sc.D., of the Massachusetts Institute of Technology, Cambridge.

MUSCULOSKELETAL INVESTIGATIONS

The architecture of the more than 600 muscles and 200 bones of the human body has been shaped by gravity. The musculoskeletal system needs gravity to function normally. Without it, the muscles waste away and bones become smaller and weaker.

In microgravity, leg muscles often become weakened from lack of use. Muscle atrophy noted in returning astronauts is indicated by loss of lean body mass, reduced muscle mass in the calves, and a decrease in muscle strength. These changes may be caused by decreased protein synthesis, increased protein breakdown, or both.



MTD 930921-4545

Acceleration Recording Unit and Collar

Weightlessness also causes a slow loss of calcium and phosphorous from the bones. Exercise regimens have been only partially successful in preventing the loss of skeletal density.

The SLS-2 investigations will study the nature and progression of muscle degradation and the mechanisms that cause bone loss in microgravity.

Protein Metabolism During Spaceflight

This experiment will investigate the mechanisms involved in protein metabolism, including the buildup (synthesis) and breakdown (catabolism) of protein in microgravity. Normally, there is a balance between the synthesis and catabolism of protein, but a drop in astronauts' protein levels has been observed on previous spaceflights. Microgravity-induced changes in the metabolism of protein, which lead to a decrease in muscle mass, will be determined by measuring the rates of protein buildup and breakdown.

Three times during the flight, the astronauts will orally take an amino acid with an isotope of nitrogen. Investigators will calculate how much protein is being made and broken down by measuring the amount of labeled amino acid found in samples of the astronauts' urine, saliva, and blood.

It had been thought that the decrease in muscle size, strength, and protein content observed in astronauts was caused by a decrease in protein synthesis or an increase in protein breakdown. But evidence from SLS-1 suggested that an increase in the buildup of protein and a larger increase in the breakdown of protein may be responsible for the loss of mass.

The principal investigator is T. Peter Stein, Ph.D., of the University of Medicine and Dentistry of New Jersey in Camden.

Effects of Zero Gravity on the Functional and Biochemical Properties of Antigravity Skeletal Muscle

It has been proposed that the microgravity-induced loss of muscle mass causes a loss of strength and endurance, particularly in the muscles used for standing and walking. One explanation is that the exposure to microgravity removes the stress or tension the muscles need to maintain adequate levels of the proteins and enzymes that allow cells to use oxygen to convert nutrients into energy. When the stress caused by gravity is lessened, the muscles begin to use the glycogen stored in the liver and muscles for energy, which causes muscle endurance to flag.

After the flight, the principal investigator will examine the muscles of the flight rats and the control rats to test his hypothesis that the muscles of the flight animals will lose strength and the ability to perform repetitive contractions. He will measure the strength, power, and performance capabilities of the muscles and their ability to perform sustained work.

Results from this project should be applicable to the prevention or correction of muscle atrophy and altered muscle performance in humans.

Kenneth M. Baldwin, Ph.D., is the principal investigator. He is affiliated with the University of California, Irvine.

The Effects of Microgravity on the Electron Microscopy, Histochemistry, and Protease Activities of Rat Hindlimb Muscles

This experiment will examine the hindlimb muscles of rats to determine the nature and progression of muscle atrophy that occurs in microgravity and the cellular and biochemical basis for the deterioration of antigravity muscles exposed to prolonged spaceflight.

Rat skeletal muscles from previous spaceflights have exhibited changes such as fiber tearing, blood clotting in capillaries, and abnormal swelling of tissues. The muscle fibers of rats exposed to microgravity for two weeks have shrunk nearly 40 percent, and other studies of rats indicate that the shrinkage and death of muscle fiber may be progressive.

The experiment will compare the rate of atrophy for muscles used to oppose gravity with those used for general movements. Investigators will also look for changes in the muscle tissues that may be caused by the stress of launch, microgravity, reentry, and readaptation to gravity.

During the mission, muscle samples will be taken from the hind legs of the five rats that will be dissected for the vestibular and hematology experiments and compared with samples taken from rats after the mission.

Experiment findings will be used in the effort to discover methods of preventing muscle damage among astronauts and people confined to bed on Earth.

The principal investigator is Danny A. Riley, Ph.D., of the Medical College of Wisconsin, Milwaukee.

Pathophysiology of Mineral Loss During Spaceflight

This experiment will investigate the causes of changes in calcium balance, such as calcium excretions and bone mineral loss, during spaceflight. The information gathered will be used to develop a model of calcium and bone metabolism in microgravity.

The SLS-1 experiment discovered that bone-dissolving cells worked at a higher rate than bone-building cells. This combination produces abnormalities in bones and minerals.

On this mission, investigators will study the levels of hormones and metabolites that stimulate bone-producing cells to determine if an increase in the breakdown and reassimilation of bone tissue causes significant changes in the amount of these hormones. Biochemicals in blood and urine samples taken from the astronauts will be measured to chart these changes. The rate of calcium absorption will be determined by measuring the levels of two isotopes of calcium in the blood and urine samples.

The principal investigator is Claude D. Arnaud, M.D., of the University of California, San Francisco.

Bone, Calcium, and Spaceflight

In space, bones do not grow proportionally in mass and strength as they do on Earth under the force of gravity. This experiment will identify the changes that occur early in the weight-bearing and non-weight-bearing bone tissues of growing rats and try to relate the changes to changes in the metabolism of calcium.

The rats involved in this investigation will be given ^{40}Ca, a stable nonradioactive isotope of calcium, instead of the natural calcium in their diet. This will enable researchers to measure the amount of calcium from the rats' bones in the animals' urine and feces.

One of the objectives of the experiment is to determine if exposure to microgravity causes a significant decrease in bone mineralization within the first week of flight and the bone parameters that cause the decrease or are affected by it. The investigation will also try to determine if the activity of the bone-forming cells decreases or stops during the flight.

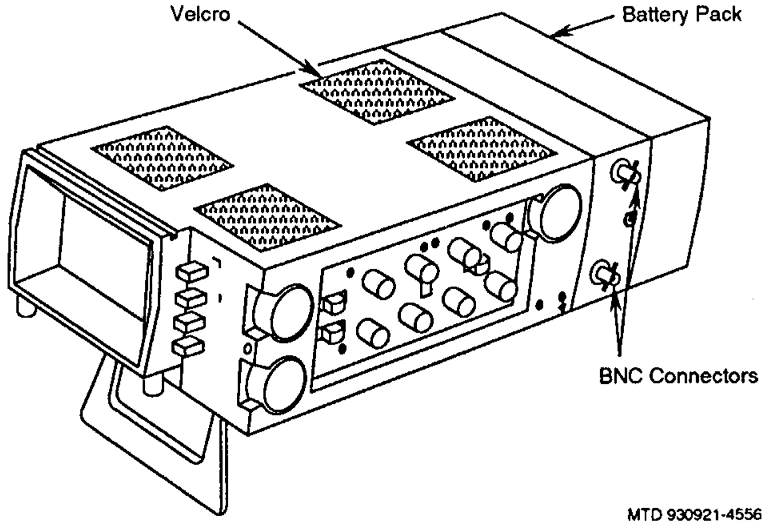
The principal investigator is Emily R. Morey-Holton, Ph.D., Ames Research Center, Moffett Field, Calif.

SLS-2 SHARED LIFE SCIENCES LABORATORY EQUIPMENT

SLS-2 investigators will use NASA's life sciences laboratory equipment (LSLE) to perform their experiments. LSLE includes a wide range of multipurpose, reusable medical and biological instruments that have been developed or modified for use in microgravity.

Human Experiments

Minioscilloscope. Two minioscilloscopes will be carried on this flight to measure, display, and record transient voltage and electrophysiological signals from the cardiovascular adaptation and neurovestibular experiment sources to verify signal strengths before the experiments begin. They may also be used as a general-purpose tool to maintain other equipment and for troubleshooting faulty equipment.



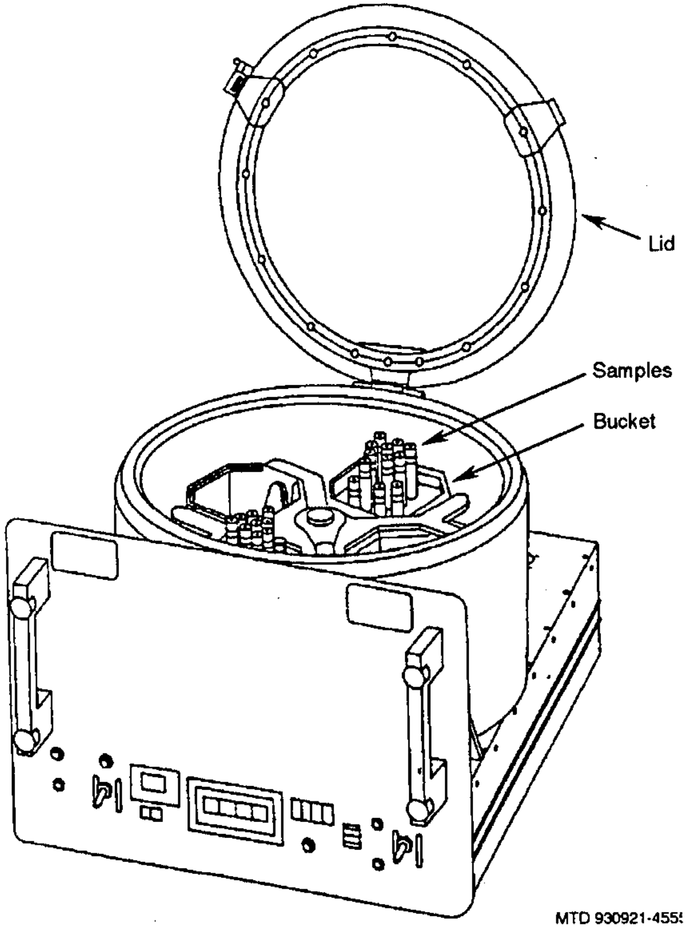
Minioscilloscope

Microcomputer. Three microcomputers are provided as part of the LSLE for use with heart, lung, and vestibular experiments. The low-power, 12-bit computers are generally used for real-time control and operation of their experiments, on-board processing of data, and formatting of data for transmittal to the ground.

Rack-Mounted Centrifuge. The centrifuge will be used in four experiments to separate plasma from blood samples taken from crew members. It can process up to 80 samples at a time.

To operate the centrifuge, which is mounted in rack 12, a crew member pulls it out of the rack, loads the samples in the centrifuge, pushes the device back into the rack, and starts it. After the process is complete, the crew member pulls out the centrifuge and removes the samples, which are frozen and returned for postflight analysis.

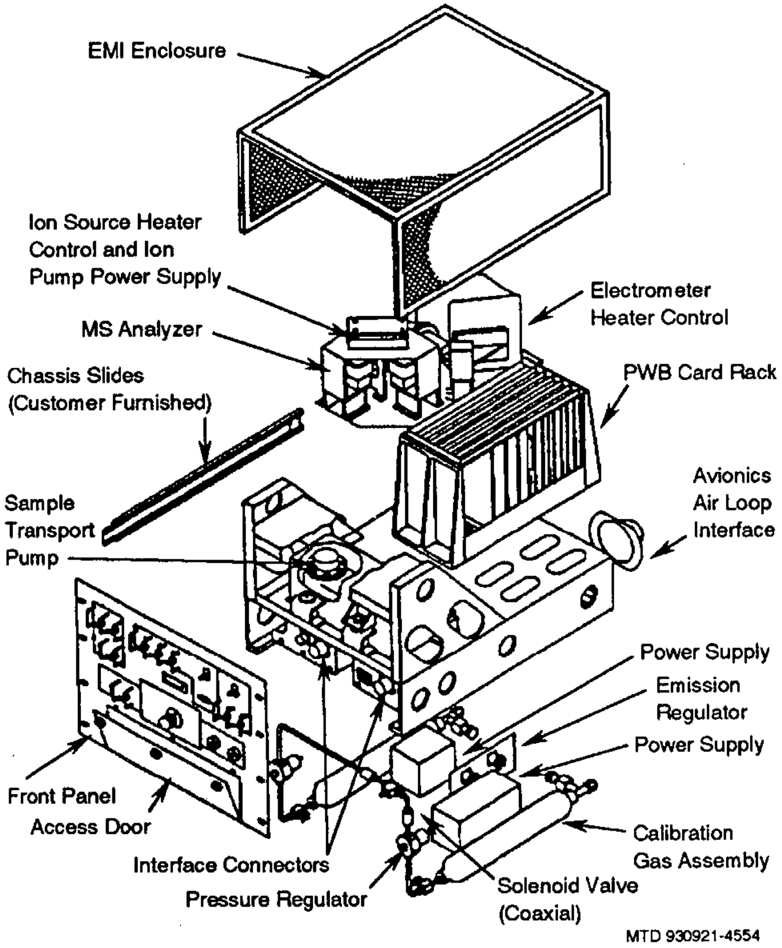
In-flight Blood Collection System. The IBCS will be used to collect and process blood samples for several experiments through-



Rack-Mounted Centrifuge

out the mission. Some of the samples will be separated in the rack-mounted centrifuge and frozen for postflight analysis.

Gas Analyzer/Mass Spectrometer. The GAMS will collect and analyze the composition of gases expelled by astronauts as they perform the cardiovascular deconditioning and pulmonary function experiments. When used with other experiments, the GAMS can determine oxygen consumption and metabolic rate, respiratory dead space, residual capacity, pulmonary capillary blood flow, pulmonary diffusing capacity cardiac output, and blood gas composition. The instrument monitors nitrogen, oxygen, carbon dioxide, water vapor, isotopic carbon monoxide, nitrous oxide, argon, helium, acetylene, and total hydrogens.



GAMS Exploded View

Two GAMS units are being flown on this mission. One is the primary unit; the other is a backup. However, the units can be run concurrently, supporting different experiments.

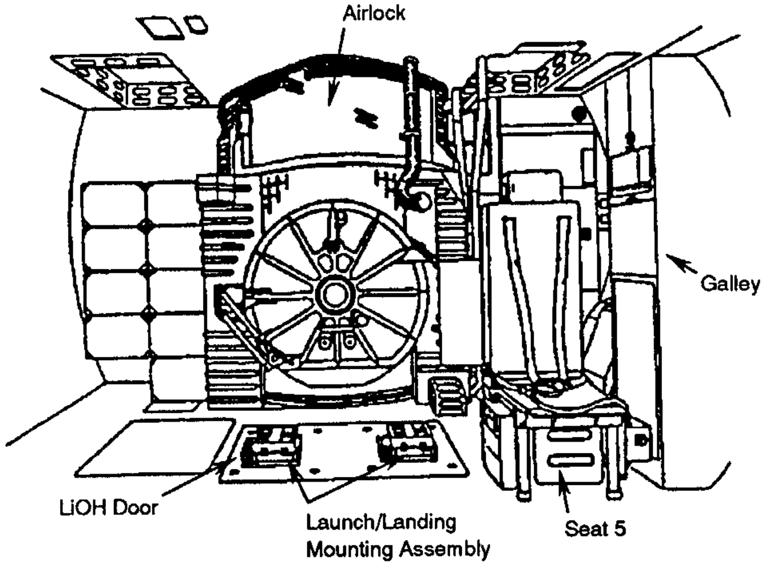
Physiological Monitoring System. The PMS will monitor crew members' heart rates, blood pressure, and ECG during the cardiovascular deconditioning and adaptation and pulmonary function experiments. The PMS data can be displayed on board, recorded, or transmitted to the ground.

Before the experiment begins, the subject removes the PMS from its stowage locker and attaches the electrodes to his body. The operation of the PMS can be controlled and programmed with a remote control/display unit, which also can display heart rate and blood pressure. After the experiment, the astronaut subject removes the sensors and puts the PMS in its locker.

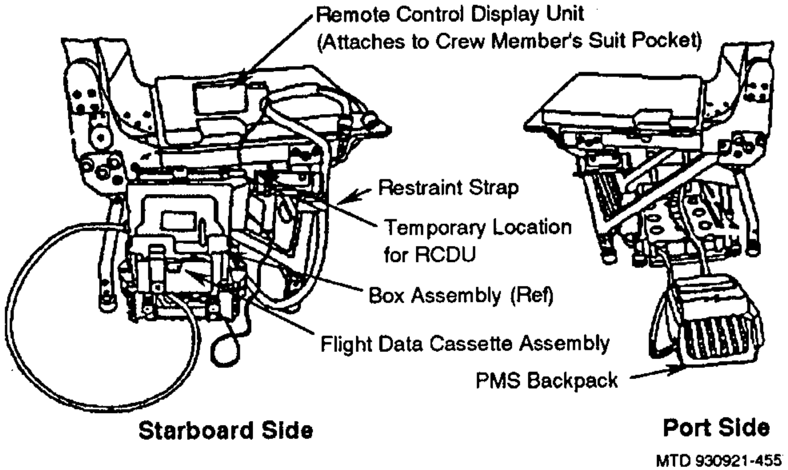
Body Mass Measuring Device. The BMMD uses a linear spring/mass pendulum platform to measure the mass of human subjects in zero gravity. The mass of the subject is determined by converting the electronically timed period of the pendulum.

After lowering himself into the BMMD seat and fastening body restraint straps, the subject moves a three-position switch to the mass position, clears the digital display, and unlocks the seat. He then tenses his muscles, holds his breath for about 10 seconds, and pushes the seat release, which causes the seat to oscillate. After the device stops, the subject records the period of oscillation shown on the digital display, turns the three-position switch to the temperature setting, resets the digital display, and records the temperature shown on the display. The recorded oscillation and temperature readings are used to obtain mass values.

Strip Chart Recorder. The SCR will be used to record cardiovascular and pulmonary experiment data, such as blood pressure, ECG, and respired volume. The recorded data can be used to verify the operation of the experiment or for postflight evaluation.

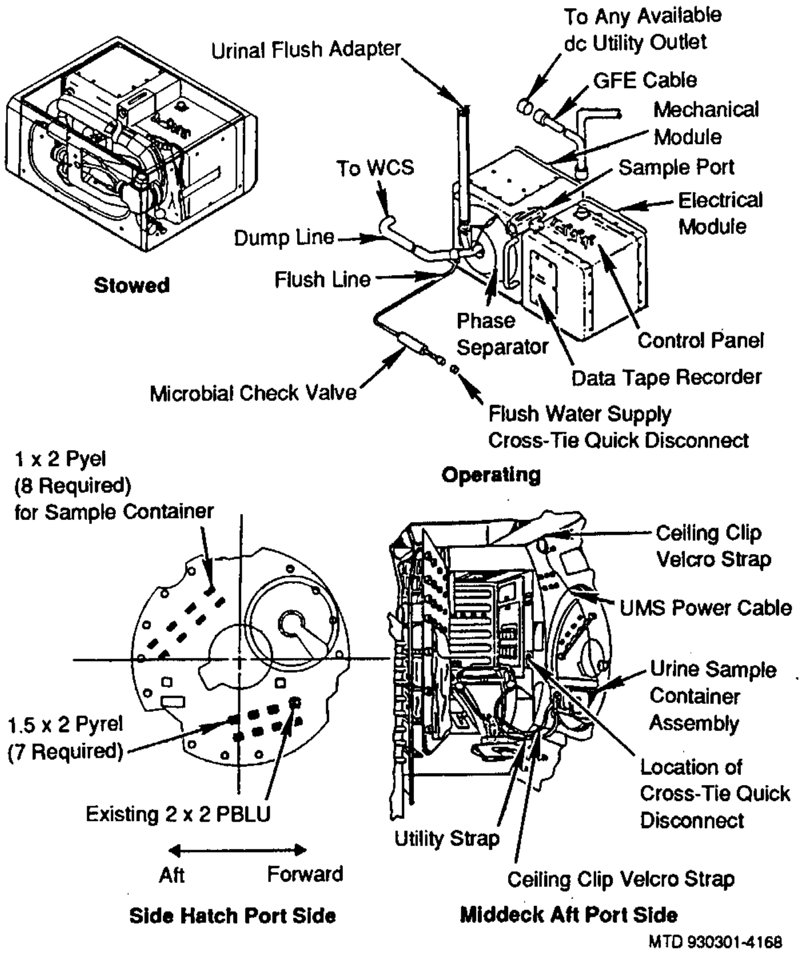


Middeck Aft



Physiological Monitoring System Experiment

Urine Monitoring System. The UMS will be used to collect and accurately measure urine samples from all seven crew members.



Urine Monitoring System

The samples are placed in the orbiter refrigerator/freezer and frozen. They will be analyzed after the flight for protein metabolism, fluid electrolyte regulation, and pathophysiology of mineral loss.

To ensure that the mass measurements of the urine samples are accurate, the UMS can be calibrated by injecting a known volume and mass of water into the UMS with a syringe. A liquid crystal display will show the mass measured.

Spacelab Refrigerator/Freezer. This unit can be used as either a refrigerator or freezer to preserve biological material. Two units are being flown on this mission; both are mounted in rack 9.

Orbiter Refrigerator/Freezer. This cooling unit operates as a refrigerator during the ascent phase of the mission and as a freezer during the rest of the flight. It is similar to the Spacelab refrigerator/freezer but is located in the crew cabin.

Cassette Data Tape Recorder. The eight-channel instrument will record central venous pressure and ECG data during the cardiovascular adaptation experiment and eye movement and acceleration data during the vestibular experiments. Two different models of the CDTR are being flown.

Temperature and Humidity Monitoring System. This self-contained, battery-operated device will measure and record the temperature and relative humidity in the Spacelab module at regular intervals. A field unit excites a transducer and measures the transducer's output, which it converts into percent relative humidity and temperature. The THMS is programmed before the flight, and no crew involvement is needed during the flight.

Cardiovascular/Cardiopulmonary Interface Panel. This panel is the primary interface that connects the components of the cardiovascular deconditioning and adaptation experiments. It is the command path from the adaptation experiment microcomputer and the deconditioning experiment CCU to the experiment hardware and receives data from the hardware and routes it to the computer and CCU. In addition, some experiment systems can be controlled through the panel.

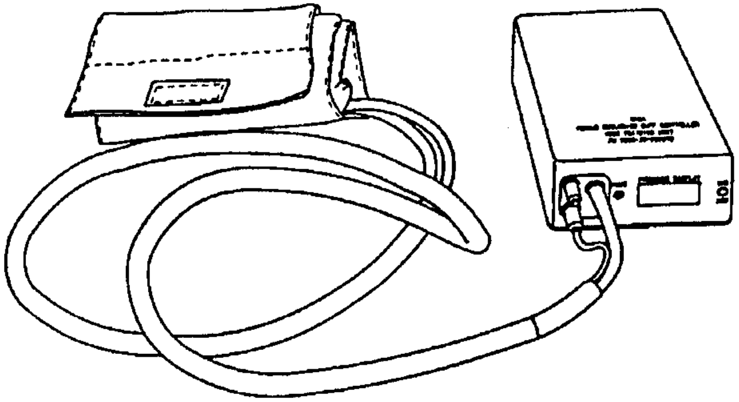
Astronaut Lung Function Experiments Bag Dryer. The ALFE bag dryer will dry rebreathing bags used in the cardiovascular deconditioning and pulmonary function experiments. The device blows air through the bags to dry them.

Venous Occlusion Cuff and Controller. The VOCC is part of the cardiovascular adaptation experiment. It consists of a controller box and a cuff that is placed on the arm or thigh and inflated with air from a pump in the controller. The controller also contains a microprocessor with preprogrammed pressure settings that the experiment subject can change.

The VOCC will be used to inhibit or stop venous blood flow in the arm or thigh of the wearer.

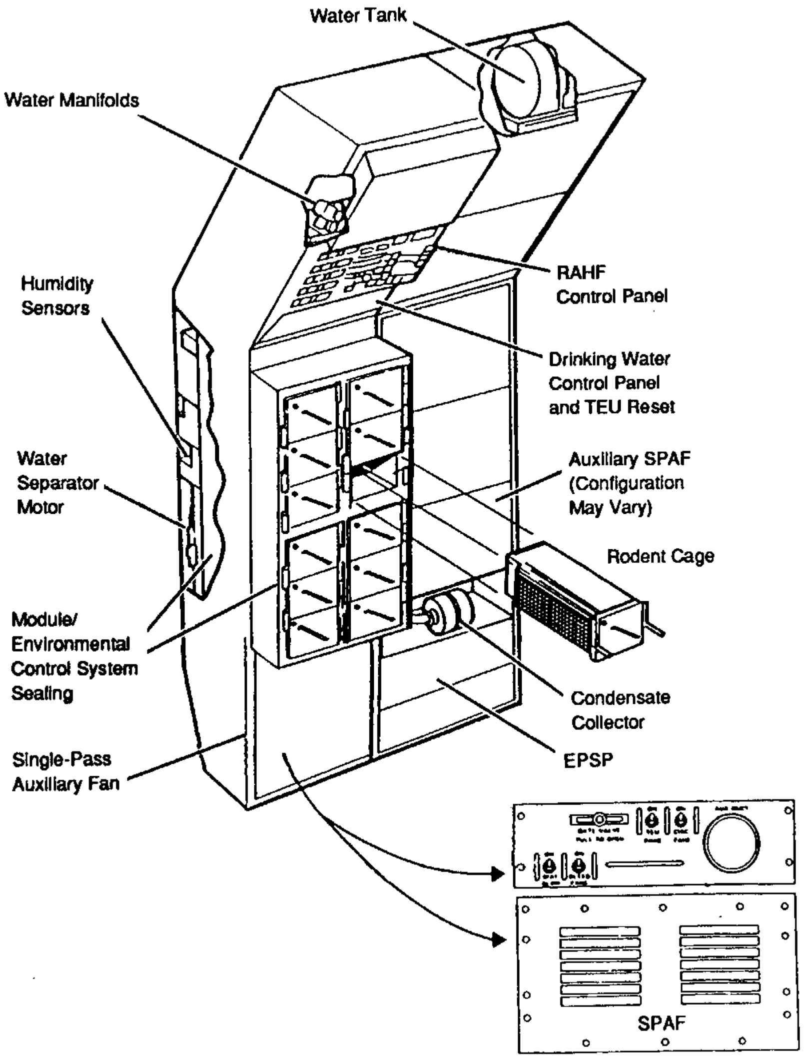
Animal Experiments

Research Animal Holding Facility. The RAHF contains all of the food, water, environmental, and sanitation arrangements for up to 24 rats. The RAHF has 12 rodent cages that can be removed, allowing easy access to the animals. Each cage can hold two rats in separate compartments. An environmental control system circulates conditioned air through the cages.



MTD 930921-4553

Venous Occlusion Cuff and Controller

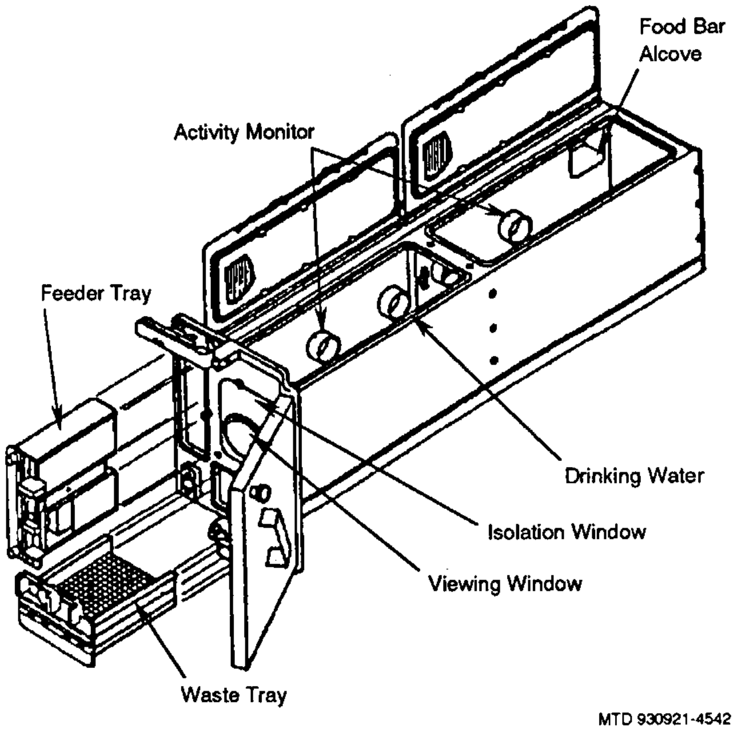


MTD 930920-4536

Generic Rodent RAHF (Landing Orientation)

The astronauts and the ground crew can monitor the activity of the rodents; their water consumption; and the temperature, humidity, and lighting in the cages. The crew will monitor the rats' food consumption on orbit and replenish their food supply.

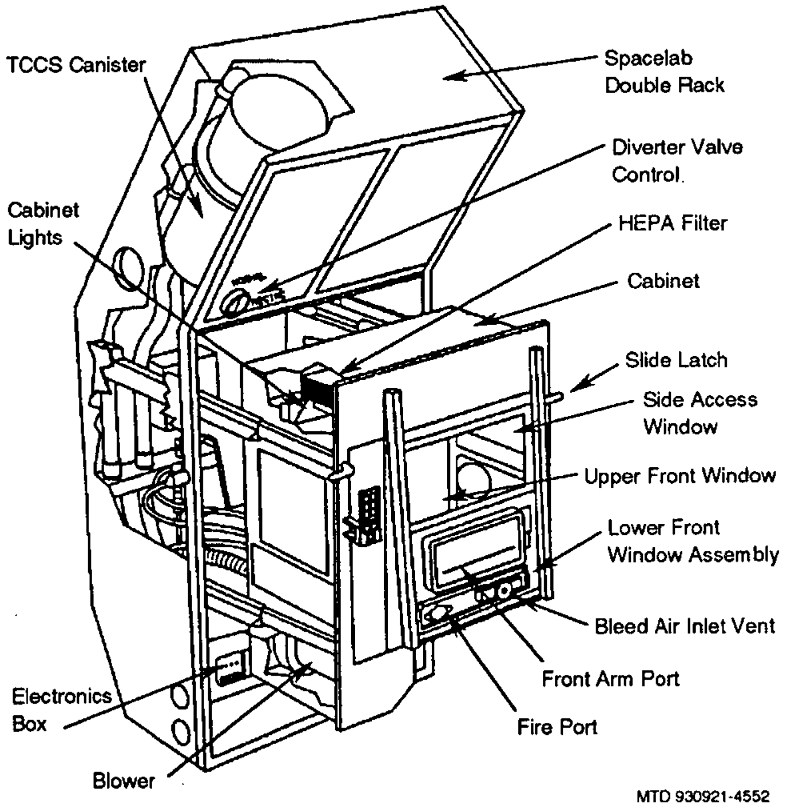
The crew can observe the rats in each cage through a window in the front of the cage. The window can be covered to shield the rats from Spacelab's interior lighting, allowing the astronauts to control the animals' light/dark cycle. Bacteriological isolation protects the astronauts and rats from cross-contamination.



Rodent Cage Assembly

Two RAHFs are being flown on this mission. They will carry a full complement of 48 white rats.

General-Purpose Workstation. The GPWS consists of a glove box with several windows and internal air circulation to prevent particles from escaping from the self-contained facility. Crew members will be able to conduct biological experiments on rats in Spacelab because the GPWS contains accidental spills of toxic materials and controls the toxic vapors generated by experiments. The astronauts



General-Purpose Workstation

will inject tracers into the rodents, draw blood, and dissect and fix rodent tissue in the GPWS.

Small Mass Measurement Instrument. The SMMI will be used to obtain weight data on the rats used in the hematology experiments. The instrument can determine the mass of small solid and semisolid items that weigh 1 to 10,000 grams, such as mice, rats, and tissue samples.

The SMMI determines mass (like the body mass measuring device) by timing the oscillations of a linear spring/mass pendulum. Mass is calculated by an internal microprocessor.

Olympus 802 Camcorder. The crew will use the camcorder to film activities in Spacelab. This commercial camcorder records audio and video on 8mm cassettes.

In-flight Refill Unit. The IRU will replenish the two RAHF water tanks during the mission with water from the orbiter's galley. The IRU can hold up to 6 liters of water.

Veterinary Kit. This kit contains items for the emergency care of rats. It includes syringes, antibiotics, needles, gauze, tape, face masks, scissors, forceps, disposable gloves, and surgical gowns.

SPACELAB

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

Spacelab is developed on a modular basis and can be varied to meet specific mission requirements. Its four principal components are the pressurized module, which contains a laboratory with a shirt-sleeve working environment; one or more open pallets that expose materials and equipment to space; a tunnel to gain access to the module; and an instrument pointing subsystem. Spacelab is not deployed free of the orbiter. The pressurized module will be used on STS-58.

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

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

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

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

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

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

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

NASA astronauts called mission specialists, as well as non-career astronauts called payload specialists, fly aboard Spacelab to operate experiments. Payload specialists are nominated by the scientists sponsoring the experiments aboard Spacelab. They are accepted, trained, and certified for flight by NASA. Their training includes familiarization with experiments and payloads as well as information and procedures to fly aboard the space shuttle. From one to four payload specialists can be accommodated for a Spacelab flight. These specialists ride into space and return to Earth in the orbiter crew compartment cabin, but they work with Spacelab on orbit. Because Spacelab missions often operate around the clock, the flight crew is usually divided into two teams. On STS-58, however, the crew will work a single shift.

PRESSURIZED MODULE

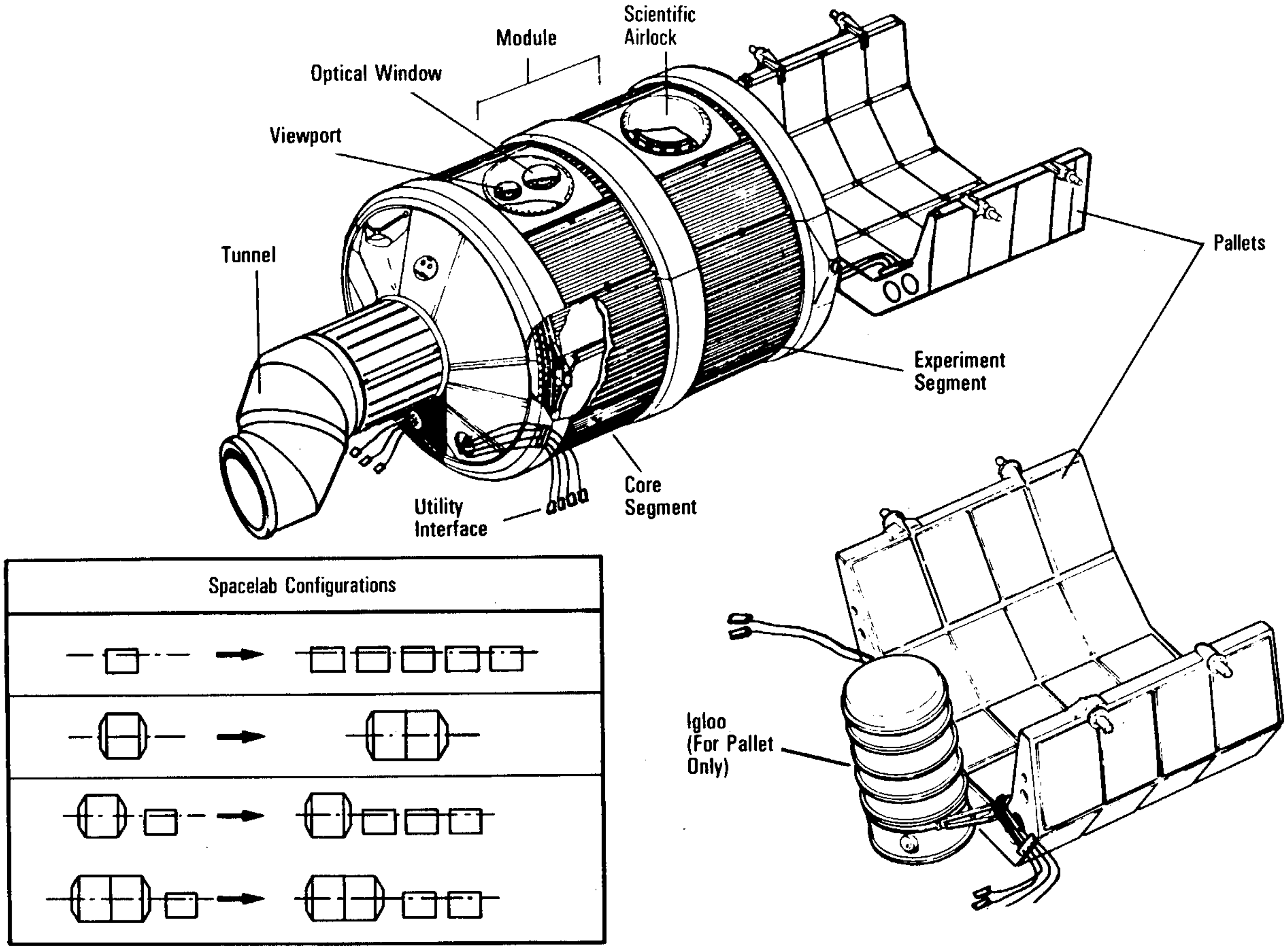
The pressurized module, or laboratory, is available in two segments. One, called the core segment, contains supporting systems, such as data processing equipment and utilities for the pressurized modules and pallets (if pallets are used in conjunction with the pressurized modules). The laboratory has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

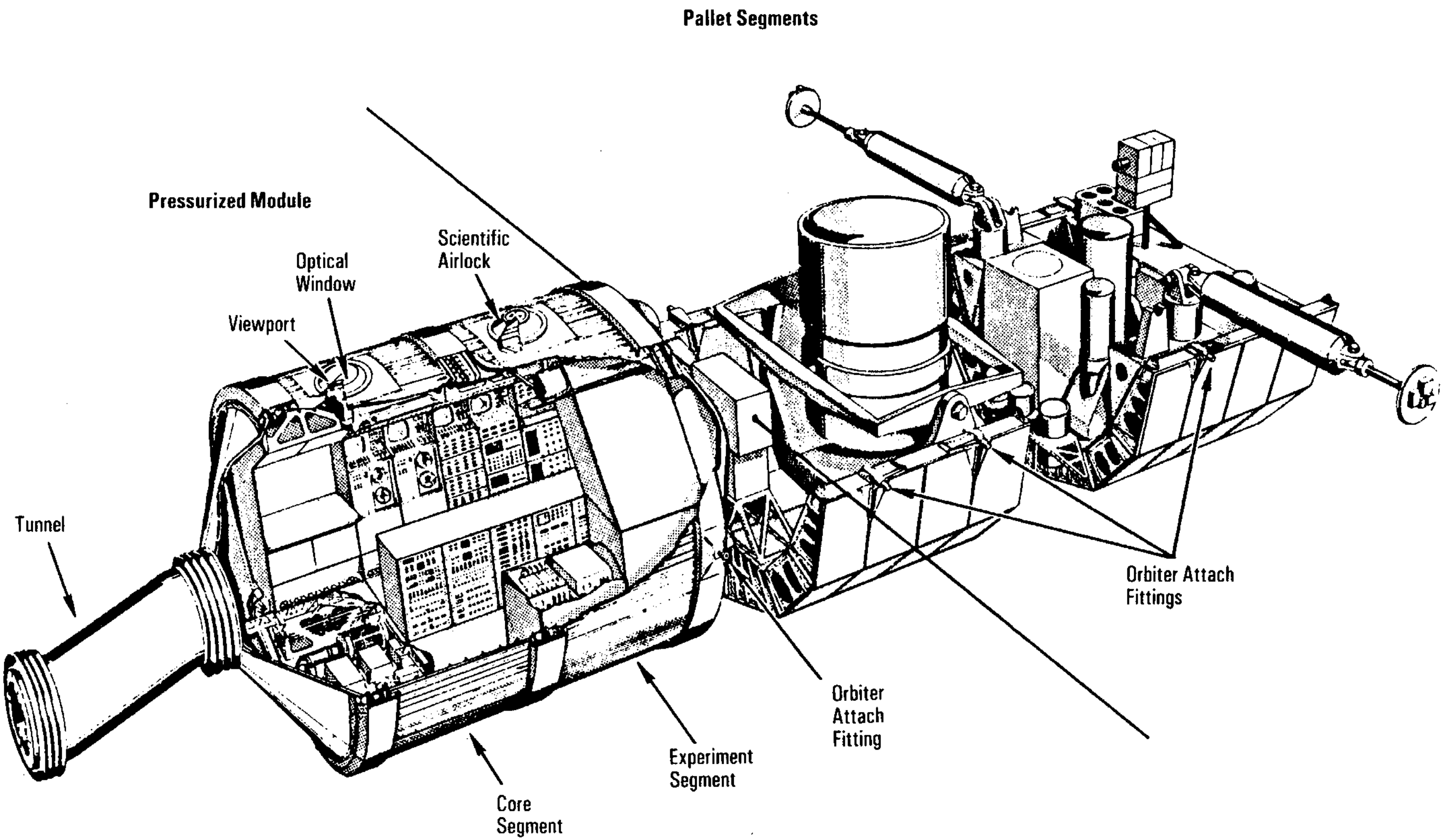
The ceiling skin panel of each segment contains a 51.2-inch-diameter opening for mounting a viewport adapter assembly, a Spacelab window adapter assembly, or scientific airlock; if none of these items are used, the openings are closed with cover plates that are bolted in place. The module shell is made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

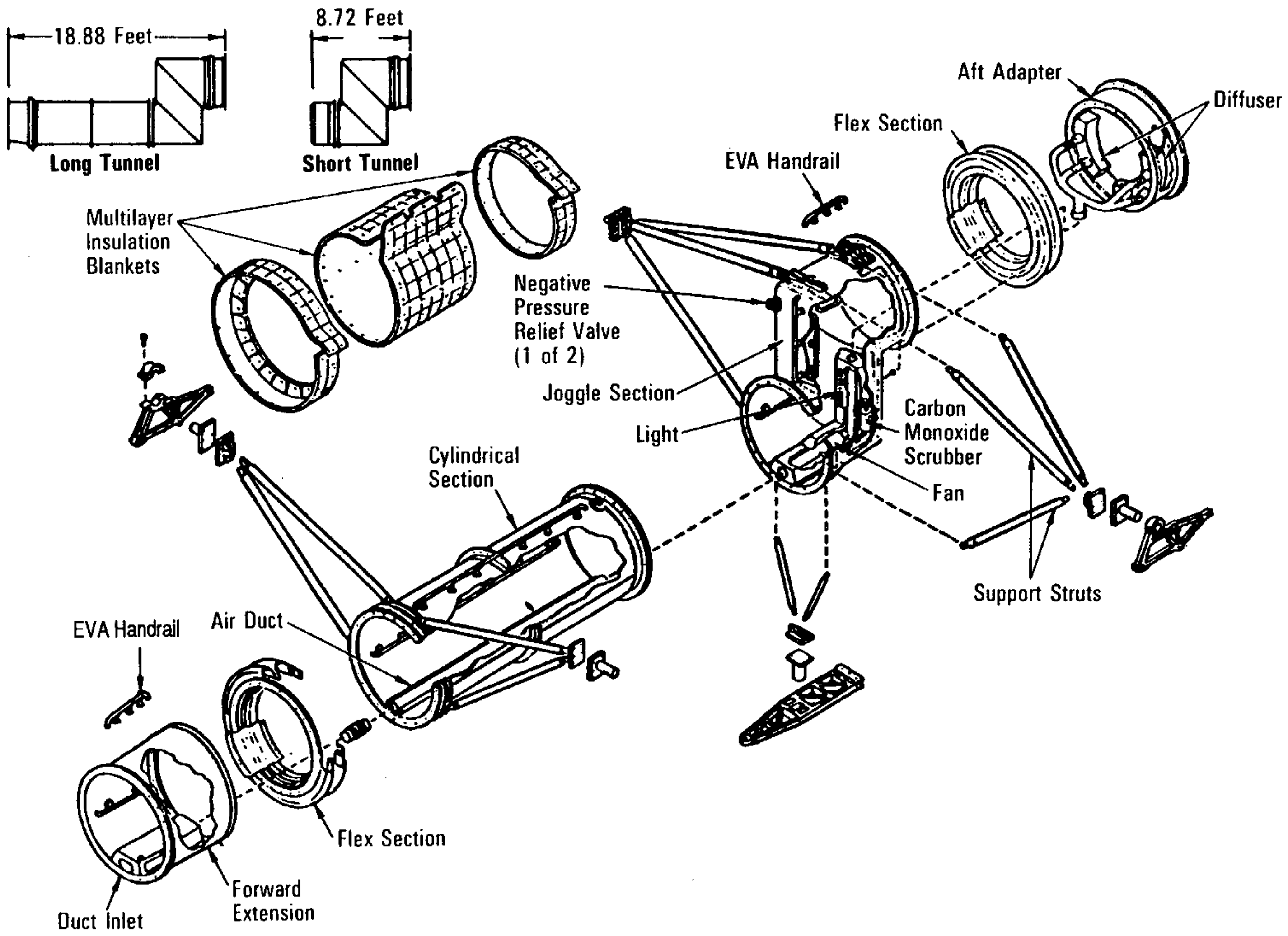
Because of the orbiter's center-of-gravity conditions, the Spacelab pressurized modules cannot be installed at the forward end of the payload bay. Therefore, a pressurized tunnel is provided for equipment and crew transfer between the orbiter's pressurized crew compartment and the Spacelab pressurized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



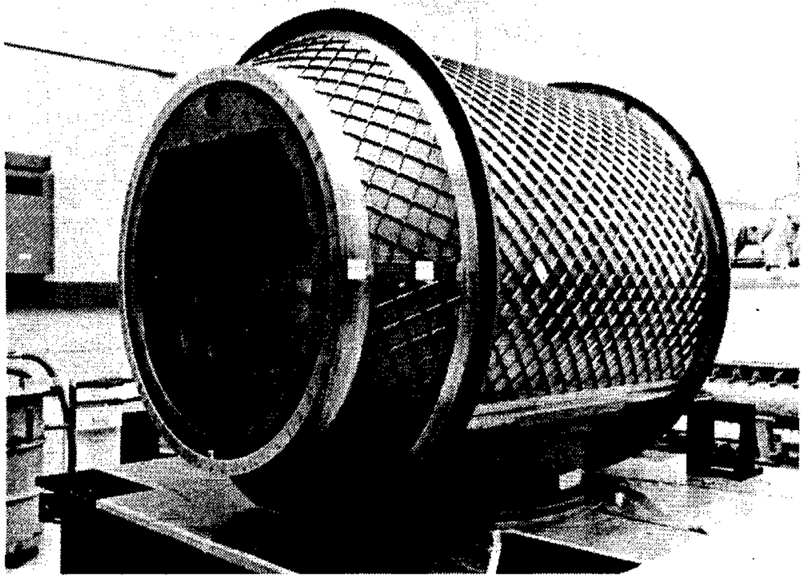
Spacelab External Design Features



European Space Agency's Spacelab



Spacelab Transfer Tunnel



Tunnel Adapter

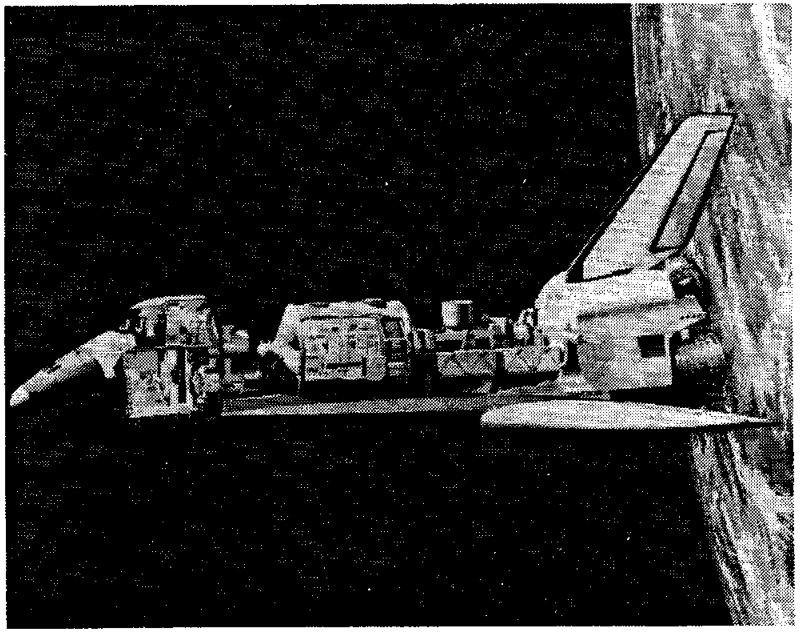
built by McDonnell Douglas Astronautics Company, Huntington Beach, Calif.

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,

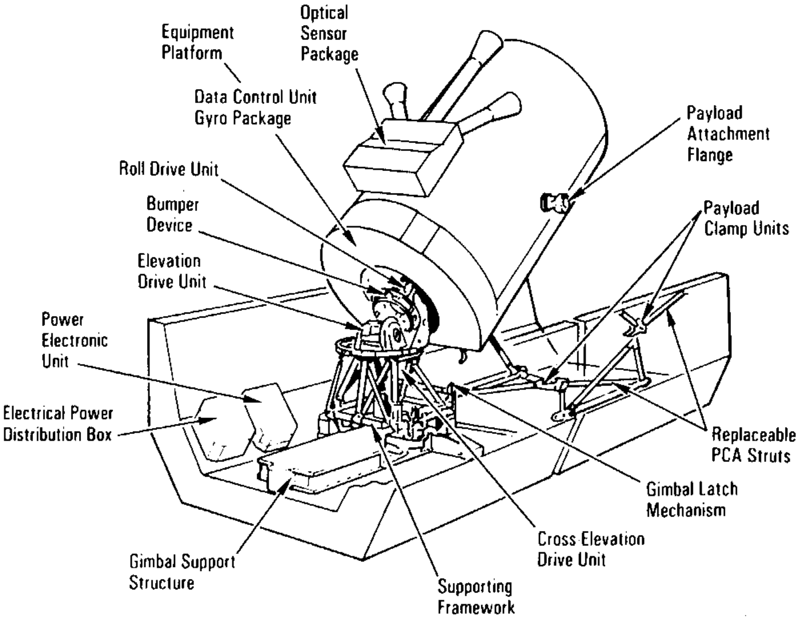


Spacelab

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.

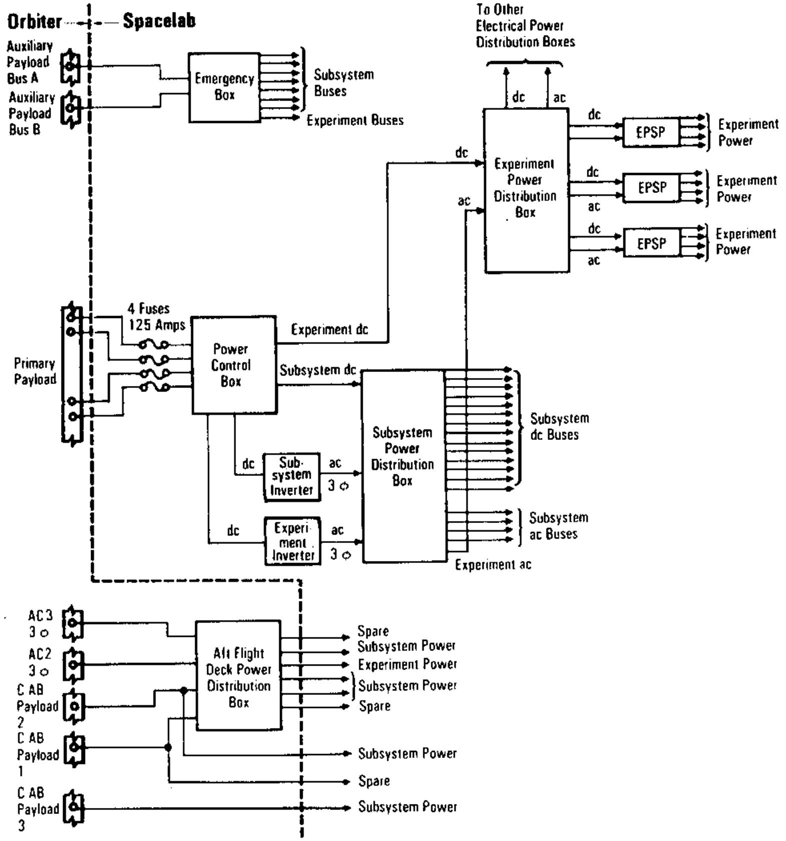
Cable ducts and cable support trays can be bolted to the forward and aft frame of each pallet to support and route electrical cables to and from the experiments and subsystem equipment mounted on the pallet. All ducts mounted on the right side of the pallet are used to route subsystem cables, and all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

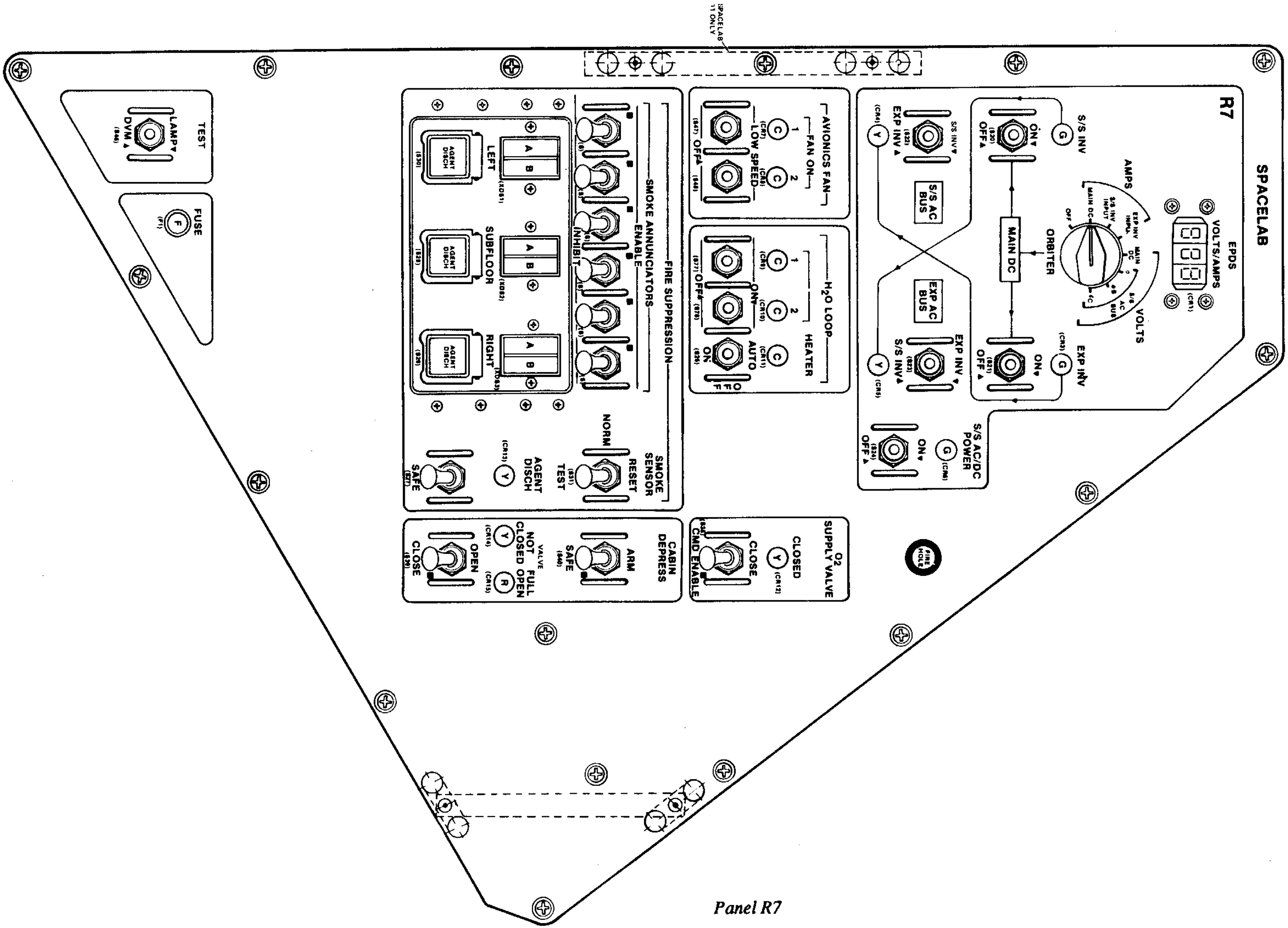
ELECTRICAL POWER

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.

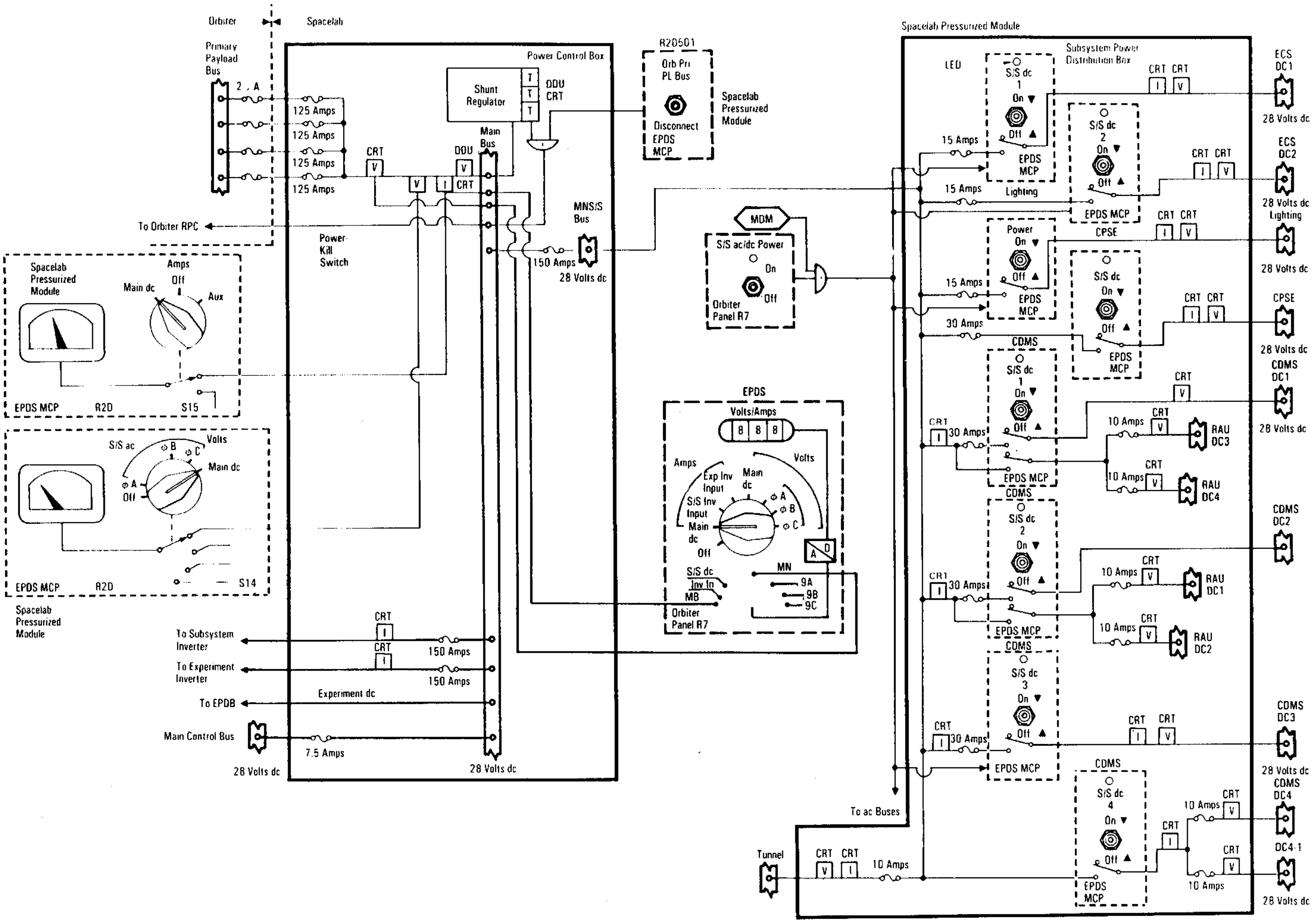
The primary dc power received in the Spacelab from the orbiter primary payload bus is nominally 28 volts, a maximum of 32 volts,



Orbiter Spacelab Electrical Power Distribution


SPACELAB 11 ONLY
TEST
LAMP▼
DVM▲
FUSE
F
FIRE SUPPRESSION
SMOKE ANNUNCIATORS
ENABLE
INHIBIT
LEFT
SUBFLOOR
RIGHT
A
B
AGENT DISCH
SMOKE SENSOR
RESET
NORM
TEST
AGENT DISCH
Y
SAFE
AVIONICS FAN
FAN ON
1
2
C
LOW SPEED
OFF▲
H2O LOOP
HEATER
ON
OFF
AUTO
R7
SPACELAB
EPDS
VOLTS/AMPS
S/S INV
G
ON▼
OFF▲
EXP INV▲
S/S INV▼
S/S AC BUS
EXP AC BUS
MAIN DC
ORBITER
AMPS
VOLTS
MAIN DC
S/S INV INPUT
EXP INV INPUT
OFF
EXP INV
S/S AC/DC POWER
CABIN DEPRESS
ARM
SAFE
VALVE
NOT CLOSED
FULL OPEN
R
OPEN
CLOSE
O2 SUPPLY VALVE
CLOSED
CMD ENABLE
FIRE HOLE

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.

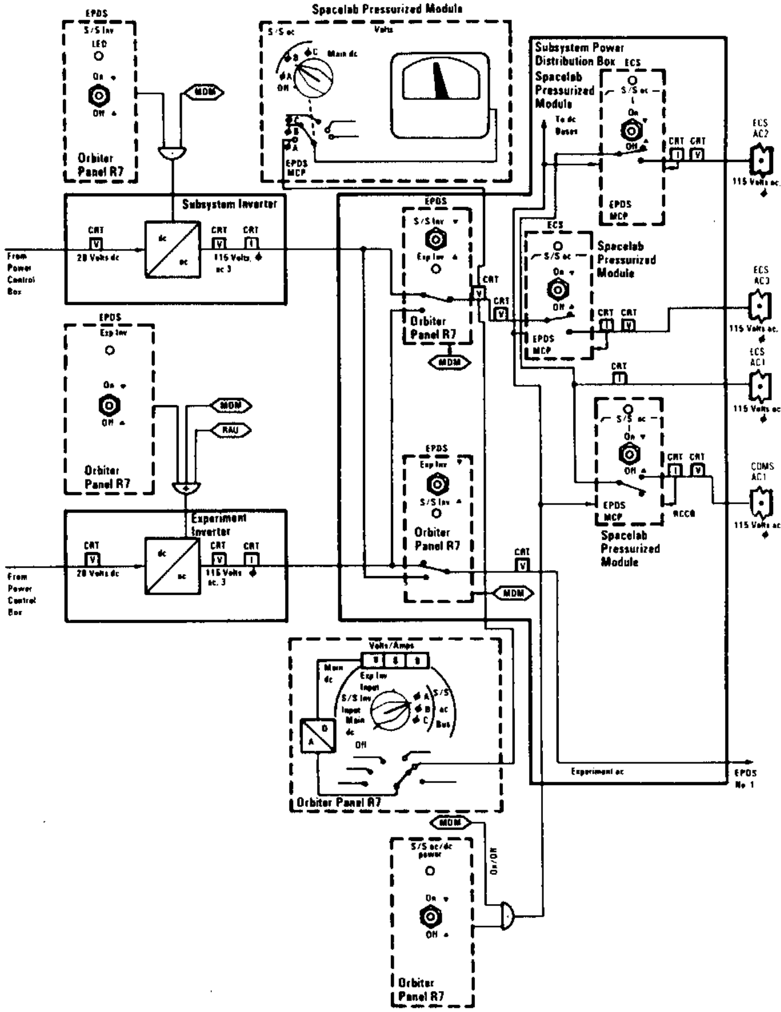
The Spacelab subsystem inverter is activated by the *S/S inv on/off* switch on panel R7 or by orbiter Spacelab CRT command. Positioning the switch to *on* activates the subsystem inverter, and a green LED above the switch on panel R7 is illuminated, indicating the inverter is operating. Positioning the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

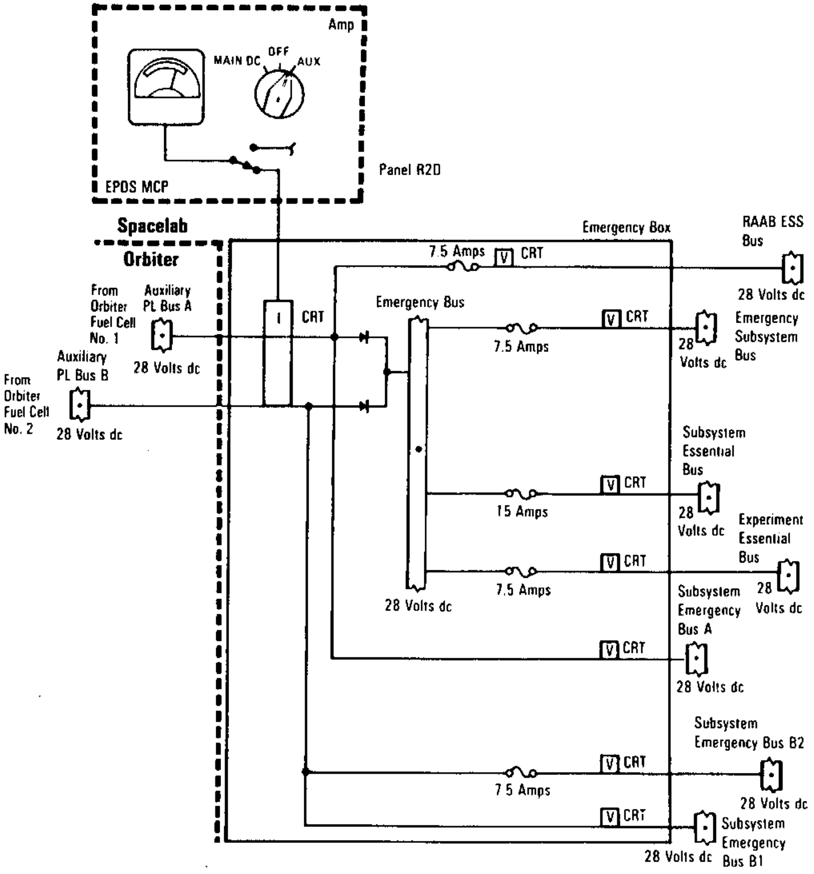
power on/off switch on orbiter panel R7 or by item commands from the orbiter CRT Spacelab displays. The status of the commanded relays is available via orbiter CRT Spacelab displays and indicated by the green LED light above the respective switch on panel R7.

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.

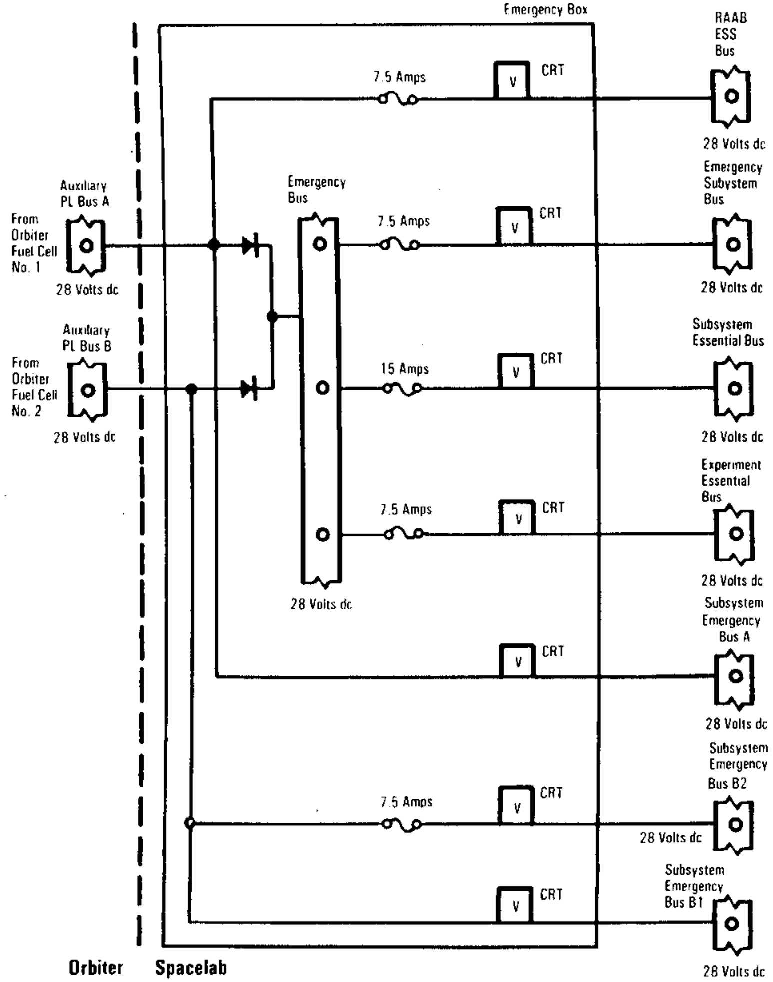
In the Spacelab pressurized module configuration, experiment power distribution boxes provide distribution, control, and monitoring facilities for the experiment electrical power distribution system, which consists of a nominal redundant 28-volt experiment main dc supply and a 115-volt, 400-hertz ac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



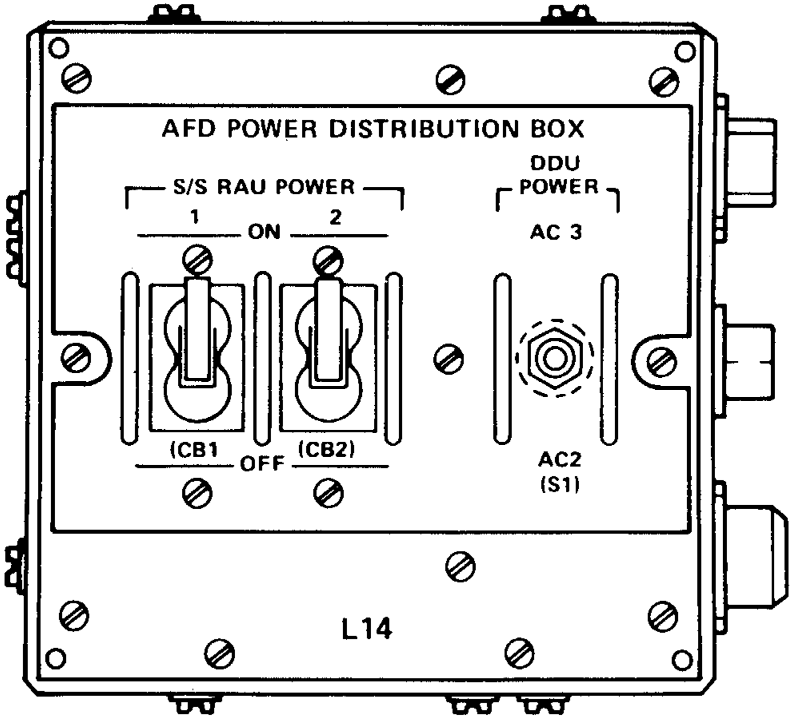
Spacelab Pressurized Module Emergency and Essential Power Distribution the experiment power distribution box is mounted with other assemblies with an adapter plate on a cold plate that is fitted on a support structure and attached to the pallet.

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.

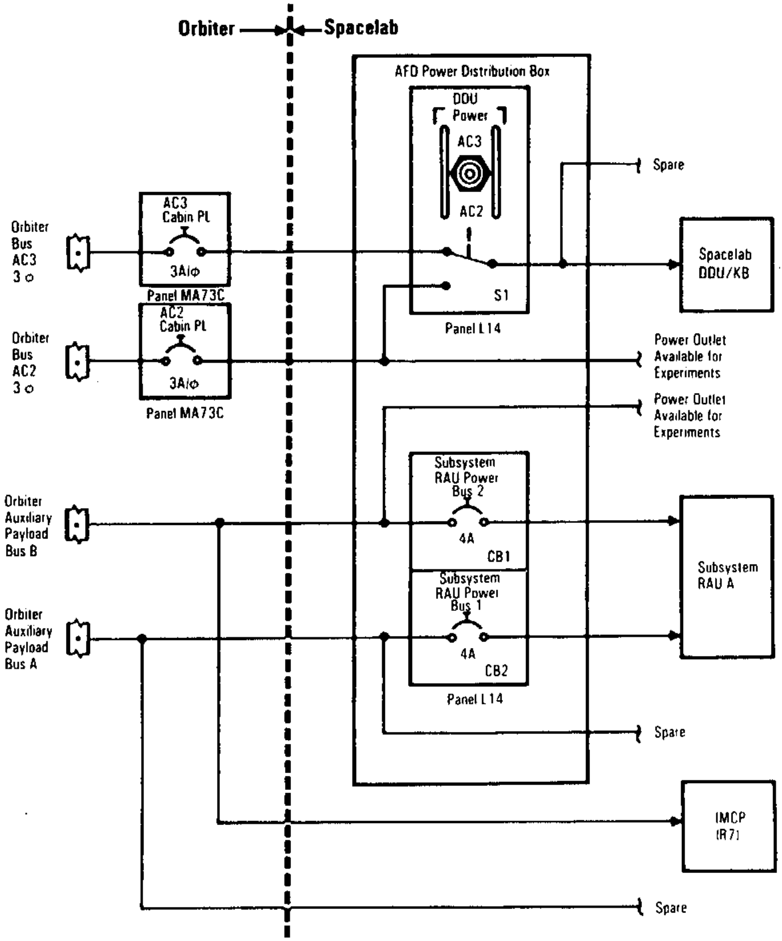
The Spacelab power distribution box at the orbiter aft flight deck payload station distributes dc and ac power to the Spacelab subsystem remote acquisition unit and the Spacelab data display system (a data display unit and keyboard). When a Spacelab data display system is installed at the mission station,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



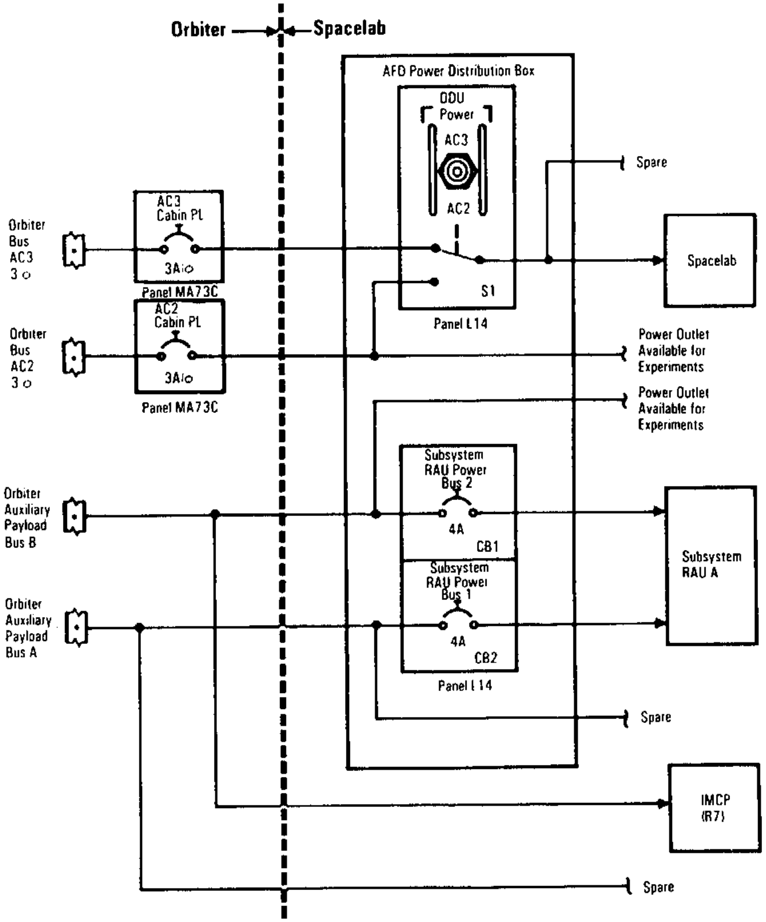
Pressurized Module Configuration—Orbiter Aft Flight Deck Power Distribution

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.

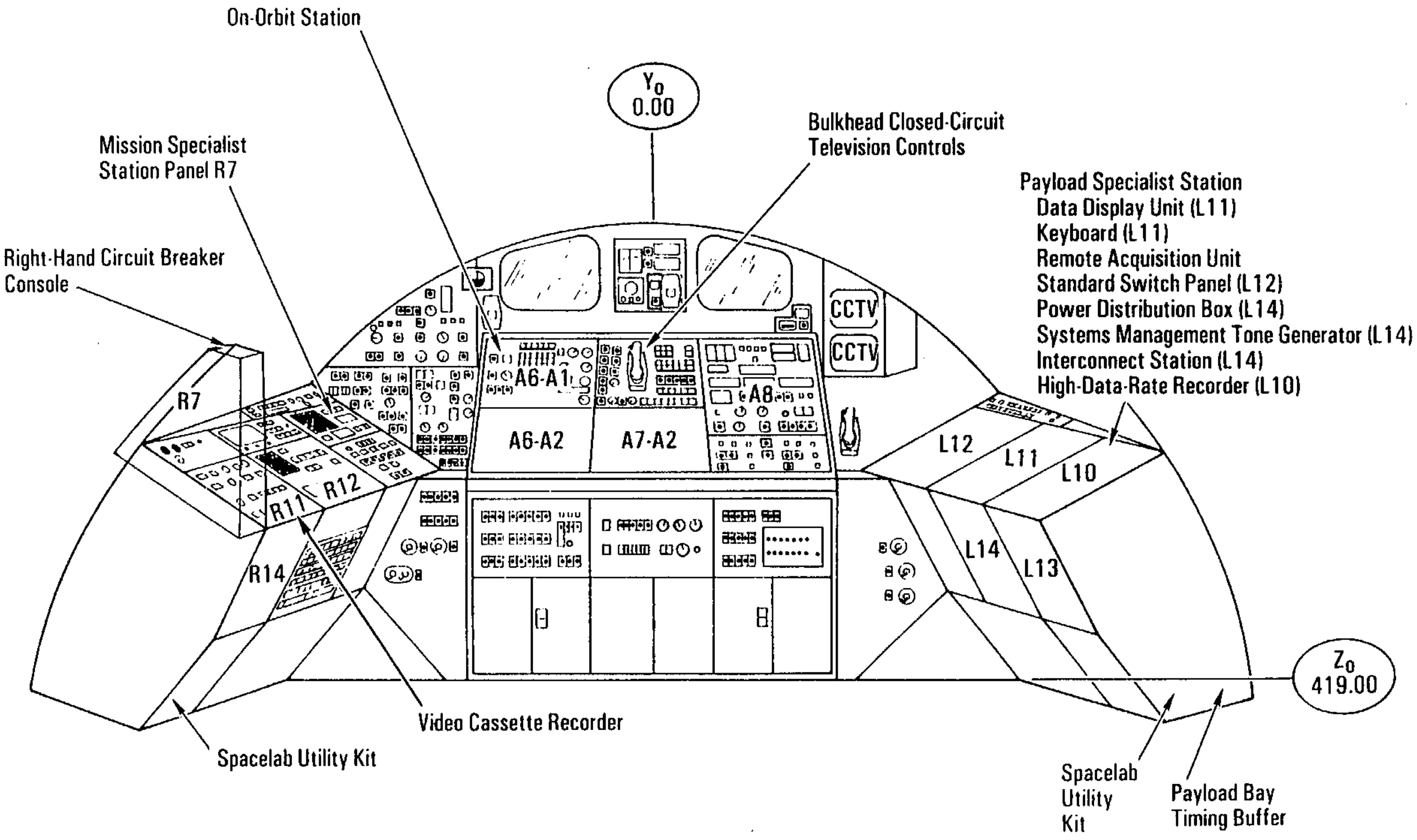
COMMAND AND DATA MANAGEMENT SYSTEM

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.

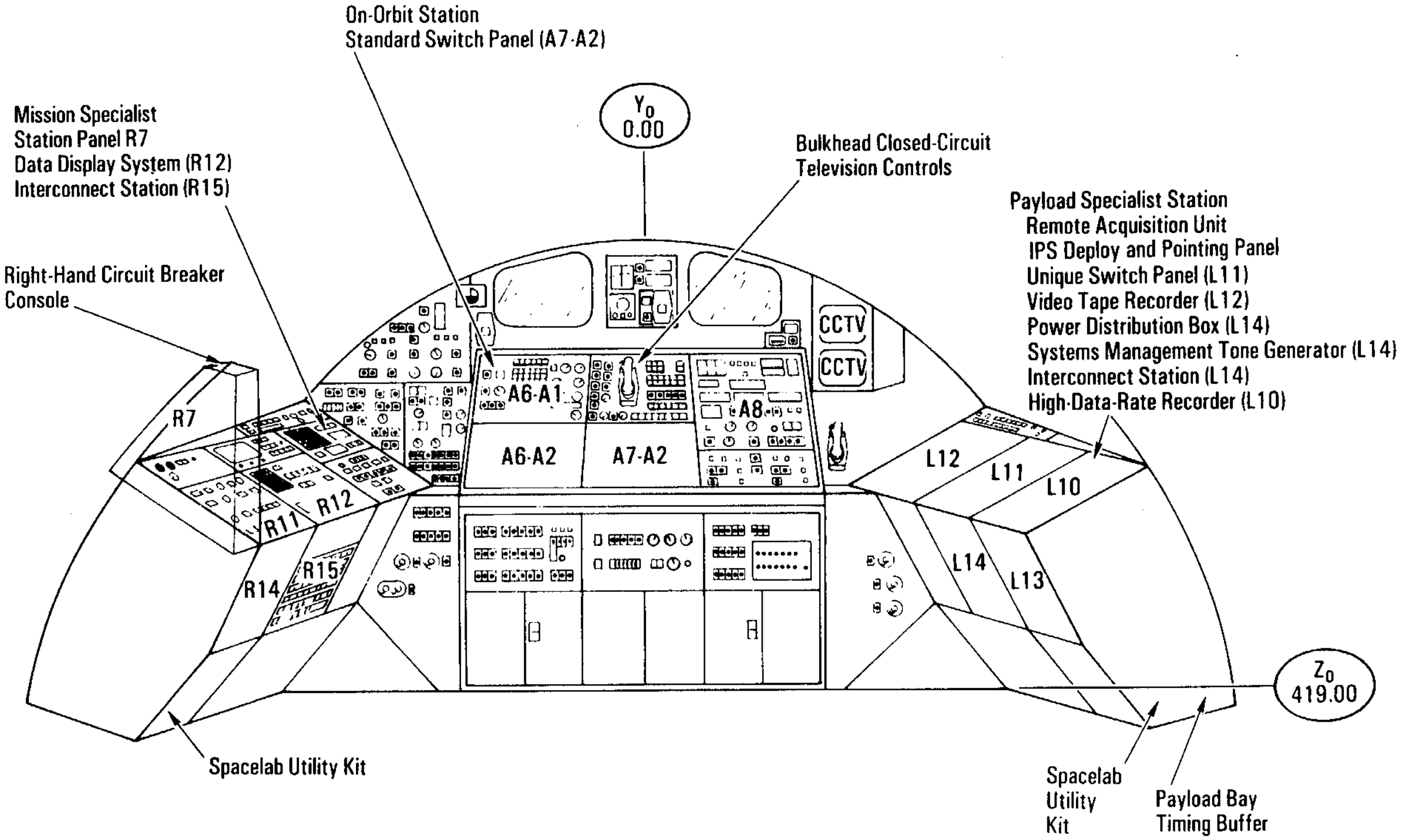


Pallet-Only Configuration—Orbiter Aft Flight Deck Power Distribution

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.

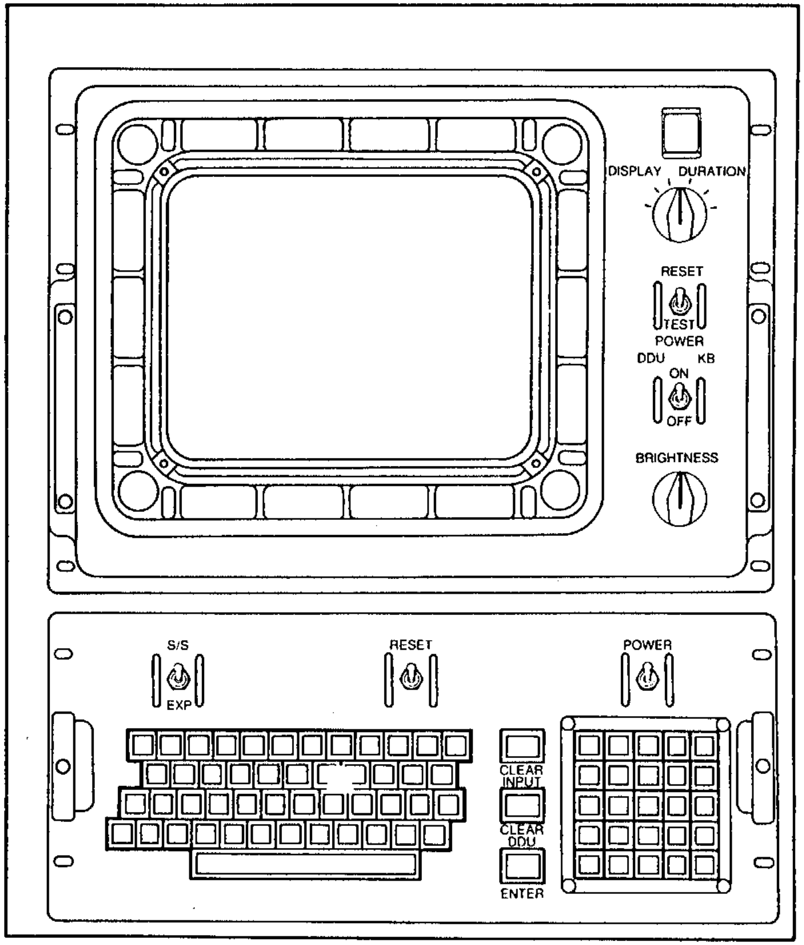
Mass Memory Unit

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.

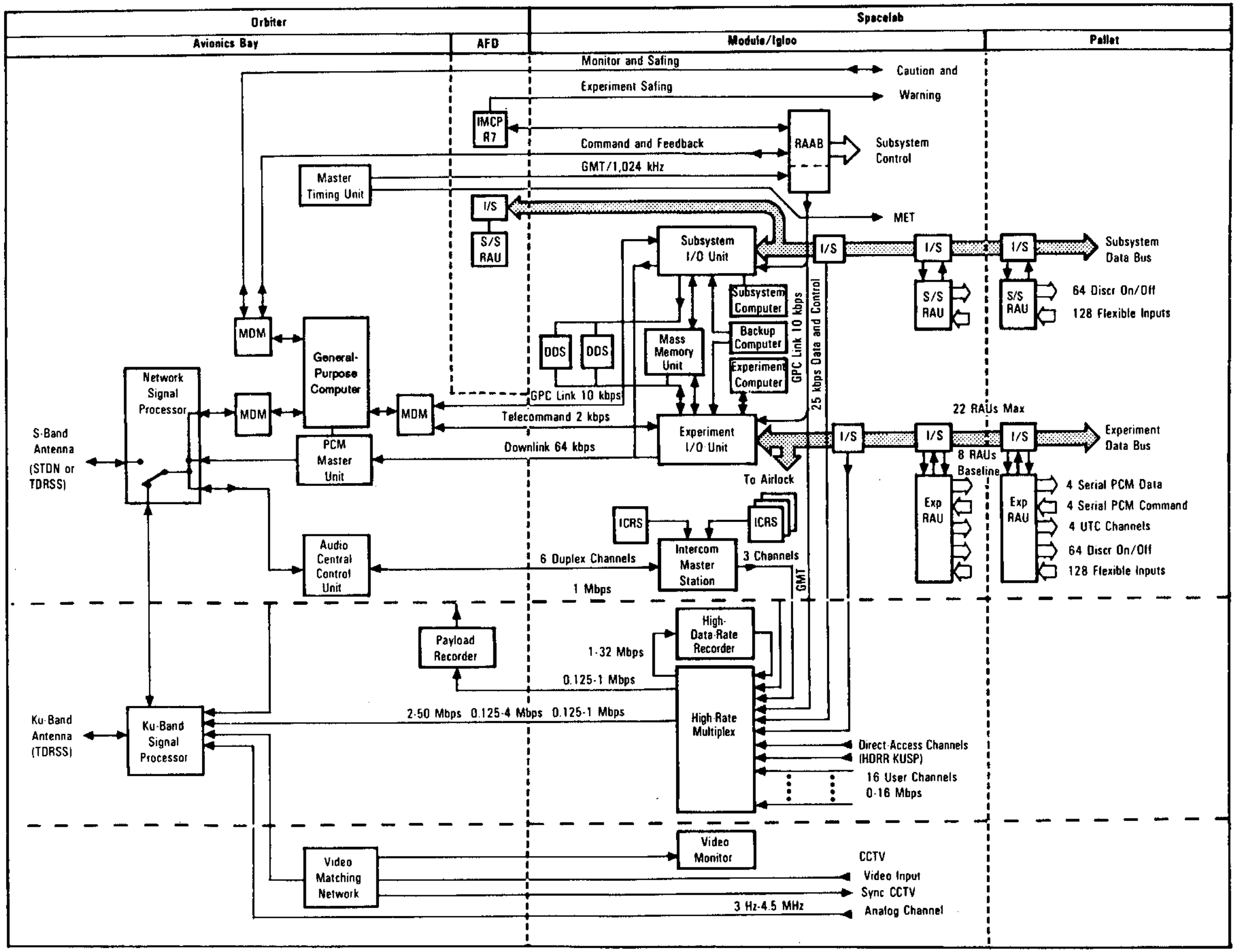
Two orbiter payload multiplexers/demultiplexers (PF1 and PF2) are used for data communications between the orbiter general-purpose computers and the Spacelab CDMS computers. The payload MDMs are under orbiter GPC control. The orbiter pulse code modulation master units under control of the orbiter computers 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.

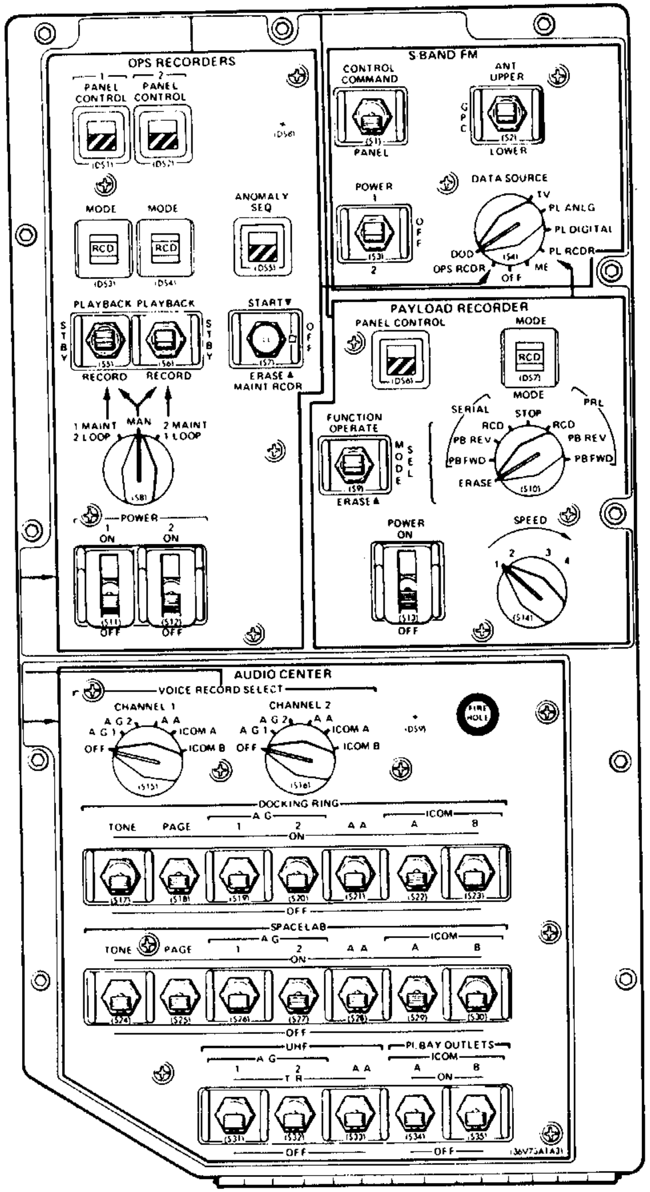
Spacelab high-rate data acquisition is provided by a high-rate multiplexer and a high-data-rate recorder. The HRM multiplexes up to 16 experiment channels, each with a maximum of 16 Mbps; two direct-access channels with data rates up to 50 Mbps; data from the Spacelab subsystem computer; experiment data 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

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



Spacelab Command and Data Management System Interfaces With the Orbiter



Panel AIA3

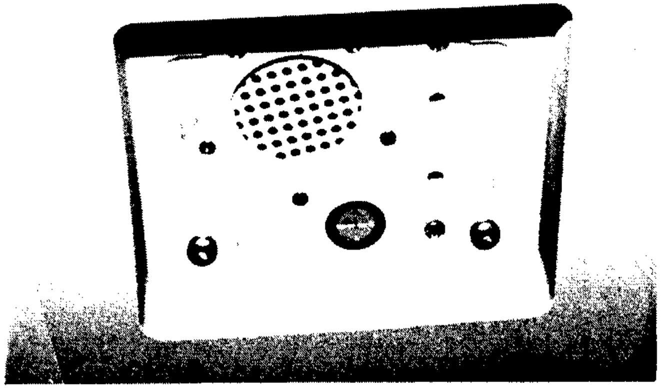
periods with no downlink capability or degraded downlink capability for playback when the capability is available. The HDRR dumps in reverse order at 2, 4, 8, 12, 16, 24, or 32 Mbps. At a rate of 32 Mbps, a tape runs for 20 minutes. The recorder can be changed manually by the flight crew; however, no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

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

Closed-Circuit Television

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

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



Spacelab Pressurized Module Aural Annunciator Located Below Panel L14

Pressurized Module Intercom

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

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

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

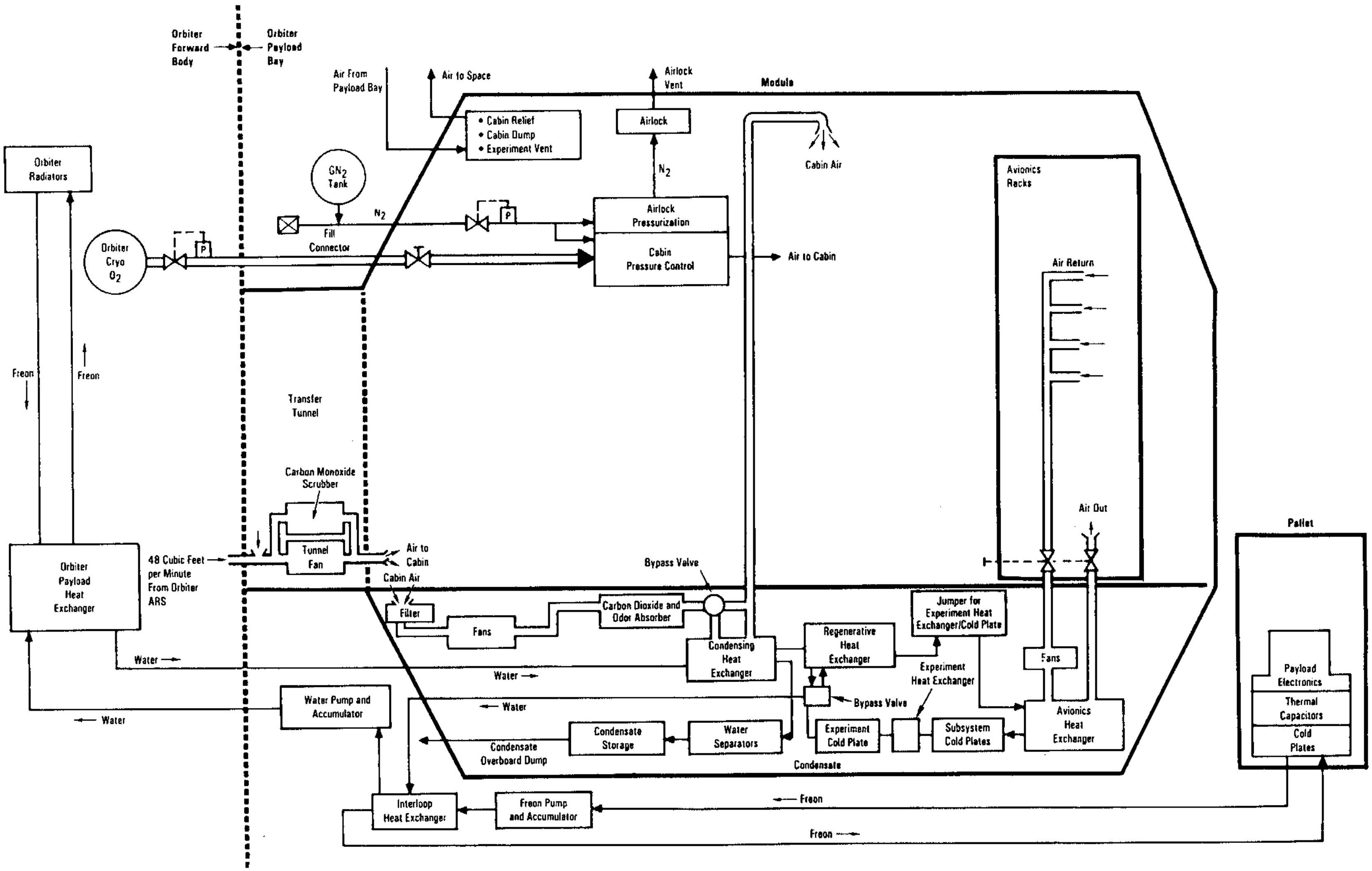
PRESSURIZED MODULE ENVIRONMENTAL CONTROL SUBSYSTEM AND LIFE SUPPORT

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

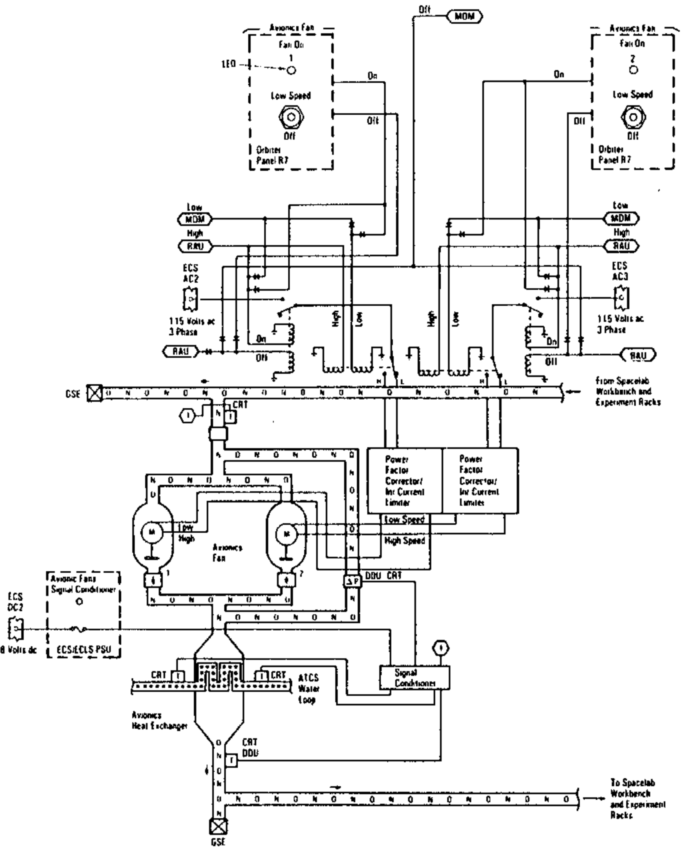
The atmosphere storage and control subsystem receives gaseous oxygen from the orbiter power reactant storage and distribution system and gaseous nitrogen from a tank located on the Spacelab module's exterior. The Spacelab ASCS regulates the gaseous oxygen and nitrogen pressure and flow rates to provide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

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

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



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



Spacelab Avionics Loop

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

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

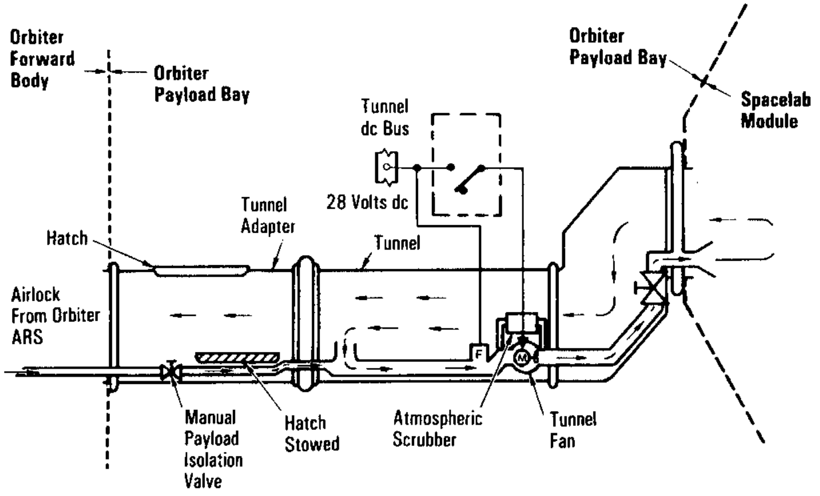
The fans are designed to switch from four-pole to eight-pole operation. The air flow through one fan is reduced from 1,923 to 639 pounds per hour, and the power is reduced from 643 to 110 watts. The two fans, powered by separate 115-volt ac buses, are activated and deactivated at low speed (eight-pole)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

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

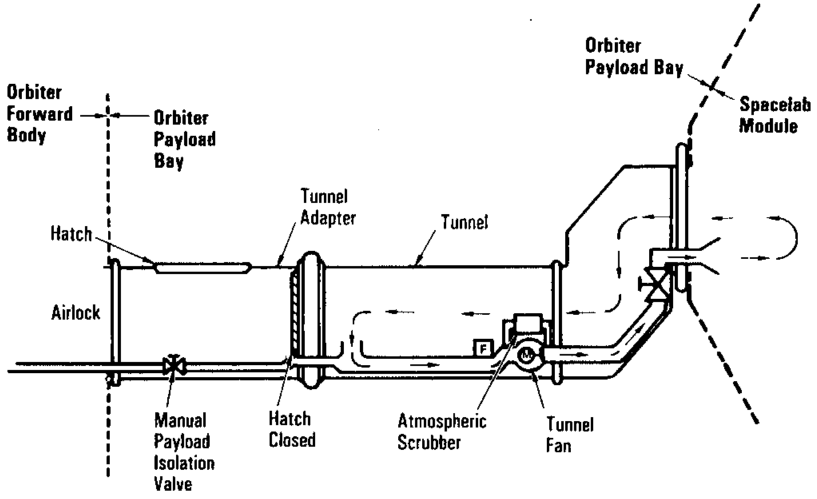
Pressurized Module/Tunnel Air Loop

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

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



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



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

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

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

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

Pressurized Module Active Thermal Control Subsystem

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

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

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

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

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

Pressurized Module Caution and Warning

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

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

Pressurized Module Emergency Conditions

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

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

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

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

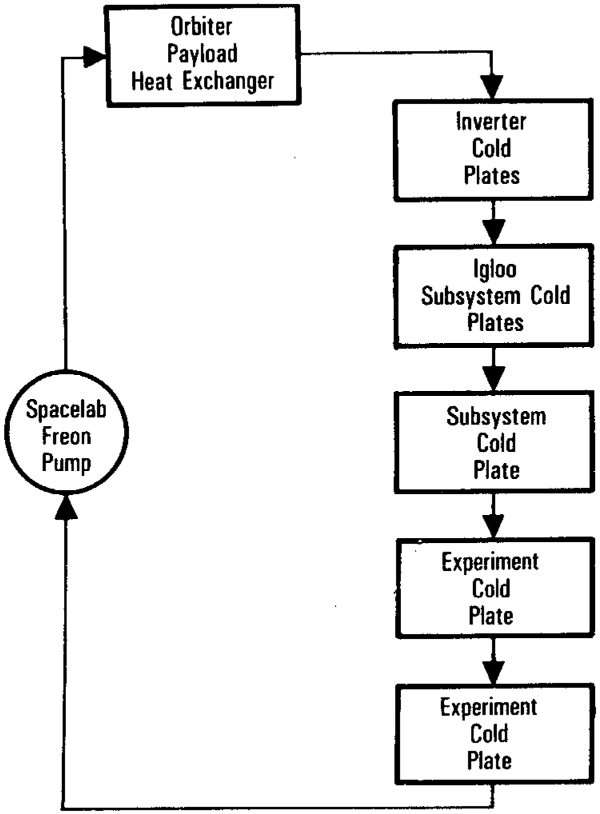
Two methods are provided for extinguishing a fire in the Spacelab module: discharging a fire suppressant into the affected area or dumping the Spacelab cabin atmosphere, when appropriate. The fire suppressant discharge consists of 15 orbiter-common fire suppression modules, each filled with the Freon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

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

PALLET-ONLY ENVIRONMENTAL CONTROL SUBSYSTEM

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

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



Freon-21 Coolant Loop for Spacelab Pallets

SHUTTLE AMATEUR RADIO EXPERIMENT II

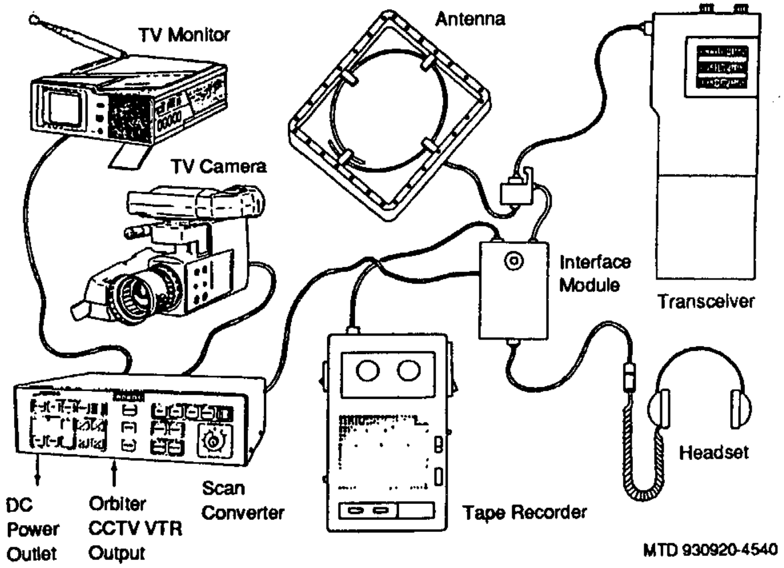
The Shuttle Amateur Radio Experiment (SAREX) was established by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club to encourage public participation in the space program through a program to demonstrate the effectiveness of conducting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

SAREX has been flown on missions STS-9, -51F, -35, -37, -45, -50, -47, -56, -55, and -57 in different configurations. Configuration C will be flown on STS-58. The equipment complement is stowed in one and one-half middeck lockers.

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

During the mission, SAREX-II will be operated at the discretion of three crew members who are licensed amateur radio operators: pilot Rick Searfoss (license pending), mission specialist Bill McArthur, and payload specialist Martin Fettman. Operating times for 16 school contacts in the U.S. and France are planned in the crew's activities.

Students in the following schools will have the opportunity to talk to orbiting astronauts for approximately four to eight minutes:



SAREX Optional Configuration

- Russellville H.S., Russellville, Ariz. (K5PXP)
- Lloyd Ferguson Elementary, League City, Texas (KB5UFJ)
- Eastern Heights Jr. H.S., Elyria, Ohio (N8AM)
- Bloomfield Elementary, Bloomfield, Mo. (N0UOP)
- Carl Hayden Community H.S., Phoenix, Ariz. (N7UJJ)
- Sycamore Middle School, Pleasant View, Tenn. (AC9R)
- Alamo Heights Junior School, San Antonio, Texas (WA5FRF)

- Nashua H.S., Nashua, N.H. (N1NHS)
- Meyzeek Middle School, Louisville, Ky. (N4OKX)
- Webber Junior H.S., Fort Collins, Colo. (N0LHW)
- Red Springs H.S., Red Springs, N.C. (W4MZP)
- Ernest Elliott School, Munster, Ind. (AJ9N)
- Space Center Intermediate School, Houston (KA5GLX)
- St. Barnabas Episcopal School, Houston (N5NYD)
- Gardens Elementary School, Pasadena, Texas (N5VSP)
- Lycee Gaston Febus, Pau, France (FE1OBV)

SAREX-II will be operated during periods when the crew members are not scheduled for orbiter or other payload activities. The antenna's window location does not affect communications and therefore does not require a specific orbiter attitude for operations.

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

The primary frequencies intended for use during the mission are 145.55 MHz for downlink from Columbia and 144.91, 144.93, 144.95, 144.97, and 144.99 MHz for uplink. The astronauts will not favor any one of these frequencies. Therefore, to talk to an astronaut, ham operators will have to select one of the frequencies chosen by the astronaut. A spacing of 600 kHz was deliberately chosen for this primary pair to accommodate those whose split-frequency capability is limited to the customary repeater offset. Digital packet will operate on 145.55 MHz for downlink transmission and 144.49 MHz for uplink transmission.

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

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

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

The amateur radio station at the Goddard Space Flight Center (WA3NAN) will operate around the clock during the mission, providing information and restransmitting live shuttle air-to-ground audio. Planned HF operating frequencies are 3.860, 7.185, 14.295, 21.395, and 28.650 MHz.

ORBITER EXPERIMENTS PROGRAM

The space shuttle has provided an opportunity for researchers to perform flight experiments on a full-scale lifting vehicle during atmospheric entry. To take advantage of this opportunity, NASA's Office of Aeronautics, Exploration, and Technology in 1976 instituted the orbiter experiments (OEX) program.

The OEX program provides a mechanism for flight research experiments to be developed and flown aboard a space shuttle orbiter. Since the program's inception, 13 experiments have been developed. The principal investigators for these experiments represent NASA's Langley and Ames Research centers, Johnson Space Center, and Goddard Space Flight Center.

One experiment will be flown on STS-58: the Orbital Acceleration Research Experiment (OARE).

ORBITER EXPERIMENTS SUPPORT SYSTEMS FOR OV-102 (COLUMBIA)

The support system for the orbiter experiments was developed to record data obtained and to provide time correlation for the recorded data. The information obtained through the sensors of the OEX instruments must be recorded during the orbiter mission because there is no real-time or delayed downlink of OEX data. In addition, the analog data produced by certain instruments must be digitized for recording.

The support system for OEX comprises three subsystems: the OEX recorder, the system control module and the pulse code modulation system. The SCM is the primary interface between the OEX recorder and the experiment instruments and between the recorder and the orbiter systems. It transmits operating commands to the experiments. After such commands are transmitted, it controls the operation of the recorder to correspond to the experiment operation. The SCM is a microprocessor-based, solid-state control unit that commands the OEX tape recorder and the OEX and modular auxiliary data system.

The PCM system accepts both digital and analog data from the experiments. It digitizes the analog data and molds it and the digital data received directly from the experiments into a single digital data stream that is recorded on the OEX recorder. The PCM also receives time information from the orbiter timing buffer and injects it into the digital data stream to provide the required time correlation for the OEX data.

The SCM selects any of 32 inputs and routes them to any of 28 recorder tracks or four-line driver outputs to the T-O umbilical; executes real-time commands; controls experiments and data system components; and provides manual, semiautomatic, and automatic control.

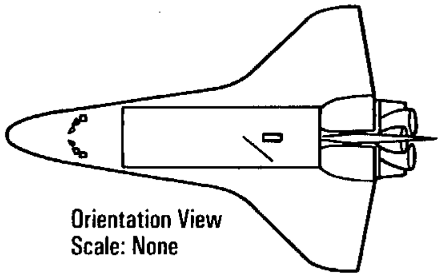
The recorder carries 9,400 feet of magnetic tape that permits up to two hours of recording time at a tape speed of 15 inches per second. After the orbiter returns, the data tape is played back and recorded on a ground system. The tape is not usually removed from the recorder.

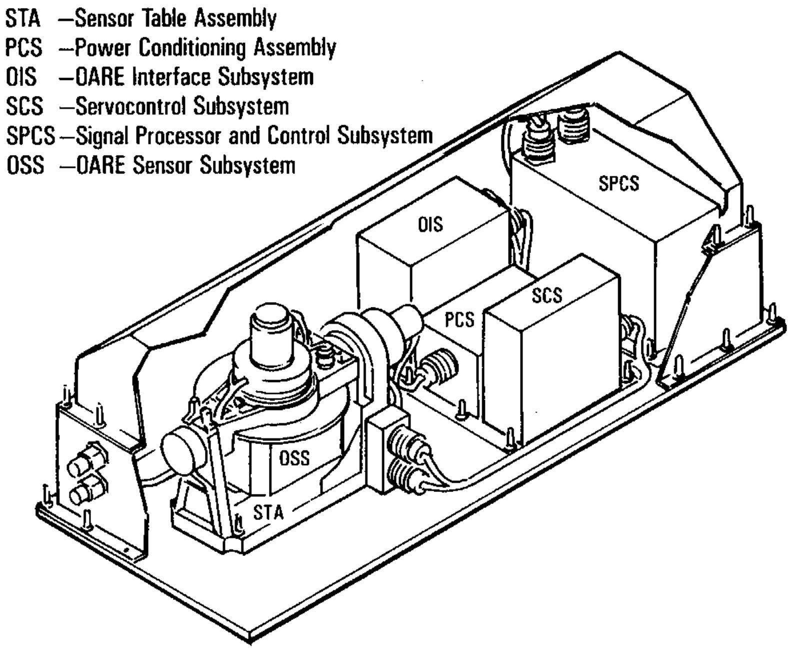
ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

The OARE extends the altitude range over which vehicle acceleration data can be obtained to orbital altitudes. Aerodynamic data are acquired on orbit and during the high-altitude portion of atmospheric entry. The OARE instrument comprises a three-axis set of extremely sensitive linear accelerometers. The OARE sensors can measure acceleration levels as small as one part per billion of Earth's gravity.

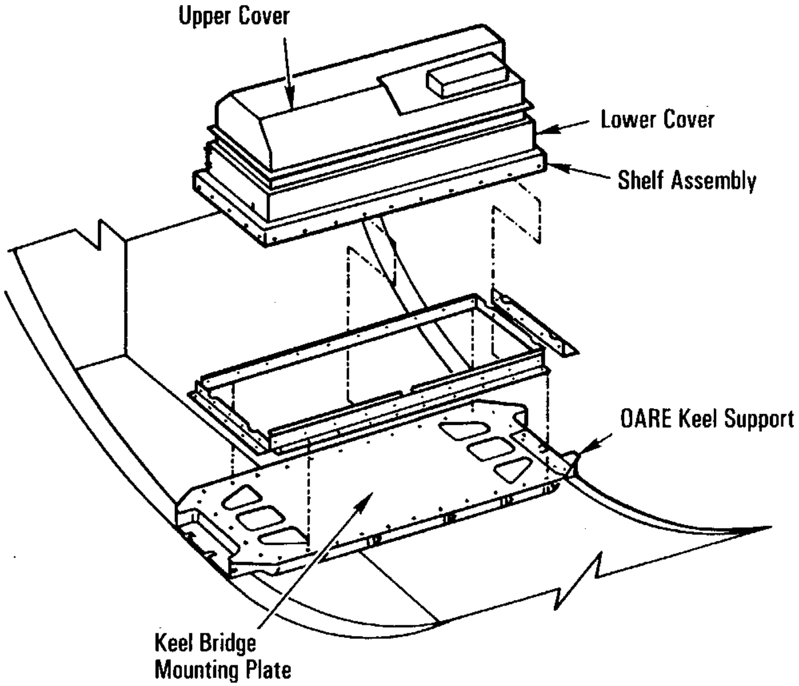
Because of their extreme measurement sensitivity, the OARE sensors cannot be adequately calibrated on the ground (in a 1-g environment). Consequently, the sensors are mounted on a rotary calibration table, which allows the instrument to be accurately calibrated on orbit.

The OARE instrument is installed on a special mounting plate in the orbiter's payload bay. OARE data are recorded on the mission payload recorder and in the OARE's own solid-state memory for postflight analysis.





OARE Installation



OARE Experiment

This is the third flight for the OARE instrument. The OARE equipment made its maiden flight on STS-40 in June 1991. OARE was operated for about 3-1/2 days in orbit. The flight data was partially compromised by an equipment malfunction. The problems were isolated after the flight, and the equipment was repaired and flown a second time on STS-50 (June 1992). The instrument operated continuously for 14 days in orbit and gathered data of excellent quality. Although all of the data has not been fully analyzed, it has been sought by other investigators involved with microgravity experimentations on the flight.

For STS-58, the plan is to operate the equipment over the entire 13 days of the flight. This means that the OARE flight computer is preprogrammed to take into account the duration of the flight so that the flight data will fit into its 4-megabyte memory storage.

The OARE pitch, yaw, and roll maneuvers, performed on STS-40 and STS-50, also will be performed on this flight. These maneuvers are an important source of information about shuttle physical characteristics such as vehicle center of gravity. The maneuvers can also be used to check the automatic calibration procedures. For STS-58, the maneuvers will be performed on flight days 2, 7, and 13. In addition, the gravity gradient, turn-drag maneuver will be performed on flight day 2.

The OARE flight hardware consists of four electronics boxes and a table assembly with a container mounted on its surface. This container houses the electrostatic-suspended proof-mass accelerometer sensor. The whole system weighs about 107 pounds and is 17 by 13 by 41 inches and requires about 110 watts of power.

The OARE is manifested as a complex DTO and is mounted on a special keel bridge that spans bay 11 of the orbiter. This is essentially the floor of the orbiter payload bay, near the aft end of the bay.

The principal investigator is Robert C. Blanchard of Langley Research Center. The project manager is R. Giesecke, NASA Johnson Space Center, Houston.

EXTENDED-DURATION ORBITER (EDO)

Rockwell International Corporation's Space Systems Division designed, developed, certified, and produced an EDO mission kit that allows a shuttle to remain in orbit for up to 16 days, plus a two-day contingency capability. (A nominal shuttle mission lasts eight days.) The first EDO mission, STS-50, was flown in June and July of 1992 by the shuttle Columbia. The primary payload on the 13-day, 19.5-hour flight was the United States Microgravity Laboratory (USML) 1. Columbia set the previous record for a shuttle flight of 10 days and approximately 21 hours in January 1990 on STS-32.

The EDO modification program has several goals: to reduce the number of flights required to accomplish tasks; lower risks, costs, and vehicle wear; and substantially increase the volume of data that can be collected on a mission. Some of the areas that may benefit from additional on-orbit time are—

- Zero-gravity materials processing research in semiconductors, glasses, ceramics, biologicals, alloys, catalysts, and superpure materials
- Life sciences research in microgravity horticulture, basic physiology, and psychology, including human adaptation to zero gravity in preparation for longer spaceflights
- Advanced space operations development, including assembly and on-orbit servicing and maintenance of the space station and other space structures
- Scientific observation missions in such areas as astrophysics and Earth remote sensing

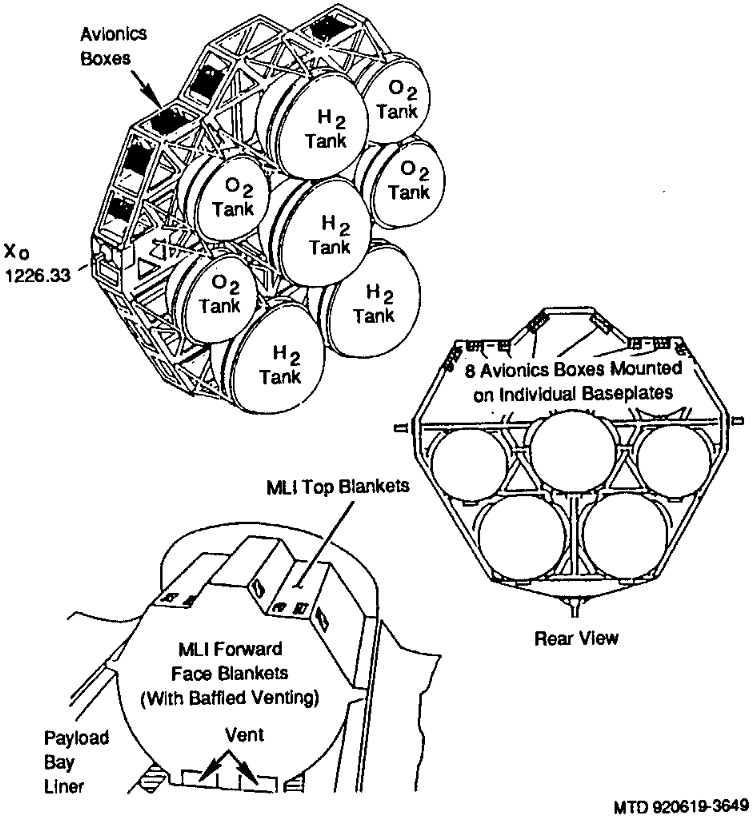
Some of the major elements of the 16-day EDO mission kit produced by Rockwell are a set of cryogenic liquid hydrogen and liquid oxygen tanks mounted on a special pallet in the payload bay that provide supplemental reactants for the shuttle's electrical generation system, a regenerating system that removes carbon dioxide from the crew cabin atmosphere, an improved waste collection system, additional nitrogen tanks for the crew cabin atmosphere, and the creation of more habitable volume and equipment storage space in the crew cabin.

ADDITIONAL CRYOGENIC TANKS

Columbia has the internal connections for a 3,500-pound, 15-foot-diameter structural pallet that is installed in the rear of the orbiter's payload bay and holds four sets of hydrogen and oxygen tanks, associated control panels, and avionics equipment. The tanks, which supplement Columbia's five liquid hydrogen and liquid oxygen tank sets, store 368 pounds of liquid hydrogen at -418 degrees Fahrenheit and 3,125 pounds of liquid oxygen at -285 degrees Fahrenheit. Fully loaded, the pallet weighs approximately 7,000 pounds. Reactants from the EDO pallet are fed to Columbia's three electrical power fuel cells, which convert them into enough electrical energy to support the average four-person household for approximately six months (an average power level of approximately 19 kW for 16 days, with an additional two-day 12-kW contingency capability). In addition, approximately 3,500 pounds of pure drinking water is produced for crew consumption. For a 28-day mission, four additional tank sets would be required.

ADDITIONAL NITROGEN TANKS

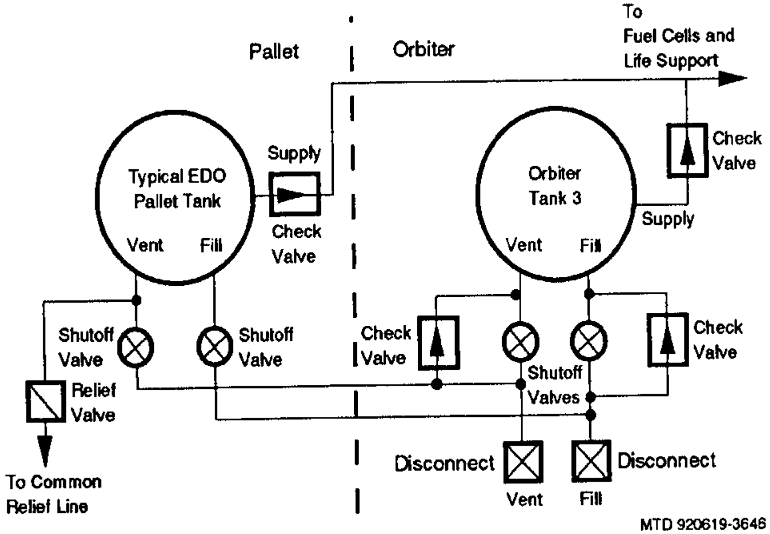
Additional nitrogen tanks have been installed near Columbia's original nitrogen tanks below the payload bay. The nitrogen is used to maintain the crew cabin atmosphere.



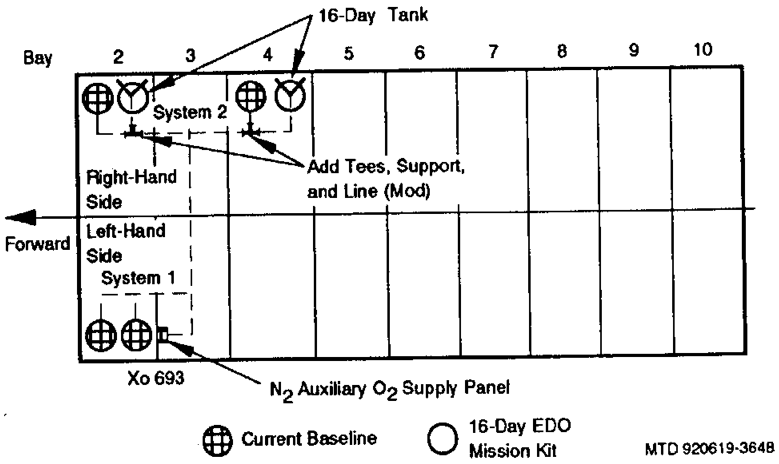
Extended-Duration Orbiter Cryogenic Pallet Structure

IMPROVED WASTE COLLECTION SYSTEM

Columbia has also been fitted to accommodate an improved waste collection system, but the new system will not be installed until mid-1994. The IWCS, which compacts human waste, has unlimited capacity and is more comfortable and sanitary. It also eliminates many of the mechanical problems experienced with the current toilet. Endeavour carried a development unit of the IWCS on the STS-54 flight in January and STS-57 in June.



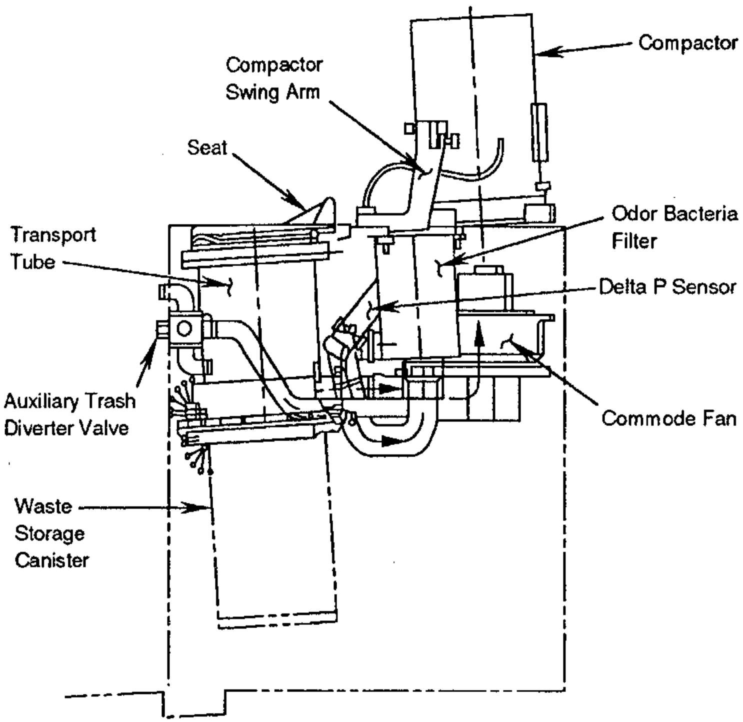
Typical EDO Pallet Tank Ties Into Orbiter Tank Set 3



EDO Nitrogen Supply System

REGENERABLE CARBON DIOXIDE REMOVAL SYSTEM

Columbia is outfitted with a regenerable carbon dioxide removal system (RCRS), which removes carbon dioxide and odors

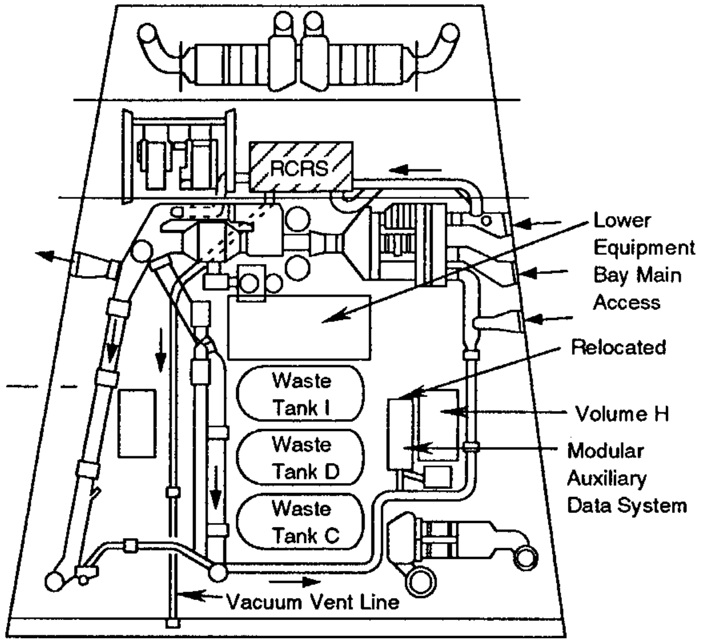


MTD 920619-3645

Improved Waste Collection System

from the crew cabin atmosphere. The regenerative system eliminates the need to carry large amounts of lithium hydroxide (LiOH) canisters on long flights. Currently, the crew must change LiOH canisters daily as part of spacecraft housekeeping. On a typical shuttle mission, two or more canisters are used each day. A 16-day mission would require a prohibitive number of canisters.

The RCRS passes cabin air over one of the unit's two beds of solid amine every 15 minutes and exposes the other bed to space through a series of valves. The absorption of carbon dioxide in the active bed generates heat, which warms the other bed and expels carbon dioxide into space. The RCRS also recovers some nitrogen for reuse. It is located under the middeck floor.



MTD 920619-3647

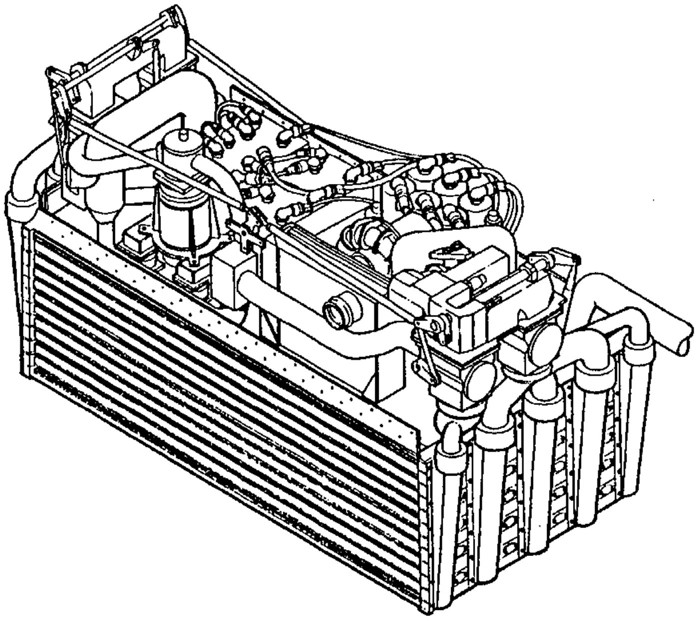
Regenerable Carbon Dioxide Removal System Location

ADDITIONAL CABIN STOWAGE

Columbia's crew stowage volume has been expanded by adding an airlock stowage bay and removing the no-longer-needed lithium hydroxide canisters from the lower equipment bay. About 127 cubic feet of additional stowage space is needed for longer flights.

Major subcontractors to Rockwell on the EDO program include Hamilton Standard, South Windsor, Conn. (improved waste collection system, regenerable carbon dioxide removal system); Ball Aerospace Corporation, Boulder, Colo. (cryogenic pallet tanks); Aerodyne Control Corporation, Long Island, N.Y. (cryogenic isolation valves); and Parker Hannifin, Irvine, Calif. (various valves).

Rockwell modified the shuttle orbiter Columbia for a 16-day EDO capability during a major modification period at Rockwell's

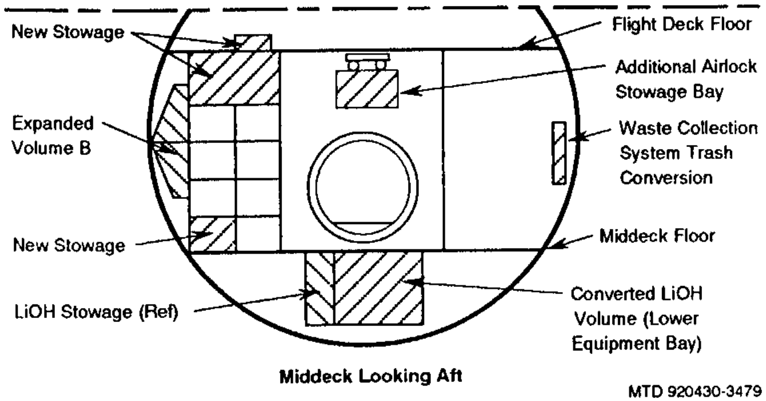


MTD 920618-3644

Regenerable Carbon Dioxide Removal System

Orbiter Assembly and Modification Facility in Palmdale, Calif., from August 1991 to February 1992.

Although no plans have been made to use Endeavour for extended-duration missions, it has been fitted with the internal plumbing and electrical provisions needed for EDO mission kits that could enable the spacecraft to stay in orbit as long as 28 days. Atlantis is being equipped to accommodate a 28-day capability at Rockwell's Orbiter Assembly and Modification Facility.



MTD 920430-3479

Expanded Crew Stowage

NASA will offer the use of the EDO mission kit as an optional service to all shuttle customers. EDO flights include Spacelab Life Sciences 2, being flown on this mission; International Microgravity Laboratory 2 (STS-65) in 1994; United States Microgravity Laboratory 2 in 1995; and SLS-3 in 1996.

In the future, NASA may authorize further expansions of on-orbit stay times to 30, 45, 60, or even 90 days.

DEVELOPMENT TEST OBJECTIVES

Ascent aerodynamic distributed loads verification on Columbia (DTO 236). This DTO will collect data on wing aerodynamic distributed loads to allow verification of the aerodynamic database. This mission will fly a more negative angle of attack.

Forward RCS test—control surface effects (DTO 250). This DTO is the fourth in a series of forward reaction control system flight test maneuvers showing aerodynamic effects created when FRCS side-firing thrusters are used to eliminate RCS propellant. This test will be done only if DTO 248 is performed successfully. This FRCS dump test will include programmed control surface deflections (between Mach 4 and Mach 2.6).

Elevon deflection load sensitivity verification for Columbia (DTO 253). This DTO will collect wing (including elevon) ascent aerodynamic and strain data for Columbia to verify the sensitivity of the aerodynamic loads to elevon movement and will support the verification and development of a revised aerodynamic database with sufficient confidence to minimize wind placards on the space shuttle vehicle. Wind placards are in effect during ascent, based on various performance parameters and structural load indicators. Actual launch constraints will be determined by computer simulations of launch trajectories using measured day-of-launch winds. Elevon repositioning is required in conjunction with alpha biasing for DTO 236. In addition to the MADS instrumentation required for DTO 236, this DTO also requires control surface position measurements and elevon actuator pressure measurements.

Ascent wing structural capability evaluation (DTO 301D). The purpose of this DTO is to verify that the orbiter wing structure is at or near its design condition during lift-off and ascent with payloads near the maximum weight. The DTO will determine flight loads and structural capability and will determine if any unacceptable dynamic effects exist. This is a data-collection-only test and requires no specific activity other than recording and returning specified data.

Entry structural capability evaluation (DTO 307D). This DTO will collect structure load data for different payload weights and configurations to expand the database of flight loads during entry, approach, and landing to verify the adequacy of the structure at or near design conditions and to demonstrate structural system operational capability, determine flight loads, and verify the stress/temperature response of critical structural components. This is a data-collection-only test and requires no specific activity other than recording and returning specified data.

Payload bay acoustic evaluation (DTO 308D). This DTO will obtain vibration and acoustic data during ascent to define the operational vibroacoustic input environment for payloads and the PDRS. This is a data-collection-only test and requires no specific activity other than recording and returning specified data.

ET TPS performance, methods 1, 2, and 3 (DTO 312). This DTO will obtain photographs of the external tank after separation in order to determine TPS charring patterns, identify regions of TPS material spallation, evaluate overall TPS performance, and identify potential sources of debris that could damage the orbiter. The cameras are located in the orbiter umbilical well and in the flight deck. Method 1 requires an aft RCS +X maneuver, and methods 2 and 3 require a pitch maneuver.

Orbiter/payload acceleration and acoustics environment data (DTO 319D). This DTO will obtain low-frequency (0 to 50 Hz) payload/orbiter interface data to develop computer techniques for predicting payload loads and responses. Acceleration and acoustic pressure data will be analyzed to verify the adequacy of Shuttle structural dynamic loads analyses.

On-orbit PRSD cryogenic hydrogen boiloff (DTO 413). When predicted on-orbit PRSD boiloff rates and data from the testing of boiloff rates are compared with on-orbit flight data, the actual boiloff rate is much higher than that predicted for cryogenic hydrogen. This DTO will determine accurate power reactant stowage and distribution (PRSD) boiloff rates of shuttle vehicles. This information will be used to predict cryogenic quantities more accurately for long-duration missions. It is desired that the orbiter be placed in a gravity gradient-type attitude like that which will be used while it is docked to the space station (-XLV, -ZVV) or some thermally equivalent attitude while boiloff rates are being determined.

APU shutdown test (sequence A) (DTO 414). This DTO will explore the hypothesis that delays between shutting down individual auxiliary power units on ascent can lead to "backdriving" of the nonoperational hydraulic system's speed brake hydraulic motor. Reviews of mission data have shown that when an individual APU is shut down prematurely on ascent while the remaining APUs continue operating, there is the possibility of extended hydraulic supply pressure (i.e., the hydraulic pressure of the shutdown system remains at an elevated level for a significant period of time). The explanation for this behavior is that the operational hydraulic systems are backdriving the speed brake hydraulic motor of the system that has been shut down. Performing this DTO during flight will produce the most representative data for this behavior. This DTO will be flown on multiple missions in order to create a representative database. The APUs will be shut down in the following order: 3, 1, 2. The pilot will wait at least five seconds between shutting down each APU.

Orbiter drag chute system (DTO 521). This DTO will evaluate the performance of the orbiter drag chute system through a series of landings at increasing deployment speeds. The DTO will be performed on vehicles equipped to measure drag forces imposed by the drag chute system. This DTO has two phases. Phase I consisted of two flights. The first-flight drag chute was deployed at nose gear touchdown (STS-49), and the second at initiation of derotation. The drag chute is now cleared for deployment under the Phase I conditions for subsequent missions. Phase II consists of seven flights with deployment at gradually increasing speeds, from initiation at derotation at 185 knots equivalent air speed (KEAS) to initiation at 205 KEAS. Concrete runways will be used whenever possible. For STS-58, the drag chute will be deployed after derotation (nose in the air) with five ribbons removed from the chute.

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

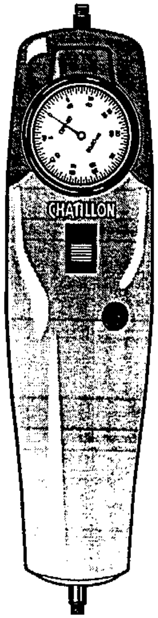
Acoustical noise dosimeter (DTO 663). This DTO will measure and record decibel levels in the middeck, the sleep stations, and the Spacelab module with an audio dosimeter. Crew members will complete a questionnaire during the flight regarding noise levels. Baseline data of time-averaged acoustical noise levels will be obtained.

Acoustical noise sound level data (DTO 665). This DTO will use a sound level meter to obtain baseline data of octave-band acoustical noise levels in the middeck, flight deck, sleep stations, and Spacelab module during routine orbiter and experiment operations. The Spacelab sound level meter will also record sound level readings for the SLS-2 payload.

Portable in-flight landing operations trainer (DTO 667). The purpose of this DTO is to verify that the portable in-flight landing operations trainer (PILOT) simulator will help the shuttle commander and pilot maintain the highest possible level of proficiency for the end-of-mission approach and landing task on EDO flights through the use of an on-orbit trainer/simulator that strongly reinforces visual cues over the temporal, proprioceptive, and otolithic cues. This on-orbit trainer/simulator will also give the commander and pilot a tool to combat degradation of motor skills used in landing. For the complete evaluation and refinement of PILOT, six EDO flights are required. A laptop PC with landing software and a spare RHC (essentially a landing simulator) are used for this DTO.

OEX Orbital Acceleration Research Experiment (OARE) (DTO 910). The OARE will acquire accurate measurements of low-level aerodynamic acceleration on the orbiter in the free-molecular flow regime of the upper atmosphere.

Columbia acceleration data collection to support microgravity disturbances (DSO 314). The purpose of this DSO is to measure orbiter accelerations during thruster firings, crew exercise, and other disturbances using the high-resolution acceleration package (HIRAP). This data will be used to define the acceleration environment of the orbiter during microgravity experiments. The aerodynamic coefficients identification package (ACIP) is required, and the OARE is desired.



Button Position	Operation
Up	Pointer will hold maximum reading on inside scale for a push from the top and pull from the bottom.
Center	Returns pointer to zero
Down	Pointer will hold maximum reading on outside scale for a pull from the top and push from the bottom.

MTD 930921-4560

Force Gauge

Dried blood method for in-flight stowage (protocols 1 and 2) (DSO 325). This DSO will test the techniques used for taking dried blood samples. It will include an assessment of the paper filters and the effects of microgravity on the collection process. Protocol 1 requires that the crew draw blood from a subject and prepare several dried blood samples as well as some frozen control samples for analysis on the ground. Frozen blood collected before the flight will be used for protocol 2, which is a reserve DSO and is not scheduled in the flight plan.

Window impact observation (DSO 326). This DSO is designed to link window damage found during orbiter turnaround processing to mission time, attitude, and altitude. This data will aid the effort to identify the sources of this damage significantly. The crew will check the windows every morning and evening for new abrasions and will record its findings in a log.

Inter-Mars tissue equivalent proportional counter (ITEPC) (DSO 485). The purpose of this DSO is to demonstrate the ability of hardware to withstand the radiation environment of spaceflight in preparation for the Mars '94 mission and to demonstrate the expanded capability of experiment software over the previously flown middeck TEPC. In addition, the experiment will gather key data on the radiation environment for future extravehicular activities (EVAs) and single-event-upset data that affect the orbiter's hardware. This experiment will be flown on an adaptive payload carrier (APC) mounted in the payload bay on the starboard side of bay 2. It consists of a spectrometer, radiation detector, and support electronics. The equipment is activated by the crew after insertion and is deactivated during deorbit preparations.

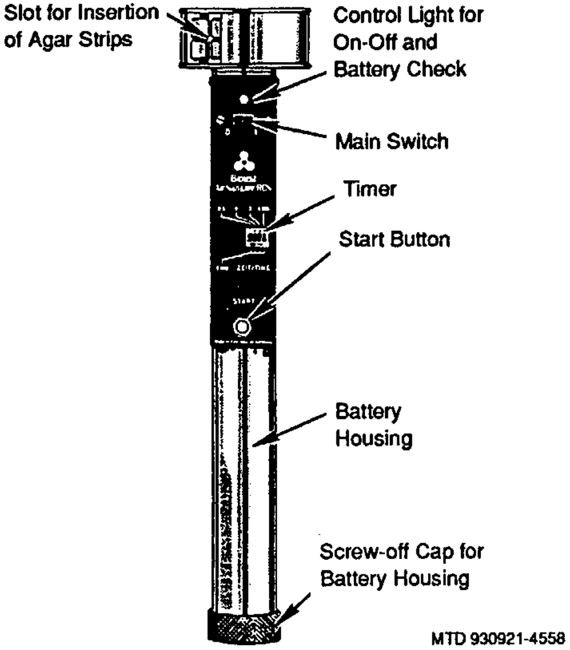
Immunological assessment of crew members (DSO 487). This DSO will examine the mechanisms of spaceflight-induced alterations in the human immune function. As shuttle mission durations increase, the potential for the development of infectious illnesses in crew members also increases. This investigation will assess immune system function using the immune cells from the standard flight medicine blood draw.

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

Visual-vestibular integration as a function of adaptation (DSO 604*). The objective of this DSO is to investigate visual-vestibular and perceptual adaptive responses as a function of mission duration. The operational impact of these responses on the crew members' ability to conduct entry, landing, and egress procedures will also be investigated. These data will be used to develop training and/or countermeasures to assure the safety and success of extended missions by promoting optimal neurosensory function needed for entry, landing, and possible emergency egress. The crew will perform investigation OI-3 before and after flight only.

Postural equilibrium control during landing/egress (DSO 605*). This DSO will quantify the effects that in-flight neurosensory adaptations to zero-g have on postflight control of postural equilibrium.

Air monitoring instrument evaluation (microbial air sampler) (DSO 611*). This DSO is designed to evaluate and verify air monitoring equipment to ensure its proper function and operation during flight. Data collected on contaminant levels during missions of varying durations will be used to establish baseline levels and to evaluate potential risks to crew health and safety. Contaminants being detected include thermodegradation products, volatile organics, toxic compounds, airborne particulates, and airborne microorganisms. The microbial air sampler (MAS) configuration will be flown on STS-58.



MAS

Energy utilization (DSO 612*). This DSO will be used to develop, verify, and optimize appropriate countermeasures for maintaining entry, landing, and egress capabilities after extended-duration flights. This requires the prevention of muscle atrophy, weight loss, and negative nitrogen and potassium balances. Crew members will provide urine and saliva samples and will keep a log of all exercise and food and fluid intake. Measurements will also be taken of the crew members' blood glucose levels.

---

*EDO buildup—medical evaluation DSO

The effect of prolonged spaceflight on head and gaze stability during locomotion (DSO 614*). This DSO will characterize preflight and postflight head and body movement as well as gaze stability during walking, running, and jumping, all of which are important factors during egress from the shuttle.

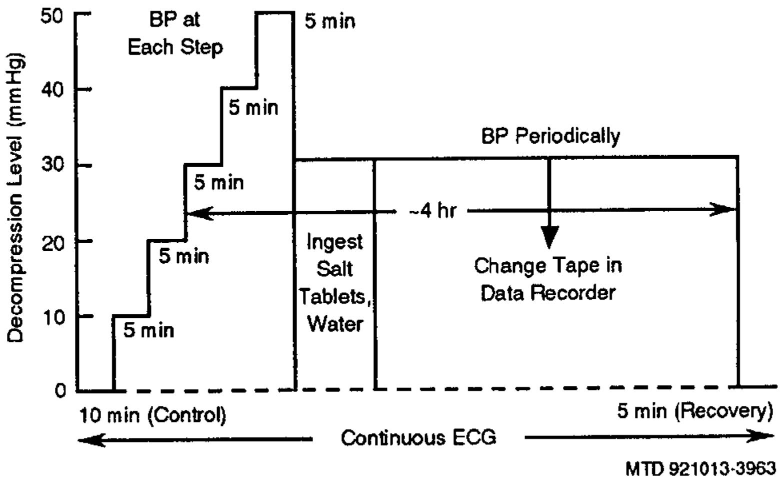
Physiological evaluation of astronaut seat egress ability at wheel stop (DSO 620*). The purpose of this DSO is to determine the nature and magnitude of equilibrium control, the effect of head position on postural stability, and vision as it affects stability immediately after flight. This DSO will enable appropriate countermeasures to be designed to ensure that the crew can perform an emergency egress.

In-flight LBNP test of countermeasures and end-of-mission countermeasure trial (DSO 623*). This experiment will evaluate the effectiveness of selected cardiovascular countermeasures during flight by testing an individual's tolerance to the LBNP (ramp) stress protocol. In addition, the effectiveness of the LBNP (soak) countermeasure at the end of shuttle flights will be assessed.

Pre- and postflight measurement of cardiorespiratory responses to submaximal exercise (DSO 624*). This DSO will help evaluate the changes in aerobic capacity before, during, and after flight. The crew will wear a heart watch during exercise.

Cardiovascular and cerebrovascular responses to standing before and after spaceflight (DSO 626*). This DSO will characterize the integrated response of the arterial pressure control system to standing before and after spaceflight.

Educational activities (objective 1) (DSO 802). The first objective of this DSO is to produce educational products that will capture the interest of students and motivate them to pursue careers in science, engineering, and mathematics. These products will include video lessons of approximately 20 minutes featuring scenes recorded both on orbit and on the ground. The on-orbit video will be approximately one third of the finished video product. This DSO will support the videotaping of on-orbit educational activities performed by the flight crew as well as other educational activities that are deemed appropriate by the Educational Working Group and the flight crew. The second objective of this DSO is to support the live TV downlink of educational activities performed by the flight crew. Typically, these activities will be limited to one or two 30-minute live downlinks.



LBNP Soak Protocol

Documentary television (DSO 901). The purpose of DSO 901 is to provide live television transmission or VTR dumps of crew activities and spacecraft functions, including payload bay views, Shuttle and payload crew activities, VTR downlink of crew activities, in-flight crew press conferences, orbiter operations, payload deployment/retrieval and operations, Earth views, rendezvous and proximity operations, and unscheduled activities. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. Operational air-to-ground and/or

---

*EDO buildup—medical evaluation DSO

operational intercom audio are used for the broadcast. Video tape recording may be used when live television is not possible.

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

Documentary still photography (DSO 903). This DSO requires still photography of crew activities in the orbiter and Spacelab and mission-related scenes of general public and historical interest. Still photographs of exterior and interior scenes will be taken in 70mm and 35mm formats, respectively.

Assessment of human factors (configuration A) (DSO 904). This DSO will evaluate human-machine interactions during routine Spacelab operations, including stowage, hand and foot restraints, wire and cable interferences, Spacelab tunnel translation, and time lines. Sound and vibration data, crew comments, and crew performance will also be analyzed.

STS-58 PRELAUNCH COUNTDOWN TIME LINE

T - (MINUS) HR:MIN:SEC	EVENT
06:00:00	Verification of the launch commit criteria is complete at this time. The liquid oxygen and liquid hydrogen systems chill-down commences in order to condition the ground line and valves as well as the external tank (ET) for cryo loading. Orbiter fuel cell power plant activation is performed.
05:50:00	The space shuttle main engine (SSME) liquid hydrogen chill-down sequence is initiated by the launch processing system (LPS). The liquid hydrogen recirculation valves are opened and start the liquid hydrogen recirculation pumps. As part of the chill-down sequence, the liquid hydrogen prevalves are closed and remain closed until T minus 9.5 seconds.
05:30:00	Liquid oxygen chill-down is complete. The liquid oxygen loading begins. The liquid oxygen loading starts with a "slow fill" in order to acclimate the ET. Slow fill continues until the tank is 2-percent full.
05:15:00	The liquid oxygen and liquid hydrogen slow fill is complete and the fast fill begins. The liquid oxygen and liquid hydrogen fast fill will continue until that tank is 98-percent full.
05:00:00	The calibration of the inertial measurement units (IMUs) starts. The three IMUs are used by the orbiter navigation systems to determine the position of the orbiter in flight.
04:30:00	The orbiter fuel cell power plant activation is complete.
04:00:00	The Merritt Island (MILA) antenna, which transmits and receives communications, telemetry and ranging information, alignment verification begins.
03:45:00	The liquid hydrogen fast fill to 98 percent is complete, and a slow topping-off process is begun and stabilized to 100 percent.
03:30:00	The liquid oxygen fast fill is complete to 98 percent.
03:20:00	The main propulsion system (MPS) helium tanks begin filling from 2,000 psi to their full pressure of 4,500 psi.
03:15:00	Liquid hydrogen stable replenishment begins and continues until just minutes prior to T minus zero.
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.

T - (MINUS) HR:MIN:SEC	EVENT
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	Postingress 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.

T - (MINUS) HR:MIN:SEC	EVENT
01:35:00	The orbiter accelerometer assemblies (AAs) are powered up.
01:35:00	The orbiter reaction control system (RCS) control drivers are powered up.
01:35:00	The flight crew starts the communications checks.
01:25:00	The SRB RGA torque test begins.
01:20:00	Orbiter side hatch is closed.
01:10:00	Orbiter side hatch seal and cabin leak checks are performed.
01:01:00	IMU preflight align begins. Flight crew functions from this point on will be initiated by a call from the orbiter test conductor (OTC) to proceed. The flight crew will report back to the OTC after completion.
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.

T - (MINUS) HR:MIN:SEC	EVENT
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.
00:30:00	The gaseous nitrogen system for the orbital maneuvering system (OMS) engines is pressurized for launch. Crew compartment vent valves are opened.
00:26:00	The ground pyro initiator controllers (PICs) are powered up. They are used to fire the SRB hold-down posts, liquid oxygen and liquid hydrogen tail service mast (TSM), and ET vent arm system pyros at lift-off and the SSME hydrogen gas burn system prior to SSME ignition.
00:25:00	Simultaneous air-to-ground voice communications are checked. Weather aircraft are launched.
00:22:00	The primary avionics software system (PASS) is transferred to the BFS computer in order for both systems to have the same data. In case of a PASS computer system failure, the BFS computer will take over control of the shuttle vehicle during flight.
00:21:00	The crew compartment cabin vent valves are closed.
00:20:00	A 10-minute planned hold starts.
<u>Hold 10 Minutes</u>	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 on-board 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.
<u>Counting</u>	Transition to MM-101. The PASS on-board computers are dumped and compared to verify the proper on-board 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 on-board 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.

T - (MINUS) HR:MIN:SEC	EVENT
	All test support team members verify they are "go for launch."
00:12:00	Emergency aircraft and personnel are verified on station.
00:10:00	All orbiter aerosurfaces and actuators are verified to be in the proper configuration for hydraulic pressure application. The NASA test director gets a "go for launch" verification from the launch team.
00:09:00	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 on-board 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.
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

T - (MINUS) HR:MIN:SEC	EVENT
	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 on-board 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 on-board tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.
00:02:30	The caution/warning memory is cleared.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.

T - (MINUS) HR:MIN:SEC	EVENT
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 on-board 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.
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 on-board 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 on-board 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.

T - (MINUS) HR:MIN:SEC	EVENT
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 on-board computers that they have a "go" for SSME start. The GLS retains hold capability until just prior to SRB ignition.
00:00:09.7	Liquid hydrogen recirculation pumps are turned off. The recirculation pumps provide for flow of fuel through the SSMEs during the terminal count. These are supplied by ground power and are powered in preparation for SSME start.
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 on-board computers command the three MPS liquid hydrogen prevalves to open. (The MPS's 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 on-board 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 on-board 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	EVENT
00:00:00	The two SRBs are ignited under command of the four on-board 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 on-board 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-58 MISSION HIGHLIGHTS TIME LINE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	DAY ZERO
0/00:00:07	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:10	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down, wings level.
0/00:00:19	Roll maneuver ends.
0/00:00:26	All three SSMEs throttle down from 100 to 67 percent for maximum aerodynamic load (max q).
0/00:00:51	Max q occurs.
0/00:01:01	All three SSMEs throttle to 104 percent.
0/00:02:04	SRBs separate. When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:04:04	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:07:11	Single engine press to main engine cutoff (MECO).
0/00:07:35	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:34	MECO occurs at approximate velocity 25,865 feet per second, 44 by 149 nautical miles (51 by 172 statute miles).
0/00:08:42	Zero thrust.
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

---

Editor's Note: This time line lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-58 Flight Plan.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs.
	– Remaining residual propellants are vented to space vacuum, inerting the MPS.
	– Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads.
	– MPS vacuum inerting terminates.
0/00:42	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 8 seconds in duration, at 199 fps, 154 by 153 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS), payload specialist seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.
0/00:59	MS configures aft flight station.
0/01:02	MS unstows, sets up, and activates PGSC.
0/01:05	MS configures for payload bay door operations.
0/01:06	Pilot activates payload bus (panel R1).
0/01:08	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive Y velocity vector attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:17	Commander activates radiators.
0/01:28	MS opens payload bay doors.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	Commander and pilot seat egress.
0/01:39	Commander and pilot clothing configuration.
0/01:40	MS/PS clothing configuration.
0/01:41	Cardiovascular operations.
0/01:45	Metabolic operations.
0/01:51	MS activates teleprinter (if flown).
0/01:52	Commander begins post-payload bay door operations and radiator configuration.
0/01:55	MS/PS remove and stow seats.
0/01:56	Commander starts ST self-test and opens door.
0/01:57	MS configures and activates WCS.
0/01:58	MS activates UMS.
0/01:59	MS activates switch configuration/galley.
0/02:00	MS stows escape pole.
0/02:01	Pilot activates auxiliary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:05	Commander configures verniercontrols.
0/02:08	Mission Control Center (MCC), Houston (H), informs crew to "go for Spacelab activation."
0/02:12	Commander, pilot configure controls for on-orbit.
0/02:19	Pilot enables hydraulic thermal conditioning.
0/02:24	MS resets caution/warning (C/W).
0/02:25	Spacelab activation.
0/02:28	Pilot plots fuel cell performance.
0/02:30	Ku-band antenna deployment.
0/02:40	Ku-band antenna activation.
0/02:50	Priority Group B powerdown.
0/03:05	EDO activation.
0/03:22	Ingress Spacelab.
0/04:50	Payload activation.
0/06:10	Rodent health check.
0/06:10	DTO 623.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/06:15	Echocardiograph operations.
0/06:55	Vestibular operations—drop tests.
0/07:15	DSO 314.
0/08:00	DSO 326.
0/09:00	Crew begins presleep activities.
0/11:00	Crew begins sleep period.
0/19:00	Crew begins postsleep operations.
0/19:00	DSO 612.
0/19:40	Metabolic operations.
0/22:15	Cardiovascular operations.
0/23:15	DTO 663.
0/23:35	PAO event.
0/23:50	DSO 326.
0/23:52	Echocardiograph operations.

MET DAY ONE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:00	DSO 326.
1/00:45	DSO 612.
1/01:00	DSO 611.
1/01:31	Vestibular operations—rotating dome.
1/01:55	DSO 612.
1/04:00	DSO 314.
1/04:30	Rodent health check.
1/04:30	SAREX setup.
1/06:00	DSO 314.
1/06:15	SAREX operations.
1/06:30	DSO 314.
1/07:25	DSO 326.
1/08:45	DTO 663.
1/09:00	Crew begins presleep activities.
1/11:00	Crew begins sleep period.
1/19:00	Crew begins postsleep activities.
1/19:00	DSO 612.
1/19:15	DSO 612.
1/19:30	Metabolic operations.
1/22:00	DTO 663.
1/22:10	DSO 612.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/22:15	DSO 326.
1/22:35	DTO 910—OARE maneuver.
1/23:05	OARE drag.
1/23:25	DSO 325.
1/23:50	LBNP setup.
	MET DAY TWO
2/00:25	PAO event.
2/00:30	DSO 325.
2/01:02	Vestibular operations—AWARE.
2/02:10	DSO 325.
2/02:30	DSO 623—lower body negative pressure ramp test.
2/03:30	Vestibular operations—head movement comparison test.
2/03:30	DTO 623.
2/04:48	SAREX operations.
2/05:05	LBNP preparation—DSO 623.
2/05:30	Rodent health check.
2/05:30	DSO 325.
2/05:45	DSO 623.
2/06:30	UMS calibration.
2/07:30	DSO 326.
2/07:45	DTO 663 battery checkout.
2/08:00	Crew begins presleep activities.
2/11:00	Crew begins sleep period.
2/19:00	Crew begins postsleep activities.
2/19:00	DSO 612.
2/19:30	Metabolic operations.
2/22:00	DTO 663.
2/22:10	DSO 612.
2/22:30	SAREX operations.
2/22:45	Cardiovascular operations.
2/23:15	DSO 326.
	MET DAY THREE
3/00:04	SAREX operations.
3/01:40	SAREX operations.
3/03:25	PAO event.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/04:45	SAREX operations.
3/05:10	Rodent health check.
3/06:20	SAREX operations.
3/07:30	DSO 326.
3/07:50	DTO 663.
3/08:00	Crew begins presleep activities.
3/11:00	Crew begins sleep period.
3/19:00	Crew begins postsleep activities.
3/19:00	DSO 612.
3/21:45	DTO 663 battery checkout.
3/21:50	DSO 612.
3/22:00	Crew off-duty period.
	MET DAY FOUR
4/00:05	SAREX operations.
4/02:15	DTO 623.
4/02:35	DSO 326.
4/02:50	Vestibular operations—drop test.
4/03:15	SAREX operations.
4/03:35	DTO 667.
4/04:35	DSO 314.
4/04:45	SAREX operations.
4/05:00	Rodent health check.
4/05:30	Body mass measurement device calibration.
4/05:30	DTO 667.
4/06:10	DSO 326.
4/06:20	UMS calibration.
4/06:30	DTO 667—PILOT.
4/06:46	PAO event.
4/07:05	DTO 663.
4/07:15	Crew begins presleep activities.
4/10:15	Crew begins sleep period.
4/18:15	Crew begins postsleep activities.
4/18:15	DSO 612.
4/18:45	Metabolic operations.
4/21:30	DSO 326.
4/21:35	DTO 663.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/21:45	DSO 612.
4/22:55	DSO 623.
4/22:55	PAO event.
4/23:40	DSO 623—lower body negative pressure ramp test.

MET DAY FIVE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/00:05	SAREX operations.
5/01:25	SAREX operations.
5/03:10	DSO 623.
5/03:15	SAREX operations.
5/03:36	Rodent mass measurements.
5/03:50	Rodent health check.
5/06:05	RCS burn.
5/06:10	DSO 326.
5/06:50	RCS burn.
5/07:00	DTO 663 battery checkout.
5/07:15	Crew begins presleep activities.
5/09:10	SAREX operations.
5/10:15	Crew begins sleep period.
5/18:15	Crew begins postsleep activities.
5/21:15	DTO 663.
5/21:15	DSO 612.
5/21:45	DSO 326.
5/21:50	Rodent hematology.
5/22:00	DSO 802.
5/22:40	SAREX operations.
5/22:50	DSO 802.
5/23:30	DSO 802.

MET DAY SIX

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/00:00	DSO 802.
6/00:10	SAREX operations.
6/00:35	DSO 802.
6/00:50	ECLSS checkout.
6/01:20	RCRS reconfiguration.
6/02:30	DTO 623.
6/02:34	Vestibular operations—head movement comparison test.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/03:00	DTO 667—PILOT.
6/03:00	DTO 667.
6/03:30	PAO event.
6/04:00	Rodent health check.
6/04:35	UMS calibration.
6/04:57	SAREX operations.
6/05:35	DSO 802.
6/06:30	DSO 326.
6/06:45	DTO 910—OARE maneuver.
6/07:05	DTO 663.
6/07:15	Crew begins presleep activities.
6/07:30	SAREX operations.
6/10:15	Crew begins sleep period.
6/18:15	Crew begins postsleep activities.
6/18:15	DSO 612.
6/18:45	Metabolic operations.
6/21:15	DTO 663 battery checkout.
6/21:40	DSO 612.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/21:55	DSO 326.
6/22:30	DSO 611.
6/22:30	Cardiovascular operations.
6/22:45	Echocardiograph operations.
6/23:30	DSO 314.
	MET DAY SEVEN
7/00:00	DSO 314.
7/02:05	DTO 665.
7/02:15	Vestibular operations—rotating dome.
7/03:25	PAO event.
7/03:45	DSO 802.
7/03:45	Rodent health check.
7/04:30	DTO 665.
7/04:45	SAREX operations.
7/05:10	DTO 663.
7/05:20	DTO 665.
7/05:55	DTO 665.
7/06:20	DTO 663.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/06:45	DSO 326.
7/07:15	Crew begins presleep activities.
7/07:30	SAREX operations.
7/10:15	Crew begins sleep period.
7/18:15	Crew begins postsleep activities.
7/21:15	DSO 612.
7/21:30	DTO 623.
7/21:40	DSO 623.
7/21:46	Rodent hematology.
7/22:00	SAREX operations.
7/22:15	PAO event.
7/22:20	DSO 802.
7/23:55	SAREX operations.

MET DAY EIGHT

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/00:00	Vestibular operations—AWARE.
8/00:40	DSO 623—lower body negative pressure ramp test.
8/03:24	SAREX operations.
8/03:30	DSO 802.
8/04:00	DSO 802.
8/04:00	DSO 623—lower body negative pressure ramp test.
8/04:40	DSO 802.
8/05:15	Rodent health check.
8/05:55	Urine monitoring system calibration.
8/06:05	DSO 326.
8/06:15	SAREX operations.
8/06:45	DTO 663.
8/07:15	Crew begins presleep activities.
8/07:35	SAREX operations.
8/07:55	SAREX operations.
8/10:15	Crew begins sleep period.
8/18:15	Crew begins postsleep activities.
8/19:50	Fuel cell purge.
8/21:15	Crew press conference.
8/21:45	DSO 612.
8/22:00	DSO 326.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/22:12	Rodent hematology.
8/22:18	Vestibular operations—rotating chair.
	MET DAY NINE
9/00:10	SAREX operations.
9/03:21	SAREX operations.
9/04:55	Rodent health check.
9/05:31	Rodent vestibular operations.
9/07:00	DSO 326.
9/07:15	Crew begins presleep activities.
9/10:15	Crew begins sleep period.
9/18:15	Crew begins postsleep activities.
9/21:05	DSO 612.
9/21:10	DTO 623.
9/21:15	Crew off duty.
	MET DAY TEN
10/01:51	Vestibular operations—drop test.
10/02:10	PAO event.
10/02:15	DSO 326.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
10/03:30	UMS calibration.
10/03:32	Vestibular operations—rotating dome.
10/04:52	Rodent health check.
10/06:00	DSO 326.
10/06:15	DTO 663.
10/06:30	Crew begins presleep activities.
10/09:30	Crew begins sleep period.
10/17:30	Crew begins postsleep activities.
10/18:00	Metabolic operations.
10/20:30	DTO 667.
10/20:30	DTO 663.
10/20:45	DSO 326.
10/20:50	Cardiovascular operations.
10/20:55	DSO 612.
10/21:00	DTO 667—PILOT.
10/21:30	DTO 667.
10/21:50	DTO 663.
10/21:56	Echocardiograph operations.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
10/22:45	Entry training.
10/23:25	DSO 623—lower body negative pressure ramp test.

MET DAY ELEVEN

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
11/01:50	SAREX operations.
11/02:45	PAO event.
11/02:45	DTO 667.
11/03:30	DSO 314.
11/03:34	Rodent health check.
11/04:15	DSO 623.
11/05:00	DTO 663.
11/05:30	DTO 667.
11/06:00	DSO 326.
11/06:30	Crew begins presleep activities.
11/09:30	Crew begins sleep period.
11/17:30	Crew begins postsleep activities.
11/20:45	Metabolic operations.
11/20:55	DSO 326.
11/21:30	Rodent vestibular operations.
11/21:35	DSO 802.
11/22:05	DSO 802.
11/22:35	DSO 802.
11/22:35	SAREX operations.

MET DAY TWELVE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
12/00:15	SAREX operations.
12/00:35	PAO event.
12/02:10	Urine monitoring system calibration.
12/03:00	DSO 314.
12/03:30	DSO 314.
12/03:45	DSO 904.
12/04:00	DSO 904.
12/04:10	DSO 802.
12/04:55	DSO 314.
12/05:00	Rodent health check.
12/05:45	OARE.
12/05:45	SAREX stow.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
12/06:00	DSO 326.
12/06:30	Crew begins presleep activities.
12/09:30	Crew begins sleep period.
12/17:30	Crew begins postsleep activities.
12/18:00	Metabolic operations.
12/20:10	DSO 623—lower body negative pressure soak test.
12/20:45	Rodent hematology.
12/20:51	Cardiovascular operations.
12/20:55	DSO 326.
12/21:25	DSO 314.
12/21:30	FCS checkout.
12/22:30	RCS hot fire.
12/22:30	DSO 904.

MET DAY THIRTEEN

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
13/00:55	DSO 623.
13/02:15	PAO event.
13/02:35	Rodent health check.
13/02:45	DSO 904.
13/03:00	DSO 611.
13/03:15	Cabin stow.
13/03:30	Spacelab stow.
13/03:55	DSO 904.
13/05:30	Partial Spacelab deactivation.
13/06:10	DSO 620.
13/06:30	DSO 326.
13/09:25	Crew begins sleep period.
13/16:25	Crew begins postsleep activities.
13/17:25	DSO 603B.
13/18:08	Spacelab deactivation (final).
13/18:40	DTO 623.
13/18:45	EDO deactivation.
13/19:15	Priority Group B power up.
13/19:23	Begin deorbit preparation.
13/19:23	Ku-band antenna stow.
13/19:26	CRT timer setup.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
13/19:34	Commander initiates coldsoak.
13/19:43	Stow radiators, if required.
13/20:01	Commander configures DPS for deorbit preparation.
13/20:04	Mission Control Center updates IMU star pad, if required.
13/20:13	MS configures for payload bay door closure.
13/20:24	MCC-H gives "go/no-go" command for payload bay door closure.
13/20:29	Maneuver vehicle to IMU alignment attitude.
13/20:49	IMU alignment/payload bay door operations.
13/21:13	MCC gives the crew the go for OPS 3.
13/21:19	Pilot starts repressurization of SSME systems.
13/21:23	Commander and pilot perform DPS entry configuration.
13/21:32	MS deactivates ST and closes ST doors.
13/21:34	All crew members verify entry payload switch list.
13/21:49	All crew members perform entry review.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
13/21:51	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
13/22:04	Commander and pilot configure clothing.
13/22:19	MS/PS configure clothing.
13/22:30	Commander and pilot seat ingress.
13/22:32	Commander and pilot set up heads-up display (HUD).
13/22:34	Commander and pilot adjust seat, exercise brake pedals.
13/22:42	Final entry deorbit update/uplink.
13/22:48	OMS thrust vector control gimbal check is performed.
13/22:50	APU prestart.
13/23:05	Close vent doors.
13/23:09	MCC-H gives "go" for deorbit burn period.
13/23:15	Maneuver vehicle to deorbit burn attitude.
13/23:18	MS/PS ingress seats.
13/23:25	First APU is activated.
13/23:29	Deorbit burn.
13/23:32	Initiate post-deorbit burn period attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
13/23:36	Terminate post-deorbit burn attitude.
13/23:44	Dump forward RCS, if required.
13/23:45	Activate remaining APUs.
13/23:51	Entry interface, 400,000 feet altitude.
13/23:55	Automatically deactivate RCS roll thrusters.
14/00:03	Automatically deactivate RCS pitch thrusters.
14/00:04	Initiate first roll reversal.
14/00:10	Initiate second roll reversal.
14/00:11	TACAN acquisition.
14/00:13	Initiate air data system (ADS) probe deploy.
14/00:14	Initiate third roll reversal.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
14/00:16	Begin entry/terminal area energy management (TAEM).
14/00:16	Initiate payload bay venting.
14/00:18	Automatically deactivate RCS yaw thrusters.
14/00:21	Begin TAEM/approach/landing (A/L) interface.
14/00:22	Initiate landing gear deployment.
14/00:23	Vehicle has weight on main landing gear.
14/00:23	Vehicle has weight on nose landing gear.
14/00:23	Initiate main landing gear braking.
14/00:24	Wheel stop.

GLOSSARY

A/G	air-to-ground
AA	accelerometer assembly
ACIP	aerodynamic coefficients identification package
ACS	active cooling system
ADS	air data system
AEM	animal enclosure module
AFB	Air Force base
AG	airglow
A/L	approach and landing
AOS	acquisition of signal
APC	autonomous payload controller
APCS	autonomous payload control system
APU	auxiliary power unit
ARC	Ames Research Center
ARU	accelerometer recording unit
ASE	airborne support equipment
BFS	backup flight control system
BMMD	body mass measurement device
CCD	charge-coupled device
CCDS	Center for the Commercial Development of Space
CDMS	command and data management subsystem
COAS	crewman optical alignment sight
CRT	cathode ray tube
CRU	cardiopulmonary rebreathing unit
C/W	caution/warning
DACA	data acquisition and control assembly
DA	detector assembly
DC	detector controller
DAP	digital autopilot
DOD	Department of Defense
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECG	echocardiograph
ECLSS	environmental control and life support system
EDO	extended duration orbiter
EDOMP	extended duration orbiter medical project
EHF	extremely high frequency
ELV	expendable launch vehicle
EMP	enhanced multiplexer/demultiplexer pallet
EMU	extravehicular mobility unit
EOM	end of mission
EPS	electrical power system
ESC	electronic still camera
ESA	European Space Agency
ESS	equipment support section
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FCP	fuel cell power plant
FCS	flight control system
FDF	flight data file
FES	flash evaporator system
FPA	fluid processing apparatus
FPS	feet per second
FRCS	forward reaction control system
GAP	group activation pack

GAS	getaway special experiment
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GPTU	general purpose transfer unit
GPWS	general-purpose workstation
GSFC	Goddard Space Flight Center
HAINS	high accuracy inertial navigation system
HIRAP	high resolution acceleration package
HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
I/O	input/output
IR	infrared
IUS	inertial upper stage
ITEPC	InterMars issue equivalent proportional counter
IV	intravehicular
JSC	Johnson Space Center
KEAS	knots equivalent air speed
KSC	Kennedy Space Center
LBNP	lower body negative pressure
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
LSLE	life sciences laboratory equipment
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
MPM	manipulator positioning mechanism
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NCC	corrective combination maneuver
NH	differential height adjustment that adjuists the altitude of orbiter's orbit
NMI	nautical miles
NOR	Northrup Strip
NSR	coelliptic maneuver that circularizes orbiter's orbit
O&C	operations and checkout
OAA	orbiter access arm
OCP	Office of Commercial Programs
OEX	orbiter experiments
OG	orbiter glow
OMS	orbital maneuvering system
OPF	orbiter processing facility
OTC	orbiter test conductor
PAO	public affairs officer
PASS	primary avionics software system
PC	proportional counter
PCMMU	pulse code modulation master unit
PCS	pressure control system
PDU	playback/downlink unit
PGSC	payload and general support computer
PI	payload interrogator
PIC	pyro initiator controller
PILOT	pilot in-flight landing operations trainer

PMS	physiological monitoring system
POCC	Payload Operations Control Center
PRCS	primary reaction control system
PRD	payload retention device
PRLA	payload retention latch assembly
PRSD	power reactant storage and distribution
PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV

RAAN	right ascension of the ascending node
RAHF	research animal holding facility
RCRS	regenerable carbon dioxide removal system
RCS	reaction control system
RDA	rotating dome assembly
RF	radio frequency
RGA	rate gyro assembly
RMI	refrigerator/incubator module
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
SAREX	shuttle amateur radio experiment
SHF	superhigh frequency
SLS-2	Spacelab Life Sciences 2
SM	statute miles
SMMI	small mass measuring instrument
SPASP	small payload accommodations switch panel
SPOC	shuttle payload of opportunity carrier
SRB	solid rocket booster
SRM	solid rocket motor
SRSS	shuttle range safety system
SSME	space shuttle main engine
SSP	standard switch panel
SSPP	Shuttle Small Payload Project
SSPP	solar/stellar pointing platform
ST	star tracker
STA	structural test article
STS	Space Transportation System
SURS	standard umbilical retraction/retention system

TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	tracking and data relay satellite
TDRSS	tracking and data relay satellite system
TFL	telemetry format load
TI	thermal phase initiation burn
TIG	time of ignition
TIPS	thermal impulse printer system
TOS	transfer orbit stage
TPS	thermal protection system
TSM	tail service mast
TT&C	telemetry, tracking, and communications
TV	television
TVC	thrust vector control

UHF	ultrahigh frequency
UMS	urine monitoring system

VRCS	vernier reaction control system
VTR	videotape recorder

WCCS	wireless crew communication system
WCS	waste collection system