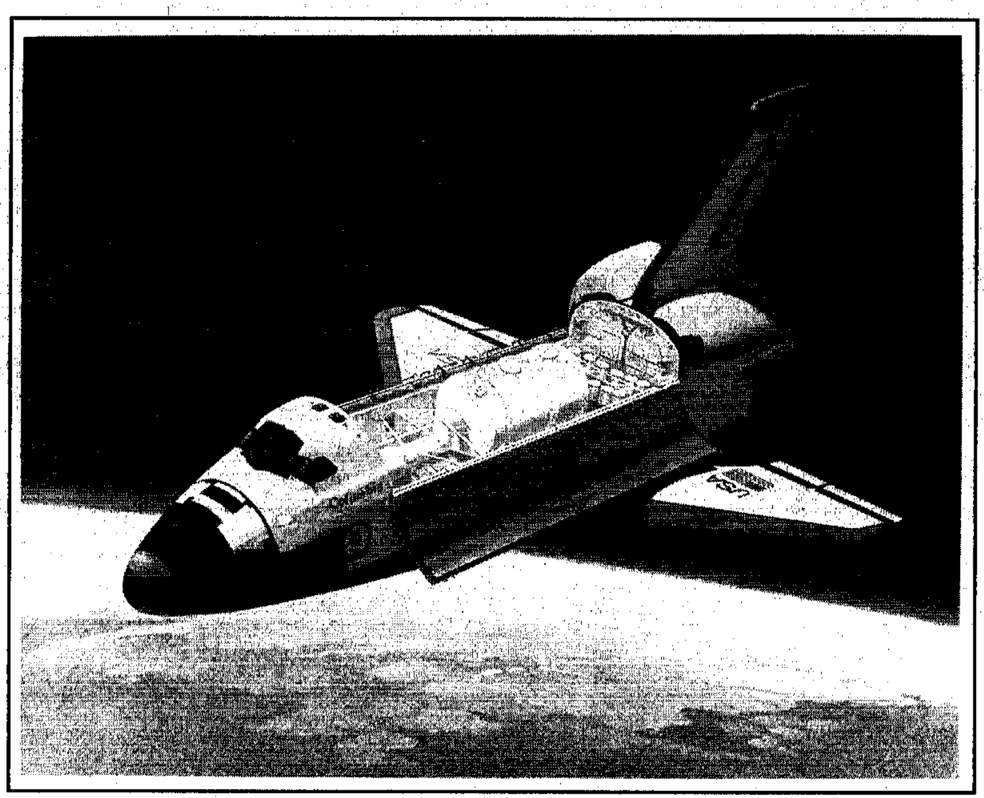

STS-40
PRESS INFORMATION

May 1991

Rockwell International
Space Systems Division

Office of Media Relations

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CONTENTS

MISSION OVERVIEW

This is the 11th flight of Columbia and the 41st for the space shuttle.

The flight crew for the STS-40 mission consists of commander Bryan D. O'Connor; pilot Sidney (Sid) M. Gutierrez; mission specialists James (Jim) P. Bagian, Tamara (Tammy) E. Jernigan, and M. Rhea Seddon; and payload specialists Francis A. (Drew) Gaffney and Millie Hughes-Fulford.

STS-40's primary mission objective is to successfully perform the planned operations of the Spacelab Life Sciences (SLS)-1 payload. The STS-40 SLS-1 mission is the first Spacelab mission dedicated exclusively to life sciences research. Four crew members (payload specialists Francis A. (Drew) Gaffney and Millie Hughes-Fulford; and mission specialists James (Jim) P. Bagian and M. Rhea Seddon) will perform experiments to see how their bodies adapt to space flight. The tests will continue for several weeks after the mission to monitor how their bodies readjust to living on Earth. SLS-1 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-1 and future missions is to find out why these changes take place and learn how to prevent or control undesirable responses.

Twenty SLS-1 investigations and eight secondary SLS-1 studies will be performed. The investigations will study six body systems, and include six cardiovascular/cardiopulmonary experiments, three blood experiments, six musculoskeletal experiments, three neurovestibular experiments, one immune system experiment, and one renal-endocrine system experiment. Of the 20 investigations, 10 involve human subjects, nine use rodents, and one uses jellyfish. Measurements will be made before and after the flight to determine how microgravity affects the rodents and jellyfish.

The primary investigations are as follows:

- **Influence of Weightlessness Upon Human Autonomic Cardiovascular Controls**

  The carotid sinus baroceptor reflex in humans is measured before, during, and after space flight to examine the relationship between the baroreflex response and the development of orthostatic intolerance.

- **Inflight Study of Cardiovascular Deconditioning**

  The effects of microgravity on circulatory and respiratory functions are determined for resting and exercising subjects by means of gas analysis, using a noninvasive rebreathing technique.

- **Correlation of Macro- and Microcirculatory Alterations During Weightlessness**

  Changes in both resting cardiovascular function and microcirculation resulting from acute and prolonged exposure to microgravity are detected by directly measuring arterial and venous blood pressures and atrial blood flow in rats.

- **Pulmonary Function During Weightlessness**

  Human pulmonary function in microgravity is observed by noninvasive measurement of parameters related to pulmonary gas exchange. Results will be compared to those obtained in Earth gravity.

- **Cardiovascular Adaptation of White Rats to Decreased Gravity of Space Shuttle/Spacelab in Flight Conditions**

  Postflight techniques are employed to determine whether rats can be used as animal models to study fluid shifts and other cardiovascular changes associated with microgravity.

- **Cardiovascular Adaptation to Microgravity**

  This study of cardiovascular function and dimensions uses a variety of test methods on subjects at rest and during exercise.

- **Regulation of Erythropoiesis During Space Flight**

  The roles of nutritional status and hemoconcentration in rat red blood cell production during space flight are studied.

- **Protein Metabolism During Space Flight**

  Human whole-body protein metabolism is studied, 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 Microgravity on Biochemical and Metabolic Properties of Skeletal Muscle in Rats**

  Alterations in the functional capacity of rat skeletal muscles are determined by the use of preflight and postflight exercise tests and tissue analysis.

- **Regulation of Blood Volume During Space Flight**

  This investigation is designed to evaluate the use of rats as models for humans in hematological studies.

- **Fluid-Electrolyte Regulation During Space Flight**

  Blood, urine, and saliva samples are analyzed for parameters that indicate changes in fluid, electrolyte, renal, and circulatory status of humans exposed to weightlessness.

- **Bone, Calcium, and Space Flight**

  Analysis of rat wastes for tracer calcium added to the diet and bone morphology examinations are used to characterize bone loss attributable to microgravity.

- **Lymphocyte Proliferation in Weightlessness**

  The effects of stress and weightlessness on human lymphocyte function and proliferation are studied in samples exposed to specific mitogens.

- **Skeletal Myosin Isoenzymes in Rats Exposed to Microgravity**

  The role of myosin isoenzymes and the alteration of muscles is studied, using inflight activity monitoring of rats and postflight tissue analysis.

- **Influence of Space Flight on Erythrokinetics in Man**

  Blood is collected from crewmembers to determine whether reduced red cell mass associated with microgravity is due to decreased production or increased hemolysis.

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

  Morphological, biochemical, and histochemical changes in muscles attributable to launch and reentry stress, inflight atrophy, and postflight repair are determined by inflight activity monitoring and postflight analysis of enzymes.

- **Pathophysiology of Mineral Loss During Space Flight**

  Dual stable isotopes of calcium are administered to crewmembers (one orally and one intravenously) to determine whether elevated fecal calcium is caused by decreased gastrointestinal absorption or by active gastrointestinal excretion.

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

  The biochemical and structural integrity of the otolith organs of the rat are studied postflight to determine the chronic and/or progressive effects of space flight.

- **Effects of Microgravity-Induced Weightlessness on Aurelia Ephyra Differentiation and Statolith Synthesis**

  Jellyfish will be observed to determine how metamorphosis in microgravity affects development, swimming behavior, statolith mineralization, and overall morphology.

- **Vestibular Experiments in Spacelab**

  A study of human vestibular function and adaptation is performed using several techniques with emphasis on otolith system measurements.

Eight secondary studies will gather data that complement the major investigations or develop space facilities for future missions. The secondary studies are as follows:

- **Noninvasive Estimation of Central Venous Pressure During Space Flight**

  This investigation uses a noninvasive technique to measure central venous pressure.

- **Solid Surface Combustion Experiment (SSCE)**

  SSCE will study combustion phenomena in microgravity.

- **Space Acceleration Measurement System (SAMS)**

  Three triaxial sensor heads will be installed in Spacelab to record on-orbit acceleration levels.

- **Characterization of Airborne Particulate Matter**

  This hardware verification test will look for potentially hazardous particles and help determine their sources.

- **Validation of Intravenous Fluid System**

  This hardware verification test will verify Space Station Health Maintenance Facility equipment and medical procedures.

- **Particulate Containment Demonstration Test**

  This hardware verification test will be carried out using the General Purpose Work Station (GPWS), the General Purpose Transfer Unit (GPTU), and the Research Animal Holding Facility (RAHF).

- **Small Mass Measurement Instrument (SMMI)**

  This is a hardware verification test of a rack-mounted Life-Sciences Laboratory Equipment (LSLE) item that can determine the mass of small objects.

- **Medical Restraint Systems**

  Assembly of the Medical Restraint Systems, a prototype surgical workstation, will be evaluated in microgravity.

Three middeck payloads, the Physiological Monitoring System (PMS), Urine Monitoring System (UMS), and Animal Enclosure Modules (AEM), are used in the performance of SLS-1 primary and secondary studies. PMS evaluates crew motion sickness. UMS obtains samples of urine from each crew member for storage in a refrigerator/freezer. UMS interconnects with the water from the galley and the orbiter waste collection system. AEM will be flown to demonstrate the adequate housing of a number of rats in a middeck locker.

STS-40 secondary payloads include the Middeck Zero-gravity Dynamics Experiment (MODE) and 12 Getaway Special (GAS) canister experiments mounted on a GAS Bridge Assembly (GBA) in Columbia's payload bay.

The MODE is housed in Columbia's middeck and is a precursor flight experiment (pre STS-48 evaluation) to evaluate attachment setups.

The 12 GAS experiments aboard STS-40 are as follows:

- **Solid-State Microaccelerometer Experiment (G-021)**

  This experiment will test new solid-state microaccelerator integrated circuits under low-gravity conditions.

- **Experiment in Crystal Growth (G-052)**

  G-052 will melt and regrow gallium arsenide crystals in the absence of convective effects.

- **Orbital Ball Bearing Experiment (G-O91)**

  G-O91 is a ball bearing experiment consisting of a pellet of low-melting point tin-lead-bismuth alloy which will be melted under low-gravity conditions.

- **In-Space Commercial Processing (G-105)**

  G-105 consists of six experiments performing various tests concerned with aqueous phases, growing organic crystals and thin films, electrodepositing various metallic materials, collecting cosmic ray interactions, and measuring cosmic radiation on genetic and chromosomal structure of yeast.

- **Foamed Ultralight Metals (G-286)**

  G-286 will produce three types of lightweight foamed metal samples.

- **Chemical Precipitate Formation (G-405)**

  G-405 will record the formation of several types of chemical precipitates in the microgravity environment.

- **Five Microgravity Experiments (G-408)**

  G-408 consists of five experiments performing various tests covering determining whether low gravity promotes the growth of large zeolite crystals, studying several methods for measuring the behavior of a two-phase fluid system, photographing film fogging by radiation in low-Earth orbit, recording low-level accelerations while in orbit, and cataloguing the environmental conditions internal to the canister.

- **Flower and Vegetable Seeds Exposure to Space (G-451)**

  G-451 will investigate the possibilities of ecological alteration and mutation of plant species when flown in low Earth orbit.

- **Semiconductor Crystal Growth Experiment (G-455)**

  G-455 consists of two experiments that investigate the structure and formation of crystal growth and defects in crystal growth in microgravity.

- **Six Active Soldering Experiments (G-486)**

  G-486 will investigate the process of soldering in microgravity and in a vacuum.

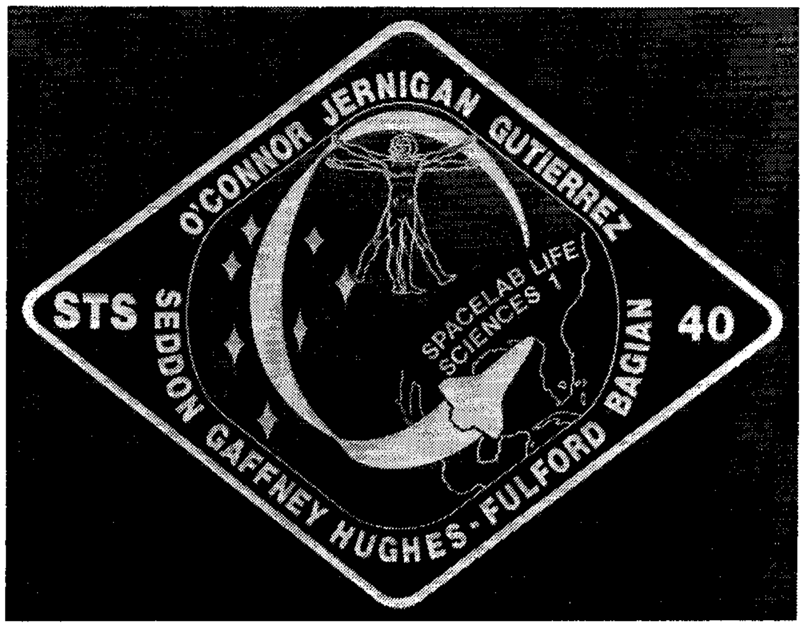
- **Orbiter Stability Experiment (G-507)**

  G-507 consists of two experiments: the orbiter stability experiment (OSE) and a passive experiment to evaluate fogging of photographic emissions due to energetic particles. The OSE will measure the high-frequency variations of the STS orbiter's orientation due to vibrations during routing in-flight operations.

- **The Effect of Cosmic Radiation on Floppy Disks and Plant Seeds Exposure to Microgravity (G-616)**

  G-616 will study the effects of cosmic rays, background radiation, and the Earth's magnetic field on floppy disk storage media.

Seven Orbiter Experiments (OEX) Program experiments will be flown on STS-40, along with 22 development test objectives and 9 detailed supplementary objectives.



STS-40 Mission Insignia

MISSION STATISTICS

Vehicle: Columbia (OV-102), 11th flight

Launch Date/Time:
5/22/91 8:00 a.m., EDT
7:00 a.m., CDT
5:00 a.m., PDT

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

Launch Window: 2 hours

Mission Duration: 9 days, 3 hours, 50 minutes

Landing: Nominal end of mission on Orbit 147
5/31/91 11:50 a.m., EDT
10:50 a.m., CDT
8:50 a.m., PDT

Runway: Nominal end-of-mission landing on concrete runway 22, Edwards Air Force Base (EAFB), Calif. Weather alternates are Northrup Strip (NOR), White Sands, New Mexico; and KSC.

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

Return to Launch Site: KSC

Abort-Once-Around: EAFB; alternates are NOR and KSC

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

Altitude: 160 by 150 nautical miles (184 by 172 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,519,081 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 250,398 pounds

Payload Weight Up: Approximately 25,942 pounds

Payload Weight Down: Approximately 25,942 pounds

Orbiter Weight at Landing: Approximately 225,492 pounds

Payloads—Cargo Bay (* denotes primary payload): Spacelab Life Sciences (SLS)-1 with long module*, GAS Bridge Assembly with 12 Getaway Specials (GAS), OEX Orbiter Acceleration Research Experiment (OARE)

Payloads—Middeck: Physiological Monitoring System (PMS), Urine Monitoring System (UMS), Animal Enclosure Modules (AEM), Middeck Zero-gravity Dynamics Experiment (MODE)

Flight Crew Members:

Commander: Bryan D. O'Connor, second space shuttle flight

Pilot: Sidney (Sid) M. Gutierrez, first space shuttle flight

Mission Specialist 1: James (Jim) P. Bagian, second space shuttle flight

Mission Specialist 2: Tamara (Tammy) E. Jernigan, first space shuttle flight

Mission Specialist 3: M. Rhea Seddon, second space shuttle flight

Payload Specialist 1: Francis A. (Drew) Gaffney, first space shuttle flight

Payload Specialist 2: Millie Hughes-Fulford, first space shuttle flight

Ascent Seating:

Flight deck, front left seat, commander Bryan D. O'Connor

Flight deck, front right seat, pilot Sidney (Sid) M. Gutierrez

Flight deck, aft center seat, mission specialist Tamara (Tammy) E. Jernigan

Flight deck, aft right seat, mission specialist James (Jim) P. Bagian

Middeck, mission specialist M. Rhea Seddon

Middeck, payload specialist Francis A. (Drew) Gaffney

Middeck, payload specialist Millie Hughes-Fulford

Entry Seating:

Flight deck, aft center seat, mission specialist Tamara (Tammy) E. Jernigan

Flight deck, aft right seat, mission specialist M. Rhea Seddon

Middeck, mission specialist James (Jim) P. Bagian

Middeck, payload specialist Francis A. (Drew) Gaffney

Middeck, payload specialist Millie Hughes-Fulford

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut-1 is James (Jim) P. Bagian; EV-2 is Tamara (Tammy) E. Jernigan

Intravehicular Astronaut: Sidney (Sid) M. Gutierrez

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 galley and the four-tier-bunk sleep stations are installed in Columbia's middeck.
- The new, upgraded general-purpose computers are not installed on Columbia for STS-40 but will be installed during Columbia's major modification period later this year. The SLS-1 Spacelab payload, however, is equipped with the new IBM AP-101S GPCs.
- There will be no airborne digitizer unit or teleprinter requirements for this flight.
- The Spacelab will be unpowered on Flight Day 9 based on premission consumables analysis. Twenty-four hours have been built into the mission time for this effort, which is intended to help prepare for eventual extended duration orbiter (EDO) missions.
- Unlike most Spacelab flights, this mission has single-shift payload operations.
- STS-40 will be the first shuttle mission to use the crew transport vehicle (CTV) for crew engress. The CTV supports STS-40 overall science objectives and is intended to minimize the effects of gravity on the metabolic state of crew members by keeping them inactive before/during transport to medical

facilities. An elevating cabin with canted couches will be put in place at the orbiter crew hatch. The CTV provides extra room for de-suiting and medical technologists to support immediate postlanding measurements. It will be available for future Edwards landings, particularly on EDO flights.

- Following this flight and removal of the Spacelab payload at KSC, Columbia will be readied for ferry flight to Rockwell International's Space Systems Division facility in Palmdale, Calif. The orbiter is scheduled to undergo extensive modifications, including changes to accommodate an extended duration mission capability, during a six-month period from August 1991 to January 1992. Columbia's next scheduled flight is STS-50, a planned extended duration mission with the United States Microgravity Laboratory payload, targeted for launch in May 1992.

MISSION OBJECTIVES

- Primary Payload
  - — Spacelab Life Sciences (SLS)-1 with long module
- Secondary Payloads
  - — GAS Bridge Assembly with 12 Getaway Specials
  - — Orbiter Experiments (OEX)
  - — Middeck Zero-Gravity Dynamics Experiment (MODE)
- Development Test Objectives (DTOs)/Detailed Supplementary Objectives (DSOs)

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1
- Launch
- OMS-2
- Spacelab activation
- Metabolic experiment operations
- Echocardiograph operations
- Jellyfish incubator activation and specimen loading in Spacelab module
- Activation of five GAS payloads

Flight Day 2
- Baroreflex tests
- Pulmonary function tests
- Echocardiograph activities
- Cardiovascular operations
- Ames Research Center operations
- Activation of three GAS payloads

Flight Day 3
- Ames Research Center operations
- Rotating dome operations
- Echocardiograph activities
- DTOs
- Activation of GAS payloads

Flight Day 4
- Baroreflex/pulmonary function tests
- Ames Research Center operations
- Activation of GAS payloads

Flight Day 5
- Pulmonary function tests
- Cardiovascular operations
- Echocardiograph activities

Flight Day 6
- Rotating dome operations
- Echocardiograph activities
- Cardiovascular operations
- Ames Research Center operations

Flight Day 7
- DTOs
- Ames Research Center operations

Flight Day 8
- Baroreflex tests
- Echocardiograph activities
- Cardiovascular operations

Flight Day 9
- Pulmonary function tests
- Flight control systems checkout
- Echocardiograph tests
- Cardiovascular operations
- Cabin stow
- Partial Spacelab deactivation

Flight Day 10
- Spacelab deactivation
- Deorbit preparation
- Deorbit burn
- Landing

Notes:

- Due to power requirements and the length of the mission, an equipment powerdown (referred to as a Group B powerdown), is executed on Flight Day 1 to conserve cryogenics for a full mission duration plus two extension days (if required). Powerdown activities include powering off three of Columbia's four CRTs, placing three of Columbia's five general purpose computers on standby mode, placing one of Columbia's three inertial measurement units on standby mode, and powering off three of Columbia's eight flight-critical multiplexers (two forward, one aft).

- An approved exemption allows for an 18-hour crew day on Flight Day 1.

- An approved exemption allows use of the first hour of presleep activities for payload activities.

- 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.

- Flight Day 7 is currently scheduled to be unpowered. Energy buy backs, which result from lower than expected payload usage, will be used for operations based on the following priorities:

    - Spacelab Life Sciences 1
    - EDO day (including EDO DSOs)
    - Ninth day of Spacelab operations
    - DTO 910—OARE
    - GAS experiments
    - Remaining DTOs
    - Remaining DSOs

STS-40 CREW ASSIGNMENTS

Note: *denotes backup responsibility

Commander (Bryan D. O'Connor):

Overall mission decisions

Orbiter—safety, DPS, GN&C, ECLSS, Communications/Instrumentation, C&W, SPOC*, HP41C*, Earth observations*, LES/escape*, Photo/TV/CCTV

Payload--OARE*, GAS*

DTOs/DSOs—cabin air monitoring, air cleaner, HUD/COAS, TPEC*, water filter*, aerobics

Spacelab systems—computers*, electrical*, environment*

Pilot (Sidney M. Gutierrez):

Orbiter—MPS, OMS/RCS, APU/hydraulics, EPS, payload bay door/radiator, IFM, intravehicular astronaut 1, HP41C, Earth observations, photo/TV/CCTV*, crew equipment

Payload—OARE, GAS, MODE*

DTOs/DSOs—cabin air monitoring*, air cleaner*, HUD/COAS*, TPEC, water filter

Spacelab Systems—computers*, electrical*, environment*, IFM*

Mission Specialist 1 (James P. Bagian):

Orbiter—IFM*, extravehicular astronaut 1, medical/medical DSOs, LES/escape, crew equipment

Payload—SLS-l medical experiments

Spacelab Systems—computers*, electrical, environment*, IFM*

Mission Specialist 2 (Tamara E. Jernigan):

Orbiter—DPS*, MPS*, OMS/RCS*, APU/hydraulics*, GN&C*, EPS*, ECLSS*, Communications/instrumentation*, C&W*, payload bay doors/radiator*, extravehicular astronaut 2, SPOC, FDF

Payload—SLS-l*, SMIDEX, MODE, photo/TV

Spacelab Systems—computers*, electrical*, environment*

Mission Specialist 3 (M. Rhea Seddon):

Orbiter—medical/medical DSOs

Payload—SLS-l medical experiments, SMIDEX*, photo/TV*

Spacelab Systems—computers, electrical*, environment

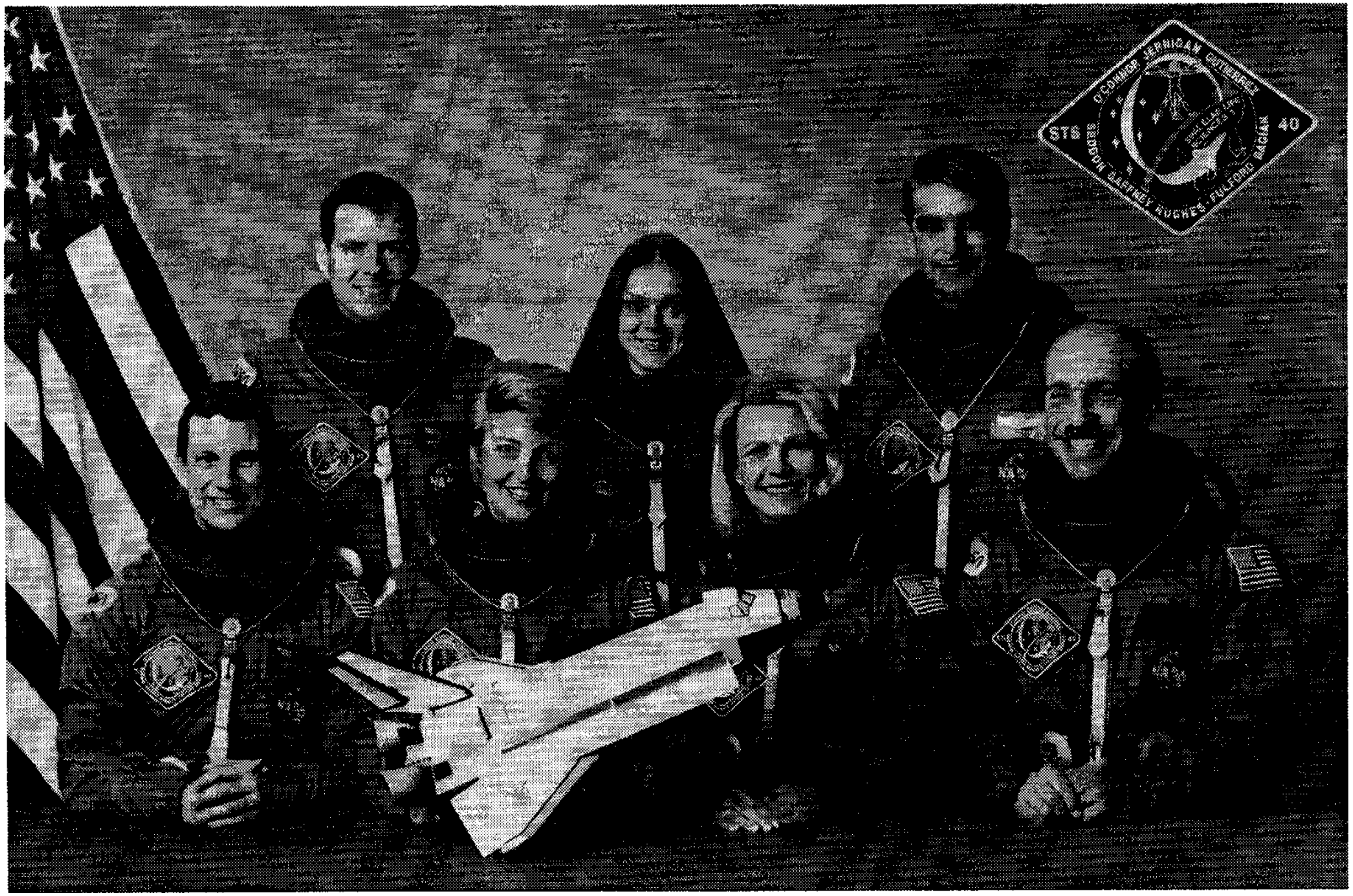
Payload Specialist 1 (Francis A. [Drew] Gaffney):

Payload—SLS-1 medical experiments*

Payload Specialist 2 (Millie Hughes-Fulford):

Orbiter—communications/instrumentation*

Payload—SLS-1 medical experiments*



STS-40 Crewmembers (left to right): Payload Specialist Francis A. (Drew) Gaffney, Commander Bryan D. O'Connor, Payload Specialist Millie Hughes-Fulford, Mission Specialist Tamara E. Jernigan, Payload Specialist M. Rhea Seddon, Pilot Sidney M. Gutierrez, and Mission Specialist James P. Bagian

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

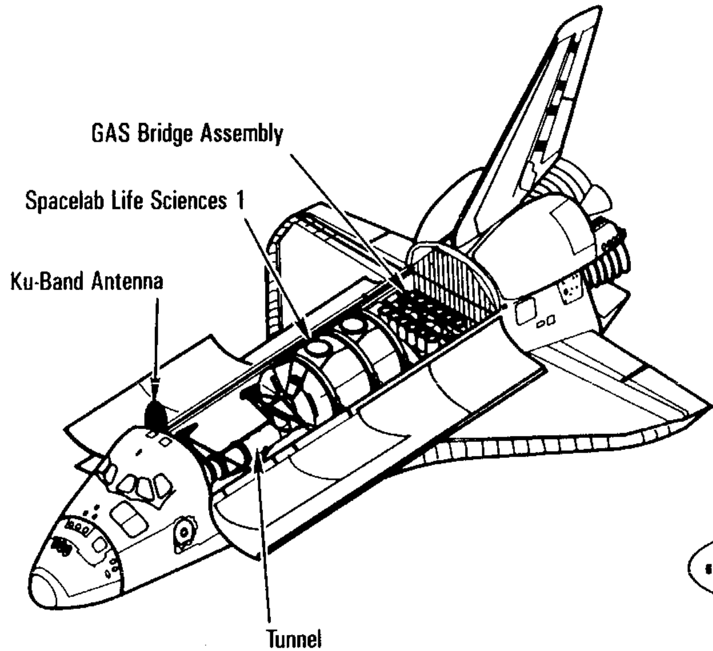
- Ascent aerodynamic distributed loads verification on OV-102 (DTO 236)
- Entry aerodynamic control surfaces test, part 5 (DTO 242)
- Ascent structural capability evaluation (DTO 301D)
- Ascent compartment venting evaluation (DTO 305D)
- Descent compartment venting evaluation (DTO 306D)
- Entry structural capability (DTO 307D)
- ET TPS performance (DTO 312)
- Hot nosewheel steering runway evaluation (DTO 517)
- Cabin air monitoring (DTO 623)
- Camcorder demonstration, Canon AIA Mark2 (DTO 630)
- On-orbit cabin air cleaner evaluation (DTO 637)
- Water separator filter performance evaluation (DTO 647)
- TDRS S-band forward link RF power level evaluation (DTO 700-1)
- Heads-up display backup to crew optical alignment sight (DTO 785)
- Vent uplink capability (DTO 796)
- Crosswind landing performance (DTO 805)
- Additional stowage evaluation for extended duration orbiter (DTO 823)
- OEX shuttle infrared leeside temperature sensing (DTO 901)
- OEX shuttle upper atmosphere mass spectrometer (DTO 902)
- OEX shuttle entry air data system (DTO 903)
- OEX orbital acceleration research experiment (DTO 910)
- OEX aerothermal instrumentation package (DTO 911)

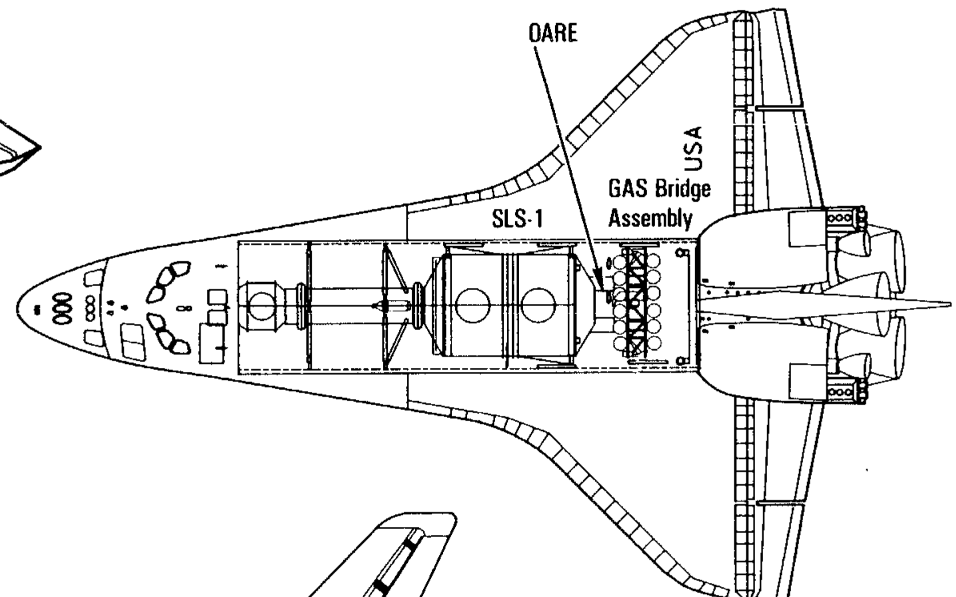
DSOs

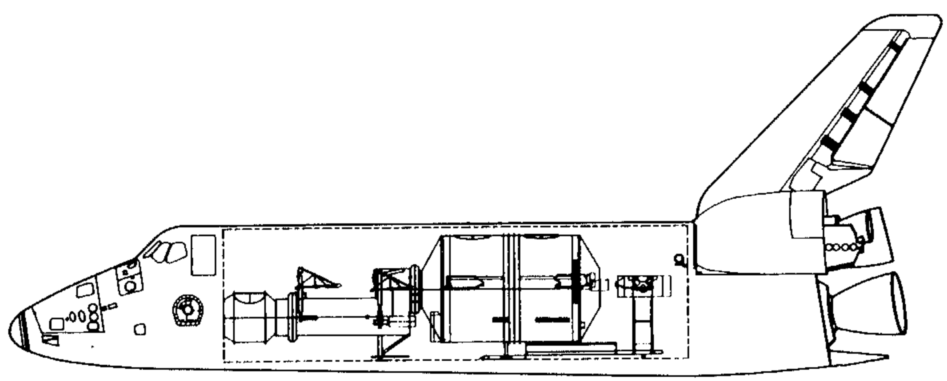
- In-flight radiation dose distribution, tissue equivalent proportional counter only, activation on Flight Day 2 (DSO 469)
- In-flight aerobic exercise (DSO 476)
- Changes in baroreceptor reflex function (DSO 601)
- Postural equilibrium control during landing egress (DSO 605)
- Air monitoring instrument evaluation and atmospheric characterization, microbial air sample and archival organic sampler (DSO 611)

- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)
- Assessment of human factors (DSO 904)

PAYLOAD CONFIGURATION







BACKGROUND

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 various physiological responses encountered as the animals experienced the stresses of launch and reentry and the weightless environment. These first true 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 same 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 inflight 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.

During Apollo, astronauts worked productively on the moon. While inflight observations were relatively simple, the Apollo astronauts were examined extensively prior to and subsequent to each flight. Apollo astronauts reported a few minor physiological problems, such as space motion sickness, but were otherwise able to live and work productively in space.

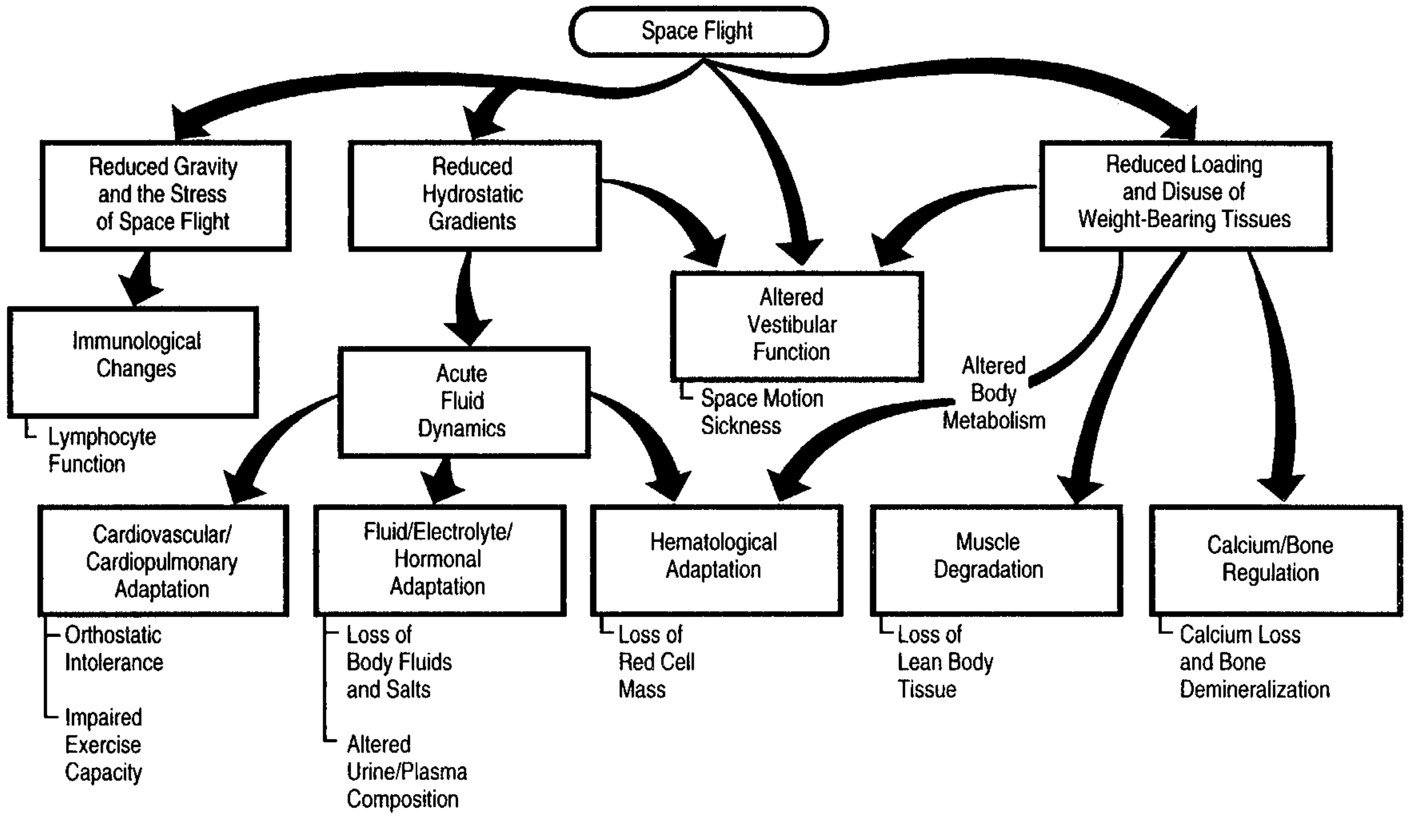
While scientists were continuing to learn more and more about human responses to microgravity, America's Mercury, Gemini, and Apollo spacecraft were too small to house the precise research equipment needed to properly study the effects of living in weightlessness. Scientists were finally able to make 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 Skylab and space shuttle life science investigations, life scientists developed detailed plans for studying the entire body's response to space flight while also 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 1 mission is the first of these missions designed to make interrelated physiological measurements in space and is part of NASA's vigorous inquiry to study the nature of life, ensure the success of human space flight, and bring the benefits of space back home to Earth.

THE SLS-1 MISSION

SLS-l's primary objective is to study the mechanisms, magnitudes, and time courses of certain physiological changes that occur during space flight and to investigate the consequences of the body's adaptation to microgravity and readjustment to 1-g. Operating on a 12-hour shift, the SLS-l crew will perform 20 experiments. The investigations study six body systems, including cardiovascular/ cardiopulmonary (heart, lungs, and blood vessels), blood (blood plasma and red blood cells), musculoskeletal (muscles and bones), neurovestibular (brain and nerves, eyes, and inner ear), immune (white blood cells), and renal-endocrine (kidneys and hormone-secreting organs). Eight secondary studies will gather data that complement the major investigations or perform functional tests of hardware and operations that are pertinent to the future of the space life sciences program. SLS-1 will provide an opportunity for scientists to study the acute effects of weightless exposure in a comprehensive, interrelated fashion using both humans and animals (laboratory rats and jellyfish).

NASA's Ames Research Center is responsible for development of the nonhuman experiments, while the Johnson Space Center is responsible for the development of the human experiments. JSC is also responsible for overall SLS-1 mission management. The project offices at these centers are responsible for providing new experiment hardware as well as core equipment from the life sciences hardware inventory.



SLS-1 Experiments Will Help Define the Relationships Between Various Physiological Systems and Gravity

MTD-910515-1340

Preflight baseline data collection will be performed primarily at JSC with several tests scheduled at the Kennedy Space Center just prior to launch. Investigators will perform postflight tests at the Ames-Dryden Flight Research Facility at Edwards Air Force Base, California.

Much of the research to be performed on SLS-1 also has the potential to help us more clearly understand the nature of medical disorders experienced on Earth. For example, cardiovascular experiments may help scientists learn more about disorders such as hypertension and heart failure, while musculoskeletal

Primary STS-40 Mission Responsibility

JSC Mission Operations	MSFC	JSC New Initiatives	JSC Life Science	ARC Life Science

• Overall Flight Management
• Flight Safety
• Payload Integration
• FDF Development
• Flight Timeline
• Spacelab Systems Operations
	• Spacelab Systems Engineering Support (D. Stonemetz–MSFC) (P. Hamby–MSFC) (J. Grubbs–CSR)
	• Spacelab POCC Support
	  • PAYCOM for the Mission (C. Reid)
	  • POCC Facility
	  • HOSC Personnel
		• Mission Management (Dan Womack) in POCC at MSFC, Representative at JSC CSR
		• NASA POD's (K. Newkirk) (G. Gutschewski)
		• Operations Contract With GE
		  • Payload Timeline Integration (L. Irwin)
		  • Payload Systems Integration (Charles Phillips)
		  • Payload Data Management (Rhonda Alcorn)
		  • Crew Training (Joyce Schultz)
		  • GE POD's (Everett Cole) (Harry Sim)
		  • PFDF Book Management
			• Responsible for Human Life Science
			• Lead Mission Scientist (SA/H. Schneider)
			• PI's in SMA (Bldg. 36 at JSC (C. Huntoon)
			• JSC Project Representative at MSFC POCC (B. Walters)
			• PI's at KSC for Launch Support
			• Science Contract With GE
			  • Science Support
			  • Payload Experiment Timeline
			  • Experiment Hardware Support
			  • Crew Training
			  • Experiment CL Development
				• Responsible for Animal Life Science
				• PI's in TMA at ARC
				• ARC Project Representative at MSFC (Bonnie Dalton)
				• PI at KSC for Animal Loading
				• Crew Training
				• PFDF Development for Experiment CL

investigations may increase our insight into bone diseases such as osteoporosis, muscle disorders, and the vital role of force and pressure on musculoskeletal structure and metabolism.

A broad range of instruments—some unique hardware and others standard equipment—will be used by the human subjects throughout the mission. Equipment will include a neck chamber, cardiopulmonary rebreathing unit, gas analyzer mass spectrometer, rotating dome, inflight blood collection system, urine monitoring system, bag-in-box assembly, strip chart recorders, physiological monitoring system, incubators, low-gravity centrifuge, echocardiograph, and venous occlusion cuff controller.

Ames Research Center hardware developed to support these experiments includes a small mass measuring instrument (SMMI), a refrigerator/incubator module (R/IM), general purpose workstation (GPWS) and general purpose transfer unit (GPTU), two animal enclosure units (AEM), and a rodent research animal holding facility (RAHF).

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. Previous missions have identified physiological changes associated with this adaptation: redistribution of body fluids, space sickness, and other responses to microgravity exposure among more slowly changing systems such as muscle and bone.

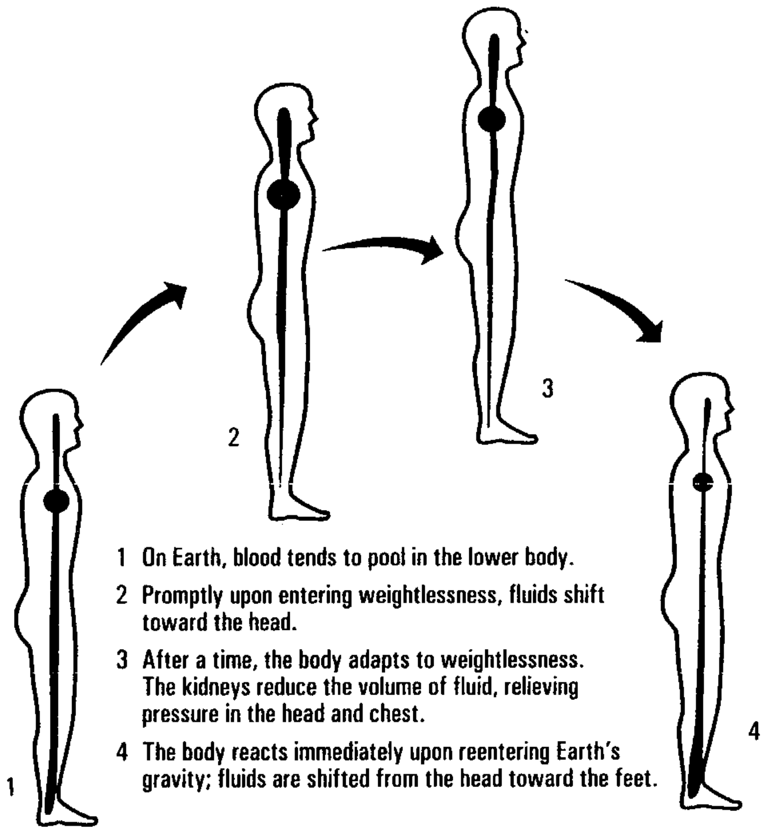
Although these changes appear to be part of the body's natural adaptation to microgravity, they may not be harmless, because the body must readjust to gravity upon return to Earth. Following a short period of readaptation to 1-g, the changes appear to reverse. However, after flights of six months or 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 space flight 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. SLS-1 experiments will define the events that lead to the redistribution of blood and other fluids and identify how the heart, lungs, renal/endocrine system, and rest of the body respond.

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-1 investigations will attempt to discover its causes and define its effects on the body.

Muscle atrophy, bone deterioration, and cellular disturbances begin immediately after microgravity exposure and may continue indefinitely. SLS-1 investigations will measure changes in muscles and bones and examine red and white blood cells.

SLS-1 research builds on information collected during other missions and ground-based studies. Some SLS-1 investigations repeat measurements recorded on previous missions. To follow the time course of adaptive processes, experiments will be performed at specific times and at regular intervals before, during, and after the mission. SLS-1 marks the first time measurements will be made immediately upon exposure to weightlessness. Data collected during the first two days of the mission will be particularly valuable in understanding the events that initiate changes in the body.

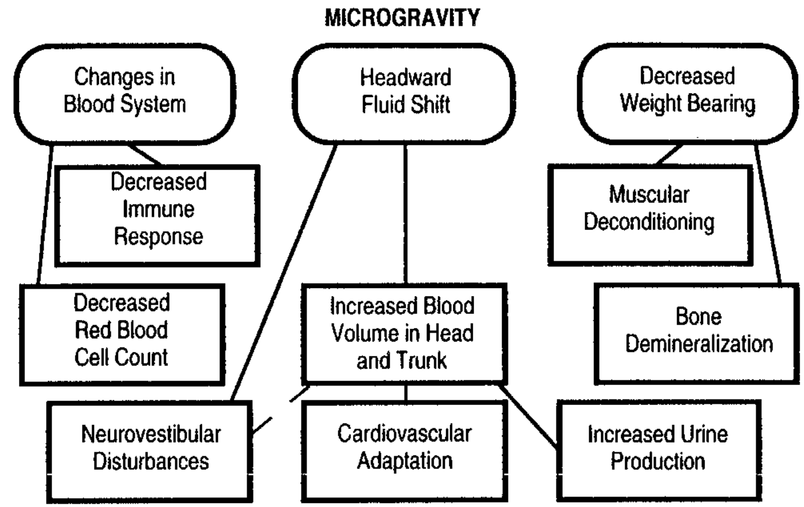


Human Physiological Fluid Shift in Weightlessness

SLS-l scientists compare the physiological systems of different species. Studies with rodents and jellyfish are designed to see whether they have some of the same responses measured in people and to provide critical data that are unavailable from human subjects.

THE SLS-1 LABORATORY

The majority of the SLS-l experiments will be performed in an enclosed pressurized Spacelab module, a reusable laboratory

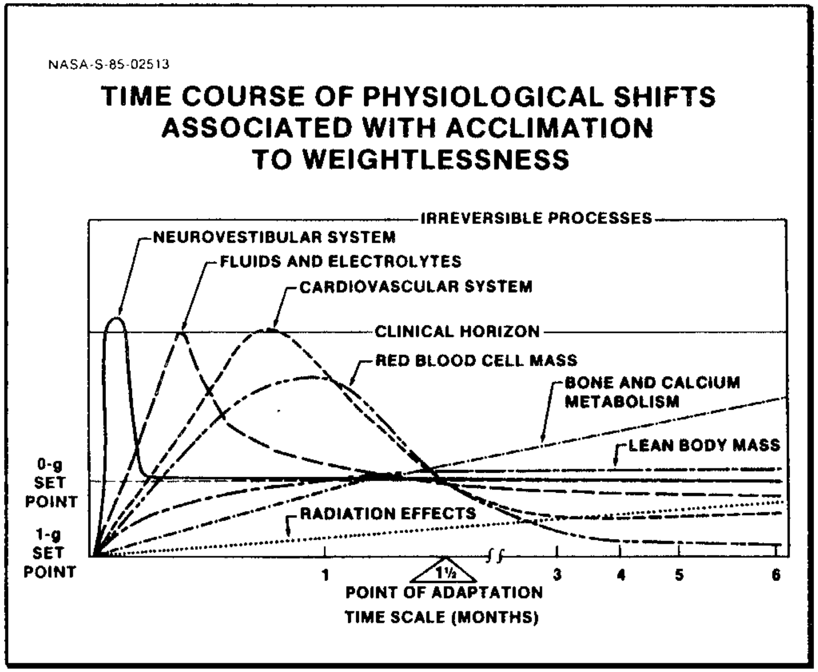


Major Physiological Systems Interact As the Body Adopts to Weightlessness

carried in the shuttle's payload bay. Previous Spacelab missions focused on experiments in several different disciplines such as astronomy, life sciences, and materials science. SLS-l, however, is the first mission to convert Spacelab into a biological research center.

The SLS-l Spacelab long module consists of a core segment and an experiment segment providing pressurized volume for the payload. The SLS-l module is a cylindrical room 23 feet long and 16 feet wide, about the size of a bus. The module contains utilities, computers, work areas, and instrument racks for experiments. The shuttle crew enters Spacelab through a tunnel connected to the shuttle middeck.

For SLS-l, 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. Some of the smaller equipment is located in shuttle middeck lockers. There are eight double racks and four



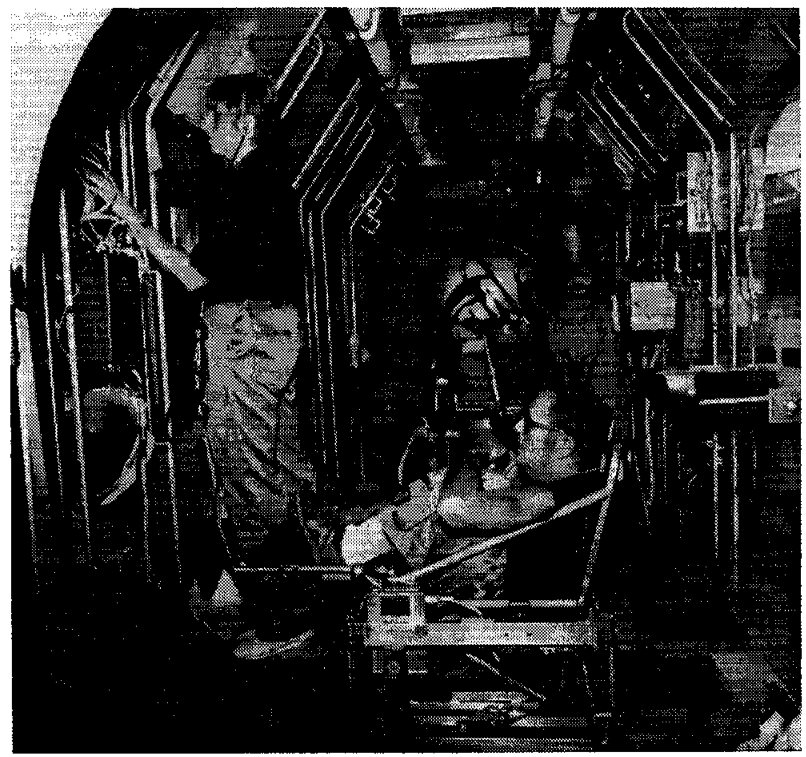
Time Course of Physiological Shifts Associated With Acclimation to Weightlessness

single racks that contain the four different categories of equipment needed to support SLS-1. These include:

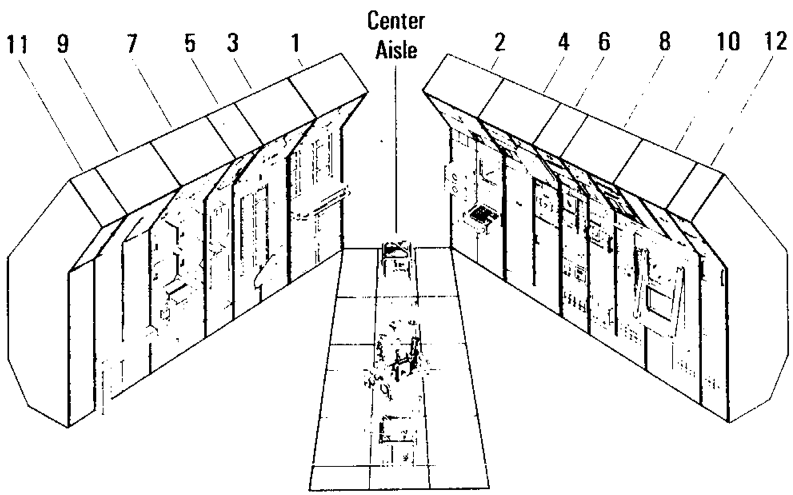
- Experiment-Unique Hardware (hardware developed to support a specific experiment)
- Mission-Dependent Equipment (hardware furnished by various national STS organizations)
- Mission-Peculiar Equipment (hardware furnished by mission manager and designed for the particular payload)
- Life Sciences Laboratory Equipment (Reusable hardware available for life sciences investigations)

In addition to the racks of equipment in the Spacelab, four items are mounted in the center aisle: the body mass measuring device (BMMD), bicycle ergometer, body restraint system (BRS), and the triangular grid foot restraint.

SLS-1 investigators will coordinate their research and share equipment. Most of them will use NASA Life Sciences Laboratory Equipment, an inventory of multipurpose, reusable medical and biological instruments that have been developed or modified for use in microgravity. This equipment includes animal holding facilities, refrigerator/freezers, small and large mass measuring devices, and a special work station. These instruments



SLS-1 Training



SLS-1 Spacelab Configuration

Port Racks

Rack 1:	Workbench
Rack 3:	Research Animal Holding Facility
Rack 5:	SMIDEX single rack Jellyfish experiment Space Acceleration Measurement System
Rack 7:	SMIDEX double rack Solid Surface Combustion Experiment Noninvasive Central Venous Pressure Intravenous Infusion Pump American Flight Echocardiograph Surgical Work Station
Rack 9:	Refrigerator/Freezer Small Mass Measurement Instrument
Rack 11:	Baroreflex Neck Pressure Chamber and electronics Rotating Dome Incubator Low-g Centrifuge

Center Aisle

Body Restraint System

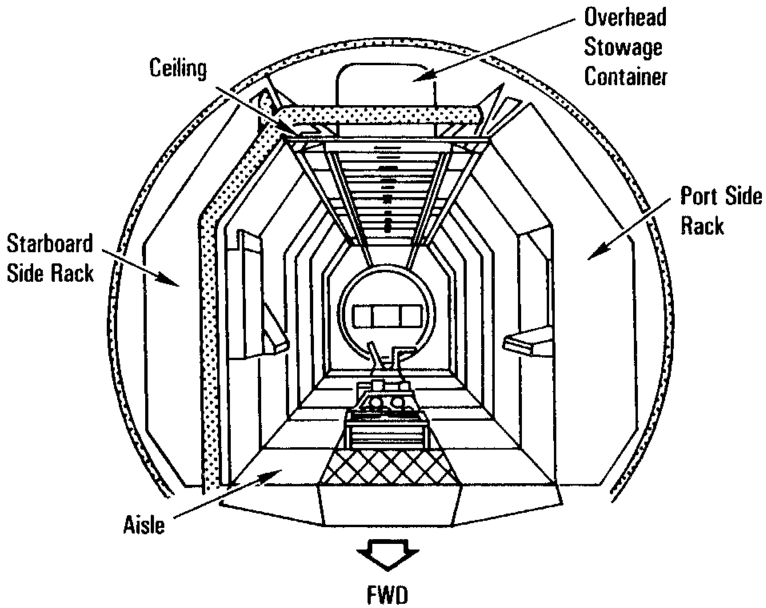
Bicycle Ergometer

Body Mass Measurement Device

Starboard Racks

Rack 2:	Control Center
Rack 4:	Television and video monitoring equipment Spacelab support services Gas Analyzer Mass Spectrometer
Rack 6:	Echocardiograph Experiment Command and Data System/Microcomputer System
Rack 8:	Gas Analyzer Mass Spectrometer Rebreathing Assembly Unit Life Sciences Laboratory Equipment (LSLE) Microcomputers Vacuum Interface Assembly Video Monitor Cardiovascular/Cardiopulmonary Interface Panel Cardiopulmonary Control Unit Gas Tank Assembly
Rack 10:	General Purpose Work Station
Rack 12:	LSLE Centrifuge

SLS-1 Spacelab Configuration



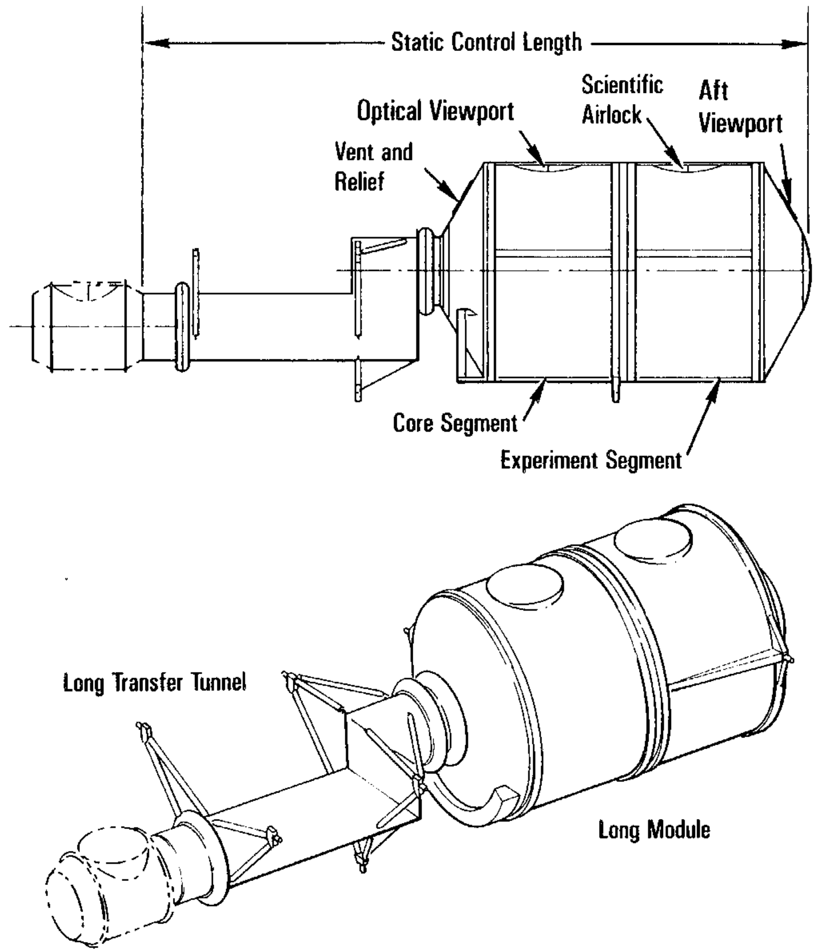
Spacelab Module (Front View)

are augmented by unique equipment designed for particular investigations.

SLS-1 is the first mission to use the Spacelab Middeck Experiments (SMIDEX), a facility for housing experiments that fit in middeck lockers. SMIDEX allows extra space inside Spacelab to be used for several small experiments. SMIDEX will be installed in one single and one double Spacelab racks.

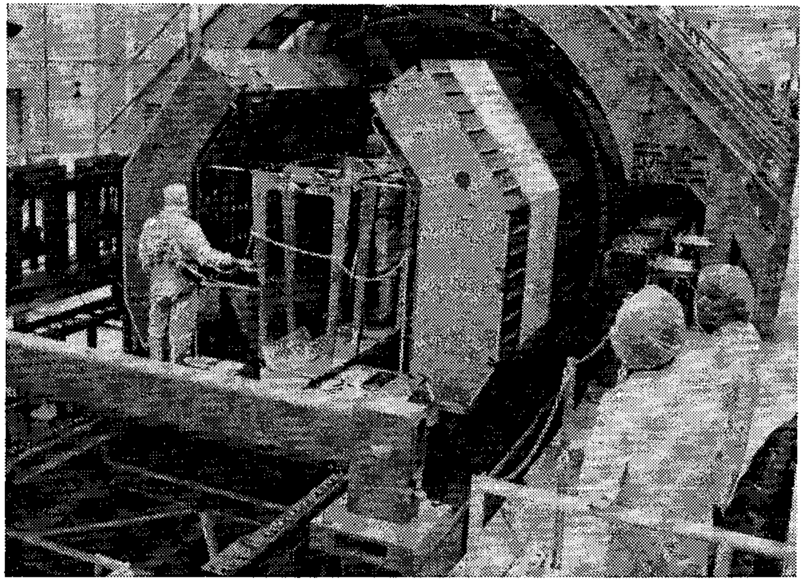
SLS-1 MISSION OPERATIONS

During the flight, personnel on the ground work in concert with the crew in space to complete the mission objectives. Shuttle operations are directed from the Mission Control Center at JSC, and close contact is maintained with the mission management team stationed in the Payload Operations Control Center (POCC) at Marshall Space Flight Center in Huntsville, Alabama.

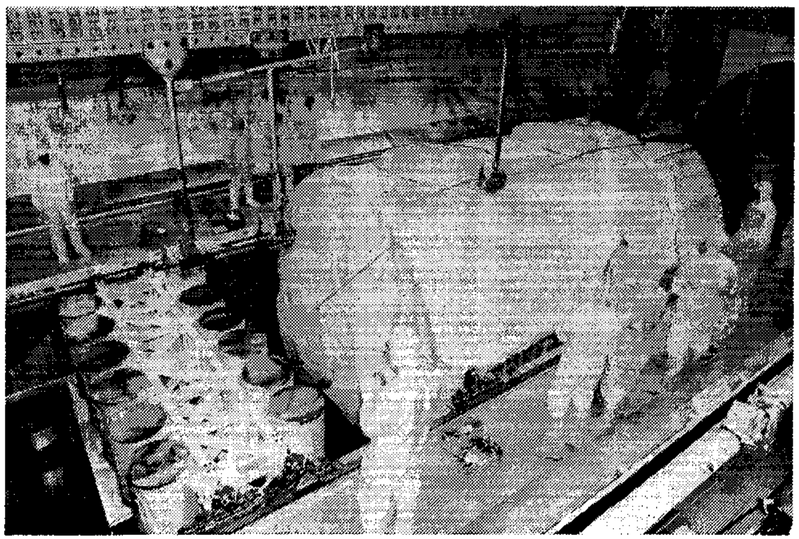


SLS-1 Payload Bay Layout

From the POCC, the mission manager, the mission scientist, and other key members of the SLS-1 team oversee the full range of Spacelab operations. The POCC contains banks of television monitors, computers, and communications consoles. The payload flight operations cadre assesses and responds to up-to-the-minute information, replans as necessary, advises the crew of changes in



SLS-1 Preflight Assembly and Checkout



SLS-1 Preflight Assembly and Checkout

the schedule, and works to solve problems and keep the mission flowing smoothly.

Investigators monitor experiments minute by minute, analyze results as experiments happen, and if necessary help adjust experiment operations to increase scientific return. Some scientists monitor experiments from the POCC while others work in the Science Monitoring Area, a work station at JSC that is equipped with the tools needed to monitor and analyze life sciences data. Other investigators support the mission from Hangar L at KSC and the Life Sciences Payload Receiving Facility at Edwards Air Force Base, California, which are both designed for preparing biological experiments for flight, for doing ground control experiments simultaneously with flight experiments, and for analyzing data. Data are transmitted from Spacelab to these work areas, and video and audio communications make it possible for scientists on the ground to follow the progress of their research and talk with the crew if necessary. All data are recorded, and investigators may request computer tapes, voice recordings, and videotapes that contain information about their experiments.

After the shuttle lands, the crew members depart to medical facilities for short examinations. Payload crew members participate in the postflight portions of the experiments. Technicians remove samples and experiment equipment from Spacelab and the shuttle middeck. Specimens such as blood samples and cultures are given immediately to investigators for analysis. Animals are sent to an ARC Life Sciences Payload Receiving Facility located within minutes of the landing site.

CARDIOVASCULAR/CARDIOPULMONARY INVESTIGATIONS

During space flight, 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 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 3 to 5 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.

Upon return to Earth, 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 space flight, 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 phenomenon usually return to normal after a few days back on Earth. However, scientists do not clearly understand the exact mechanisms that cause these changes or what will happen with prolonged exposure to microgravity. SLS-1 experiments are the first to measure fluid distribution and cardiovascular adaptation over the course of an entire mission.

Thorough studies of the lungs have yet to be made. 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. Previous astronauts have described small decreases in lung capacity, which scientists speculate may be related to increases in blood volume in the upper body but need more precise measurements to verify.

The cardiovascular/cardiopulmonary system interacts with every organ in the body; thus, small changes in this system may effect the entire body. Six of the SLS-1 experiments will focus on the heart, lungs, and blood vessels. Four will use crew members as subjects, with the other two using rodents. These experiments will record the most complete measurements ever made early in a mission when adaptation begins and continue through readaptation to 1-g. Extensive measurements will be made of heart size, blood pressure, heart rate, blood volume, blood flow patterns, blood vessel characteristics, and lung functions. Images of the heart, blood vessel pressure measurements, and data from renal/endocrine system investigations make it possible to follow this system's adjustment as the body redistributes fluid.

Cardiovascular Adaptation to Microgravity (Exp. No. 294)

Principal investigator: C. Gunnar Blomqvist, M.D.
University of Texas Southwestern Medical Center
Dallas, Texas

This experiment will focus on the acute changes in cardiovascular function, heart dimensions and function at rest, response to maximal exercise and control mechanisms.

The experiment seeks to increase the understanding of microgravity-induced changes in the cardiovascular structure and function responsible for a common problem during return to normal gravity of orthostatic hypotension or the inability to maintain normal blood pressure and flow while in an upright position.

Central venous pressure—measurements of changes in the blood pressure in the great veins near the heart—will be observed in one crew member. A cardiologist will insert a catheter into a vein in the arm and position it near the heart prior to flight. Measurements then will be recorded for 24 hours beginning prior to launch and extending for at least 4 hours into space flight, at which time the catheter is removed. The catheter data will indicate the degree of body fluid redistribution and the speed at which the redistribution occurs.

Echocardiograph measurements, a method of sending high frequency sound into the body to provide a view of the heart, will be performed on crew members each day.

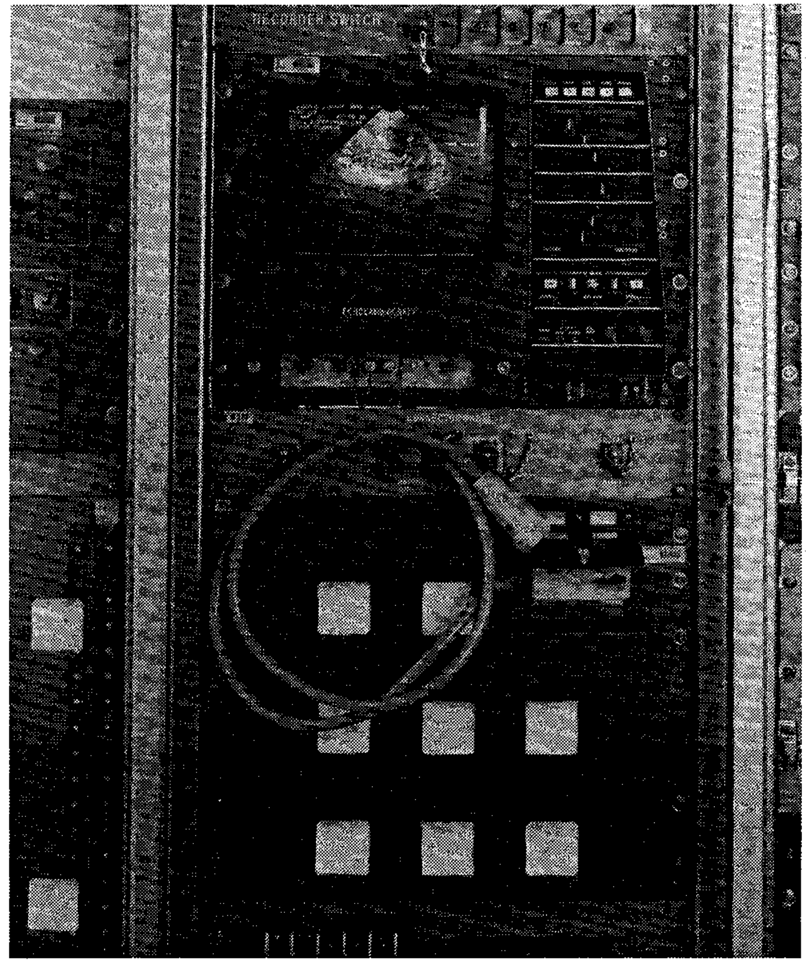
Leg flow and compliance measurements will gather information on leg blood flow and leg vein pressure-volume relationships. During flow measurements, blood in the veins of the leg will be stopped for a short period of time by inflating a cuff above the knee. Compliance measurements, the amount of blood that pools for a given increased pressure in the veins, will be obtained by inflating and incrementally deflating the cuff over different pressures and holding that pressure until the volume of the leg reaches an equilibrium.

Inflight Study of Cardiovascular Deconditioning (Exp. No. 066)

Principal investigator: Leon E. Farhi, M.D.
State University of New York at Buffalo
Buffalo, New York

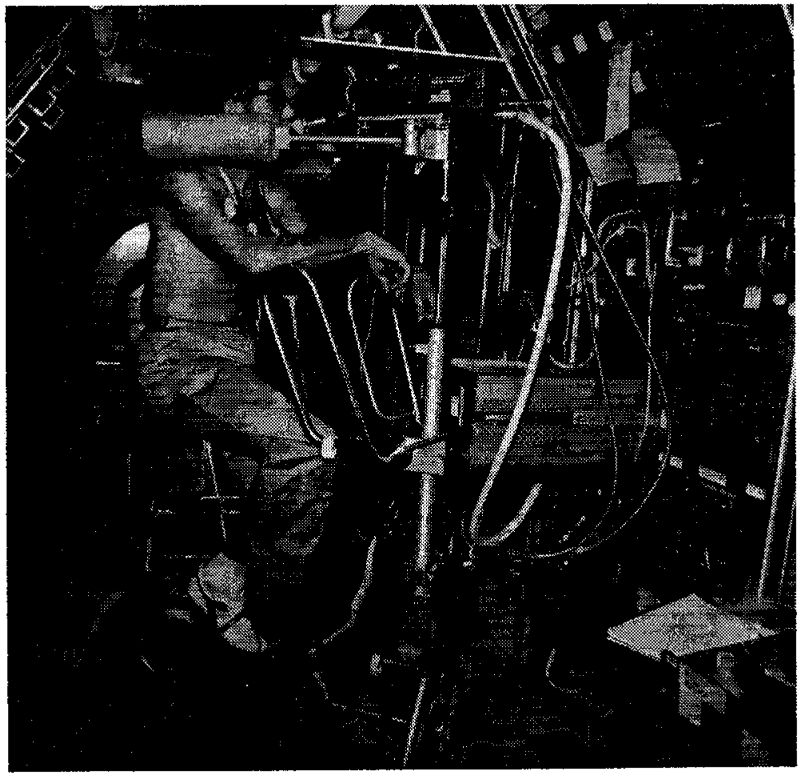
Just how rapidly astronauts become accustomed to microgravity and then readjust to the normal gravitational forces on Earth is the focus of this study. By analyzing the gas composition of a mixture which the STS-40 astronauts "rebreathe," investigators will calculate how much blood is being delivered by the heart to the body during space flight.

This experiment uses a noninvasive technique of prolonged expiration and rebreathing—inhaling in previously exhaled gases—to measure the cardiovascular and respiratory changes. The technique furnishes information on functions including the amount of blood pumped out of the heart, oxygen usage and carbon dioxide released by the body, heart contractions, blood pressure and lung functioning.



SLS-1 Echocardiograph Shows a Heart Image

Astronauts will perform the rebreathing technique while resting and while pedaling on an exercise bike to provide a look at their ability to cope with added physical stress. On the first and last days of the STS-40 mission, only resting measurements will be taken. Rest and graded exercise measurements are made on most other days.



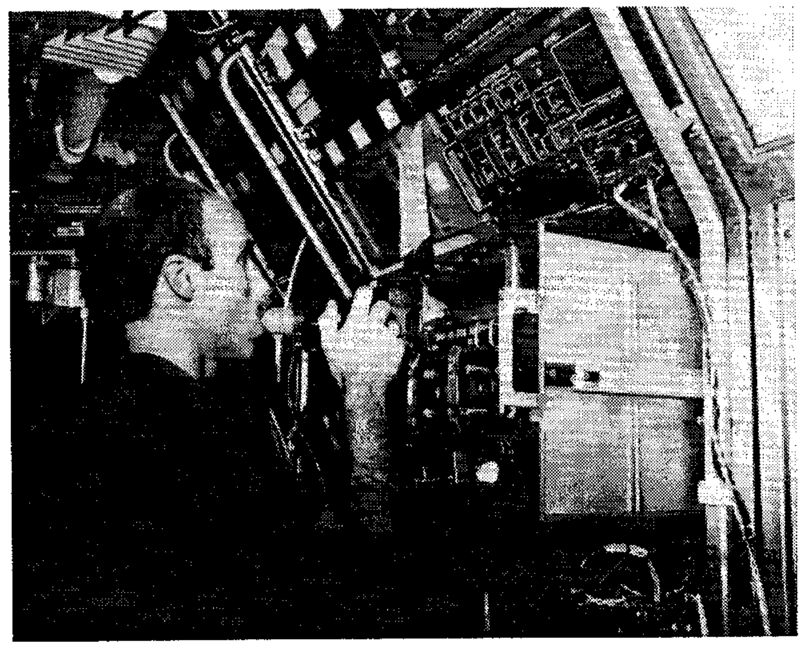
Cardiovascular Rebreathing Unit

Pulmonary Function During Weightlessness (Exp. No. 198)
Principal investigator: John B. West, M.D., Ph.D.
University of California at San Diego
La Jolla, California

This investigation is the first comprehensive assessment of human pulmonary function during space flight. This experiment provides an opportunity for study of the properties of the human lung without the influence of gravity. In the microgravity Spacelab, a model of lung function will be developed to serve as a basis for comparison for the normal and diseased lung. Also, investigators will glean information about the lung for planning longer space missions.

There will be a series of eight breath tests conducted with measurements taken at rest and after breathing various test bag mixtures. The test assembly allows the subject to switch from breathing cabin air to inhaling premixed gases in separate breathing bags. Breathing exercises involve the inhalation of specially prepared gas mixtures.

The tests are designed to examine the distribution and movement of blood and gas within the pulmonary system and how these measurements compare to normal respiration. By measuring gas concentrations, the flow of gas through the lungs into the blood stream and rate of blood flow into the lungs, investigators



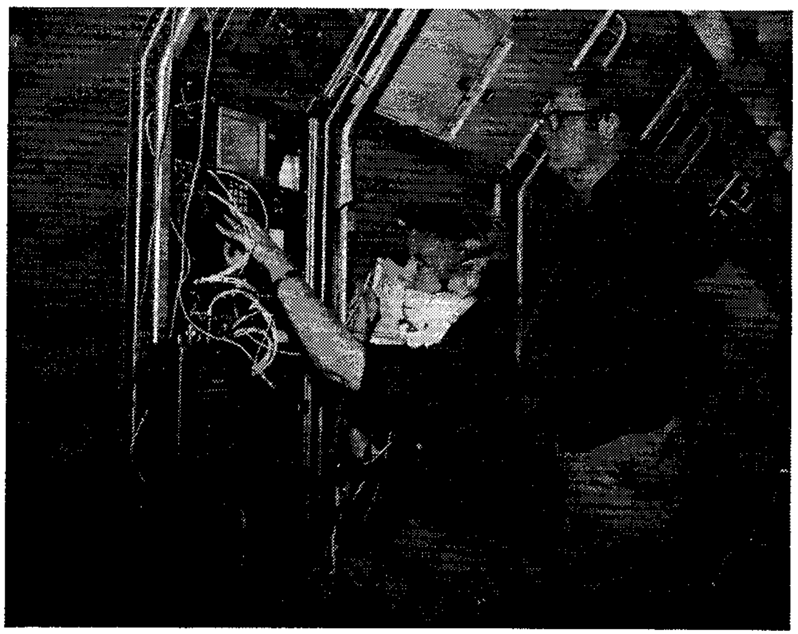
SLS-1 Mission Specialist James P. Bagian
Trains on the Rebreathing Assembly

hope to better understand the human pulmonary function here on Earth and learn how gravity plays a part in influencing lung function.

Influence of Weightlessness Upon Human Autonomic Cardiovascular Controls (Exp. No. 022)

Principal investigator: Dwain L. Eckberg, M.D.
Medical College of Virginia
Richmond, Virginia

This experiment will investigate the theory that lightheadedness and a reduction in blood pressures in astronauts upon standing after landing may arise because the normal reflex system regulating blood pressure behaves differently after having adapted to a microgravity environment.



Payload Specialist Millie Hughes-Fulford and Dr. Robert Ward Phillips Practice Operations With the Baroreflex Neck Pressure Chamber

For this experiment, some SLS-1 crewmembers will wear neck chambers that resemble whip-lash collars to detect blood pressure in the neck. Investigators will take blood pressure measurements both before and after the flight for comparison. Astronauts will take the same measurements themselves on orbit to map changes that occur during spaceflight.

Cardiovascular Adaptation of White Rats to Decreased Gravity of Space Shuttle/Spacelab in Flight Conditions (Exp. No. 248)

Principal investigator: Vojin P. Popovic, M.D.
Emory University Medical School
Atlanta, Georgia

This investigation identifies changes that take place throughout the rodent circulatory system.

Cardiovascular alterations during exposure of man to weightlessness and the subsequent readaptation after return to earth are known to occur, but the underlying mechanisms are not understood. These physiological adjustments result in orthostatic intolerance and a decreased exercise tolerance. The purpose of this study is to document cardiovascular changes resulting from weightlessness and the subsequent readaptation to unit gravity using the rats as a model. Cardiovascular measurements made pre and post-flight, and measurements taken from ground control rats will determine changes in venous pressure and blood flow. An ultra-sound probe placed around each rodent's aorta measures changes in blood flow from the heart. Two pressure transducers connected to catheters in the carotid artery and the right side of the heart measure arterial and venous blood pressure. Regular postflight measurements will chart cardiovascular readaptation to Earth's gravity. These results will determine how suitable rodents are as models of human cardiovascular changes associated with spaceflight and how closely those changes induced in groundbased studies mimic those that occur as a result of space flight.

Correlation of Macro- and Microcirculatory Alterations During Weightlessness (Exp. No. 166)
Principal investigator: Dr. Phillip M. Hutchins
Bowman Gray School of Medicine
Winston-Salem, North Carolina

This second rodent cardiovascular experiment uses the same test subjects as experiment 248 to correlate circulatory alterations caused by weightlessness with blood pressure and flow changes. Similar changes may be involved in cardiovascular deconditioning and orthostatic intolerance in humans.

The purpose of this investigation is to clarify the basic hemodynamic and microvascular mechanisms responsible for orthostatic intolerance following the elimination of gravitational influence and its attendant hypodynamia. During spaceflight, cardiac output is known to increase and thus increased tissue perfusion must also occur.

In hypertension, an increased cardiac output with overperfusion of body tissues beyond metabolic demands leads to a long-term reduction in the number of arterioles and an increase in the number of venules. Thus, mechanisms leading to cardiovascular deconditioning during exposure to weightlessness may share common factors with the mechanisms leading to the development of hypertension. If the mechanisms are similar, and an increased number of venules develops during spaceflight, these new venules will likely have poor vascular tone. Consequently, upon return to Earth, the hydrostic pressure changes produced by gravity may not be countered by compensatory venoconstriction in this expanded venous pool, which could account for the observed orthostatic intolerance. A change in ratio of arterioles to venules would also favor fluid reabsorption into the vascular space and tend to elevate venous return already increased by the cephalad fluid shift. A microcirculatory chamber, a one centimeter viewing area implanted on the surface of each animal's skin, will allow scientists to look at rodent blood vessels under a microscope and note changes in blood vessel morphology or any new blood vessels that have formed, a procedure that is impractical to perform on people. These activities will provide baseline information to develop inflight measurements for future experiments.

RENAL/ENDOCRINE SYSTEM INVESTIGATIONS

The kidneys and hormone-secreting organs and glands such as the adrenals, pituitary, and thyroid are part of the body's regulatory system. Responses to weightlessness by the renal/endocrine system may be closely related to cardiovascular responses. Experiment results suggest that as microgravity causes fluid to migrate toward the head, the cardiovascular system perceives an increase in blood volume, and the renal/endocrine system reacts by removing fluids and electrolytes. Scientists, however, do not know the mechanisms that mediate changes in fluid and electrolyte balance. In addition, astronauts may experience space motion sickness, which compounds the problem by decreasing their desire to eat and drink.

The effect of microgravity on the body's regulation of hormone concentrations is unclear. Evidence suggests that hormone secretion is altered, but related effects on the kidneys, blood vessels, and heart have not been studied. An understanding of this relationship may shed light on diseases such as high blood pressure and heart failure as well as space flight deconditioning.

Changes in the renal/endocrine system appear to occur in two phases: an acute phase, lasting from hours to days, and an adaptive phase, lasting from days to weeks. A significant reduction in body fluids and electrolytes characterizes the acute phase; the adaptive phase is the period of adjustment to the new fluid volumes and compositions.

SLS-1 investigations collect data early in flight when rapid changes are expected to occur in kidney function and hormone levels. Prior to this mission, scientists used ground-based simulations to develop hypotheses about what happens to the body during the first hours in space. However, because few measurements have been made during the initial hours of missions, ground-based models have not been validated. During SLS-1, samples are taken every time a crew member voids so that scientists can identify any early changes in fluid balance.

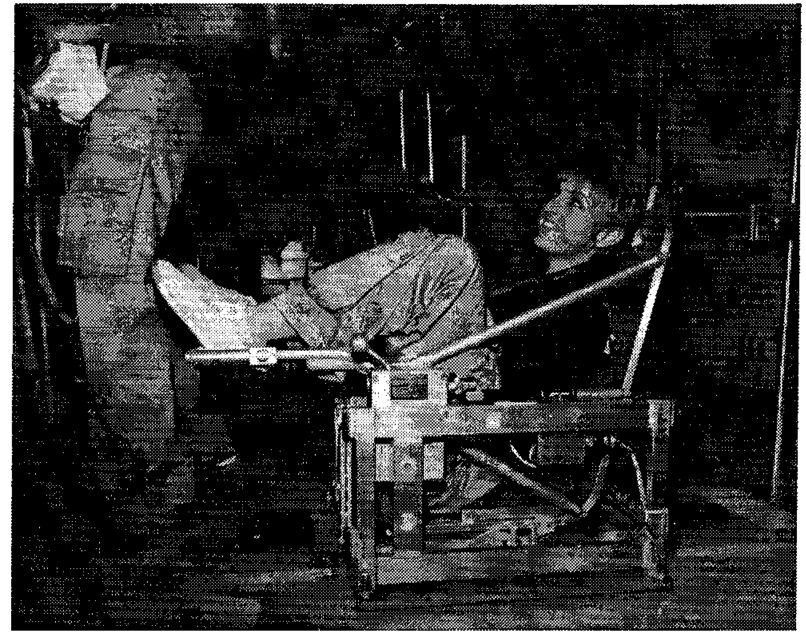
Fluid-Electrolyte Regulation During Space Flight (Exp. No. 192)
Principal investigator: Carolyn Leach-Huntoon, Ph.D. NASA Johnson Space Center Houston, Texas

Adaptation to the weightless environment is known to change fluid, electrolyte, renal and circulatory processes in humans. A shift of body fluids from the lower limbs to the upper body occurs to all astronauts while in space.

This experiment makes detailed measurements before, during and after flight to determine immediate and long-term changes in kidney function; changes in water, salt and mineral balance; shifts in body fluids from cells and tissues; and immediate and long-term changes in levels of hormones which affect kidney function and circulation.

Test protocol requires that crew members collect urine samples throughout the flight. Body mass is measured daily and a log is kept of all food, fluids and medication taken in flight. Fasting blood samples are collected from the crew members as soon as possible inflight and at specified intervals on selected flight days thereafter.

Tests will determine the amount of certain tracers that can be released from a given volume of blood or plasma into urine in a specified amount of time, measuring the rate and loss of body water and determining changes in blood plasma volume and extracellular fluid. Measurements will be made two times inflight by collecting blood samples at timed intervals after each subject has received a precalculated dose of a tracer, a chemical which allows the compound to be tracked as it moves through the body.



Payload Specialist Millie Hughes-Fulford in SLS-1 Body Mass Measurement Device

Total body water is measured during flight using water labeled with a heavy isotope of oxygen.

Each subject drinks a premeasured dose of the tracer and subsequently collects urine samples at timed intervals. Plasma volume and extracellular fluid volume are measured by collecting blood samples at timed intervals after tracer injections. Hormonal changes are investigated by sensitive assays of both plasma and urine.

BLOOD SYSTEM INVESTIGATIONS

SLS-1 hematology investigations will study two parts of the blood system: the liquid portion called plasma, which contains water, proteins, nutrients, electrolytes, hormones, and metabolic wastes, and the cellular portion, which includes red blood cells and platelets.

Plasma constitutes more than half of blood volume. By analyzing plasma, investigators can find out what types of nutrients are circulating throughout the body and determine whether an astronaut is well-hydrated. They can also measure the levels of hormones and other constituents that plasma transports.

A pinhead-size drop of blood contains some 5 million red blood cells. These cells, known as erythrocytes, transport oxygen throughout the body. Previous space flight studies have shown consistent reductions in the circulating red cell mass and blood plasma volume of crew members. Scientists postulate that when microgravity causes fluid to move toward the head, the body perceives an increase in fluid and reduces body liquids such as blood plasma. This results in an increased proportion of solids, such as cells, to plasma in the blood. Thus, the body may try to reduce what it perceives as too many erythrocytes. A decrease in red blood cells may impair a crew member's ability to function with full efficiency upon return to Earth.

While red blood cell loss has been clinically insignificant, doctors consider it a potentially adverse response that may require control during inflight illness or injury, repeated space flight, and long-duration missions. If the body adjusts to microgravity and produces a normal quantity of blood cells, lengthy stays in space may cause no problem; however, if the reduction becomes more severe with time, investigators will have to determine why.

Limited data gathered in space and ground-based studies suggests two theories to explain this "space anemia." First, the body may limit erythrocyte production by suppressing erythropoietin, a hormone that stimulates red blood cell production in the bone marrow. A second theory postulates that red cell production may remain unchanged but that the body destroys erythrocytes faster that it creates them, thus decreasing their numbers. Other aspects of adaptation, such as altered nutrition and bone loss, also may influence red blood cell counts. Sufficient data does not exist to confirm or refute these theories.

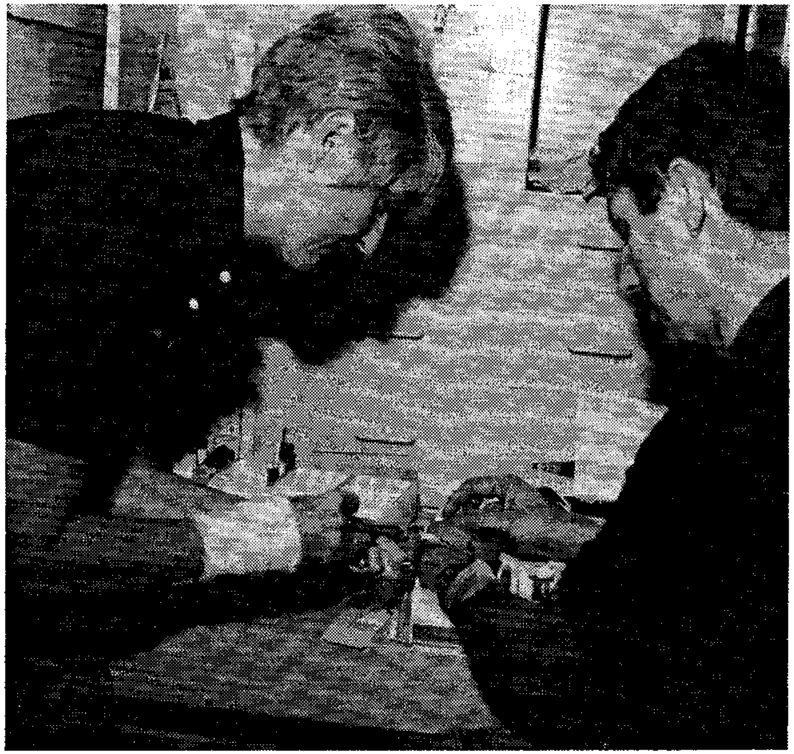
Previous space studies have provided only limited inflight blood analysis and have not included extensive measurements of red blood cell parameters. Three SLS-l investigations examine the mechanisms that may contribute to erythrocyte loss. One experiment studies human responses, while the other two use rodents as subjects. This is the first time that scientists have studied the blood characteristics of rodents so extensively with regard to space flight. The use of animal models will permit close control of experimental conditions and allow invasive testing of tissue samples; specifically the spleen, marrow, and liver. To quality the rat as a suitable hematologic model for humans, data from these investigations will be compared with those from similar tests done on human blood samples. All three experiments make inflight and postflight measurements of blood volume, hormones, and other blood constituents to see if and how red blood cell production is suppressed. Results from the renal/endocrine experiment will help hematologists interpret data by measuring several factors that influence red blood cell population size.

The Influence of Space Flight on Erythrokinetics in Man (Exp. No. 261)

Principal investigator: Clarence P. Alfrey, M.D.
Baylor College of Medicine
Houston, Texas

The most consistent finding from space flight is the decrease in circulating red blood cells or erythrocytes and subsequent reduction in the oxygen carrying capacity of the blood. This experiment studies the mechanisms which may be responsible for this decrease, including the effect of space flight on red blood cell production rate and the role of changes in body weight and plasma volume on red blood cell production.

Blood samples taken pre-, post- and inflight will trace the life of astronauts' red blood cells. By measuring the volume of red blood cells and plasma, researchers will check the rate of production and destruction of blood in both normal and microgravity conditions.



SLS-1 Payload Specialists Millie Hughes-Fulford and Francis A. (Drew) Gaffney Practice Blood Draw Procedures

On Flight Day two, crew members will receive an injection of a tracer that will measure the amount of new red blood cells. Tracers (chemicals that will attach to the red blood cell to allow them to be tracked) injected before launch will measure the destruction rate of red blood cells. Crew members will draw blood samples on the second, third, fourth, eight and ninth days of flight.

Regulation of Blood Volume During Space Flight (Exp. No. 141)

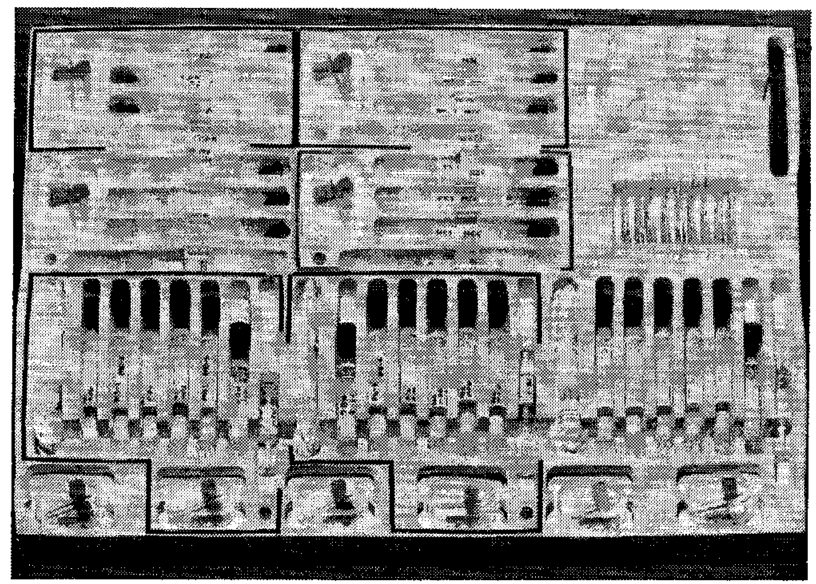
Principal investigator: Clarence P. Alfrey, M.D.
Baylor College of Medicine
Houston, Texas

Regulation of Erythropoiesis During Space Flight (Exp. No. 012)

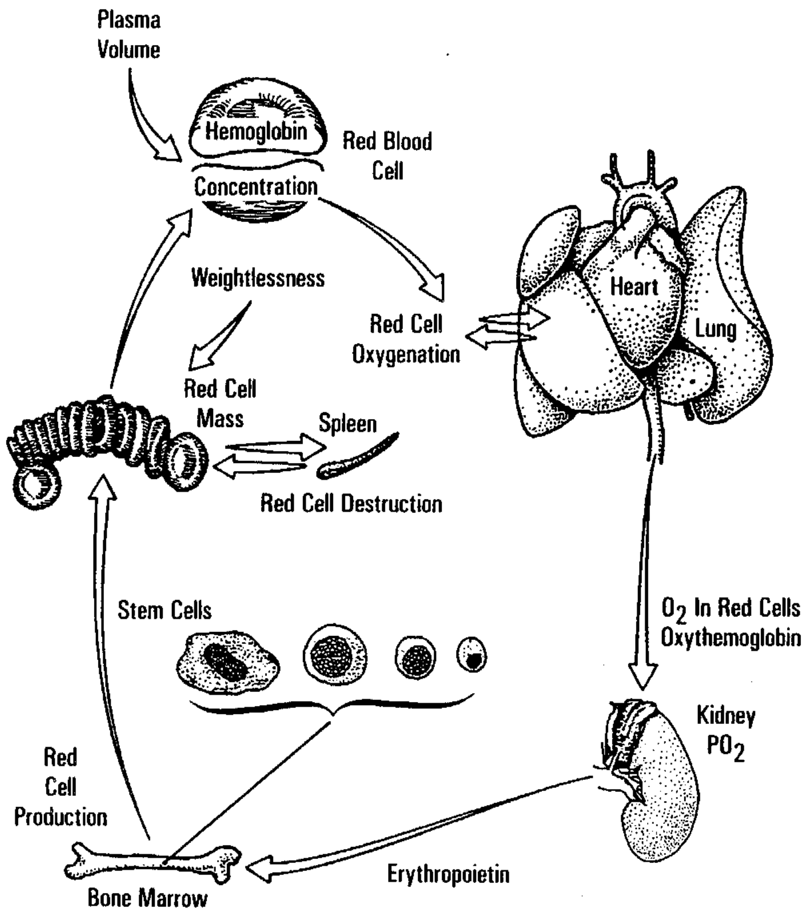
Principal investigator: Robert D. Lange, M.D.
University of Tennessee Medical Center
Knoxville, Tennessee

This combined investigation will explore the mechanisms for changes seen in red blood cell mass and blood volume in crews on previous space flights. Several factors known to affect erythropoiesis will be examined. It also will determine whether comparable changes occur in the rat and if the rat is a satisfactory model for studying microgravity-induced changes in human blood.

Previous space flight crews have consistently exhibited dcreased red blood cell mass and plasma volume. The



Blood Collection Equipment



Regulation of Red Blood Cell Production
(Erythropoiesis)

mechanisms responsible for these changes are not know, although a decrease in red blood cell production may play a role in altered red cell mass.

The SLS-1 hematology experiments will study two parts of the blood system: the liquid portion (plasma), which contains water, proteins, nutrients, electrolytes, hormones and metabolic wastes and a cellular portion, which contains red and white blood cells and platelets.

IMMUNE SYSTEM INVESTIGATIONS

The SLS-1 immunology investigation examines lymphocytes, one kind of white blood cell that helps the body resist infection. These cells recognize harmful foreign substances, such as bacteria, and eliminate them.

Analyses of lymphocytes from crew members on the first 12 shuttle flights revealed decreases in the number of circulating lymphocytes; postflight results showed that the lymphocytes were not as effective in responding to challenges. However, astronauts have shown no increased susceptibility to disease, and white blood cell counts return to normal a few weeks after landing. These changes must be understood and controlled because they could have undesirable consequences on longer missions.

Space flight may reduce white blood cell counts and effectiveness either because microgravity causes a decrease in lymphocyte production or because the stress of space flight alters cell counts or function. (Studies on Earth strongly suggest that the body's lymphocyte count is lower during periods of increased stress.) Researchers have conducted most previous immunology studies pre- and postflight, but it has been difficult to separate the direct effects of microgravity from the indirect effects resulting from the stress of postflight recovery.

An experiment flown on Spacelab 1 contributed substantially to understanding the immune system's operation in space. Lymphocytes go through a process called activation in which they identify a foreign substance, produce the appropriate antibody, and proliferate to make sufficient amounts of the antibody. Lymphocyte cultures flown on the Spacelab 1 mission lost almost all ability to respond to foreign challenge. Proliferation of the flight lymphocytes was less than 3 percent of that for ground-control lymphocytes. Although the cells were alive, they did not respond to the stimulus. The experiment was repeated on Spacelab D1 with cultures exposed to microgravity, cultures on a 1-g centrifuge, and blood taken from the crew members during the mission. Cultures on the centrifuge, which simulates gravity, were important because factors other than microgravity were candidates for altering the cells' response. The Spacelab 1 results were confirmed: cell activation in the cultures exposed to microgravity was depressed when compared with control cultures on the flight centrifuge and on the ground.

Activation of lymphocytes in the crew blood samples was markedly depressed in samples taken in flight as well as in samples drawn 1 hour after landing; the activation process in crew members' white blood cells did not fully return to normal until 1 to 2 weeks after landing. The next step is to discover which stage of the activation process is affected, to postulate a mechanism for the change, and to determine whether the effect can be prevented.

Lymphocyte Proliferation in Weightlessness (Exp. No. 240)
Principal investigator: Augusto Cogoli, Ph.D.
Swiss Federal Institute of Technology
Zurich, Switzerland

Following investigations carried out during Spacelab 1 and the German D1 shuttle missions, this experiment will investigate the effect of weightlessness on the activation of lymphocyte reproduction. The study also will test whether there is a possible alteration of the cells responsible for part of the immune defense system during space flight.

STS-40 will repeat the basic Spacelab-1 experiment. Lymphocytes will be purified from human blood collected 12 hours before launch. The cells will be resuspended in a culture medium, sealed in culture blocks and stowed on Columbia's middeck. Inflight, the samples will be exposed to a mitogen (a substance that promotes cell division) and allowed to grow in the weightless environment. Some of the samples also will be exposed to varying gravity levels on the low-gravity centrifuge. These samples will serve as a control group as they will experience the same environmental conditions with the exception of microgravity.

The simulation of the lymphocytes to reproduce is determined by monitoring the incorporation of a chemical isotope tracer into the cells' DNA. Investigators will gather further information on lymphocytes from blood samples taken from the crew inflight.

MUSCULOSKELETAL SYSTEM INVESTIGATIONS

The architecture of the more than 600 muscles and 200 bones of the human body has been shaped by gravity. The musculoskeletal system requires gravity to function normally. Without it, muscles waste away, and bones become smaller and weaker. Doctors have observed these effects in bed rest patients whose movement and exercise have been curtailed. Similar effects have also been observed in space flight crews.

In microgravity, leg muscles often become weakened from lack of use because astronauts can "float" instead of walk. Specific changes include a loss of nitrogen from the muscle, loss of lower body mass, reduced muscle mass in the calves, and decreased muscle strength. These changes may occur through a decrease in protein synthesis or an increase in protein breakdown or both.

Rodent experiments on Spacelab 3 permitted researchers to observe and document fundamental changes in muscles exposed to weightlessness. Rodents flown in space for 7 days lost 40 percent of mass in the leg muscles that are normally used to oppose gravity. Related findings include almost total absence of muscle tone and a marked decrease in the diameters of muscle fibers. In addition, the biochemical process that generates energy in muscle cells was almost totally absent. Detailed tissue analyses from flight rodents confirmed the hypothesis that microgravity exposure results in a decrease of muscle fibers used to maintain an upright position in gravity and an increase in fibers used for rapid, active exercise.

Human studies during the longer Skylab missions showed that the most significant muscle losses occurred during the first months of flight. Exercise on a treadmill and a stationary bicycle appeared to inhibit muscle and nitrogen loss but did not curtail it completely. Muscle fatigue contributes to postflight complications, creating a temporarily reduced state of physical fitness. Full recovery of muscular strength takes from weeks to months, depending on the duration of the flight.

Weightlessness also causes a slow loss of bone minerals (calcium and phosphorus). Crew members from previous flights have shown a negative calcium balance throughout the missions. Most of the loss is thought to occur in the leg bones and the spine which are responsible for erect posture and locomotion. Rodents flown on the Spacelab 3 mission exhibited some interesting changes in bone: decreased skeletal growth early in the mission; reduced concentrations of a protein (osteocalcin) that bone-forming cells secrete, suggesting a reduction in the activity of these cells, and reduced leg strength and bone mass in the spine indicating that animal bones become significantly more fragile after even brief exposure to microgravity.

So far, investigators do not know whether the body would continue to lose calcium indefinitely or whether the loss would level off at a certain point. To date, exercise regimens have not halted skeletal wasting or reduced calcium loss. Some previous studies indicate that diet may be a potential aid in calcium regulation.

An understanding of the time course and extent of muscle and bone alterations is critical to determining how long humans may safely remain in space and what can be done to halt negative effects. Development of effective countermeasures to bone loss in space may contribute to improved therapy or management of osteoporosis.

Six SLS-1 experiments study the mechanisms responsible for muscle and bone loss in humans and rodents. These experiments will further determine which muscles are affected and what biochemical mechanisms are responsible for altering the nitrogen balance of muscles and the calcium balance of bones.

Protein Metabolism During Space Flight (Exp. No. 120)

Principal investigator: T. Peter Stein, Ph.D.
University of Medicine and Dentistry of New Jersey
Camden, New Jersey

This study involves several tests looking at the mechanisms involved in protein metabolism including changes in protein synthesis rates, muscle breakdown rates and use of dietary nitrogen in a weightless environment.

This experiment will examine whole body protein metabolism by measuring the concentration of 15N-glycine, an amino acid in protein, in saliva and urine samples from crew members and ground control subjects preflight, inflight and postflight.

Crew members will collect urine samples throughout the flight. On the second and eighth flight days, astronauts also will take oral doses of 15N-glycine. Crew members will collect and freeze a urine sample 10 hours after the ingestion of the glycine for postflight analyses. Urinary 3-methyl histidine, a marker for muscle protein breakdown, also will be monitored.

Effects of Microgravity on Biochemical and Metabolic Properties of Skeletal Muscle in Rats (Exp. No. 127)

Principal investigator: Kenneth M. Baldwin, Ph.D.
University of California
Irvine, California

It has been proposed that a loss of muscle mass in astronauts during weightlessness produces the observed loss of strength and endurance, particularly in the anti-gravity muscles. One explanation is that exposure to microgravity results in the removal of sufficient stress or tension on the muscles to maintain adequate levels of certain proteins and enzymes.

These proteins and enzymes enable cells to use oxygen to convert nutrients into energy. When gravitational stress is reduced, protein activity also decreases and muscles become more dependent on glycogen stored in the liver and muscles for energy. As the body metazolizes glycogen, muscle endurance decreases.

Radioactive carbon compounds will be used to evaluate energy metabolism in the hind leg muscles of the rats exposed to microgravity. The concentration of the enzymes reflects the kind of metabolic activity occurring in muscles during periods of reduced gravitational stress. In addition, skeletal muscle cells of flight and ground-control animals will be compared to assess any changes in the concentration of enzymes that break down glycogen.

Effects of Microgravity on the Electron Microscopy, Histochemistry, and Protease Activities of Rat Hindlimb Muscle (Exp. No. 303)

Principal investigator: Danny A. Riley, Ph.D.
Medical College of Wisconsin
Milwaukee, Wisconsin

The anti-gravity skeletal muscles of astronauts exposed to microgravity for extended periods exhibit progressive weakness. Studies of rodents flown in space for 7 days on a previous mission have shown a 40 percent loss of mass in the anti-gravity leg muscles. Other studies indicate the loss of strength may result from simple muscle fiber shrinkage, death of muscle cells and/or degeneration of motor innervation. In addition, the biochemical process that generates energy in muscle cells was almost totally absent. The progressive atrophy of certain muscles in microgravity is the focus of this study, which compares the atrophy rates of muscles used primarily to oppose gravity with those muscles used for movement.

Skeletal Myosin Isoenzymes in Rats Exposed to Microgravity (Exp. No. 247)

Principal investigator: Joseph Foon Yoong Hoh, Ph.D.
University of Sydney
Sydney, Australia

Skeletal muscle fibers exist in two forms, classified as slow-twitch or fast-twitch, depending on how fast they contract. The two forms develop similar forces when contracting but they contract at different speeds. The speed of contraction is directly related to the amount of the protein myosin in muscle fibers. Myosin is made up of five isoenzymes, which differ in structure and in enzyme activity.

In Earth's gravity, a low-firing frequency stimulates the slow-twitch fibers, which support a body against gravity. The fast-twitch fibers, which are related to body movement, contract in response to high-frequency nerve impulses.

This study will examine how microgravity affects the speed of muscle contractions. Because stimuli to the slow-twitch anti-gravity muscles should be greatly reduced in microgravity, the concentration of myosin isoenzymes in these fibers should be lower. This experiment should provide additional data to help explain how microgravity affects the speed of muscle contractions and the growth and proliferation of slow-twitch and fast-twitch muscle fibers.

Pathophysiology of Mineral Loss During Space Flight (Exp. No. 305)

Principal investigator: Claude D. Arnaud, M.D.
University of California
San Francisco, California

Changes in calcium balance during space flight is an area of concern for researchers since the changes appear to be similar to those observed in humans with osteoporosis, a condition in which bone mass decreases and the bones become porous and brittle and are prone to fracturing or breaking. Because of potential health problems for astronauts returning to Earth after long space flights, the mechanisms which cause these changes are of great interest in space medicine.

This experiment will measure the changes which occur during space flight in circulating levels of calcium metabolizing hormones and to directly measure the uptake and release of calcium in the body. Investigators believe there may be significant changes in the amount of these hormones produced due to an increase in the breakdown and reassimilation of bone tissue and that these changes begin to occur within hours after entering the weightless environment.

Each crew member will be weighed daily and will keep a log of all food, fluids and medications ingested. They also will draw blood samples on selected days to determine the role of calcium regulating hormones on the observed changes in calcium balance. The experiment is repeated on selected days preflight and postflight. A simultaneous ground experiment is performed using non-crew member subjects.

Bone, Calcium, and Space Flight (Exp. No. 194)
Principal investigator: Emily Morey-Holton, Ph.D.
NASA Ames Research Center
Moffett Field, California

Weightlessness causes a slow loss of calcium and phosphorous from the bones during and immediately following space flight. Negative calcium balance, decreased bone density and inhibition of bone formation have been reported. Most of the loss is thought to occur in the leg bones and the spine, which are responsible for movement and erect posture.

Previous studies of rodents exposed to microgravity have shown decreased skeletal growth early in the mission; reduced concentrations of a protein secreted by bone-forming cells, suggesting a reduction in the activity of these cells; and reduced leg bone breaking strength and reduced bone mass in the spine.

Formation of bone probably does not cease abruptly, but more likely decreases gradually as the number and/or activity of bone-forming cells decreases. This experiment will allow more precise calculation of the length of flight time required to significantly inhibit bone formation in rats.

Dr. Morey-Holton's experiment focuses on growth that occurs in a number of specific bones such as the leg, spine and jaw. The study also will document alterations in bone growth patterns and bone-breaking strength in rodents exposed to weightlessness and it will determine whether bone formation returns to normal levels after space flight.

NEUROVESTIBULAR SYSTEM 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 instance, 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 1-g environment. This conflict results in disorientation.

Neurosensory research in space has focused on space motion sickness because changes in neurovestibular activity may cause this ailment, which has affected about one-half of all space travelers. Symptoms may include pallor, loss of appetite, nausea, and vomiting. Although the symptoms are similar to Earth motion sickness, scientists are unsure if the stimulus is the same.

The body adapts quickly: the most severe symptoms occur during the first days of flight and disappear after a few days. However, NASA wants to improve crew efficiency and comfort by eliminating space sickness. Although astronauts have used some drugs successfully to reduce nausea, no treatment expels the symptoms. Experiments have focused on identifying the underlying causes of this problem and ways to treat it and on studying how the nervous system adapts to microgravity.

During the Spacelab 1 and D1 missions, a group of complementary experiments sponsored by American, Canadian, and European scientists studied how the sensory system adapts to weightlessness. Research examined the interrelated functioning of the inner ear, the eyes, and the reflexes. Crew members reported that head movements as well as visual disorientation provoked space motion sickness. Posture disturbances and modified reflex activity in the muscles also were recorded. These results and others seemed to fit the sensory conflict theory.

Investigators are repeating several of these experiments on SLS-1. Signs and symptoms of space motion sickness are measured, and human spatial orientation and posture control are measured during the course of adaptation to microgravity. Experiments with rodents and jellyfish examine the structure of gravity-sensitive organs to see if weightlessness causes any anatomical changes to vestibular organs.

Vestibular Experiments in Spacelab (Exp. No. 072)

Principal investigator: Laurence R. Young, Sc.D.
Massachusetts Institute of Technology
Cambridge, Massachusetts

A joint U.S./Canadian research program has been developed to perform a set of closely related experiments to investigate space motion sickness, any associated changes in inner ear vestibular function during weightlessness and the impact of those changes postflight. Parts of this experiment will be carried out inflight, other parts on the ground both pre- and post-flight.

As part of the inflight activities, the team will study the interaction between conflicting visual, vestibular and tactile information. Investigators expect crew members to become increasingly dependent on visual and tactile cues for spatial orientation. The test calls for a crew member to place his/her head in a rotating dome hemispherical display to induce a sensation of self-rotation in the direction opposite to the dome rotation. The astronaut will then move a joy stick to indicate his/her perception of self-motion.

Awareness of position by astronauts is important for reaching tasks especially during landing operations. The objective of several tests during the flight will document the loss of sense of orientation and limb position in the absence of visual cues and will determine what mechanisms underlie the phenomenon.

During the presleep period, crewmembers will view several targets placed about the interior of Spacelab. They then will be blindfolded and asked to describe the position of their limbs in reference to their torso and to point to the targets. In post sleep, crew members upon waking and while blindfolded perceive their posture, position of their limbs and location of familiar orbiter structures, recording the accuracy of their perceptions.

The next two parts of this experiment will be performed as time permits on the SLS-1 mission or continued on a later Spacelab mission. Both experiments have been previously performed by crewmembers in space.

The next part looks at the causes and treatment of space motion sickness (SMS) and evaluates the success of Earth-based tests to predict SMS susceptibility. Two crew members will wear an acceleration recording unit (ARU) to measure all head movement and to provide detailed commentary regarding the time, course and signs of SMS. Subjects wearing the ARU will wear the collar for several hours during the mission and if desired, when symptoms occur. The influence of the collar on the resulting head movement pattern and SMS will be monitored.

Another battery of tests performed preflight will attempt to determine which test or combination of tests could aid in predicting SMS.

A Study of the Effects of Space Travel on Mammalian Gravity Receptors (Exp. No. 238)

Principal investigator: Muriel Ross, Ph.D.
NASA Ames Research Center
Moffett Field, California

The neurovestibular system, which helps animals orient their bodies, is very sensitive to gravity. In space, gravity no longer influences the tiny otolith crystals, which are small, calcified gravity receptors in the inner ear. In microgravity, information sent to the brain from the inner ear and other sensory organs may conflict with cues anticipated from past experiences in Earth's normal gravity field. This conflict results in disorientation.

Previous flight experience has shown that vestibular symptoms, including nausea, vomiting and dizziness and instability when standing, occur in more than half of the astronauts during the first few days of flight, with some symptoms lasting for up to 10 days post-flight.

This study investigates structural changes that may occur within the inner ear in response to the microgravity of space. It seeks to define the effects of prolonged weightlessness on the otoliths. Scientists suspect that otolith degeneration may occur as a result of changes in the body's calcium levels, carbohydrate and protein metabolism, body fluid distribution and hormone secretions.

The study also will examine the degree to which any changes noted remain static, progress or recover during a 7-day period post-flight.

The Effects of Microgravity-Induced Weightlessness on Aurelia Ephyra Differentiation and Statolith Synthesis (Exp. DCL)

Principal investigator: Dorothy B. Spangenberg, Ph.D.
Eastern Virginia Medical School
Norfolk, Virginia

Jellyfish are among the simplest organisms possessing a nervous system. They use structures called rhopalia to maintain their correct orientation in water. Rhopalia have statoliths that are analogous to mammalian otoliths, the gravity-sensing organs of the inner ear that help mammals maintain balance.

The purpose of this investigation is to determine the role microgravity plays in the development and function of gravity-receptor structures of Aurelia (a type of jellyfish). Ephyrae are a tiny form of the jellyfish. This experiment will study the gravity receptors of ephyrae to determine how microgravity influences their development and fuction, as well as the animals' swimming behavior.

SECONDARY INVESTIGATIONS

The primary SLS-1 experiments investigate the biology of humans and other animals in space, but eight secondary studies are also included to gather data that complement the major investigations or to develop space facilities for future missions. These studies include the following:

- Particulate Containment Demonstration Test
- Small Mass Measurement Instrument
- Surgical Work Station
- Intravenous Pump

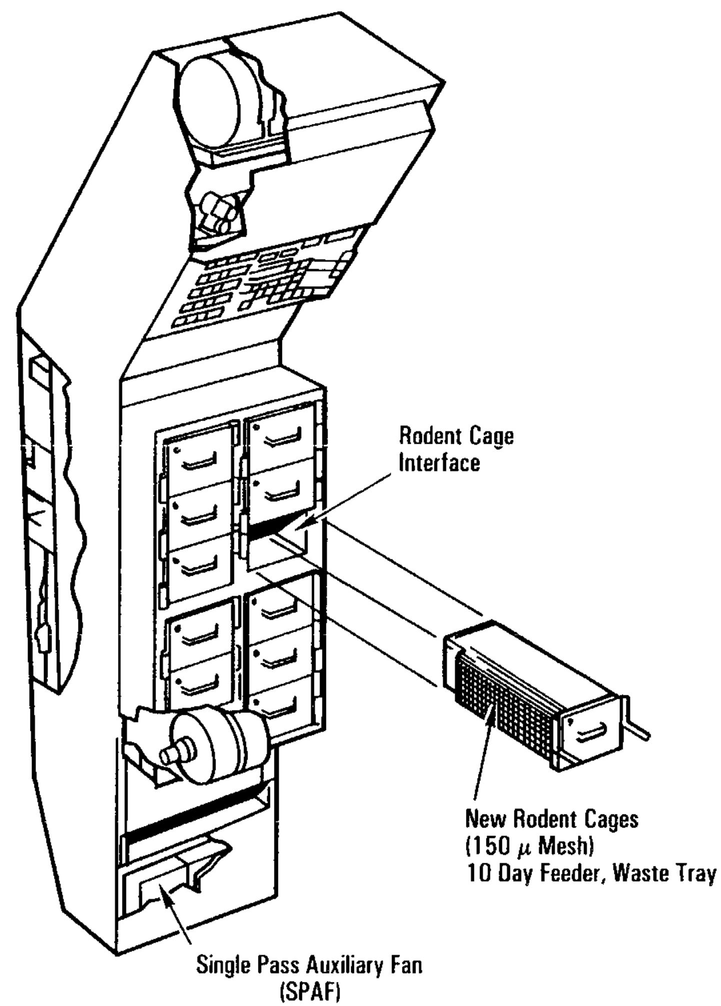
- Airborne Particles
- Noninvasive Central Venous Pressure
- Space Acceleration Measurement System
- Solid Surface Combustion Experiment

Particulate Containment Demonstration Test

Although the SLS-1 crew members do not handle the flight rodents, on subsequent missions the crew may transfer animals to work stations for laboratory procedures. In preparation for these activities, NASA has designed facilities for housing, carrying, handling, and measuring animals and has developed procedures for efficient operations and for the comfort and safety of both the crew and the animals.

A Research Animal Holding Facility (RAHF) contains 12 rodent cages, each of which can house two laboratory rats. The facility contains all food, water, enviromental, and sanitation arrangements for each of its inhabitants and permits access to the animals if the need arises. A monitoring system gathers feeding, activity, and environmental data. During the SLS-1 mission, the RAHF carries 20 rats in a demonstration of its capability to adequately house rodents and to contain the debris that they produce during a mission.

The SLS-1 RAHF is a modified version of the unit flown on Spacelab-3. The unit has been modified to contain particulates, primarily at the cage level. A high energy fan has been installed in the unit to facilitate particulate containment during activities requiring opening of the RAHF module, i.e., cage removal, food changeout, waste tray changeout. In contrast to the AEMs, the RAHF does accommodate manipulation of animals in flight. The RAHF is a self-contained unit providing food, water, waste containment, temperature, and air flow control. Temperature, humidity, activity, and water consumption are monitored on the ground as well as in the Spacelab. During the SLS-1 mission,



Research Animal Holding Facility (RAHF)

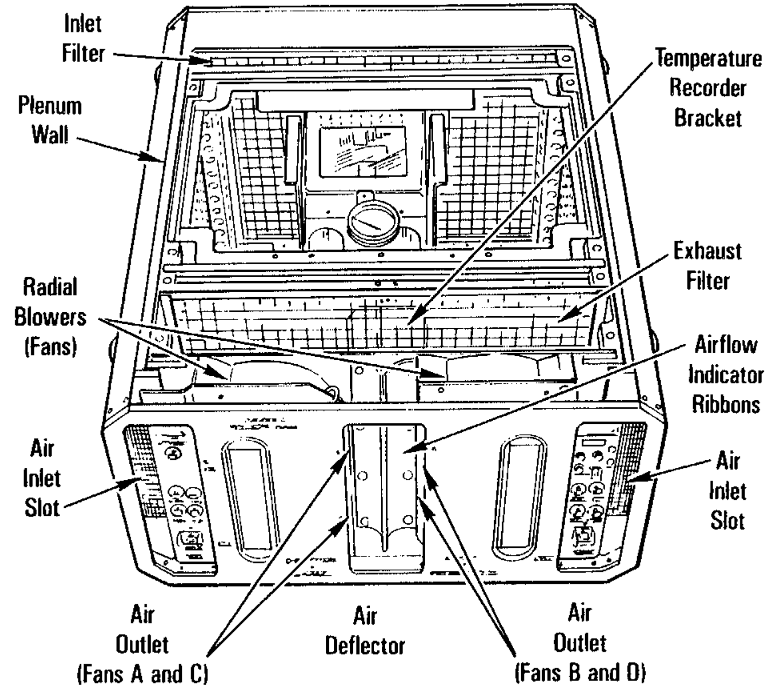
animals will be housed in 20 cage compartments; 4 empty cage compartments will be used for engineering tests. In addition to providing engineering data on particulate containment, use of the

RAHF for animal maintenance will provide data for investigators in the cardiovascular, muscular, hematology/immunology, vestibular, and bone disciplines.

In the shuttle middeck, nine rats occupy two Animal Enclosure Modules (AEMs). One AEM will hold four rodents surgically implanted for cardiovascular studies. Data obtained from the five animals flown in the second AEM will be compared with that obtained from the animals housed in the RAHF. The AEMs increase flight opportunities for passive animal experiments in the shuttle. These modules differ from the RAHF in that they hold up to five rodents, the crew cannot access animals, and no data are gathered automatically. Like the RAHF, the AEMs provide ventilation, waste containment, water, and food for the mission. Investigators compare animals living in the AEMs with those in the RAHF to evaluate the modules as animal maintenance and housing facilities.

When future rodent investigations call for the crew to service a holding cage or to handle laboratory animals, the crew must be able to access the cage and transport animals from the holding facilities to a work station without releasing debris into the Spacelab. The General Purpose Transfer Unit (GPTU), a sock-like bag that affixes to the RAHF cage module and to the access window of the General Purpose Work Station (GPWS), contains rodent cages during animal transfer operations. During SLS-1, the effectiveness of the GPTU is demonstrated by the transfer of one empty RAHF cage to the work station.

The work station itself is a closed, retractable cabinet for laboratory activities that require the crew to handle chemicals and manipulate samples. Crew members can introduce samples into the GPWS through a side access door and handle the specimen through gauntlets in the front of the enclosure. A mesh grill and forced air flow keep solid particles, liquid spills, and gaseous containments within the cabinet. The work station is a prototype for an animal laboratory facility aboard Space Station Freedom.



Animal Enclosure Module

During the Particulate Containment Demonstration Test, developed by NASA Ames Research Center, representative 10-day accumulations of food crumbs, rat hair, and simulated rodent wastes are released both into the work station and two empty RAHF cages to verify their ability to contain animal debris. The GPWS is also evaluated for fluid containment as colored water is released within the cabinet to simulate spills and animal urination. After these facility tests, the crew remove one of the cages from the RAHF, move it to the workstation in the transfer bag, and place it in the cabinet through the access window. The shuttle environment is monitored for escaping contaminants by an air sampler, photography, and crew observations and comments.

Small Mass Measurement Instrument

One measure of health is weight gain or loss during space flight; however, in the weightless environment of the orbiting shuttle, scientists substitute measurements of mass for measurements of weight. A major instrument for the second SLS mission, the Small Mass Measuring Instrument for small animals and tissue samples, is to be calibrated during SLS-1. By ascertaining the stability of the device during SLS-1, the time required to recalibrate the instrument on later missions will be minimal. The experiment uses calibration masses similar to those of flight rodents.

Surgical Work Station

Two pieces of medical equipment that are to be incorporated into the Health Maintenance Facility for Space Station Freedom are to be verified aboard SLS-1. The Health Maintenance Facility will be the site for the more comprehensive health monitoring activities, diagnoses, and treatments required during long missions. SLS-1 crew members evaluate the effectiveness and convenience of the restraining features of a surgical work station, including a restraint surface for the patient, a restraining belt for the medical officer, and a table for instruments and equipment. The two principal investigators for this demonstration are Dr. David K. Broadwell, Project Manager for the Health Maintenance Facility, NASA Johnson Space Center, Houston, Texas; and Dr. Bruce A. Houtchens, the University of Texas Health Science Center at Houston, Texas.

Intravenous Pump

The second instrument to be evaluated is a pump for intravenous infusions. Many medical techniques involving fluid transfers make use of Earth's gravity in their operations, but because fluids behave differently in space than on Earth, it is critical to develop instruments that transfer fluids accurately and efficiently in low-gravity. The intravenous infusion pump to be verified uses wavelike contractions, not gravitational attraction, to transport fluid through an occluded tube in much the same way that food moves through the alimentary canal. Crew members validate that the pump can deliver a prescribed amount of fluid at a specific rate. Dr. David K. Broadwell is also the principal investigator for this evaluation.

Airborne Particles

Shuttle crew members have reported occasional eye and respiratory tract irritation from debris floating in living and working areas. An environmental monitor collects repirable particles from the air for postflight analysis. Investigators identify possible contaminating sources. Findings from this investigation will be used to assess the effectiveness of the shuttle's current environmental control and life support system and to develop environmental monitoring system standards for long-duration flights. Dr. Dane Russo of the NASA Johnson Space Center, Houston, Texas, is the principal investigator.

Noninvasive Central Venous Pressure

Another investigation evaluates a noninvasive technique for measuring central venous pressure. To track changes in central venous pressure during the flight, a crew member breathes into a specially designed mouthpiece that creates resistance to exhaled air. By monitoring the pressure in the mouthpiece and monitoring blood flow in the jugular vein, scientists can calculate the central venous pressure. If these noninvasive measurements are consistent with those made by intravenous catheters, it will be easier and more convenient to gather body fluid data from experiment subjects and to monitor the cardiovascular health of the crew. Dr. J. B. Charles of NASA Johnson Space Center, Houston, Texas, is the principal investigator.

Space Acceleration Measurement System

The Space Acceleration Measurement System enhances SLS-1 science data return by making more sensitive measurements of acceleration than similar orbiter instruments. Many of the SLS-1 investigations, particularly the neurovestibular experiments, use these data to complement their specific biological measurements. Three sensors are located in different areas of the Spacelab (on the SMIDEX support structure, near the Solid Surface Combustion Experiment within SMIDEX, and on the floor near the bicycle ergometer) to measure microgravity accelerations. The Space Acceleration Measurement System was developed by NASA Lewis Research Center, Cleveland, Ohio.

Solid Surface Combustion Experiment

Crew and payload safety is a primary emphasis of all space programs. A microgravity science investigation that complements life sciences research, the Solid Surface Combustion Experiment, is also aboard SLS-1. This investigation studies how flames produced by solid fuels behave in microgravity. These findings will influence the selection of materials suitable for spacecraft achitecture and the development of operating procedures when flammable materials are present. The principal investigator is Dr. R.A. Altenkirch of Mississippi State University, Mississippi State, Mississippi.

SPACELAB

On Sept. 24, 1973, a memorandum of understanding was signed between the European Space Agency, formerly known as the European Space Research Organization, and NASA with NASA's George C. Marshall Space Flight Center as lead center for ESA to design and develop Spacelab, a unique laboratory facility carried in the cargo bay of the space shuttle orbiter that converts the shuttle into a versatile on-orbit research center.

The reusable laboratory can be used to conduct a wide variety of experiments in such fields as life sciences, plasma physics, astronomy, high-energy astrophysics, solar physics, atmospheric physics, materials sciences and Earth observations.

Spacelab is developed on a modular basis and can be varied to meet specific mission requirements. Its four principal components are the pressurized module, which contains a laboratory with a shirt-sleeve working environment; one or more open pallets that expose materials and equipment to space; a tunnel to gain access to the module; and an instrument pointing subsystem. Spacelab is not deployed free of the orbiter. The open pallets and instrument pointing subsystem will not be used on STS-40.

The European Space Agency developed Spacelab as an essential part of the United States' Space Transportation System. Eleven European nations are involved: Germany, Belgium, Denmark, Spain, France, United Kingdom, Ireland, Italy, the Netherlands, Switzerland, and, as an observer state, Austria.

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

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

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

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

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

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

NASA astronauts called mission specialists, as well as non-career astronauts called payload specialists, fly aboard Spacelab to operate experiments. Payload specialists are nominated by the scientists sponsoring the experiments aboard Spacelab. They are accepted, trained and certified for flight by NASA. Their training includes familiarization with experiments and payloads as well as information and procedures to fly aboard the space shuttle. From one to four payload specialists can be accommodated for a Spacelab flight. These specialists ride into space and return to Earth in the orbiter crew compartment cabin—but they work with Spacelab on orbit. Because Spacelab missions, once on orbit, may operate on a 24-hour basis, the flight crew is usually divided into two teams. The STS-40 crew will work 12-hour shifts.

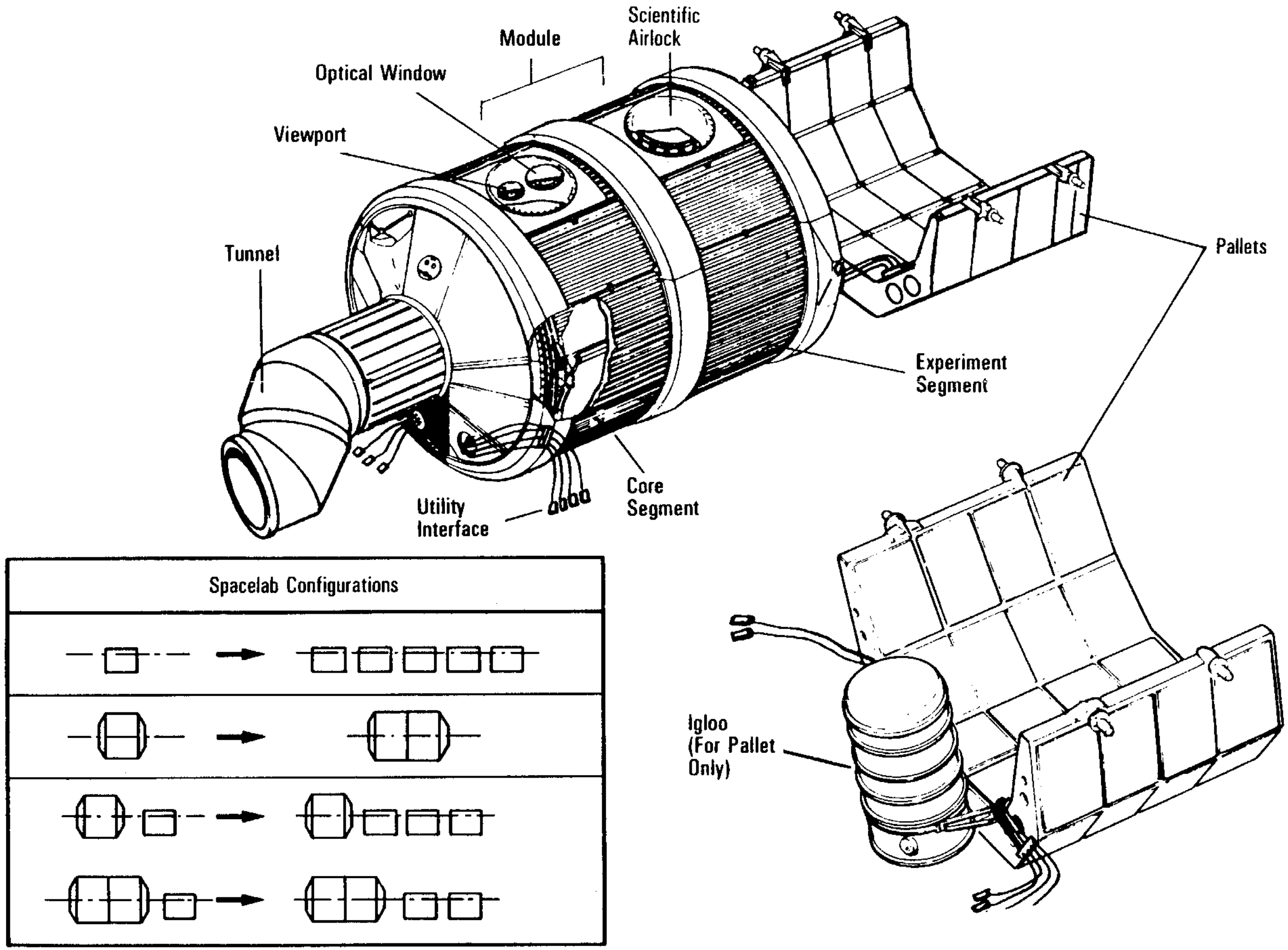
PRESSURIZED MODULE, OR LABORATORY. The pressurized module, or laboratory, is available in two segments. One, called the core segment, contains supporting systems, such as data processing equipment and utilities for the pressurized modules and pallets (if pallets are used in conjunction with the pressurized modules). The laboratory has fixtures, such as floormounted 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 long module configuration will be used on STS-40.

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 segment or segments are covered with passive thermal control insulation.

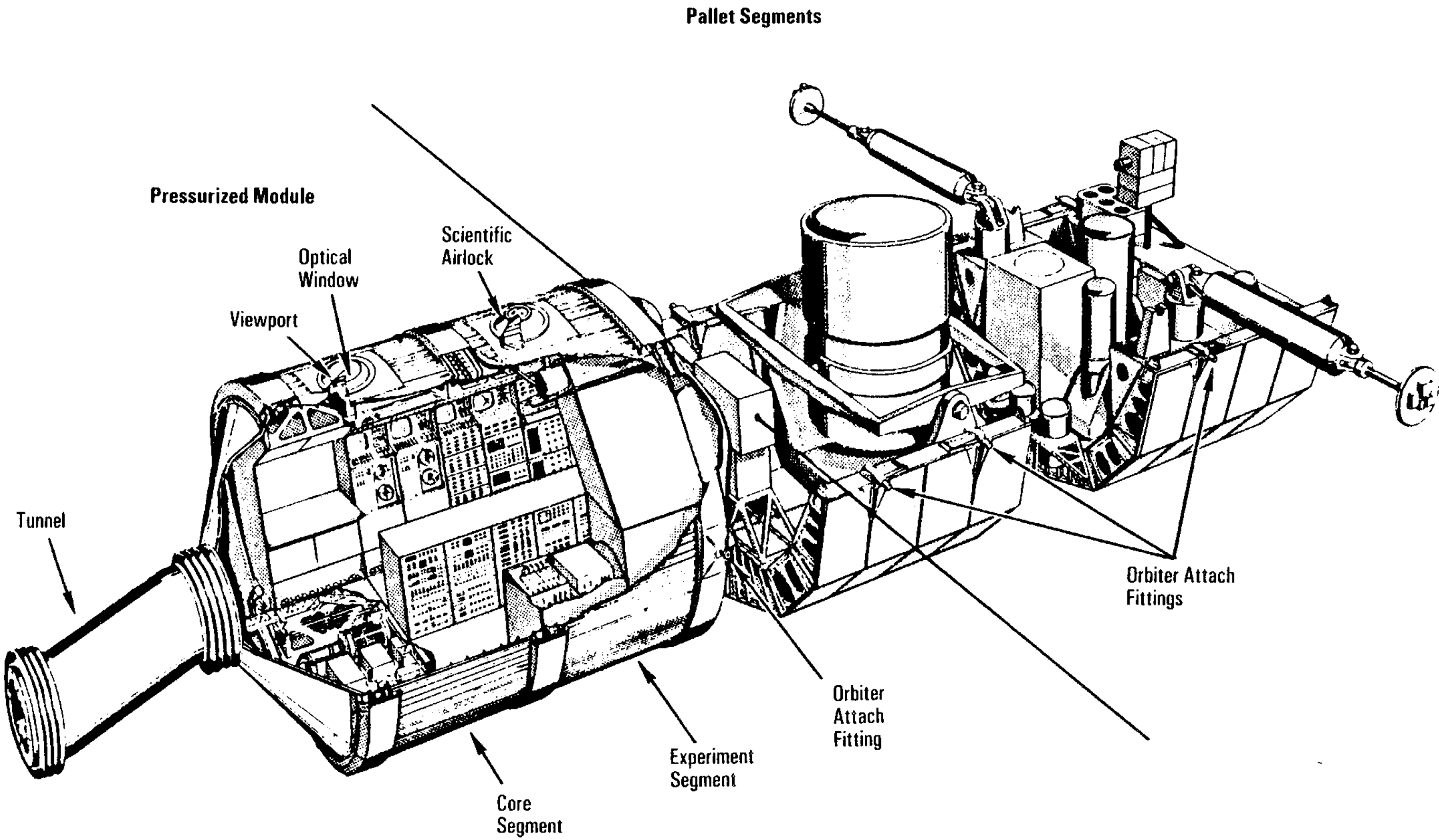
The ceiling skin panel of each segment contains a 51.2-inch-diameter opening for mounting a viewport adapter assembly, a Spacelab window adapter assembly or scientific airlock; if none of these items are used, the openings are closed with cover plates that are bolted in place. The module shell is made 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 first put together outside the module, checked out as a unit, then slid into the module where connections are made between the rack-mounted experiment equipment, the subsystems in the core segment, and the primary structure.

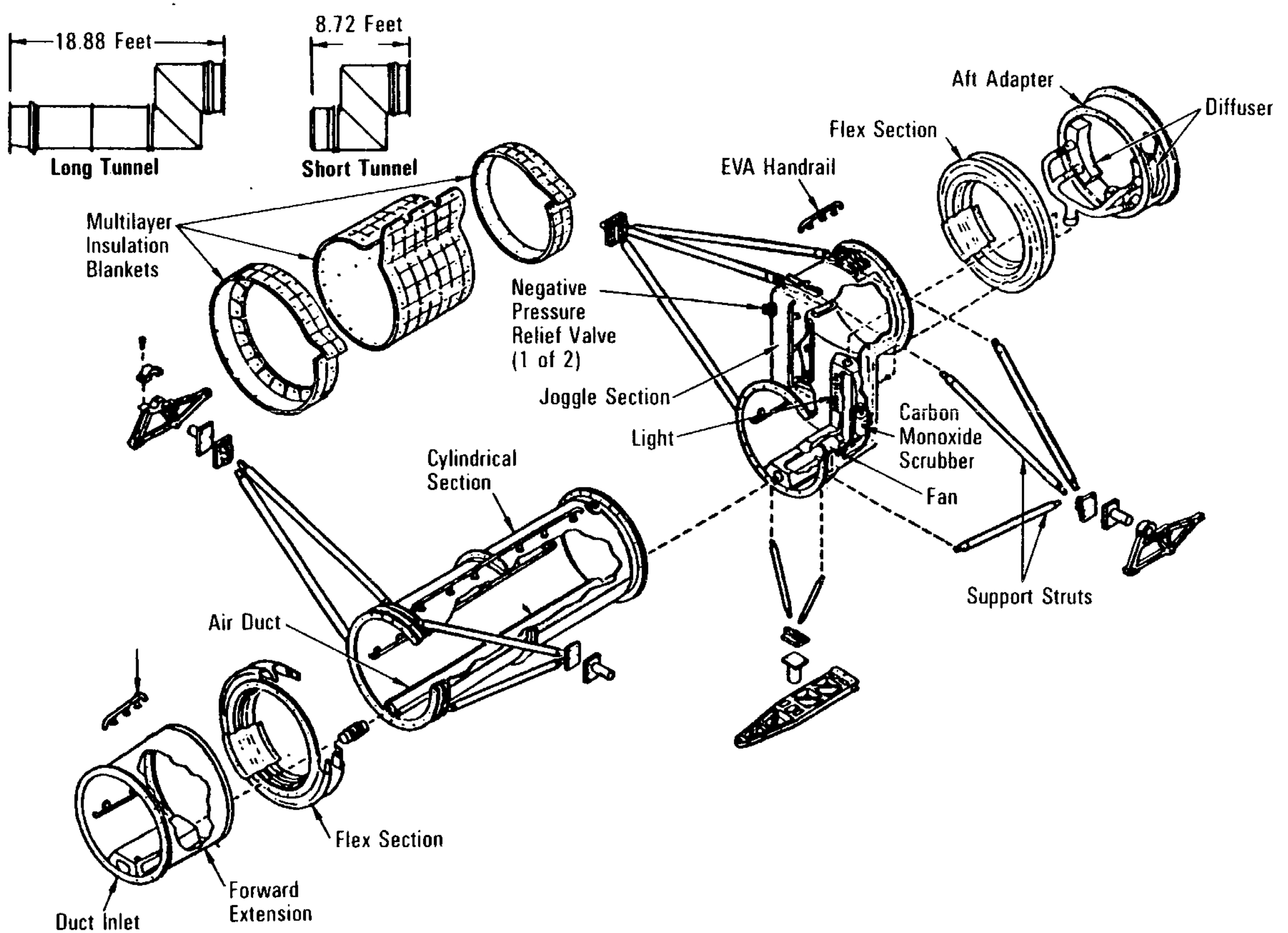
Because of the orbiter's center-of-gravity conditions, the Spacelab pressurized module or modules cannot be installed at the forward end of the payload bay. Therefore, a pressurized tunnel is provided for equipment and crew transfer between the orbiter's pressurized crew compartment and the Spacelab pressurized module or 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 long tunnel configuration will be employed on STS-40. The joggle section of the tunnel compensates for the 42.1-inch vertical offset of the orbiter middeck to the Spacelab pressurized module's



Spacelab External Design Features



European Space Agency's Spacelab



Spacelab Transfer Tunnel

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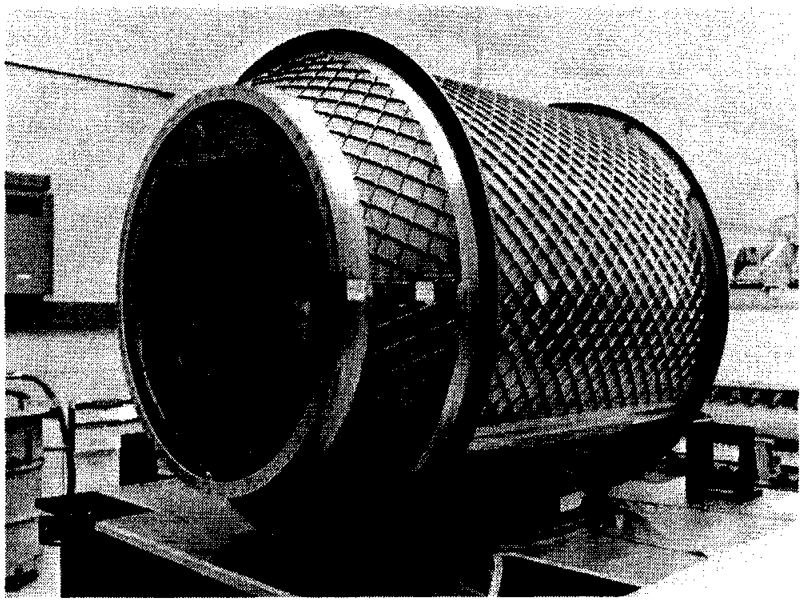


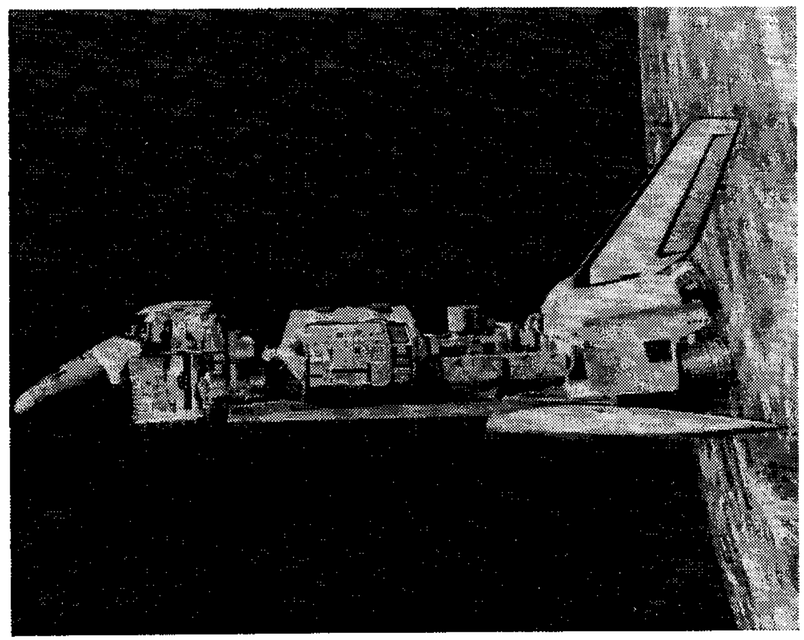
Tunnel Adapter

centerline. There are flexible sections on each end of the tunnel near the orbiter and Spacelab interfaces. The tunnel is 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 module or 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 module or modules. If an EVA is required, no flight crew members are permitted in the Spacelab tunnel or module.

INSTRUMENT POINTING SUBSYSTEM. Although not applicable to the STS-40 SLS-1 mission, 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 smallrocket-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

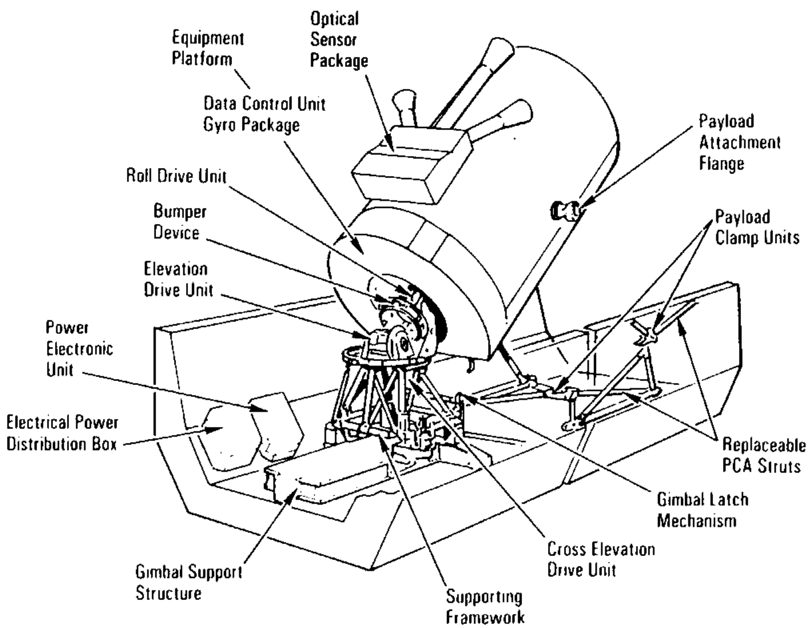


Spacelab

landing, 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 wetlubricated 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 long periods of pointing at a single object, others slow scan mapping, still others 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.

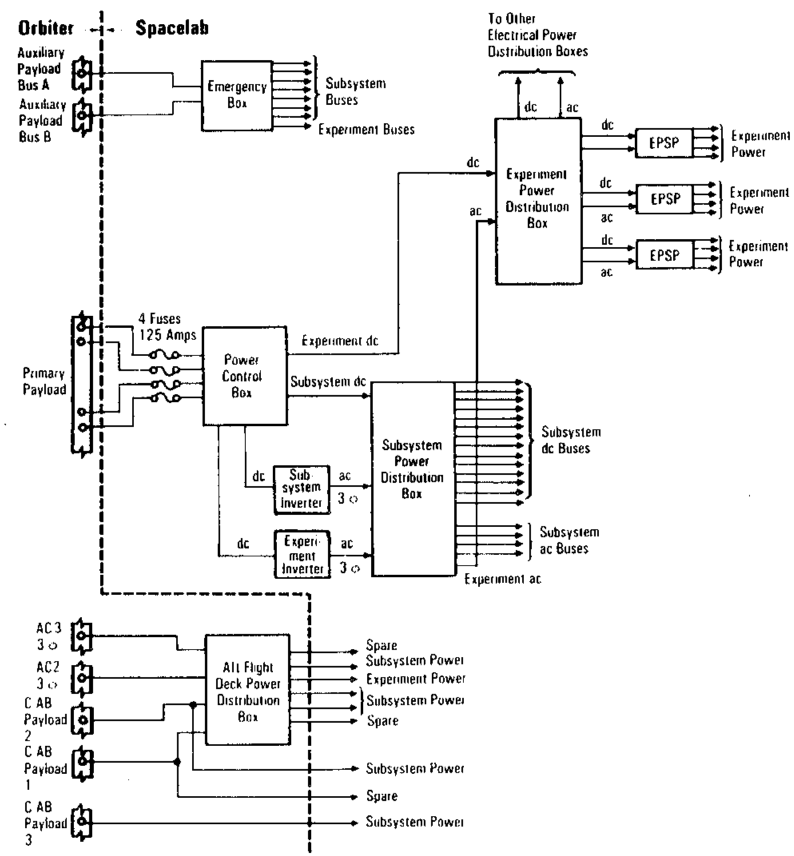
The pallets are designed for large instruments, experiments requiring direct exposure to space or systems needing unobstructed or broad fields of view, such as telescopes, antennas and sensors (e.g., radiometers and radars). The U-shaped pallets are covered with aluminum honeycomb panels. A series of 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 ft. (4 meters) wide and 10 ft. (3 meters) long.

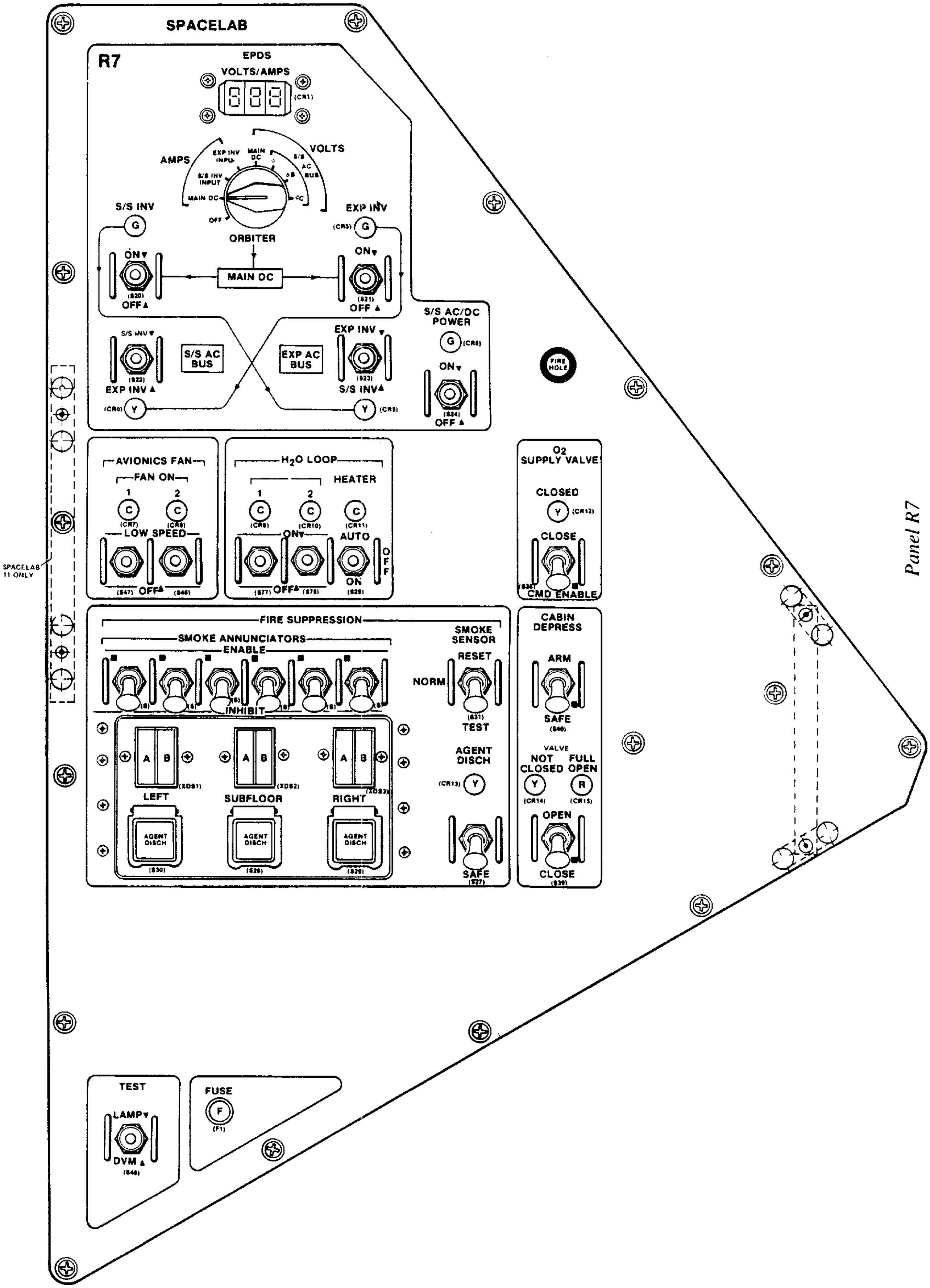
Cable ducts and cable support trays can be bolted to the forward and aft frame of each pallet to support and route electrical cables to and from the experiments and subsystem equipment mounted on the pallet. All ducts mounted on the starboard (right) side of the pallet are used to route subsystem cables,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



Orbiter Spacelab Electrical Power Distribution


SPACELAB
R7
EPDS
VOLTS/AMPS
AMPS
VOLTS
MAIN DC
ORBITER
S/S INV
EXP INV
ON
OFF
S/S AC BUS
EXP AC BUS
S/S AC/DC POWER
FIRE HOLE
AVIONICS FAN
FAN ON
LOW SPEED
H2O LOOP
HEATER
AUTO
OFF
O2 SUPPLY VALVE
CLOSED
CLOSE
CMD ENABLE
FIRE SUPPRESSION
SMOKE ANNUNCIATORS
ENABLE
INHIBIT
SMOKE SENSOR
RESET
NORM
TEST
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LEFT
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DVM
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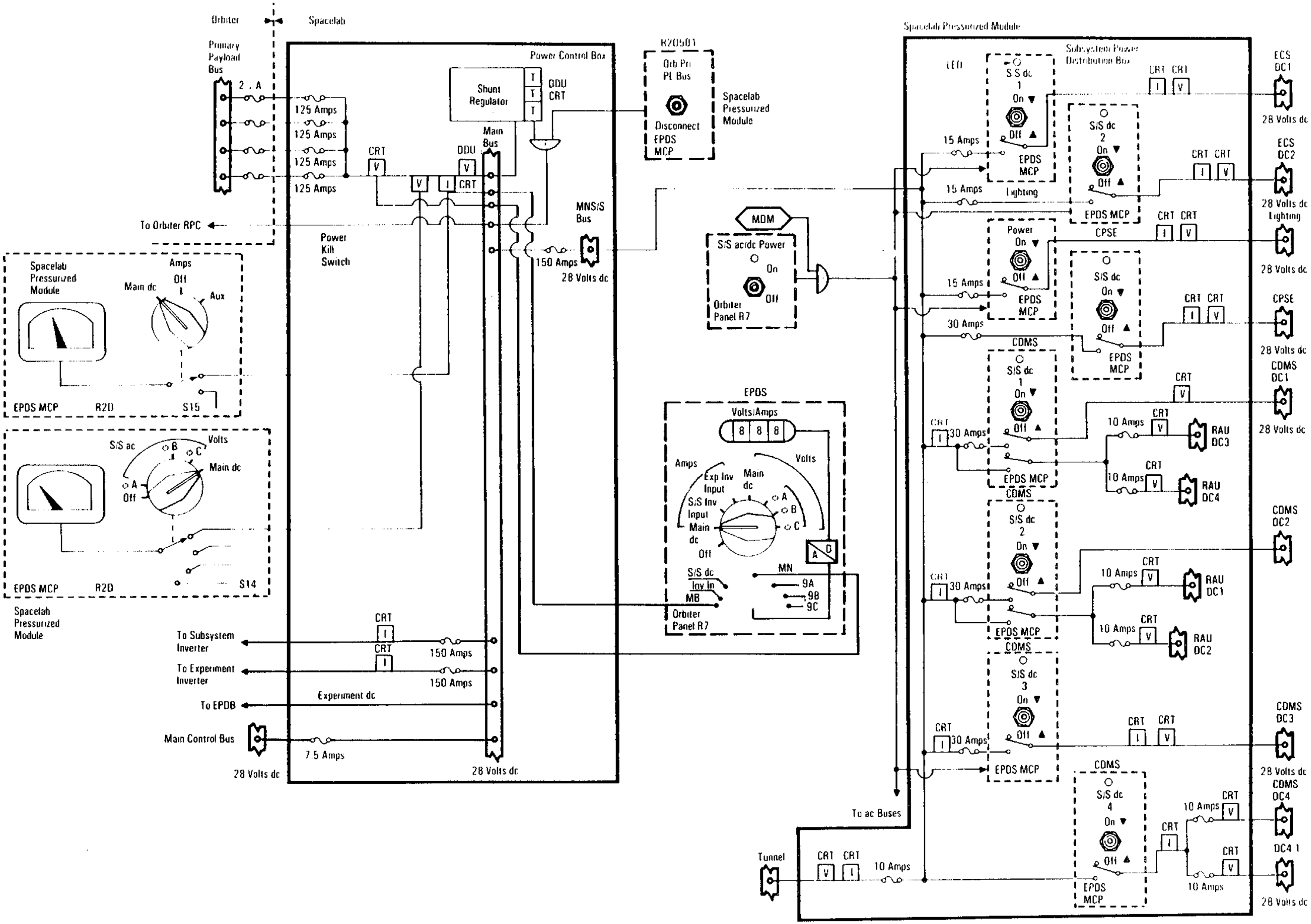
Panel R7



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

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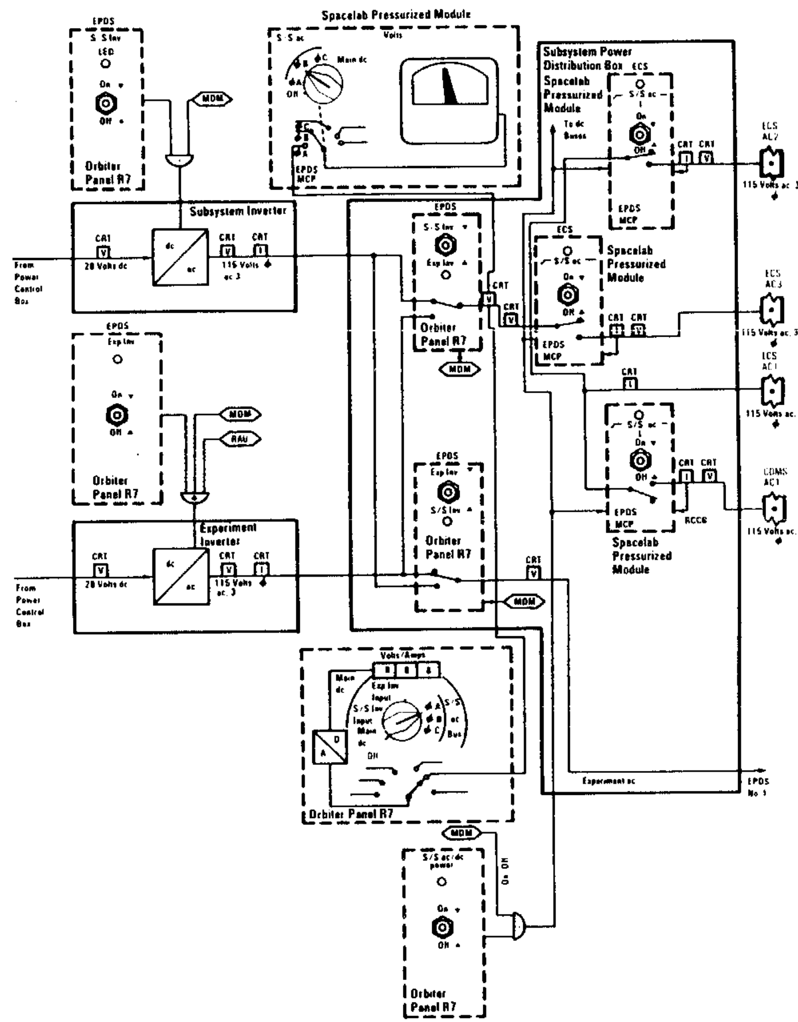
The primary dc power received in the Spacelab from the orbiter primary payload bus is nominally 28 volts, a maximum of 32 volts and a worst-case minimum of 23 volts. The four redundant power feeders from the orbiter supply the Spacelab power control box with power through 125-amp fuses. Spacelab main 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



Spacelab Electric Power Distribution—
Subsystem ac Power Distribution

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.

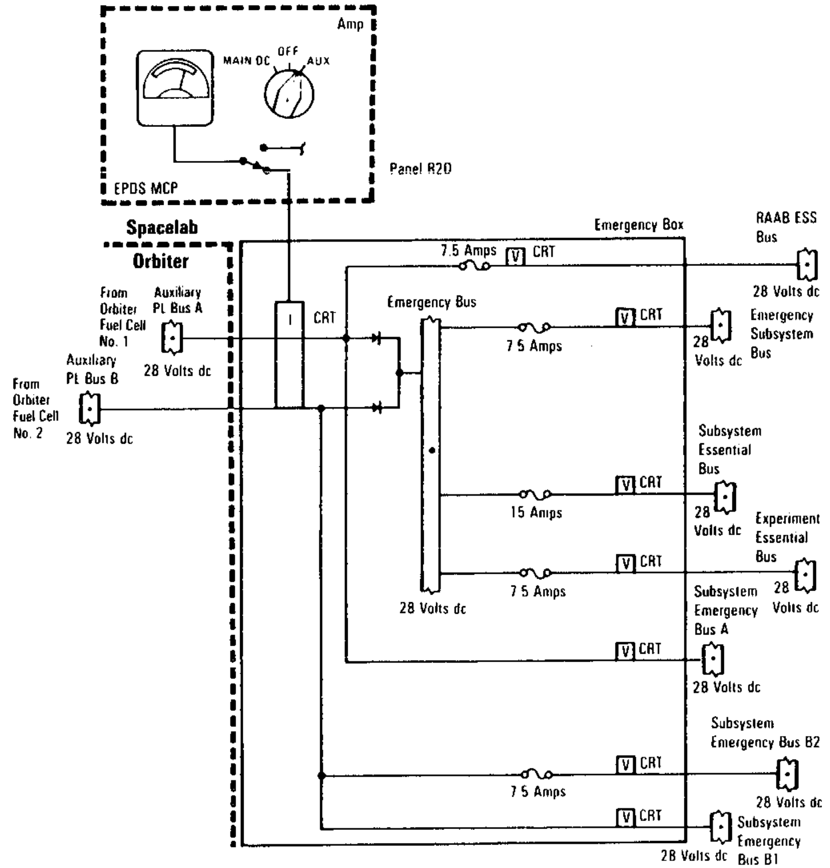
In the pressurized module configuration, the subsystem power distribution box ac bus feeds several Spacelab subsystem power buses controlled by switches on the Spacelab EPDS MCP. All functions on this panel can be initiated simultaneously by the *S/S ac/dc power on/off* switch on orbiter panel R7 or 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.

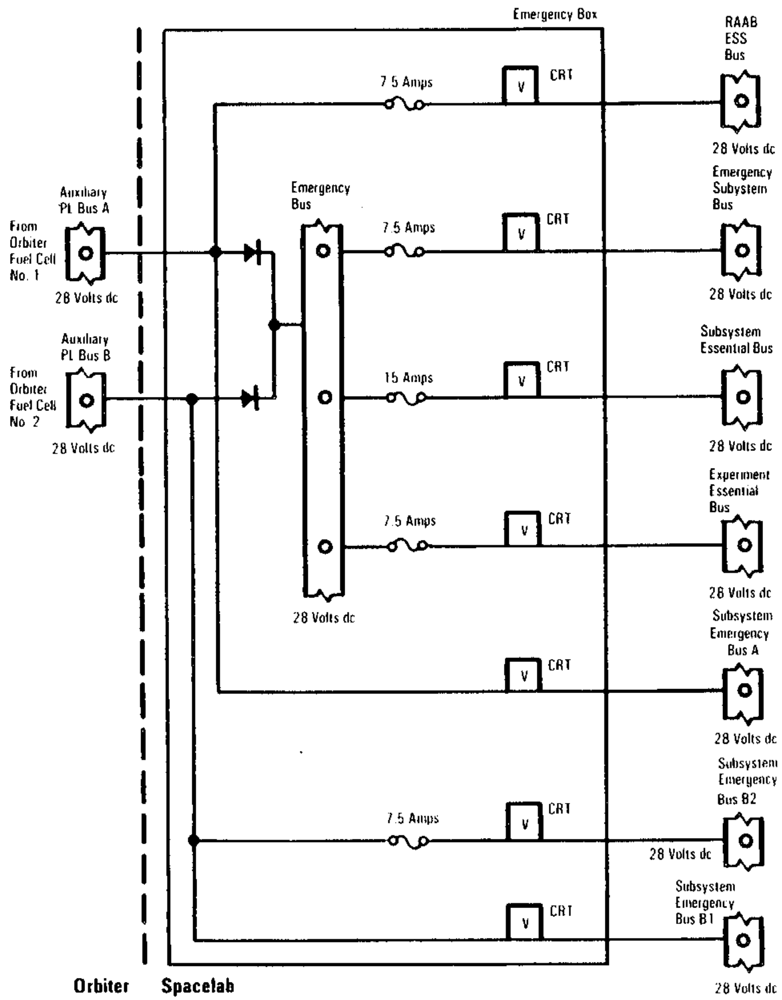
Emergency and essential dc power for the pallet-only configuration is also provided by orbiter auxiliary payload buses A and B, which send dc power to the Spacelab emergency box located in the igloo. The Spacelab emergency box provides emergency or essential power to Spacelab subsystem equipment. The 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

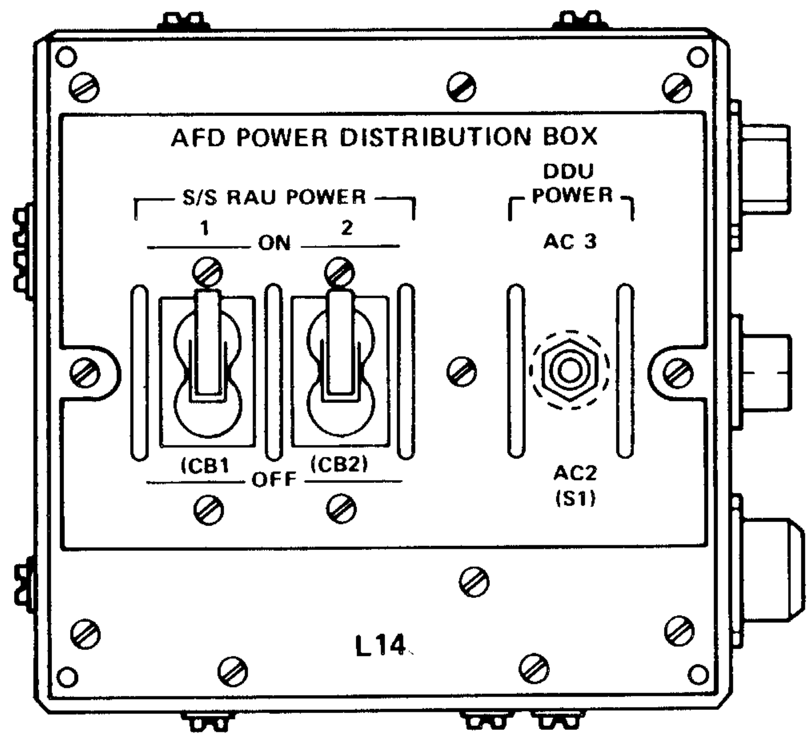


Spacelab Pressurized Module Emergency and Essential Power Distribution experiment main dc supply and a 115-volt, 400-hertz ac experiment supply. One distribution box (EPDB 1) is located under the core segment floor on a support structure; for the long module configuration, two additional units (EPDBs 2 and 3) are installed. In the pallet-only configuration, 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



Spacelab Pallet Emergency and Essential Power Distribution



Panel L14

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 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.

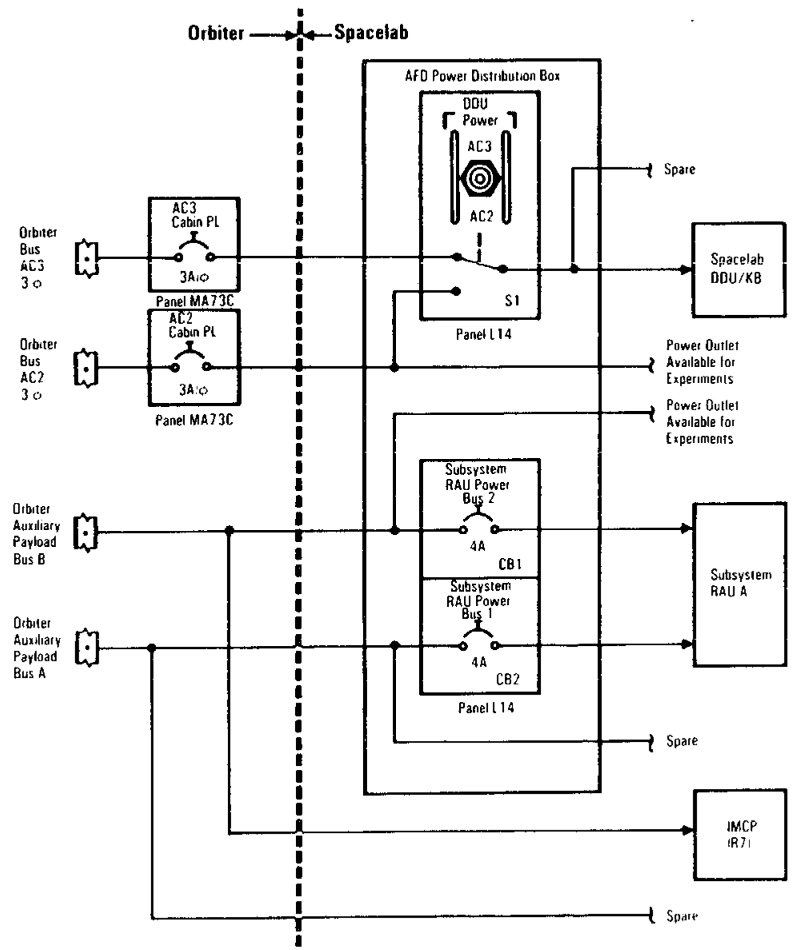
The Spacelab power distribution box at the orbiter aft flight deck payload station distributes dc and ac power to the Spacelab subsystem remote acquisition unit and the Spacelab data display system (a data display unit and keyboard). When a Spacelab data display system is installed at the mission station,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



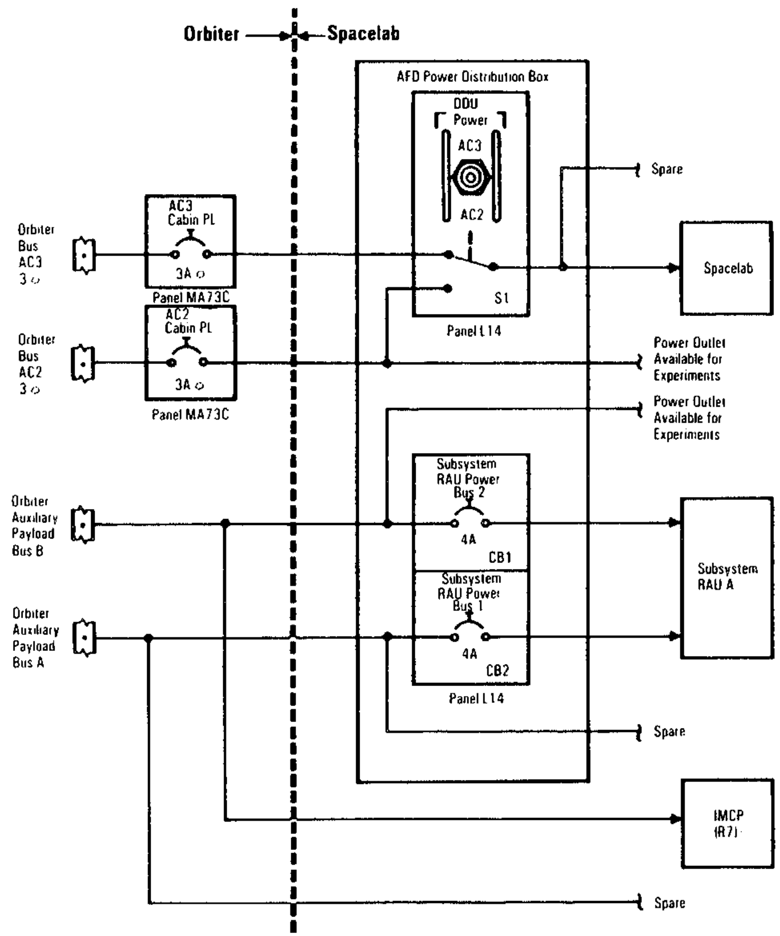
Pressurized Module Configuration—Orbiter Aft Flight Deck Power Distribution delivered by a dedicated experiment power control box. The dc and ac output is distributed to experiments and experiment-supporting RAUs (dc only). The number of switching panels and their locations depend on the mission configuration.

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

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

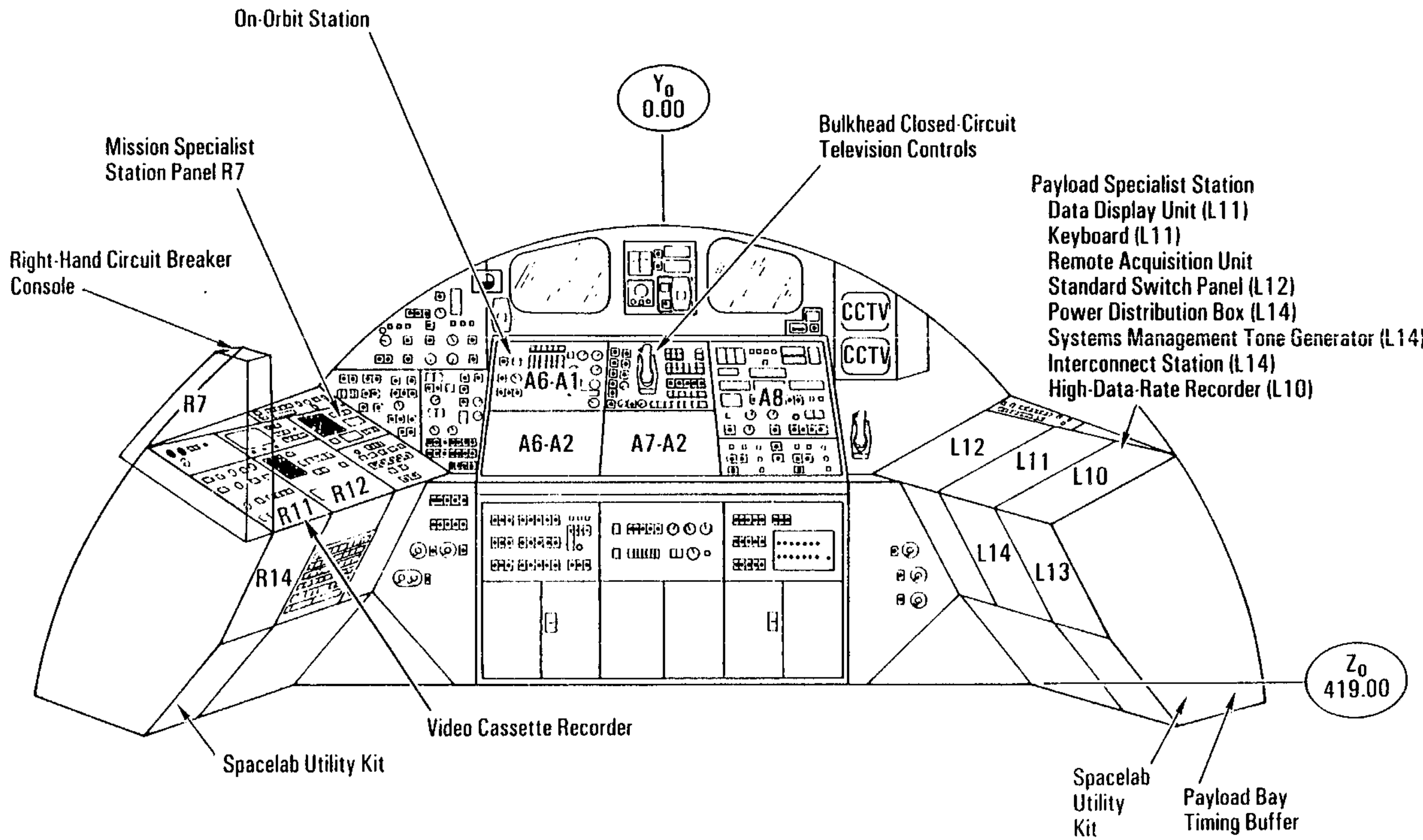
COMMAND AND DATA MANAGEMENT SYSTEM. The Spacelab command and data management system provides a variety of services to Spacelab experiments and subsystems. Most of the CDMS commands are carried out through the use of the computerized system aboard Spacelab, called the data processing assembly. The DPA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

The CDMS includes three identical computers and assorted peripherals. One computer is dedicated to Spacelab experiments, one supports Spacelab subsystems, and the third is a backup. The flight crew monitors and operates Spacelab subsystems and

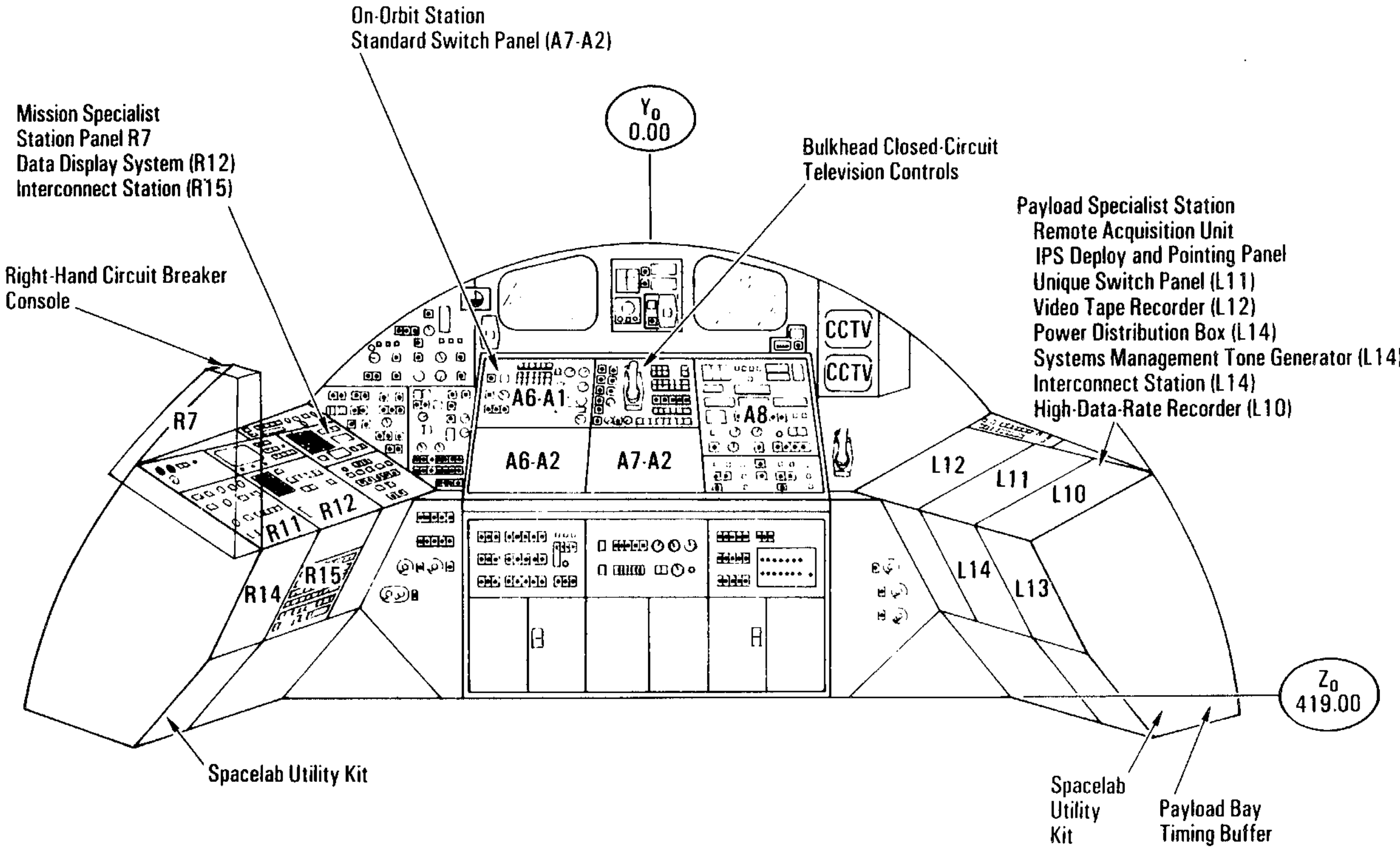


Pallet-Only Configuration—Orbiter Aft Flight Deck Power Distribution

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



Example of a Spacelab Pressurized Module Aft Flight Deck Panel Configuration



Example of a Spacelab Pallet-Only Aft Flight Deck Panel Configuration for basic Spacelab services that are available to support experiments, such as electrical power distribution, equipment cooling and scientific airlock operations (in the case of the pressurized module). The backup computer can function in the place of either computer.

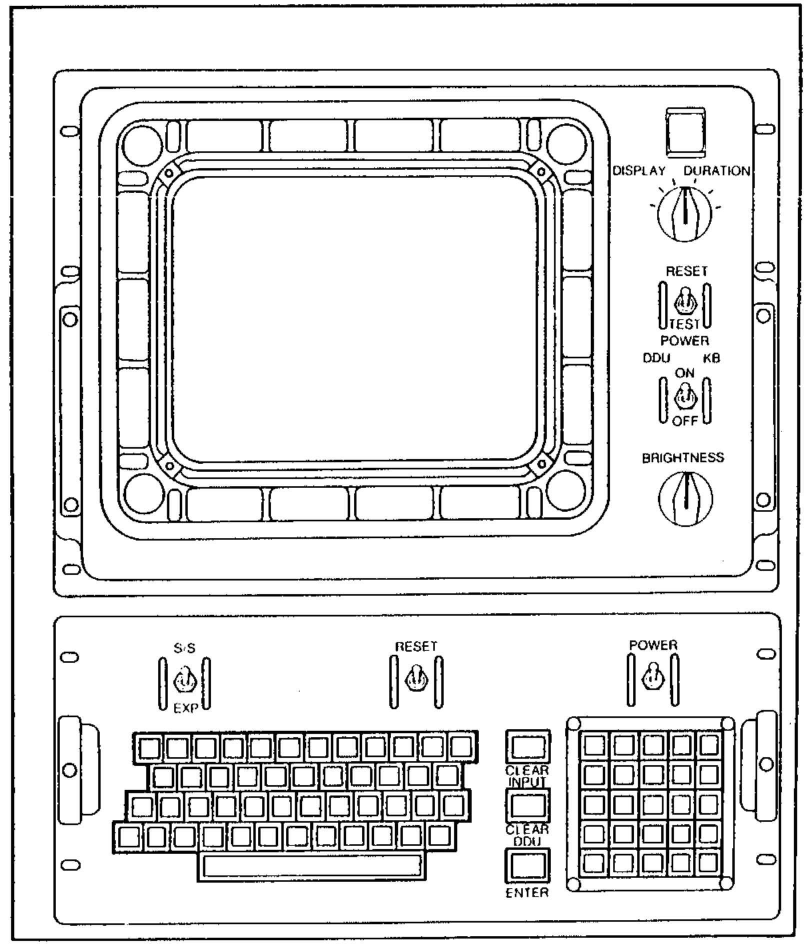
An input/output unit buffers all communications between the computer and the rest of the subsystem. The experiment computer also has at least one RAU (and as many as eight, depending on the payload) for interfacing between experiments and the subsystem. The subsystem computer may have as many as nine 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 onboard 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) in three colors (green, yellow and red). In addition to 128 alphanumeric symbols, the unit can also display



Data Display Unit and Keyboard

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.

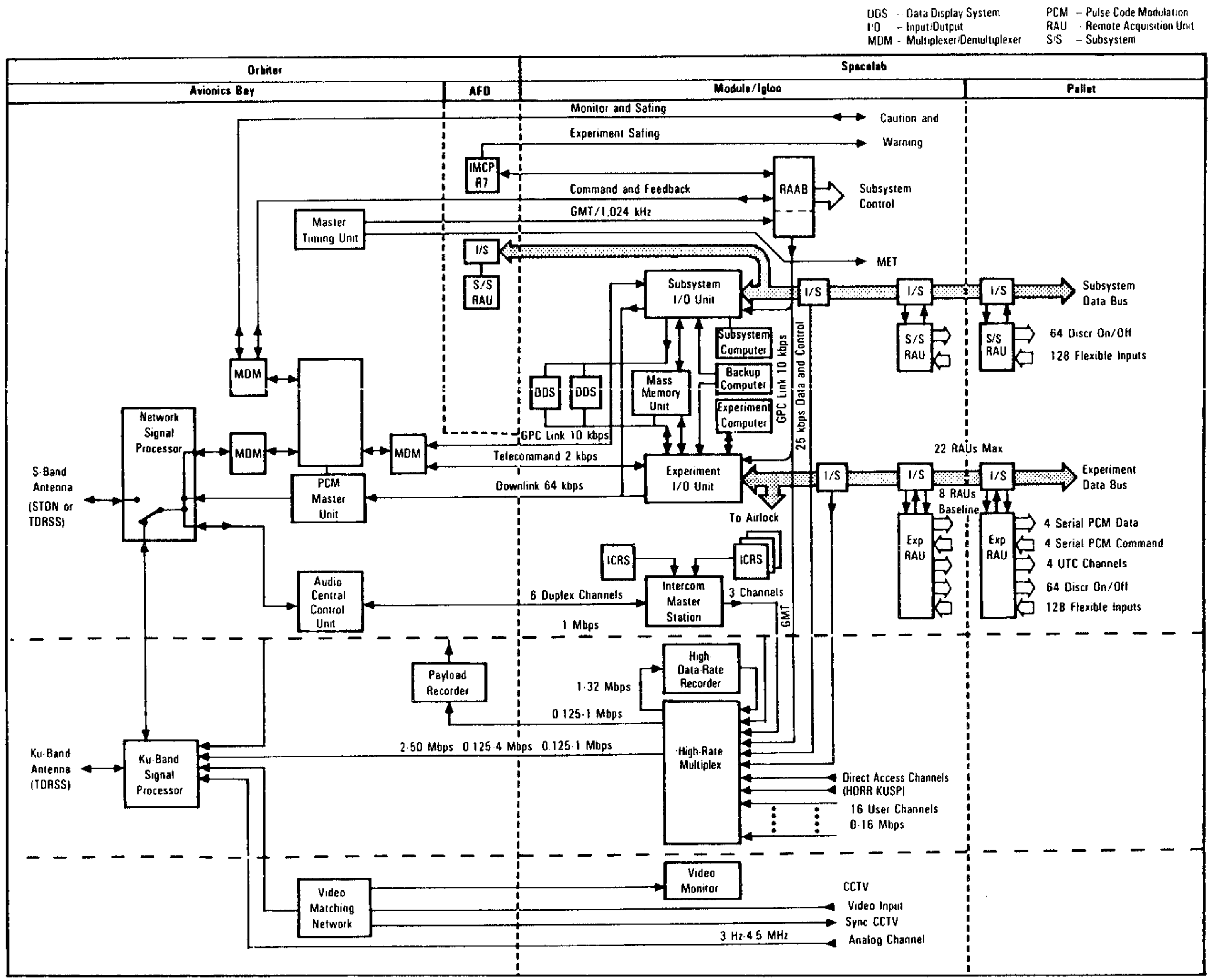
The subsystem computer functions mainly to monitor and control other Spacelab subsystems and equipment, such as the electrical power distribution subsystem and the environmental control subsystem. These functions are performed by the subsystem computer operating software.

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.

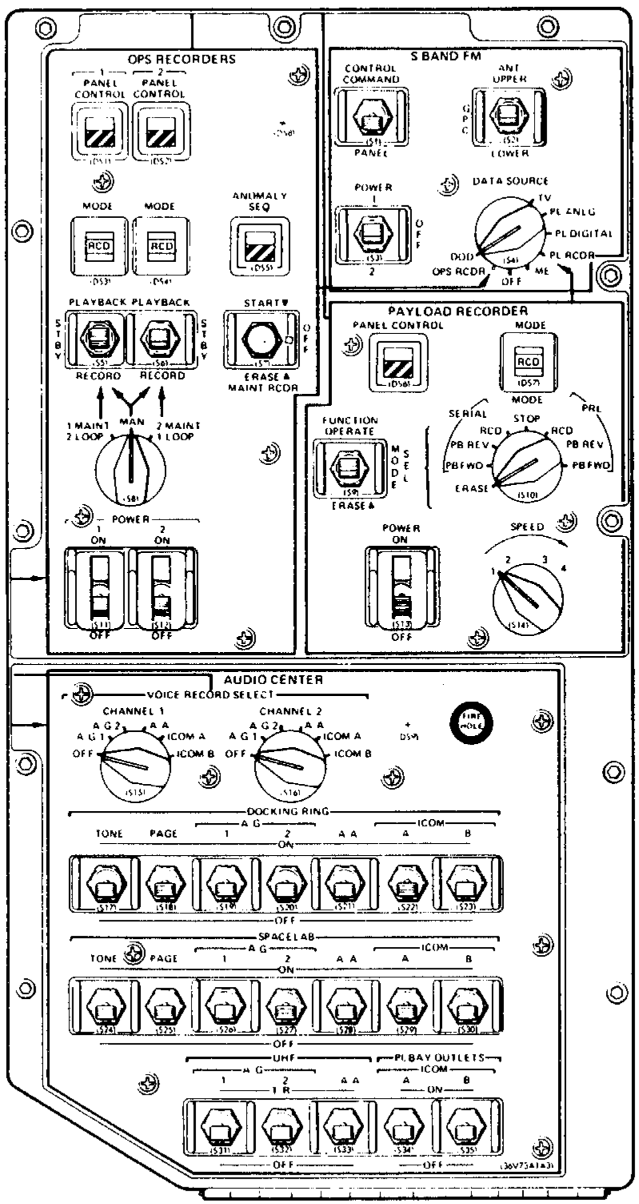
The Spacelab experiment computer interfaces with two telemetry systems. The orbiter PCMMU allows the orbiter to acquire data for onboard monitoring of systems and provides the Mission Control Center in Houston with system performance data for real-time display and recording through the orbiter network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



Spacelab Command and Data Management System Interfaces With the Orbiter



Panel A1A3

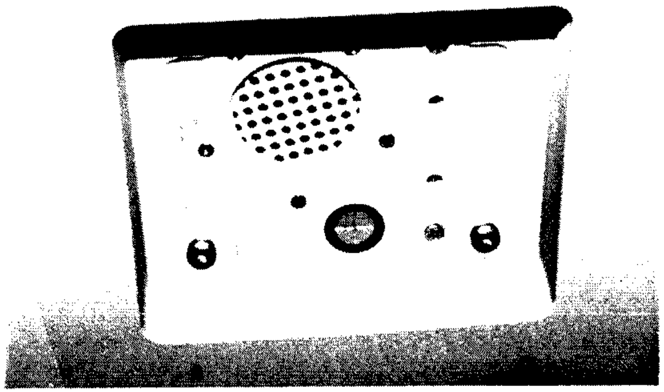
or 32 Mbps. At a rate of 32 Mbps, a tape runs for 20 minutes. The recorder can be changed manually by the flight crew; however, no tape changes are planned because the time required to change tapes is very long and it is much more efficient to dump the tape.

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.

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.



Spacelab Pressurized Module Aural Annunciator Located Below Panel L14

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, the Spacelab or in both.

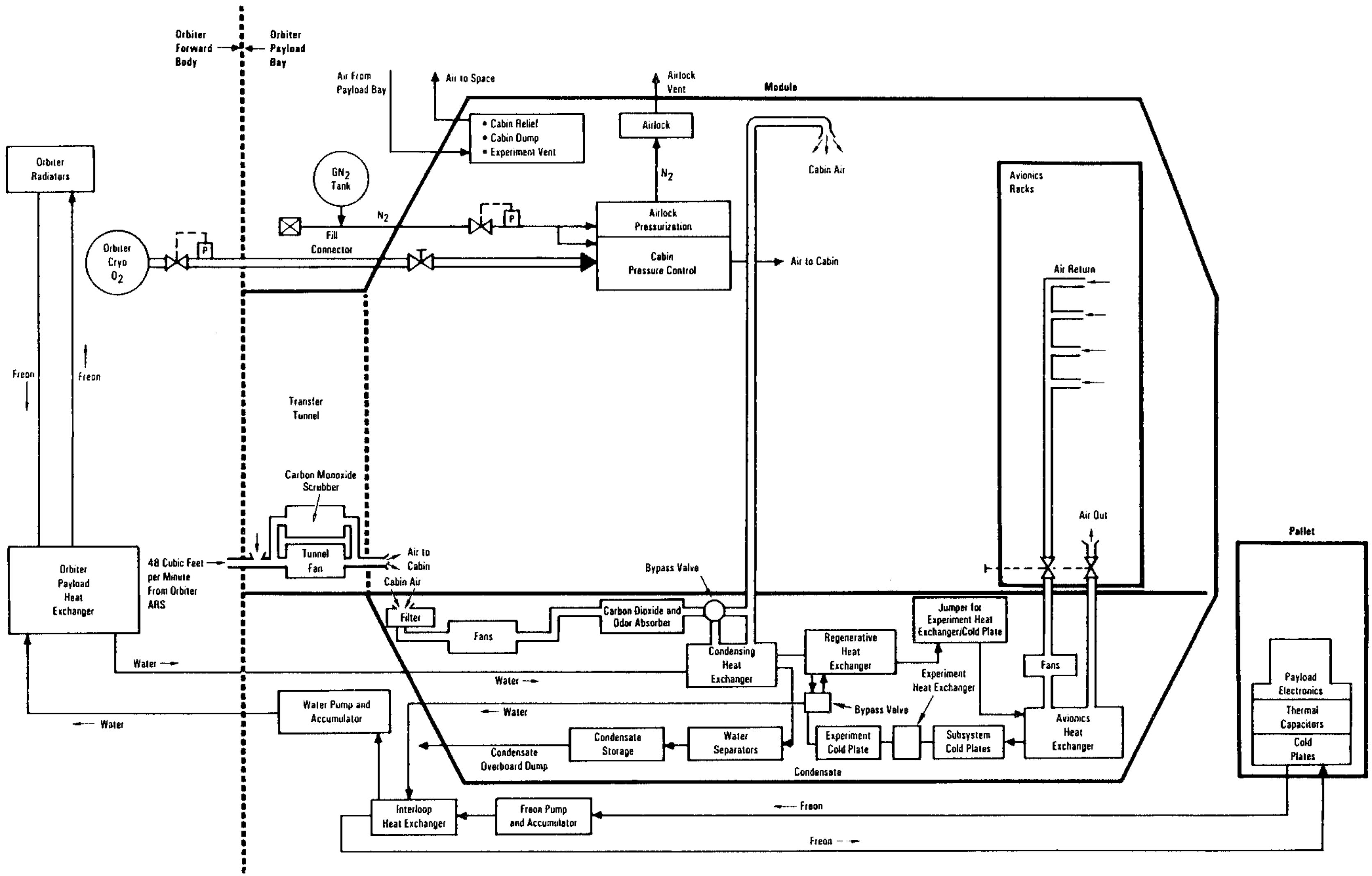
Access to orbiter channels is controlled within the orbiter. Normal voice recordings are made on the orbiter operations recorders. The Spacelab talk and listen lines are combined for distribution to the Spacelab voice digitizer in the Spacelab high-rate multiplexer for all three Spacelab channels.

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 *O2 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 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 Pressurized Module and Orbiter Environmental Control and Life Support System Interface

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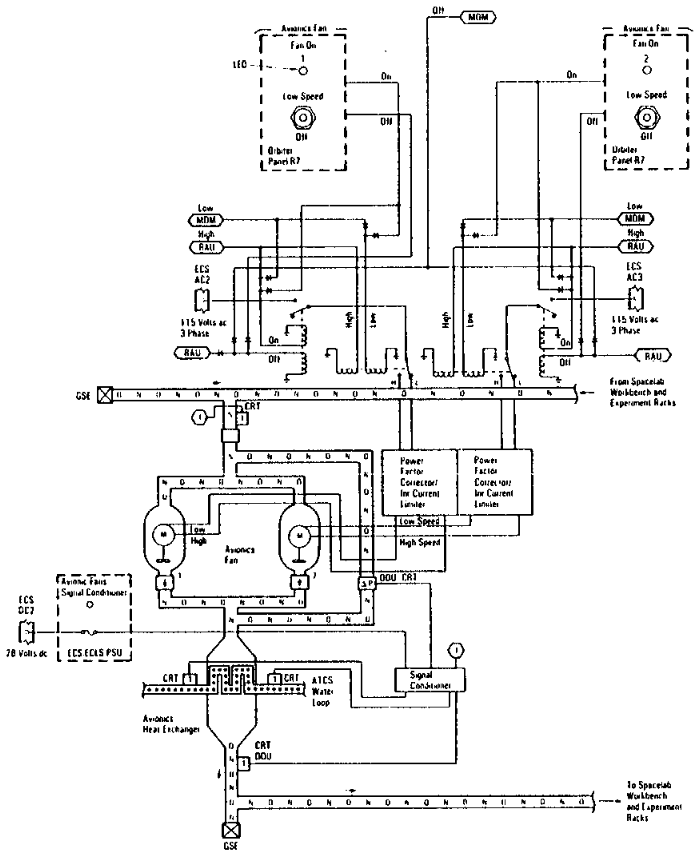


Spacelab Avionics Loop

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.

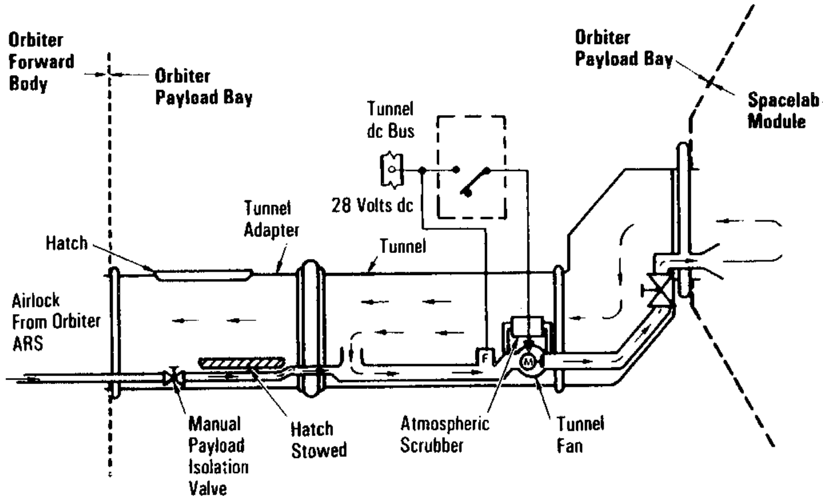
Air in the Spacelab avionics air loop is circulated by one of two dual-redundant fans, with check valves to prevent recirculation through the inactive fan and a filter upstream to protect both fans. For ascent and descent flight phases, as well as low-power modes on orbit, the avionics fans operate when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

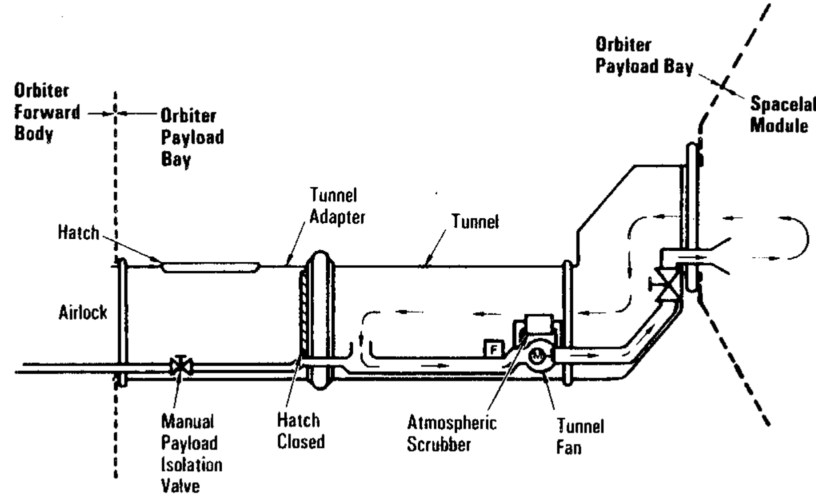
The Spacelab avionics fans can also be activated in the low-speed mode by commands from the orbiter CRT keyboard. The fans are activated in the high-speed mode (four-pole) by commands from the orbiter CRT keyboards. The orbiter MDM deactivation command deactivates both fans simultaneously, and the Spacelab 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 air loop downstream of the orbiter cabin heat exchanger and enters the tunnel adapter. In the tunnel adapter the



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



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

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.

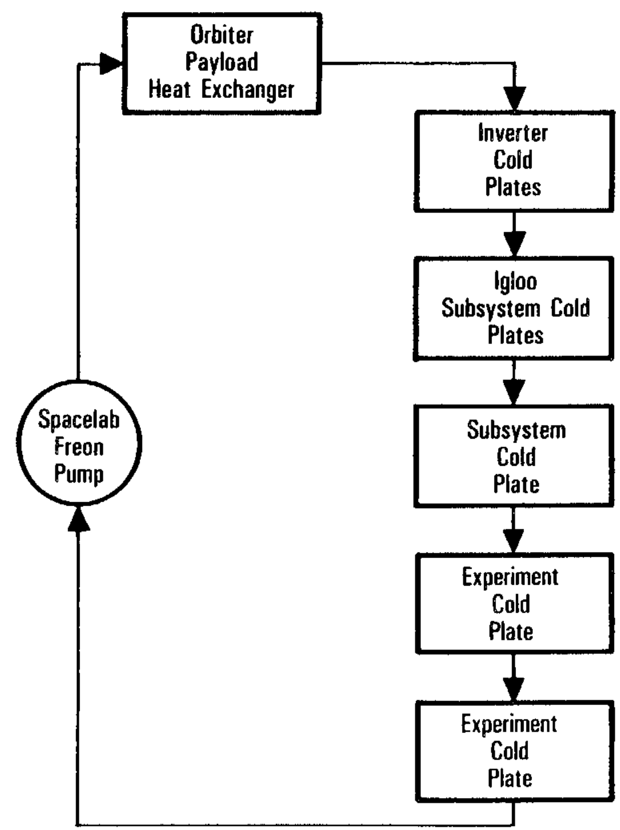
When a Spacelab fire/smoke signal is detected, an emergency tone (siren) generated by the orbiter caution and warning circuitry is transmitted by the orbiter audio central control unit and announced in the Spacelab module by the loudspeaker, and the Spacelab *master alarm* light is illuminated. The six 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

GETAWAY SPECIAL PROGRAM

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

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

To date, 55 GAS cans have flown on 15 missions. The GAS program began in 1982 and is managed by Goddard Space Flight Center, Greenbelt, Md. Clarke Prouty is GAS project manager and Larry Thomas is technical liaison officer.

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

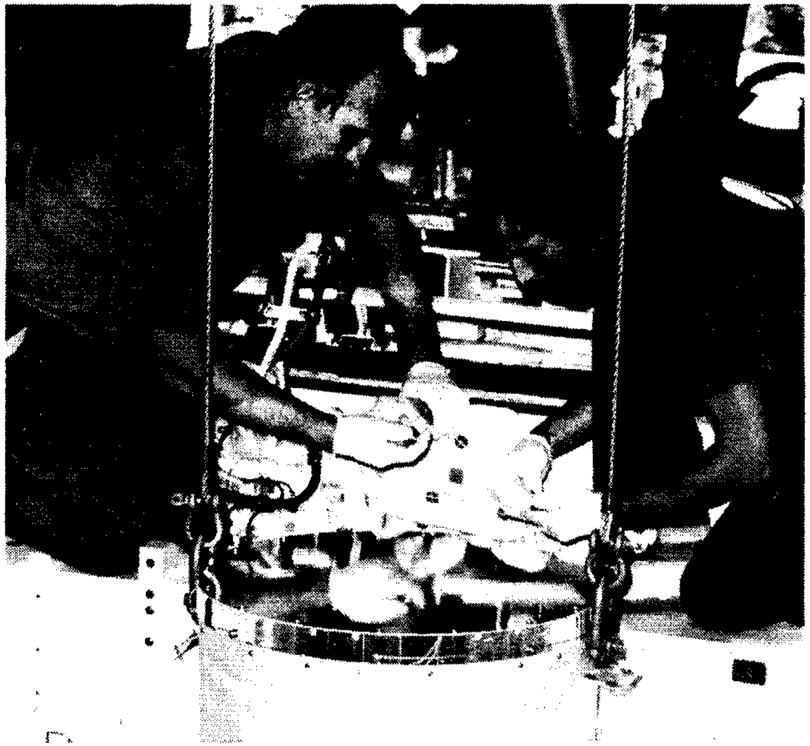
GAS requests must first be approved at NASA Headquarters in Washington, D.C., by the director of the Transporation Services Office. At that point NASA screens the propriety objectives of each request. To complete the reservation process for GAS payloads, each request must be accompanied or preceded by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

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

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

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

The GAS container provides internal pressure, which can be varied from near vacuum to about one atmosphere. The bottom and sides of the container are always thermally insulated, and the top may be insulated or not, depending on the specific experiment.



Getaway Special Container in Payload Bay

A lid that can be opened or one with a window may be required. These may also be offered as options at additional cost.

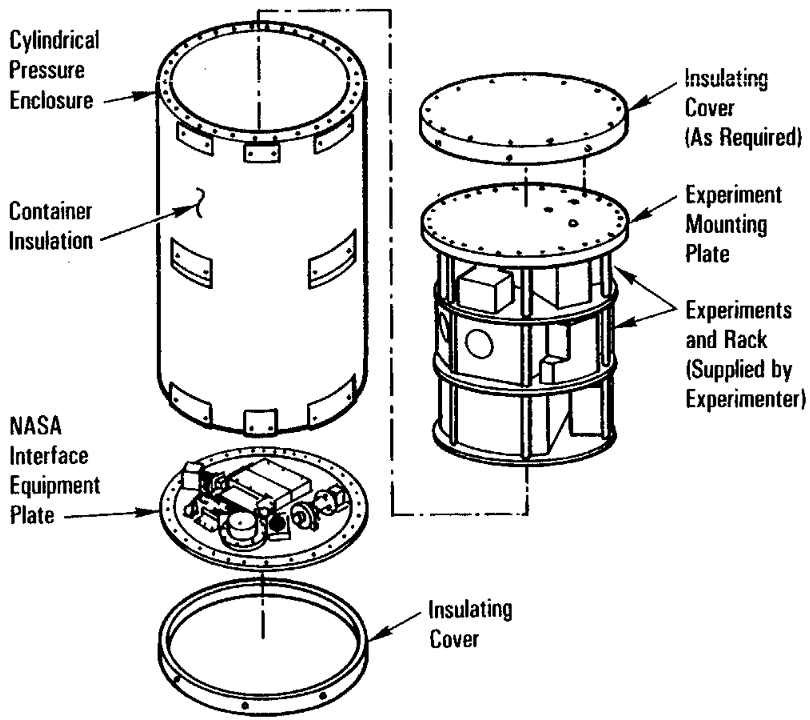
The GAS container is made of aluminum, and the circular end plates are 0.625-inch-thick aluminum. The bottom 3 inches of the container are reserved for NASA interface equipment, such as command decoders and pressure regulating systems. The container is a pressure vessel that can be evacuated before or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

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

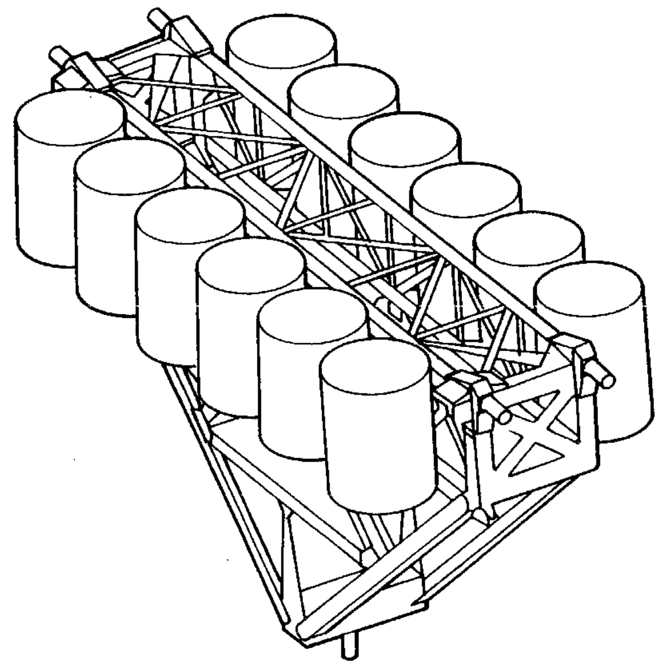
For additional information about NASA's getaway special program contact the program manager, code MC, NASA Headquarters, Washington, D.C. 20546. The primary contact for payload users is the technical liaison, Code 740, NASA Goddard Space Flight Center, Greenbelt, Md. 20771.

STS-40 GETAWAY SPECIAL EXPERIMENTS

The GAS Bridge Assembly (GBA) consists of a GAS bridge structure and 12 Getaway Special (GAS) payloads in 5 cubic-foot containers (canisters). The GBA is mounted across the payload bay in Bay 12, and measures approximately 100 inches in length.



Getaway Special (GAS) Container Concept



GAS Bridge Assembly (GBA)

The 12 GAS experiments aboard STS-40 are as follows:

1. **Solid-State Microaccelerometer Experiment (G-021)**
   Sponsor: European Space Agency

This experiment is part of ESA's In-Orbit Technology Demonstration Program, which makes use of flight opportunities on European and American carriers to fly technology experiments.

The objective of G-021 is to test a new kind of extremely sensitive, highly miniaturized accelerometer intended for applications on various ESA missions. Using a block of silicon material etched to create a frame with a mass suspended on two beams, the experiment was devised to subject accelerometers to known vibration stimuli while in the microgravity environment of the shuttle.

The extreme sensitivity of the accelerometers will require the crew to switch the experiment on prior to a sleep period in order to minimize noise created by the crew or shuttle systems that could reduce the quality of the measurements. The experiment will work autonomously and will last approximately 3 hours. The crew will switch it off after the sleep period.

The payload was designed and built by Compagnie Industrielle Radioelectrique S.A., Switzerland; and Centre Suisse D'Elecronique et de Microtechnique S.A., Switzerland. Richard Hoffman is the NASA technical manager (NTM).

2. **Experiment in Crystal Growth**
   Sponsors: GTE Laboratories Incorporated; NASA Lewis Research Center, Cleveland, Ohio; and the U.S. Air Force Wright Research and Development Center Materials Laboratory, Dayton, Ohio

G-052 is designed to grow crystals of gallium arsenide (GaAs), a versatile electronic material used in high-speed electronics and optoelectronics.

The payload will grow two selenium-doped GaAs crystals. The crystals will be 1 inch in diameter by 3.5 inches long and will be grown using a gradient freeze growth technique. Growth of the two crystals in space is part of a comprehensive research program to systematically investigate the effect of gravity-driven fluid flow on GaAs crystal growth.

The payload was designed and constructed at GTE Laboratories in Waltham, Mass. Scientists from each research institution will contribute to characterization of the space-grown crystals. The NTM is Dave Peters.

3. **Orbital Ball Bearing Experiment (G-O9l)**
   Sponsor: California State University, Northridge

A team of researchers from California State University, Northridge (CSUN) has build an experiment apparatus called the Orbital Ball Bearing Experiment (OBBEX) to test the effects of melting cylindrical metal pellets (low-melting point tin-lead-bismuth alloy) in microgravity. If successful, this experiment may produce a type of ball bearing that has never before been built.

A primary goal of the OBBEX experiment is to create the world's first seamless, hollow ball bearing. The hollow characteristic of the ball can improve the service life rating of a ball bearing. This permits higher speeds and higher load applications and may reduce the friction encountered in normal operation.

With faculty support, the OBBEX was designed and built as part of a senior year design project at CSUN. Funding for the experiment was provided by two Southern California companies: Moore Industries, Inc., a manufacturer of industrial control systems, and Industrial Tektonics, Inc., a specialty bearing manufacturer. Additional funding was supplied by the Aerospace Corporation, the CSUN Foundation, and several individuals. Don Carson is the NTM.

4. **In-Space Commercial Processing (G-105)**
   Sponsors: U.S. Space and Rocket Center, Huntsville, Alabama; Consortium for Materials Development in Space, University of Alabama in Huntsville

Scientists at the University of Alabama in Huntsville (UAH) will use five experiments to study possible commercial in-space processing opportunities.

While Columbia is in orbit, two experiment packages in the canister will process organic films and crystals that might be used in optical communications and computers. Another will electroplate metals to study special catalytic or reactory properties, or resistance to corrosion. A fourth experiment will study technology used to refine and process organic materials, such as medical samples.

The fifth UAH experiment will collect cosmic ray interactions on film emulsion while also helping scientists assess materials that may be used in future massive cosmic ray detectors to be flown aboard the shuttle or Space Station *Freedom* or to determine exposure to energetic particles on Earth.

The sixth experiment is provided by the U.S. Space and Rocket Center, a state-owned space science museum. It will study the effects of cosmic radiation on the chromosomes and genes of a common yeast. The NTM is Larry Thomas.

5. **Foamed Ultralight Metals**
   Sponsor: Omni Publications. The experiment was contributed by students from Duke University.

G-286 is designed to demonstrate the feasibility of producing, in orbit, foams of ultralight metals for possible application as shock-absorbing panel-backing to improve the shielding of both manned and unmanned vehicles and satellites, including Space Station *Freedom*, against hypervelocity impacts either from micrometeroids or orbiting debris.

The concept of using ultralight, reactive alloys in the space environment, where their reactivity is not an issue, offers many advantages in the engineering of large-scale space structures. Similarly, the idea of using metal foams made from such alloys as shock-absorbing backing to improve the effectiveness of satellite armor may offer substantial benefits in the design of Space Station *Freedom*.

The payload was built at Duke University in the Department of Mechanical Engineering and Materials Science. The project was supported by Omni Magazine, which offered the canister as part of a national contest in 1983, and by the School of Engineering in subsequent years. The NTM is Don Carson.

6. **Chemical Precipitate Formation (G-405)**
   Sponsor: Frontiers of Science Foundation, Oklahoma City, Oklahoma

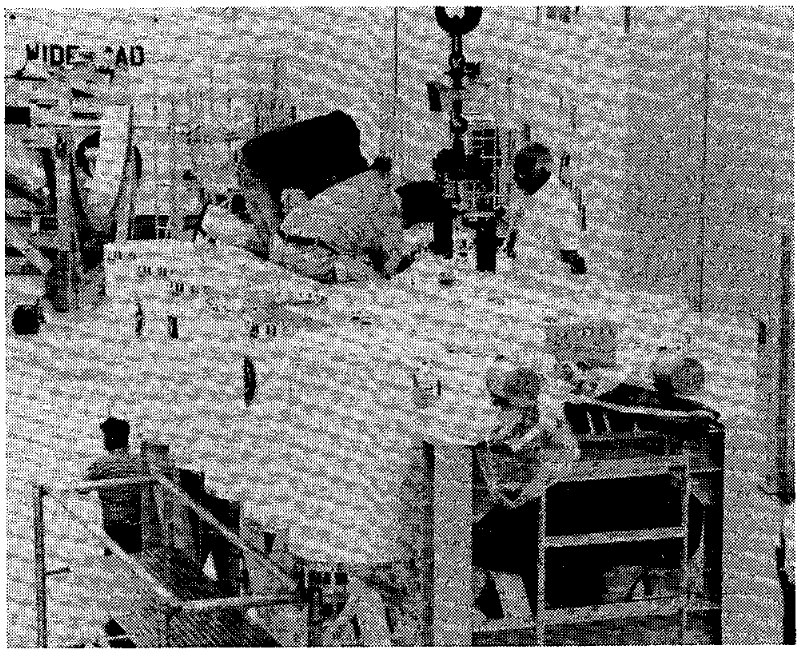
G-405 will return data concering the formation of six insoluable inorganic chemical precipitates. The experiment will investigate the rate of formation and terminal size of precipitate particles when the growth is not impaired by settling due to gravity.

The Frontiers of Science Foundation is a private, non-profit organization established to promote science education within Oklahoma. Louisiana Tech University is a co-sponsor. In 1983, the foundation sponsored a contest among high school students to conceptualize an experiment which would fly aboard the shuttle. The revisions for the payload were performed at Louisiana Tech University, where the payload manager currently serves on the faculty in mechanical engineering.

After flight and analysis of data, the payload will be donated and displayed at the Oklahoma Air and Space Museum in Oklahoma City. The NTM is Larry Thomas.

7. **Five Microgravity Experiments (G-408)**
   Sponsor: MITRE Corporation; Worcester Polytechnic Institute, Worcester, Massachusetts

Five student experiments from the Worcester Polytechnic Institute are included in one GAS canister. One will attempt to grow large zeolite crystals. Another will study the behavior of fluids in microgravity. A third, the Environmental Data Acquisition System, will record information about sound, light, temperature, and pressure within the GAS can. The fourth will measure the acceleration of the Shuttle along three axes with a high degree of precision. A fifth experiment will study the fogging of film in space. Don Carson is the NTM.



Getaway Special Checkout

8. **Flower and Vegetable Seeds Exposure to Space (G-451)**
   Sponsor: Sakana Seeds Corporation, Yokohama, Japan; Nissho Iwai American Corporation, New York, NY

G-451 will send 19 varieties of flower and vegetable seeds into space to determine how the unknown variables of microgravity will affect seed growth. After the shuttle lands and the seeds are recovered, the companies plan to distribute the seeds widely to amateur growers. Herbert Foster is the NTM.

9. **Semiconductor Crystal Growth Experiment (G-455)**
   Sponsor: Fujitsu Limited, Kawasaki, Japan; Nissho Iwai Corporation, Tokyo, Japan

G-455 consists of two experiments that investigate the potential advantages of crystal growth under microgravity. The two experiments are PbSnTe crystal growth from vapor and GaAs crystal growth from metallic solution. David Shrewsberry is the NTM.

10. **Orbiter Stability Experiment (G-507)**
    Sponsor: NASA Goddard Space Flight Center, Greenbelt, Maryland

G-507 will measure the shuttle's spectrum of small angular motions (or jitter) produced by the operation of mechanical systems, thruster firings, and human motions during normal crew activity.

In addition to the vibration measurements that will be made, Goddard's GAS can also carries a passive experiment to test the effects of radiation on photographic film. The experiment was developed and provided by Dr. Ernest Hammond of Morgan State University, Baltimore, Maryland. The NTM is Neal Barthleme.

11. **The Effect of Cosmic Radiation on Floppy Disks and Plant Seeds Exposure to Microgravity (G-616)**
    Sponsor: Redlands Unified School District, Redlands, California

G-616 consists of two experiments. The first will investigate static computer memory (floppy disks) to determine if cosmically charged particles will produce changes in data integrity or structure. The second will look for changes in the physiology or growth of 38 different types of plant seeds. Each cultivator will be examined post-flight in comparison with samples from the same seed lot, that remained on Earth, for a wide variety of possible effects or changes.

Several of the floppy disks contain programs developed by elementary school students. In addition, a large number of plant seeds will be distributed to every elementary and junior high school student in the Redlands Unified School District. Charles Kim is the NTM.

12. **Six Active Soldering Experiments (G-486)**
    Sponsor: EDSYN, Inc., Van Nuys, California

G-486 will investigate the process of soldering in microgravity and in a vacuum. The NTM is Bernard Karmilowicz.

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 program (OEX).

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 for flight. Principal investigators for these experiments represent NASA's Langley and Ames Research Centers, Johnson Space Center, and Goddard Space Flight Center.

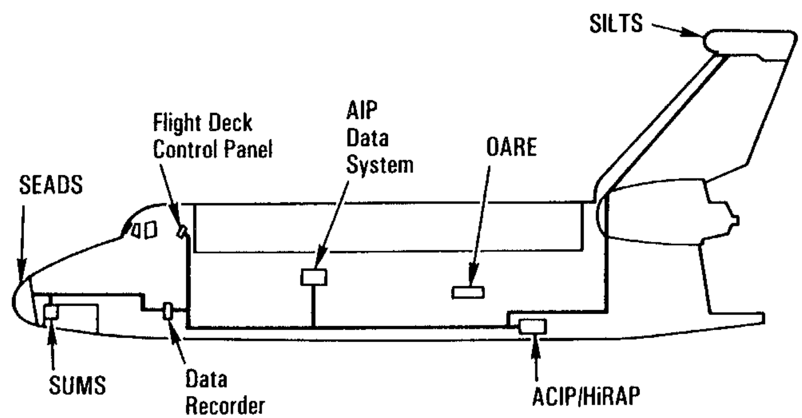
Seven OEX experiments will be flown on STS-40. Included among this group will be six experiments conceived by Langley researchers and one experiment developed by JSC.

The STS-40 OEX experiments are as follows:

- Shuttle Infrared Leeside Temperature Sensing (SILTS)
- Shuttle Entry Air Data System (SEADS)
- Shuttle Upper Atmosphere Mass Spectrometer (SUMS)
- Aerodynamic Coefficient Identification Package (ACIP)
- High-Resolution Accelerometer Package (HiRAP)
- Aerothermal Instrumentation Package (AIP)
- 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



Orbiter Experiments Program STS-40 Configuration experiment operation. The SCM is a microprocessor-based, solid-state control unit that provides a flexible means of commanding the OEX tape recorder and the OEX and modular auxiliary data system.

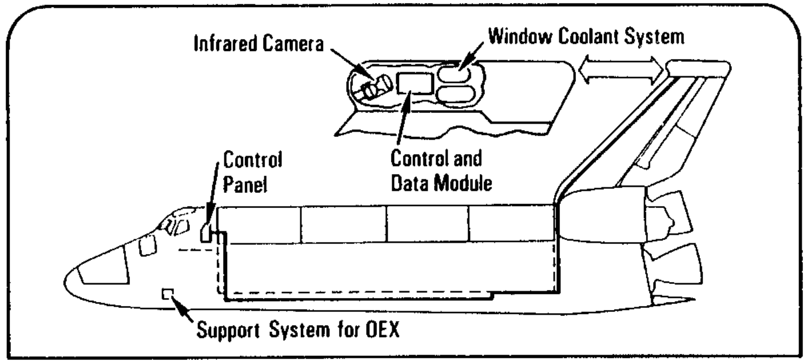
The PCM system accepts both digital and analog data from the experiments. It digitizes the analog data and molds it and the digital data received directly from the experiments into a single digital data stream that is recorded on the OEX recorder. The PCM also receives time information from the orbiter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

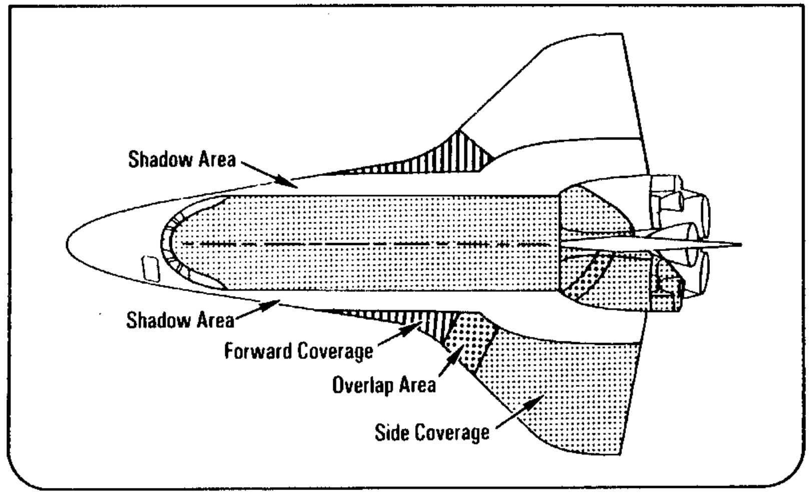
The SCM selects any of 32 inputs and routes them to any of 28 recorder tracks or four-line driver outputs to the T-O umbilical; executes real-time commands; controls experiments and data system components; and provides manual, semiautomatic and automatic control.

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 return of the orbiter, the data tape is played back for recording on a ground system. The tape is not usually removed from the recorder.

Shuttle Infrared Leeside Temperature Sensing. The SILTS experiment obtains high-resolution infrared imagery of the upper (leeward) surface of the orbiter fuselage and left wing during atmospheric entry. This information will increase understanding of leeside aeroheating phenomena and will be used to design a less conservative thermal protection system. SILTS provides the opportunity to obtain data under flight conditions for comparison with data obtained in ground-based facilities.

Six primary components make up the SILTS experiment system: (1) an infrared camera, (2) infrared-transparent windows, (3) a temperature-reference surface, (4) a data and control electronics module, (5) a pressurized nitrogen module and (6) window protection plugs. These components are installed in a pod





Shuttle Infrared Leeside Temperature Sensing System

that is mounted atop the vertical stabilizer and capped at the leading edge by a hemispherical dome. (The SILTS pod replaces the top 24 inches of the vertical stabilizer.) Within this dome, the infrared camera system is mounted in such a way that it rotates to view the orbiter leeside surfaces through either of two windows—one offering a view of the orbiter fuselage and the other a view of the left wing. The camera is sensitive to heat sources from 200 to 1,000 F.

The camera's indium-antimonide detector is cooled to cryogenic temperatures by a Joule-Thompson cryostat. The camera's field of view is 40 by 40 degrees. Its rotating prism system scans four 100-line fields each second, with a 4-1 interlace, resulting in a 400-line image.

Each of the two infrared-transparent window assemblies consists of dual silicone windows constrained within a carbon-phenolic window mount. The windows and window mount assemblies are designed to withstand the entry thermal environment to which they would be subjected without active cooling. They are, however, transpiration cooled with gaseous nitrogen during experiment operation so that they do not reach temperatures at which they would become significant radiators in the infrared. A small thermostatically controlled surface between the two window assemblies provides an in-flight temperature reference source for the infrared camera.

The pressurized nitrogen system comprises two 3,000-psi gaseous nitrogen bottles and all associated valves and plumbing. The pressure system supplies gaseous nitrogen to the cryostat for camera detector cooling, to the external window cavities for window transpiration cooling, and to pin pullers that initiate the ejection of the advanced flexible reusable surface insulation window protection plugs upon SILTS activation to expose the viewing ports and camera.

The information obtained by the camera is recorded on the OEX tape recorder. The data, when reduced and analyzed, will produce a thermal map of the viewed areas.

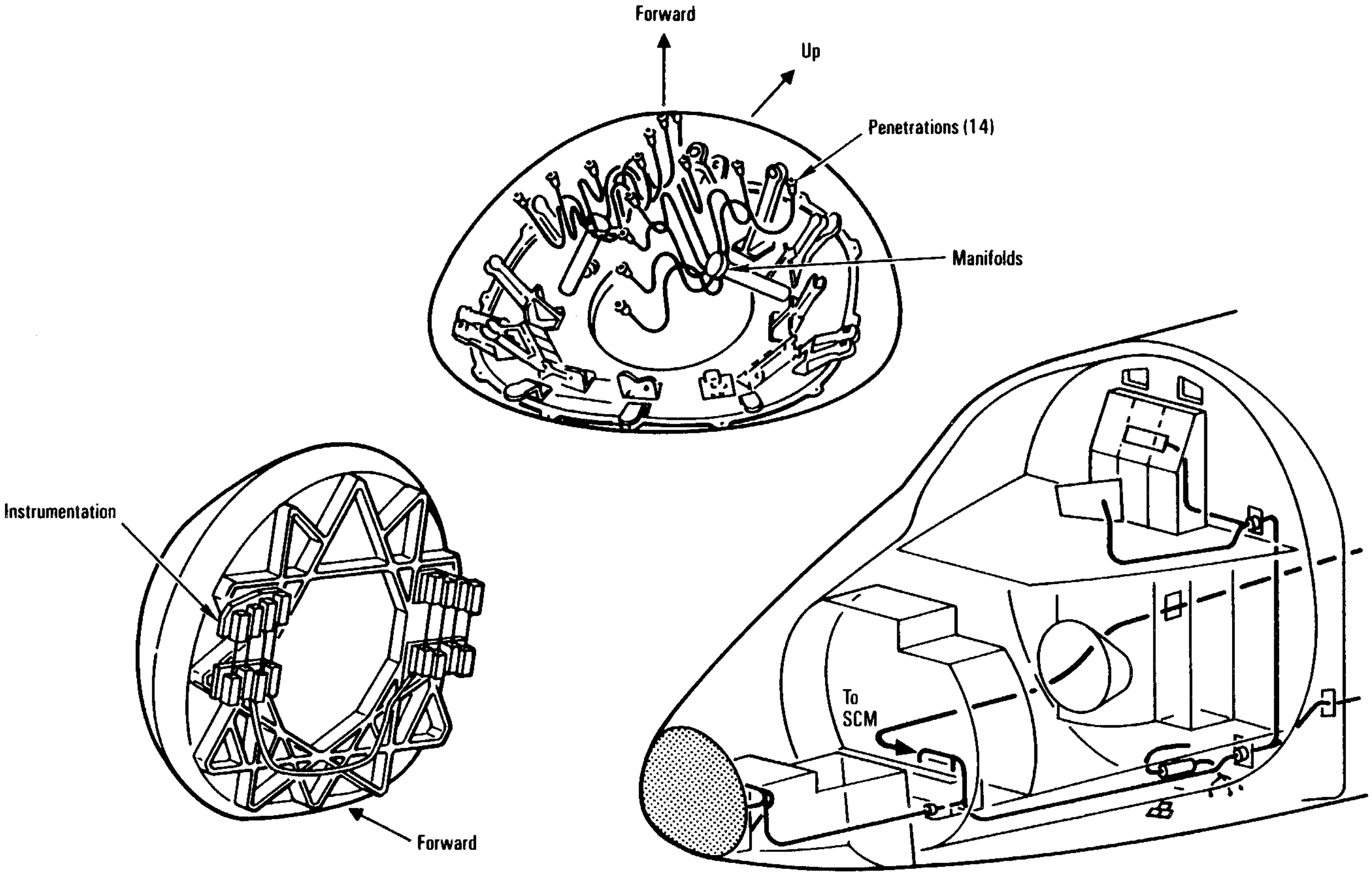
The SILTS experiment is initiated by the onboard computers approximately five minutes before entry interface, which occurs at an altitude of approximately 400,000 feet. The camera operates for approximately 18 minutes through the forward-facing window and left-facing window, alternating evenly between the two about every five seconds.

On two previous missions, the experiment obtained images of the left wing. For STS-35 and STS-40, the experiment has been configured to obtain images of the upper fuselage. SILTS has flown on four Columbia flights. David A. Throckmorton and E. Vincent Zoby of Langley Research Center are co-principal investigators.

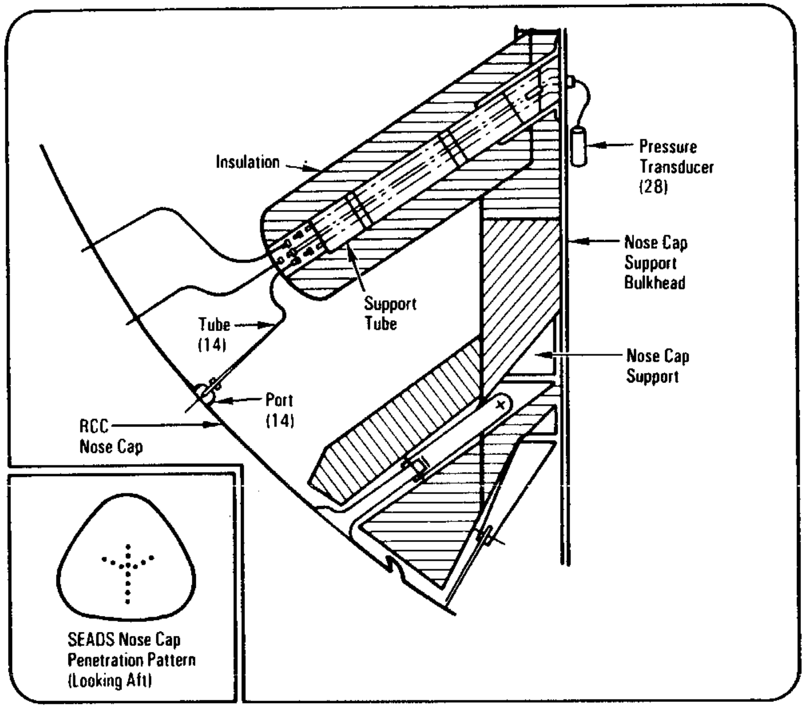
After the six planned SILTS missions, an analysis of structural loads will determine whether the SILTS pod should be removed and replaced with the original structure or remain in position for other uses. The pod thermal protection system is high-temperature reusable surface insulation black tiles, whose density is 22 pounds per cubic foot.

Shuttle Entry Air Data System. Accurate aerodynamic research requires precise knowledge of vehicle attitude and state. This information, commonly referred to as air data, includes vehicle angle of attack, angle of sideslip, free-stream dynamic pressure, Mach number and total pressure. An evaluation of the orbiter baseline air data system indicated that flight air data would not be available above approximately Mach 3.5 and that the accuracy of the air data would not satisfy aerodynamic research requirements. Therefore, SEADS was developed under the orbiter experiments program to take the measurements required for precise determination of air data across the orbiter's atmospheric flight-speed range (i.e., hypersonic, supersonic, transonic and subsonic Mach numbers) or from lift-off to 280,000 feet during ascent and from 280,000 feet to touchdown during entry.

The key to incorporating SEADS in the shuttle orbiter was the development of a technique for penetrating the orbiter's reinforced carbon-carbon nose cap to obtain the required pressure measurements. The SEADS nose cap penetration assembly evolved as a result of extensive design, fabrication and test programs that evaluated high-temperature (greater than 2,600 F) materials and configuration concepts. The coated columbium penetration assembly selected then was fabricated for installation



Shuttle Entry Air Data System



Shuttle Entry Air Data System

in a specially modified baseline geometry nose cap. The SEADS nose cap contains an array of 14 penetration assemblies, associated coated columbium pressure tubing, support structure, pressure transducers and system-monitoring instrumentation. Data from the SEADS pressure transducers are transmitted to the OEX support system and stored on the OEX tape recorder for postflight data analysis.

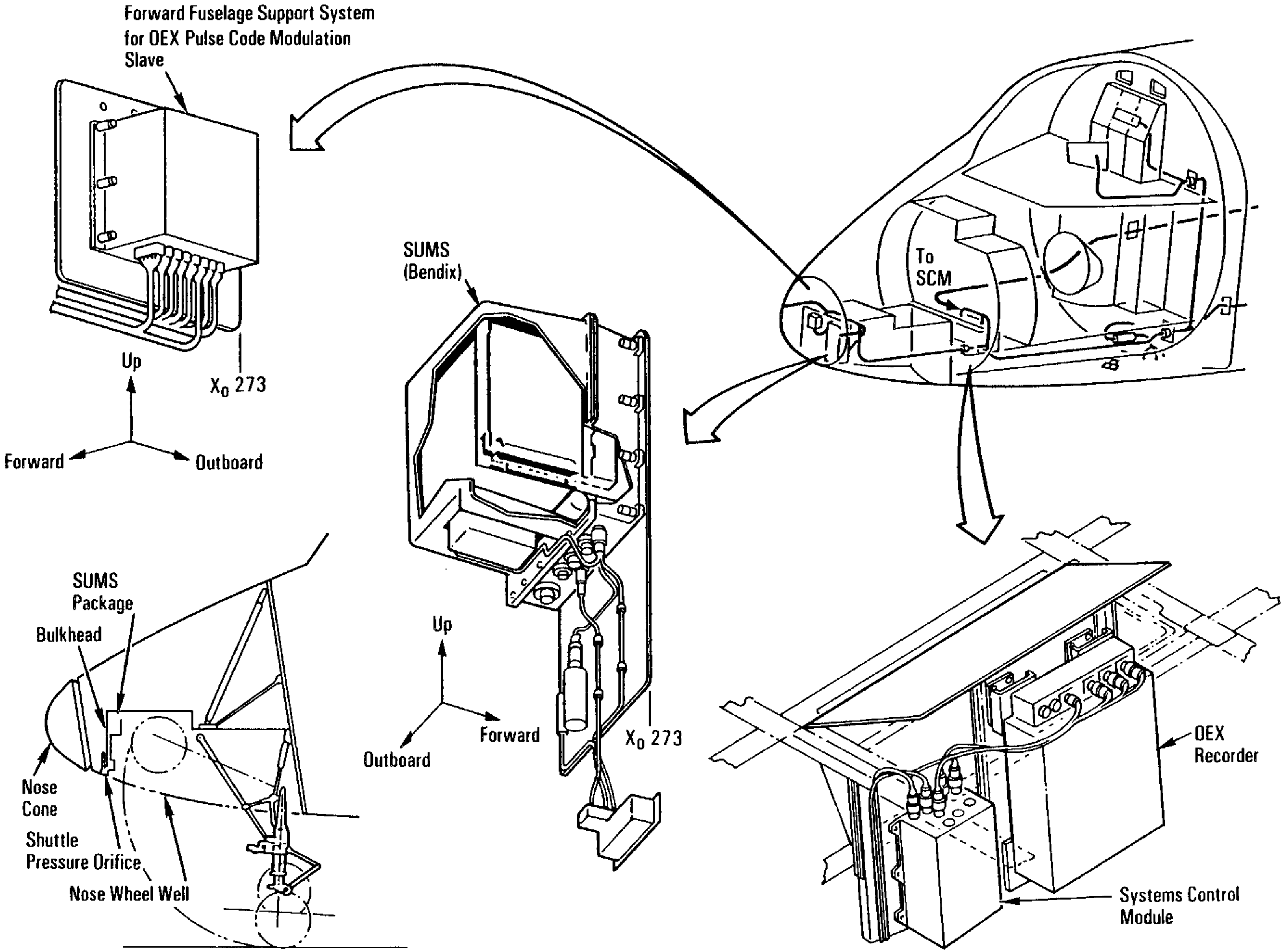
SEADS has flown on four previous flights of Columbia. Paul M. Siemers III, Langley Research Center, Hampton, Va., is the principal investigator.

Shuttle Upper Atmosphere Mass Spectrometer. The SUMS experiment will obtain measurements of free-stream density during atmospheric entry in the hypersonic, rarefied flow regime. These measurements, combined with acceleration measurements from the companion high-resolution accelerometer package experiment, will allow calculation of orbiter aerodynamic coefficients in the flow regime previously inaccessible to experimental and analytic techniques. SUMS complements SEADS by providing data at higher altitudes. The resultant flight data base will aid in future development of analysis techniques and laboratory facilities for predicting winged-entry-vehicle performance in hypersonic rarefied flow. Furthermore, SUMS will measure equilibrium gas composition at the inlet port, making the experiment a pathfinder for future mass spectrometer application in the study of aerothermodynamic properties of the transition flow field.

The SUMS experiment system consists of a sample orifice, an inlet system and a mass spectrometer. The sample orifice penetrates a thermal tile just aft of the fuselage stagnation point and just forward of the orbiter nose wheel well. The orifice is connected to the inlet system by a short tube through the forward nose wheel well bulkhead. The inlet system is connected through a longer tube to the mass spectrometer, which is mounted above the inlet system on the forward nose wheel well bulkhead. SUMS is designed for easy removal and reinstallation between flights to accommodate modification or repair.

The mass spectrometer is a flight spare unit from the Viking project's upper atmosphere mass spectrometer system. The unit has been modified to be compatible with the orbiter's mechanical, electrical and data systems. The mass spectrometer measures gases from hydrogen through carbon dioxide at a five-second rate. The inlet system contains two switchable flow restrictors that expand the measurement range of the mass spectrometer and position its measurement interval over the desired altitude range. Data from SUMS are output to the OEX data system for recording during flight operation.

SUMS is controlled by stored commands that are transmitted to the orbiter during flight and by internal software logic. Application of power for vacuum maintenance or for normal



Shuttle Upper Atmosphere Mass Spectrometer

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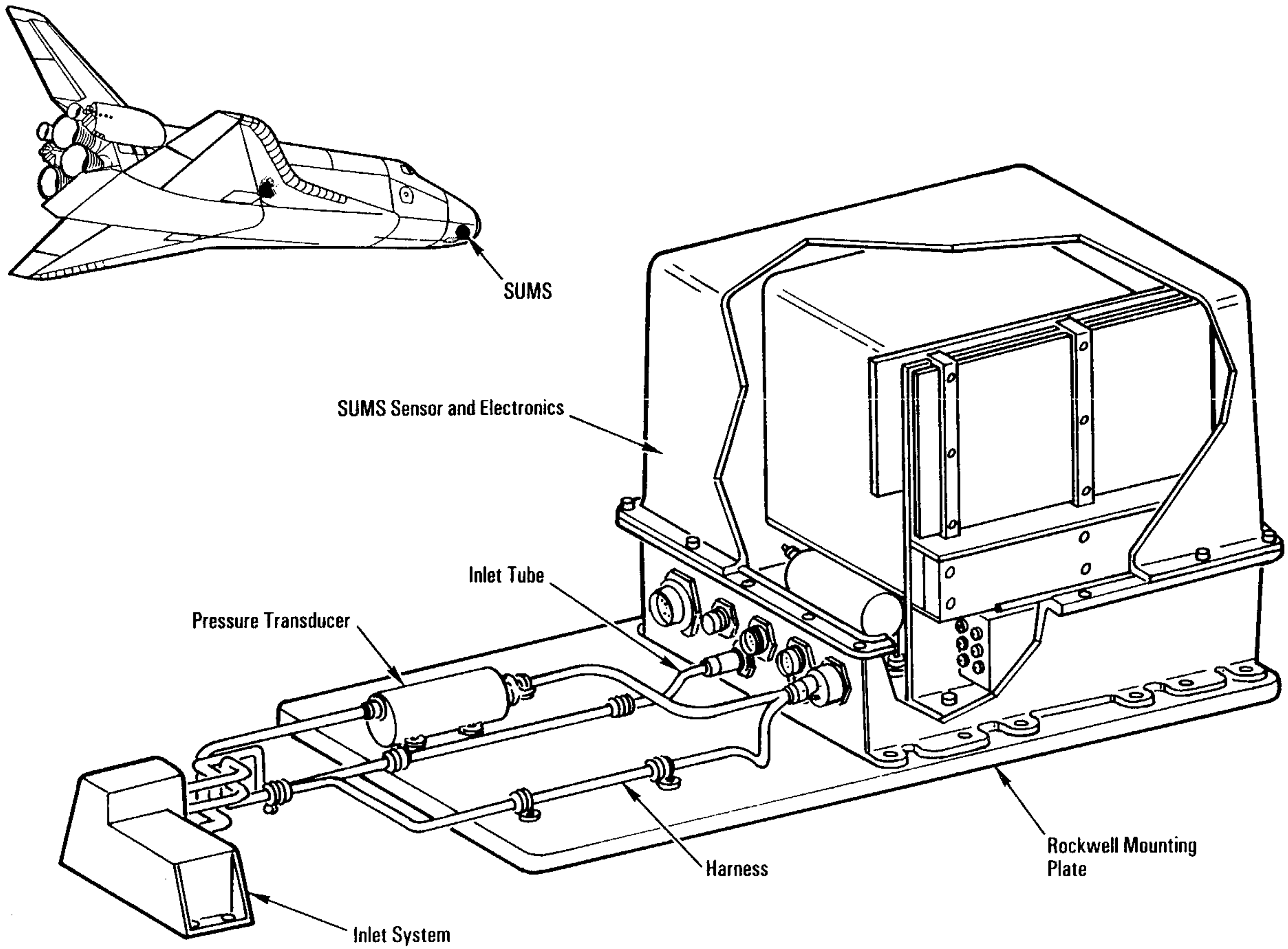


Shuttle Upper Atmosphere Mass Spectrometer operation is controlled by stored commands; while internal control of system operation, such as opening and closing valves, is performed by preprogrammed logic. SUMS will be powered on shortly before deorbit burn initiation and will sample the inlet gases down to an altitude of 40 nautical miles. At an altitude of about 59 nautical miles, the range valve will close to switch between the two flow restrictors. At 59 nautical miles, the inlet valve and protection valve will close; but the mass spectrometer will continue to operate until landing, observing the pump-down and background signals after entry.

SUMS was previously flown on STS-61C and STS-35. Robert C. Blanchard and Roy J. Duckett of Langley Research Center are co-principal investigators.

Operation of SUMS on repeated shuttle flights will not only build a substantial body of aerothermodynamic data for future winged-entry-vehicle design applications, but also add to the knowledge of mass spectrometer applications in aerothermodynamic research. As a further benefit, data will be obtained on atmospheric properties in the altitude range where experimental data are, to date, extremely sparse.

Aerodynamic Coefficient Identification Package. Although all of the generic data types required for aerodynamic parameter identification are available from the baseline orbiter systems, the data are not suitable for experimentation because of such factors as sample rate deficiencies, inadequate data resolution or computer cycle time and core size interactions. In addition, the baseline data are operational measurements that are not subject to the desired changes for conducting experiments. The ACIP is a group of sensors that will be placed on the orbiter to obtain experiment measurements unavailable through the baseline system.

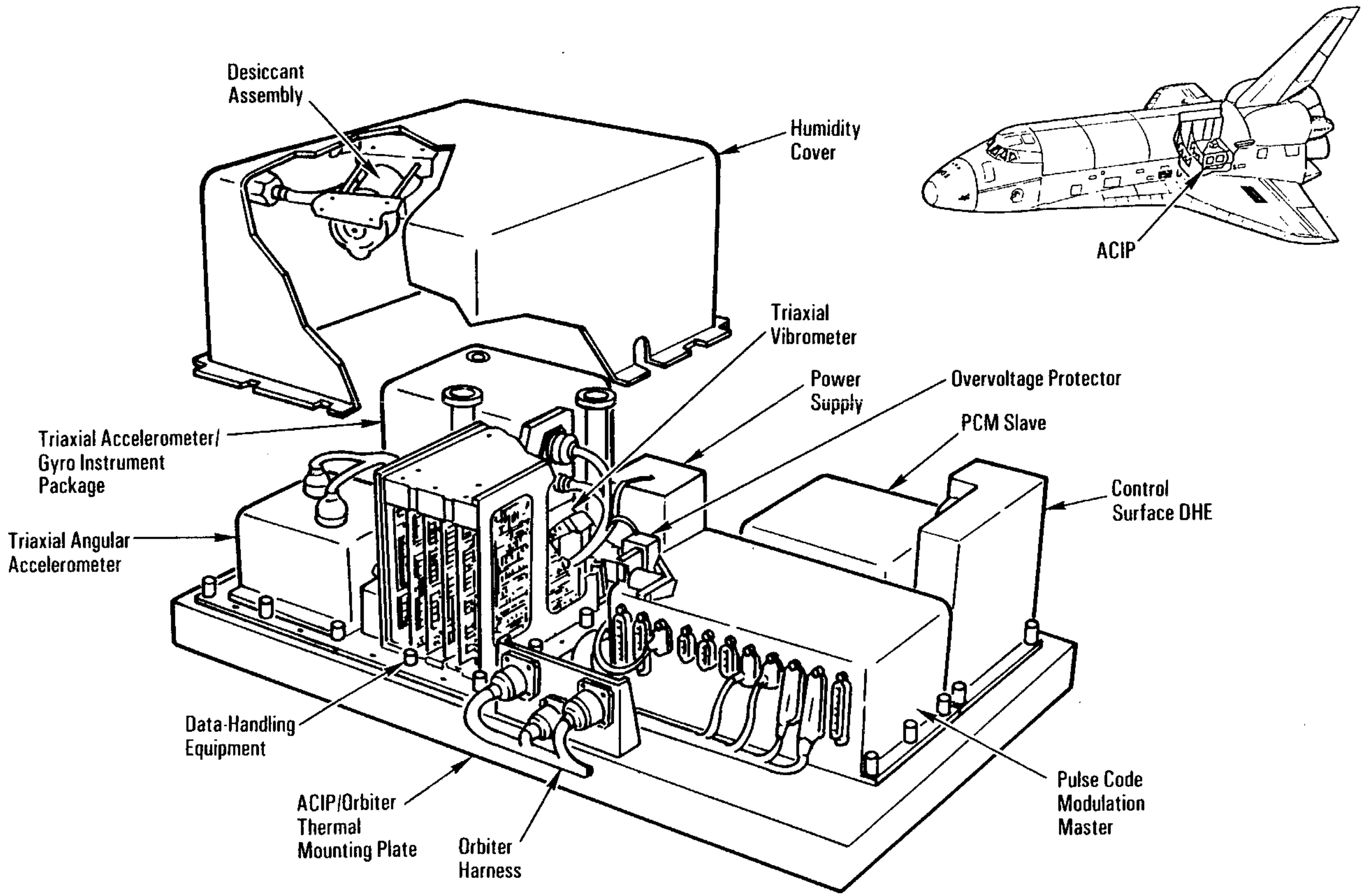
The primary ACIP objectives are as follows: (1) to collect aerodynamic data in the hypersonic, supersonic and transonic flight regimes, regions in which there has been little opportunity for gathering and accumulating practical data; (2) to establish an extensive aerodynamic data base for verifying and correlating ground-based test data, including assessments of the uncertainties in such data; and (3) to provide flight dynamics state-variable data in support of other technology areas, such as aerothermal and structural dynamics.

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

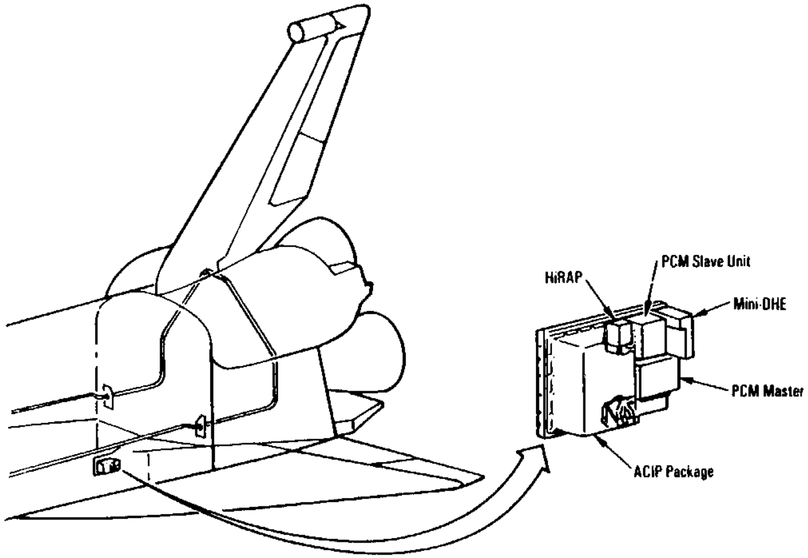
The ACIP incorporates three triads of instruments: one of linear accelerometers, one of angular accelerometers and one of rate gyros. Also included are the power conditioner for the gyros, the power control system and the housekeeping components for the instruments. The ACIP is aligned to the orbiter's axes with extreme accuracy. Its instruments continually sense the dynamic X, Y and Z attitudes and the performance characteristics of the orbiter during the launch, orbital, entry and descent phases of flight. In addition, the ACIP receives the indications of orbiter control surface positions and converts the information into higher orders of precision before recording it with the attitude data. The output signals are routed to the pulse code modulation system for formatting with orbiter time data and data from the orbiter experiments. The data are then stored in the OEX tape recorder.

The ACIP has flown on all flights of orbiters Columbia and Challenger. David B. Kanipe, Johnson Space Center, Houston, is the ACIP principal investigator.

High-Resolution Accelerometer Package. This experiment uses an orthogonal, triaxial set of sensitive linear accelerometers to take accurate measurements of low-level (down to micro-g's) aerodynamic accelerations along the orbiter's principal axes during initial re-entry into the atmosphere, i.e., in the rarefied flow regime.



Aerodynamic Coefficient Identification Package



ACIP—Aerodynamic Coefficient Identification Package
DHE—Data Handling Equipment
HiRAP—High-Resolution Accelerometer Package
PCM—Pulse Code Modulation

High-Resolution Accelerometer Package

The aerodynamic acceleration data from the HiRAP experiment, output on existing ACIP channels, have been used to calculate rarefied aerodynamic performance parameters and/or atmospheric properties pertaining to several flights, beginning with the STS-6 mission. These flight data support advances in predicting the aerodynamic behavior of winged entry vehicles in the high-speed, low-density flight regime, including free molecular flow and the transition into the hypersonic continuum. Aerodynamic performance under these conditions cannot be simulated in ground facilities; consequently, current predictions rely solely on computational techniques and extrapolations of tunnel data. For improvement or advances, these techniques depend on actual flight data to serve as benchmarks, particularly in the transition regime between free molecular flow and continuum flow.

Advancements in rarefied aerodynamics of winged entry vehicles may also prove useful in the design of future advanced orbital transfer vehicles. Such OTVs may use aerodynamic braking and maneuvering to dissipate excess orbital energy into the upper atmosphere upon return to lower orbits for rendezvous with an orbiter from the space station. A key aerodynamic parameter in the OTV design is the lift-to-drag ratio, which is measured directly in the HiRAP experiment. Furthermore, an OTV may require a flight-proven, sensitive onboard accelerometer system to overcome uncertainties in the upper atmosphere. The experience gained from the planned multiple HiRAP flights may provide valuable test data for the development of future navigation systems. In addition, the experiment provides data on key atmospheric properties (e.g., density) in a region of flight that is not readily accessible to orbital vehicles or regular meteorological soundings.

HiRAP has been flown on 12 previous missions of the orbiters Columbia and Challenger. Robert C. Blanchard, Langley Research Center, is the HiRAP principal investigator.

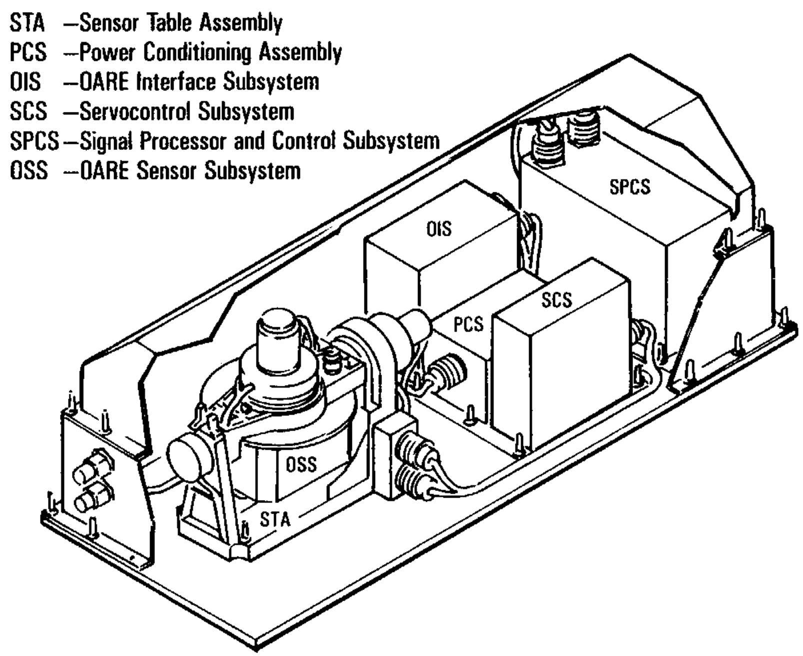
AEROTHERMAL INSTRUMENTATION PACKAGE (AIP)

The AIP comprises some 125 measurements of aerodynamic surface temperature and pressure at discrete locations on the upper surface of the orbiter's left wing and fuselage and the vertical tail. These sensors were originally part of the development flight instrumentation system that flew aboard Columbia during its Orbital Flight Test missions (STS-1 through 5). They have been reactivated through the use of an AIP-unique data handling system. Among other applications, the AIP data provide "ground-truth" information for the SILTS experiment. The AIP has flown on three previous Columbia flights. David A. Throckmorton, Langley Research Center, is principal investigator.

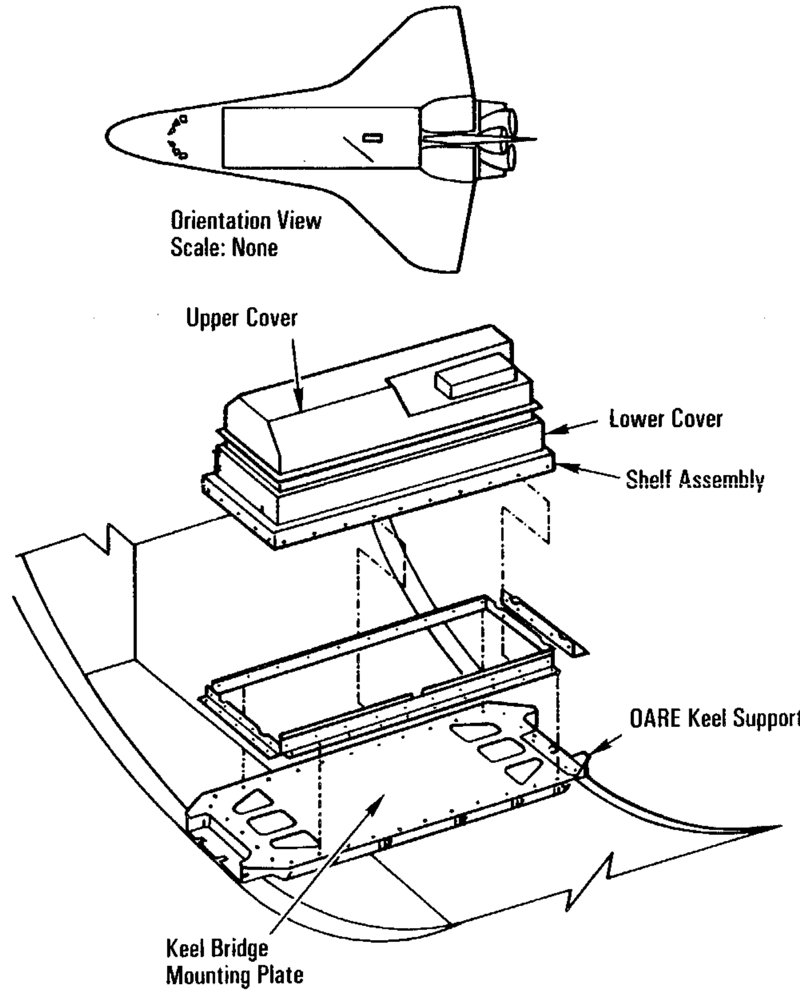
ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

The Orbital Acceleration Research Experiment (OARE) complements the ACIP and HiRAP instruments by extending the altitude range over which vehicle acceleration data can be obtained to orbital altitudes. Like the HiRAP, the OARE instrument comprises a three-axis set of extremely sensitive linear accelerometers. The OARE sensors are substantially more sensitive than the HiRAP sensors.

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 enables an accurate instrument calibration to be performed on orbit.



OARE Experiment



OARE Installation

The OARE instrument is installed for flight on a special mounting plate within the orbiter's payload bay. OARE data are recorded on the mission payload recorder. This is the first flight for the OARE instrument. Principal investigator is Robert C. Blanchard of Langley Research Center.

ASCENT AERODYNAMIC DISTRIBUTED LOADS VERIFICATION ON OV-102 (DTO 236).

ENTRY AERODYNAMIC CONTROL SURFACES TEST, PART 5 (DTO 242). The purpose of this DTO is to perform a series of programmed test input maneuvers and one manual body flap maneuver during the entry and TAEM phases to obtain aerodynamic response data. This data will be used to evaluate the effectiveness of various aerodynamic control surfaces.

ASCENT STRUCTURAL CAPABILITY EVALUATION (DTO 301D). The purpose of this DTO is to collect data to expand the data base of ascent dynamics for various weights.

ASCENT COMPARTMENT VENTING EVALUATION (DTO 305D).

DESCENT COMPARTMENT VENTING EVALUATION (DTO 306D).

ENTRY STRUCTURAL CAPABILITY (DTO 307D). This DTO will collect data to expand the data base of flight loads during entry.

ET TPS PERFORMANCE (DTO 312).

HOT NOSEWHEEL STEERING RUNWAY EVALUATION (DTO 517).

CABIN AIR MONITORING (DTO 623). This DTO will use the solid sorbent sampler to continuously sample the orbiter atmosphere throughout the flight. The sampler collects trace levels of volatile contaminants that are used to determine spacecraft air quality and the effectiveness of the orbiter's environmental control and life support system in removing these compounds from the air. The solid sorbent sampler is to be flown on all Spacelab manned module flights.

CAMCORDER DEMONSTRATION, CANON AIA MARK2 (DTO 630). This DTO will evaluate the unique hardware aspects of a camcorder, as well as crew usage and interaction. Various factors affecting camera performance will be evaluated, including low-light level operation, macro zoom capability, and fiber optics accessories.

ON-ORBIT CABIN AIR CLEANER EVALUATION (DTO 637). This DTO will flight test a proposed system to filter the cabin air. Objectives include evaluation of the air velocity produced by the fan, noise generation, and general air quality.

WATER SEPARATOR FILTER PERFORMANCE EVALUATION (DTO 647). This DTO will evaluate the performance of a filter installed at the inlet of the water separator. The proposed filter should remove debris from the air/water stream coming from the cabin heat exchanger.

TDRS S-BAND FORWARD LINK RF POWER LEVEL EVALUATION (DTO 700-1).

HEADS-UP DISPLAY BACKUP TO CREW OPTICAL ALIGNMENT SIGHT (DTO 785). This DTO will verify the suitability of the HUD as a star sighting device for IMU alignments.

VENT UPLINK CAPABILITY (DTO 796).

CROSSWIND LANDING PERFORMANCE (DTO 805).

OEX SHUTTLE INFRARED LEESIDE TEMPERATURE SENSING (DTO 901). See Orbiter Experiments Program section.

ADDITIONAL STOWAGE EVALUATION FOR EXTENDED DURATION ORBITER (DTO 823).

OEX SHUTTLE UPPER ATMOSPHERE MASS SPECTROMETER (DTO 902). See Orbiter Experiments Program section.

OEX SHUTTLE ENTRY AIR DATA SYSTEM (DTO 903). See Orbiter Experiments Program section.

OEX ORBITAL ACCELERATION RESEARCH EXPERIMENT (DTO 910). See Orbiter Experiments Program section.

OEX AEROTHERMAL INSTRUMENTATION PACKAGE (DTO 911). See Orbiter Experiments Program section.

IN-FLIGHT RADIATION DOSE DISTRIBUTION, TISSUE EQUIVALENT PROPORTIONAL COUNTER ONLY, ACTIVATION ON FLIGHT DAY 2 (DSO 469). This DSO is to establish and evaluate analytical and measurement methods for assessing and managing health risks from exposure to space radiation. Several instruments, mounted in the middeck, will measure the radiation environment inside the shuttle.

IN-FLIGHT AEROBIC EXERCISE (DSO 476). Daily inflight aerobic exercise will 1) inhibit the decrease in cardiac dimensions observed during space flight and thus improve postflight orthostatic tolerance, and 2) minimize the loss of aerobic capacity after flight. The objectives of this DSO are to document the effects of daily aerobic exercise on 1) protection of left ventricular dimensions, 2) postflight orthostatic function, and 3) the rate at which these factors return to their preflight baseline values during the postflight period. In addition, the effects of regular aerobic exercise on the maintenance of aerobic power and economy will be determined.

AIR MONITORING INSTRUMENT EVALUATION AND ATMOSPHERIC CHARACTERIZATION, MICROBIAL AIR SAMPLE AND ARCHIVAL ORGANIC SAMPLER (DSO 611). This DSO will evaluate and verify air monitoring equipment to ensure proper function and operation inflight. In addition, data will be collected on contaminant levels to establish baseline levels and to evaluate potential risks to crew health and safety.

DOCUMENTARY TELEVISION (DSO 901). This objective provides live television or VTR dumps of crew activities, orbiter operations, payload deployment/retrieval and operations, Earth views, rendezvous and proximity operations. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. The broadcasts are accompanied with operational air-to-ground and/or operational intercom audio. VTR recording may be used when live television is not possible.

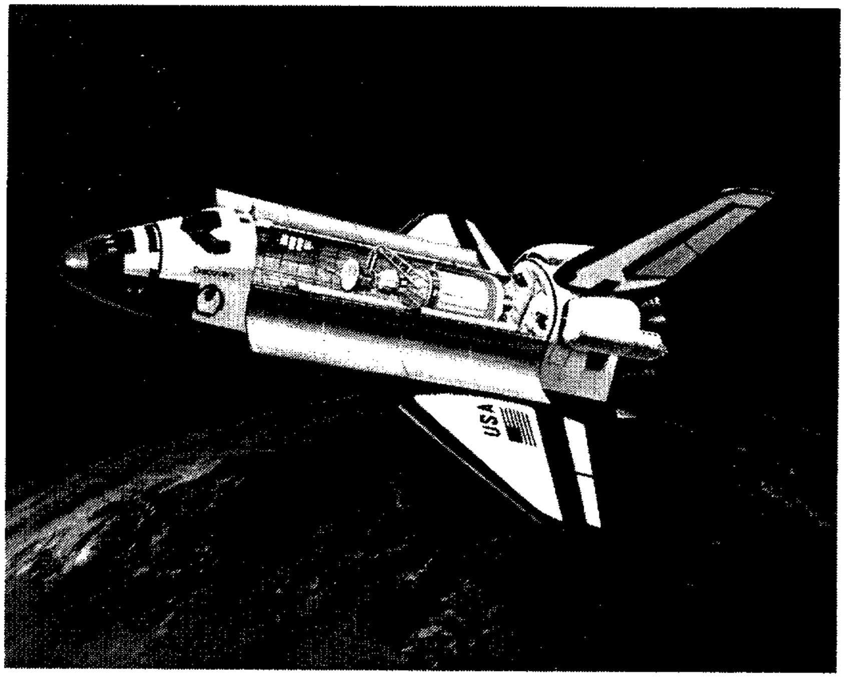
DOCUMENTARY MOTION PICTURE PHOTOGRAPHY (DSO 902). This objective provides documentary and public affairs motion picture photography of the orbiter's basic capabilities and key flight objectives. Documentation will include launch, crew activities, payload deployment, landing, and unscheduled activities of special interest.

DOCUMENTARY STILL PHOTOGRAPHY (DSO 903). This objective provides still photography of crew activities, orbiter operations, payload deployment/retrieval and operation, Earth views, and unscheduled items of interest.

ASSESSMENT OF HUMAN FACTORS (DSO 904). This DSO will analyze data from the sound and vibration recording devices relative to crew comments and crew performance. In addition, it will evaluate human–machine interactions during routine Spacelab operations (e.g., stowage, hand and foot restraints, wire and cable interface, etc.).

CHANGES IN BARORECEPTOR REFLEX FUNCTION (DSO 601).

POSTURAL EQUILIBRIUM CONTROL DURING LANDING EGRESS (DSO 605).



STS-40

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

May 1991

Rockwell International
Space Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the 11th flight of Columbia and the 41st for the space shuttle.

The flight crew for the STS-40 mission consists of commander Bryan D. O'Connor; pilot Sidney (Sid) M. Gutierrez; mission specialists James (Jim) P. Bagian, Tamara (Tammy) E. Jernigan, and M. Rhea Seddon; and payload specialists Francis A. (Drew) Gaffney and Millie Hughes-Fulford.

STS-40's primary mission objective is to successfully perform the planned operations of the Spacelab Life Sciences (SLS)-1 payload. The STS-40 SLS-1 mission is the first Spacelab mission dedicated exclusively to life sciences research. Four crew members (payload specialists Francis A. (Drew) Gaffney and Millie Hughes-Fulford; and mission specialists James (Jim) P. Bagian and M. Rhea Seddon) will perform experiments to see how their bodies adapt to space flight. The tests will continue for several weeks after the mission to monitor how their bodies readjust to living on Earth. SLS-1 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-1 and future missions is to find out why these changes take place and learn how to prevent or control undesirable responses.

Twenty SLS-1 investigations and eight secondary SLS-1 studies will be performed. The investigations will study six body systems, and include six cardiovascular/cardiopulmonary experiments, three blood experiments, six musculoskeletal experiments, three neurovestibular experiments, one immune system experiment, and one renal-endocrine system experiment. Of the 20 investigations, 10 involve human subjects, nine use rodents, and one uses jellyfish. Measurements will be made before and after the flight to determine how microgravity affects the rodents and jellyfish.

The primary investigations are as follows:

. Influence of Weightlessness Upon Human Autonomic Cardiovascular Controls

  The carotid sinus baroceptor reflex in humans is measured before, during, and after space flight to examine the relationship between the baroreflex response and the development of orthostatic intolerance.

. Inflight Study of Cardiovascular Deconditioning

  The effects of microgravity on circulatory and respiratory functions are determined for resting and exercising subjects by means of gas analysis, using a noninvasive rebreathing technique.

- Correlation of Macro- and Microcirculatory Alterations During Weightlessness

  Changes in both resting cardiovascular function and microcirculation resulting from acute and prolonged exposure to microgravity are detected by directly measuring arterial and venous blood pressures and atrial blood flow in rats.

- Pulmonary Function During Weightlessness

  Human pulmonary function in microgravity is observed by noninvasive measurement of parameters related to pulmonary gas exchange. Results will be compared to those obtained in Earth gravity.

- Cardiovascular Adaptation of White Rats to Decreased Gravity of Space Shuttle/Spacelab in Flight Conditions

  Postflight techniques are employed to determine whether rats can be used as animal models to study fluid shifts and other cardiovascular changes associated with microgravity.

- Cardiovascular Adaptation to Microgravity

  This study of cardiovascular function and dimensions uses a variety of test methods on subjects at rest and during exercise.

- Regulation of Erythropoiesis During Space Flight

  The roles of nutritional status and hemoconcentration in rat red blood cell production during space flight are studied.

- Protein Metabolism During Space Flight

  Human whole-body protein metabolism is studied, 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 Microgravity on Biochemical and Metabolic Properties of Skeletal Muscle in Rats

  Alterations in the functional capacity of rat skeletal muscles are determined by the use of preflight and postflight exercise tests and tissue analysis.

- Regulation of Blood Volume During Space Flight

  This investigation is designed to evaluate the use of rats as models for humans in hematological studies.

- Fluid-Electrolyte Regulation During Space Flight

  Blood, urine, and saliva samples are analyzed for parameters that indicate changes in fluid, electrolyte, renal, and circulatory status of humans exposed to weightlessness.

. Bone, Calcium, and Space Flight

Analysis of rat wastes for tracer calcium added to the diet and bone morphology examinations are used to characterize bone loss attributable to microgravity.

. Lymphocyte Proliferation in Weightlessness

The effects of stress and weightlessness on human lymphocyte function and proliferation are studied in samples exposed to specific mitogens.

. Skeletal Myosin Isoenzymes in Rats Exposed to Microgravity

The role of myosin isoenzymes and the alteration of muscles is studied, using inflight activity monitoring of rats and postflight tissue analysis.

. Influence of Space Flight on Erythrokinetics in Man

Blood is collected from crewmembers to determine whether reduced red cell mass associated with microgravity is due to decreased production or increased hemolysis.

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

Morphological, biochemical, and histochemical changes in muscles attributable to launch and reentry stress, inflight atrophy, and postflight repair are determined by inflight activity monitoring and postflight analysis of enzymes.

. Pathophysiology of Mineral Loss During Space Flight

Dual stable isotopes of calcium are administered to crewmembers (one orally and one intravenously) to determine whether elevated fecal calcium is caused by decreased gastrointestinal absorption or by active gastrointestinal excretion.

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

The biochemical and structural integrity of the otolith organs of the rat are studied postflight to determine the chronic and/or progressive effects of space flight.

. Effects of Microgravity-Induced Weightlessness on Aurelia Ephyra Differentiation and Statolith Synthesis

Jellyfish will be observed to determine how metamorphosis in microgravity affects development, swimming behavior, statolith mineralization, and overall morphology.

. Vestibular Experiments in Spacelab

A study of human vestibular function and adaptation is performed using several techniques with emphasis on otolith system measurements.

Eight secondary studies will gather data that complement the major investigations or develop space facilities for future missions. The secondary studies are as follows:

. Noninvasive Estimation of Central Venous Pressure During Space Flight

  This investigation uses a noninvasive technique to measure central venous pressure.

. Solid Surface Combustion Experiment (SSCE)

  SSCE will study combustion phenomena in microgravity.

. Space Acceleration Measurement System (SAMS)

  Three triaxial sensor heads will be installed in Spacelab to record on-orbit acceleration levels.

. Characterization of Airborne Particulate Matter

  This hardware verification test will look for potentially hazardous particles and help determine their sources.

. Validation of Intravenous Fluid System

  This hardware verification test will verify Space Station Health Maintenance Facility equipment and medical procedures.

. Particulate Containment Demonstration Test

  This hardware verification test will be carried out using the General Purpose Work Station (GPWS), the General Purpose Transfer Unit (GPTU), and the Research Animal Holding Facility (RAHF).

. Small Mass Measurement Instrument (SMMI)

  This is a hardware verification test of a rack-mounted Life-Sciences Laboratory Equipment (LSLE) item that can determine the mass of small objects.

. Medical Restraint Systems

  Assembly of the Medical Restraint Systems, a prototype surgical workstation, will be evaluated in microgravity.

Three middeck payloads, the Physiological Monitoring System (PMS), Urine Monitoring System (UMS), and Animal Enclosure Modules (AEM), are used in the performance of SLS-1 primary and secondary studies. PMS evaluates crew motion sickness. UMS obtains samples of urine from each crew member for storage in a refrigerator/freezer. UMS interconnects with the water from the galley and the orbiter waste collection system. AEM will be flown to demonstrate the adequate housing of a number of rats in a middeck locker.

STS-40 secondary payloads include the Middeck Zero-gravity Dynamics Experiment (MODE) and 12 Getaway Special (GAS) canister experiments mounted on a GAS Bridge Assembly (GBA) in Columbia's payload bay.

The MODE is housed in Columbia's middeck and is designed to study two aspects of nonlinear behavior of space structures and contains fluids which are gravity dependent.

The 12 GAS experiments aboard STS-40 are as follows:

. Solid-State Microaccelerometer Experiment (G-021)

  This experiment will test new solid-state microaccelerometer integrated circuits under low-gravity conditions.

. Experiment in Crystal Growth (G-052)

  G-052 will melt and regrow gallium arsenide crystals in the absence of convective effects.

. Orbital Ball Bearing Experiment (G-091)

  G-091 is a ball bearing experiment consisting of a pellet of low-melting point tin-lead-bismuth alloy which will be melted under low-gravity conditions.

. In-Space Commercial Processing (G-105)

  G-105 consists of six experiments performing various tests concerned with aqueous phases, growing organic crystals and thin films, electrodepositing various metallic materials, collecting cosmic ray interactions, and measuring cosmic radiation on genetic and chromosomal structure of yeast.

. Foamed Ultralight Metals (G-286)

  G-286 will produce three types of lightweight foamed metal samples.

. Chemical Precipitate Formation (G-405)

  G-405 will record the formation of several types of chemical precipitates in the microgravity environment.

. Five Microgravity Experiments (G-408)

  G-408 consists of five experiments performing various tests covering determining whether low gravity promotes the growth of large zeolite crystals, studying several methods for measuring the behavior of a two-phase fluid system, photographing film fogging by radiation in low-Earth orbit, recording low-level accelerations while in orbit, and cataloguing the environmental conditions internal to the canister.

. Flower and Vegetable Seeds Exposure to Space (G-451)

  G-451 will investigate the possibilities of ecological alteration and mutation of plant species when flown in low Earth orbit.

. Semiconductor Crystal Growth Experiment (G-455)

G-455 consists of two experiments that investigate the structure and formation of crystal growth and defects in crystal growth in microgravity.

. Six Active Soldering Experiments (G-486)

G-486 will investigate the process of soldering in microgravity and in a vacuum.

. Orbiter Stability Experiment (G-507)

G-507 consists of two experiments: the orbiter stability experiment (OSE) and a passive experiment to evaluate fogging of photographic emissions due to energetic particles. The OSE will measure the high-frequency variations of the STS orbiter's orientation due to vibrations during routing in-flight operations.

. The Effect of Cosmic Radiation on Floppy Disks and Plant Seeds Exposure to Microgravity (G-616)

G-616 will study the effects of cosmic rays, background radiation, and the Earth's magnetic field on floppy disk storage media.

Seven Orbiter Experiments (OEX) Program experiments will be flown on STS-40, along with 22 development test objectives and 9 detailed supplementary objectives.

MISSION STATISTICS

Vehicle: Columbia (OV-102), 11th flight

Launch Date/Time:

5/22/91 8:00 a.m., EDT
7:00 a.m., CDT
5:00 a.m., PDT

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

Launch Window: 2 hours

Mission Duration: 9 days, 3 hours, 50 minutes

Landing: Nominal end of mission on Orbit 147

5/31/91 11:50 a.m., EDT
10:50 a.m., CDT
8:50 a.m., PDT

Runway: Nominal end-of-mission landing on concrete runway 22, Edwards Air Force Base (EAFB), Calif. Weather alternates are Northrup Strip (NOR), White Sands, New Mexico; and KSC.

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

Return to Launch Site: KSC

Abort-Once-Around: EAFB; alternates are NOR and KSC

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

Altitude: 160 by 150 nautical miles (184 by 172 statute miles)

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Total Lift-off Weight: Approximately 4,519,081 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 250,398 pounds

Payload Weight Up: Approximately 25,942 pounds

Payload Weight Down: Approximately 25,942 pounds

Orbiter Weight at Landing: Approximately 225,492 pounds

Payloads--Cargo Bay (* denotes primary payload): Spacelab Life Sciences (SLS)-1 with long module*, GAS Bridge Assembly with 12 Getaway Specials (GAS), OEX Orbiter Acceleration Research Experiment (OARE)

Payloads--Middeck: Physiological Monitoring System (PMS), Urine Monitoring System (UMS), Animal Enclosure Modules (AEM), Middeck Zero-gravity Dynamics Experiment (MODE)

Flight Crew Members:
- Commander: Bryan D. O'Connor, second space shuttle flight
- Pilot: Sidney (Sid) M. Gutierrez, first space shuttle flight
- Mission Specialist 1: James (Jim) P. Bagian, second space shuttle flight
- Mission Specialist 2: Tamara (Tammy) E. Jernigan, first space shuttle flight
- Mission Specialist 3: M. Rhea Seddon, second space shuttle flight
- Payload Specialist 1: Francis A. (Drew) Gaffney, first space shuttle flight
- Payload Specialist 2: Millie Hughes-Fulford, first space shuttle flight

Ascent Seating:
- Flight deck, front left seat, commander Bryan D. O'Connor
- Flight deck, front right seat, pilot Sidney (Sid) M. Gutierrez
- Flight deck, aft center seat, mission specialist Tamara (Tammy) E. Jernigan
- Flight deck, aft right seat, mission specialist James (Jim) P. Bagian
- Middeck, mission specialist M. Rhea Seddon
- Middeck, payload specialist Francis A. (Drew) Gaffney
- Middeck, payload specialist Millie Hughes-Fulford

Entry Seating:
- Flight deck, aft center seat, mission specialist Tamara (Tammy) E. Jernigan
- Flight deck, aft right seat, mission specialist M. Rhea Seddon
- Middeck, mission specialist James (Jim) P. Bagian
- Middeck, payload specialist Francis A. (Drew) Gaffney
- Middeck, payload specialist Millie Hughes-Fulford

Extravehicular Activity Crew Members, If Required:
- Extravehicular (EV) astronaut-1 is James (Jim) P. Bagian; EV-2 is Tamara (Tammy) E. Jernigan

Intravehicular Astronaut: Sidney (Sid) M. Gutierrez

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 galley and the four-tier-bunk sleep stations are installed in Columbia's middeck.

- The new, upgraded general-purpose computers are not installed on Columbia for STS-40 but will be installed during Columbia's major modification period later this year. The SLS-1 Spacelab payload, however, is equipped with the new IBM AP-101S GPCs.

- There will be no airborne digitizer unit or teleprinter requirements for this flight.

- The Spacelab will be unpowered on Flight Day 9 based on premission consumables analysis. Twenty-four hours have been built into the mission time for this effort, which is intended to help prepare for eventual extended duration orbiter (EDO) missions.

- Unlike most Spacelab flights, this mission has single-shift payload operations.

- STS-40 will be the first shuttle mission to use the crew transport vehicle (CTV) for crew engress. The CTV supports STS-40 overall science objectives and is intended to minimize the effects of gravity on the metabolic state of crew members by keeping them inactive before/during transport to medical facilities. An elevating cabin with canted couches will be put in place at the orbiter crew hatch. The CTV provides extra room for de-suiting and medical technologists to support immediate postlanding measurements. It will be available for future Edwards landings, particularly on EDO flights.

- Following this flight and removal of the Spacelab payload at KSC, Columbia will be readied for ferry flight to Rockwell International's Space Systems Division facility in Palmdale, Calif. The orbiter is scheduled to undergo extensive modifications, including changes to accommodate an extended duration mission capability, during a six-month period from August 1991 to January 1992. Columbia's next scheduled flight is STS-50, a planned extended duration mission with the United States Microgravity Laboratory payload, targeted for launch in May 1992.

MISSION OBJECTIVES

- Primary Payload
  - Spacelab Life Sciences (SLS)-1 with long module
- Secondary Payloads
  - GAS Bridge Assembly with 12 Getaway Specials
  - Orbiter Experiments (OEX)
  - Middeck Zero-Gravity Dynamics Experiment (MODE)
- Development Test Objectives (DTOs)/Detailed Supplementary Objectives (DSOs)

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Spacelab activation
Metabolic experiment operations
Echocardiograph operations
Jellyfish incubator activation and specimen loading in Spacelab module
Activation of five GAS payloads

Flight Day 2

Baroreflex tests
Pulmonary function tests
Echocardiograph activities
Cardiovascular operations
Ames Research Center operations
Activation of three GAS payloads

Flight Day 3

Ames Research Center operations
Rotating dome operations
Echocardiograph activities
DTOs
Activation of GAS payloads

Flight Day 4

Baroreflex/pulmonary function tests
Ames Research Center operations
Activation of GAS payloads

Flight Day 5

Pulmonary function tests
Cardiovascular operations
Echocardiograph activities

Flight Day 6

Rotating dome operations
Echocardiograph activities
Cardiovascular operations
Ames Research Center operations

Flight Day 7

DTOs
Ames Research Center operations

Flight Day 8

Baroreflex tests
Echocardiograph activities
Cardiovascular operations

Flight Day 9

Pulmonary function tests
Flight control systems checkout
Echocardiograph tests
Cardiovascular operations
Cabin stow
Partial Spacelab deactivation

Flight Day 10

Spacelab deactivation
Deorbit preparation
Deorbit burn
Landing

Notes:

- Due to power requirements and the length of the mission, an equipment powerdown (referred to as a Group B powerdown), is executed on Flight Day 1 to conserve cryogenics for a full mission duration plus two extension days (if required). Powerdown activities include powering off three of Columbia's four CRTs, placing three of Columbia's five general purpose computers on standby mode, placing one of Columbia's three inertial measurement units on standby mode, and powering off three of Columbia's eight flight-critical multiplexers (two forward, one aft).

- An approved exemption allows for an 18-hour crew day on Flight Day 1.

- An approved exemption allows use of the first hour of presleep activities for payload activities.

- 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.

- Flight Day 7 is currently scheduled to be unpowered. Energy buy backs, which result from lower than expected payload usage, will be used for operations based on the following priorities:
  - Spacelab Life Sciences 1
  - EDO day (including EDO DSOs)
  - Ninth day of Spacelab operations
  - DTO 910--OARE
  - GAS experiments
  - Remaining DTOs
  - Remaining DSOs

STS-40 CREW ASSIGNMENTS

Note: * denotes backup responsibility

Commander (Bryan D. O'Connor):

Overall mission decisions

Orbiter--safety, DPS, GN&C, ECLSS, Communications/Instrumentation, C&W, SPOC*, HP41C*, Earth observations*, LES/escape*, Photo/TV/CCTV

Payload--OARE*, GAS*

DTOs/DSOs--cabin air monitoring, air cleaner, HUD/COAS, TPEC*, water filter*, aerobics

Spacelab systems--computers*, electrical*, environment*

Pilot (Sidney M. Gutierrez):

Orbiter--MPS, OMS/RCS, APU/hydraulics, EPS, payload bay door/radiator, IFM, intravehicular astronaut 1, HP41C, Earth observations, photo/TV/CCTV*, crew equiment

Payload--OARE, GAS, MODE*

DTOs/DSOs--cabin air monitoring*, air cleaner*, HUD/COAS*, TPEC, water filter

Spacelab Systems--computers*, electrical*, environment*, IFM*

Mission Specialist 1 (James P. Bagian):

Orbiter--IFM*, extravehicular astronaut 1, medical/medical DSOs, LES/escape, crew equipment

Payload--SLS-1 medical experiments

Spacelab Systems--computers*, electrical, environment*, IFM

Mission Specialist 2 (Tamara E. Jernigan):

Orbiter--DPS*, MPS*, OMS/RCS*, APU/hydraulics*, GN&C*, EPS*, ECLSS*, Communications/instrumentation*, C&W*, payload bay doors/radiator*, extravehicular astronaut 2, SPOC, FDF

Payload--SLS-1*, SMIDEX, MODE, photo/TV

Spacelab Systems--computers*, electrical*, environment*

Mission Specialist 3 (M. Rhea Seddon):

Orbiter--medical/medical DSOs

Payload--SLS-1 medical experiments, SMIDEX*, photo/TV*

Spacelab Systems--computers, electrical*, environment

Payload Specialist 1 (Francis A. [Drew] Gaffney):

Payload--SLS-1 medical experiments*

Payload Specialist 2 (Millie Hughes-Fulford):

Orbiter--communications/instrumentation*

Payload--SLS-1 medical experiments*

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- Ascent aerodynamic distributed loads verification on OV-102 (DTO 236)
- Entry aerodynamic control surfaces test, part 5 (DTO 242)
- Ascent structural capability evaluation (DTO 301D)
- Ascent compartment venting evaluation (DTO 305D)
- Descent compartment venting evaluation (DTO 306D)
- Entry structural capability (DTO 307D)
- ET TPS performance (DTO 312)
- Hot nosewheel steering runway evaluation (DTO 517)
- Cabin air monitoring (DTO 623)
- Camcorder demonstration, Canon AIA Mark2 (DTO 630)
- On-orbit cabin air cleaner evaluation (DTO 637)
- Water separator filter performance evaluation (DTO 647)
- TDRS S-band forward link RF power level evaluation (DTO 700-1)
- Heads-up display backup to crew optical alignment sight (DTO 785)
- Vent uplink capability (DTO 796)
- Crosswind landing performance (DTO 805)
- Additional stowage evaluation for extended duration orbiter (DTO 823)
- OEX shuttle infrared leeside temperature sensing (DTO 901)
- OEX shuttle upper atmosphere mass spectrometer (DTO 902)
- OEX shuttle entry air data system (DTO 903)
- OEX orbital acceleration research experiment (DTO 910)
- OEX aerothermal instrumentation package (DTO 911)

DSOs

- In-flight radiation dose distribution, tissue equivalent proportional counter only, activation on Flight Day 2 (DSO 469)
- In-flight aerobic exercise (DSO 476)
- Changes in baroreceptor reflex function (DSO 601)
- Postural equilibrium control during landing egress (DSO 605)
- Air monitoring instrument evaluation and atmospheric characterization, microbial air sample and archival organic sampler (DSO 611)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)
- Assessment of human factors (DSO 904)

STS-40 PRELAUNCH COUNTDOWN

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

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
03:10:00	Liquid oxygen stable replenishment begins and continues until just minutes prior to T-0.
03:00:00	The MILA antenna alignment is completed.
03:00:00	The orbiter closeout crew goes to the launch pad and prepares the orbiter crew compartment for flight crew ingress.
03:00:00 Holding	Begin 2-hour planned hold. An inspection team examines the ET for ice or frost formation on the launch pad during this hold.
03:00:00 Counting	Two-hour planned hold ends.
02:55:00	Flight crew departs Operations and Checkout (O&C) Building for launch pad.
02:25:00	Flight crew orbiter and seat ingress occurs.
02:10:00	Post ingress software reconfiguration occurs.
02:00:00	Checking of the launch commit criteria starts at this time.
02:00:00	The ground launch sequencer (GLS) software is initialized.
01:50:00	The solid rocket boosters' (SRBs') hydraulic pumping units' gas generator heaters are turned on and the SRBs' aft skirt gaseous nitrogen purge starts.
01:50:00	The SRB rate gyro assemblies (RGAs) are turned on. The RGAs are used by the orbiter's navigation system to determine rates of motion of the SRBs during first-stage flight.
01:35:00	The orbiter accelerometer assemblies (AAs) are powered up.
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.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
01:00:00	The orbiter RGAs and AAs are tested.
00:50:00	The flight crew starts the orbiter hydraulic auxiliary power units' (APUs') water boilers preactivation.
00:45:00	Cabin vent redundancy check is performed.
00:45:00	The GLS mainline activation is performed.
00:40:00	The eastern test range (ETR) shuttle range safety system (SRSS) terminal count closed-loop test is accomplished.
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.
00:30:00	The gaseous nitrogen system for the orbital maneuvering system (OMS) engines is pressurized for launch. Crew compartment vent valves are opened.
00:26:00	The ground pyro initiator controllers (PICs) are powered up. They are used to fire the SRB hold-down posts, liquid oxygen and liquid hydrogen tail service mast (TSM), and ET vent arm system pyros at lift-off and the SSME hydrogen gas burn system prior to SSME ignition.
00:25:00	Simultaneous air-to-ground voice communications are checked. Weather aircraft are launched.
00:22:00	The primary avionics software system (PASS) is transferred to the BFS computer in order for both systems to have the same data. In case of a PASS computer system failure, the BFS computer will take over control of the shuttle vehicle during flight.
00:21:00	The crew compartment cabin vent valves are closed.
00:20:00	A 10-minute planned hold starts.
Hold 10 Minutes	All computer programs in the firing room are verified to ensure that the proper programs are available for the final countdown. The test team is briefed on the recycle options in case of an unplanned hold. The landing convoy status is again verified and the landing sites are verified ready for launch. The IMU preflight alignment is verified complete. Preparations are made to transition the orbiter onboard computers to Major Mode (MM)-101 upon coming out of the hold. This configures the computer memory to a terminal countdown configuration.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:20:00	The 10-minute hold ends.
Counting	Transition to MM-101. The PASS onboard computers are dumped and compared to verify the proper onboard computer configuration for launch.
00:19:00	The flight crew configures the backup computer to MM-101 and the test team verifies the BFS computer is tracking the PASS computer systems. The flight crew members configure their instruments for launch.
00:18:00	The Mission Control Center-Houston (MCC-H) now loads the onboard computers with the proper guidance parameters based on the prestated lift-off time.
00:16:00	The MPS helium system is reconfigured by the flight crew for launch.
00:15:00	The OMS/RCS crossfeed valves are configured for launch. All test support team members verify they are "go for launch."
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 Hold 10 Minutes	A planned 10-minute hold starts. NASA and contractor project managers will be formally polled by the deputy director of NASA, Space Shuttle Operations, on the Space Shuttle Program Office communications loop during the T minus 9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records. All test support team members verify that they are "go for launch." Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins. From this point, the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the onboard orbiter PASS redundant-set computers.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
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 motor-driven switch called a safe and arm device (S&A).
00:04:30	As a preparation for engine start, the SSME main fuel valve heaters are turned off.
00:04:00	The final helium purge sequence, purge sequence 4, on the SSMEs is started in preparation for engine start.
00:03:55	At this point, all of the elevons, body flap, speed brake, and rudder are moved through a preprogrammed pattern. This is to ensure that they will be ready for use in flight.
00:03:30	Transfer to internal power is done. Up to this point, power to the space vehicle has been shared between ground power supplies and the onboard fuel cells. The ground power is disconnected and the vehicle goes on internal power at this time. It will remain on internal power through the rest of the mission.
00:03:25	The SSMEs' nozzles are moved (gimbaled) through a preprogrammed pattern to ensure that they will be ready for ascent flight control. At completion of the gimbal profile, the SSMEs' nozzles are in the start position.
00:02:55	ET liquid oxygen prepressurization is started. At this point, the liquid oxygen tank vent valve is closed and the ET liquid oxygen tank is pressurized to its flight pressure of 21 psi.

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:02:50	The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted.
00:02:35	Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the onboard tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.
00:02:30	The caution/warning memory is cleared.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.
00:00:47	The liquid oxygen and liquid hydrogen outboard fill and drain valves are closed.
00:00:40	The external tank bipod heaters are turned off.
00:00:38	The onboard computers position the orbiter vent doors to allow payload bay venting upon lift-off and ascent in the payload bay at SSME ignition.
	The SRB forward MDM is locked out.
00:00:37	The gaseous oxygen ET arm retract is confirmed.
00:00:31	The GLS sends "go for redundant set launch sequence start." At this point, the four PASS computers take over main control of the terminal count. Only one further command is needed from the ground, "go for main engine start," at approximately T minus 9.7 seconds. The GLS in the integration console in the launch control center still continues to monitor several hundred launch commit criteria and can issue a cutoff if a discrepancy is observed. The GLS also sequences ground equipment and sends selected vehicle commands in the last 31 seconds.

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

T - (MINUS) HR:MIN:SEC	TERMINAL COUNTDOWN EVENT
00:00:09.7	In preparation for SSME ignition, flares are ignited under the SSMEs. This burns away any free gaseous hydrogen that may have collected under the SSMEs during prestart operations. The orbiter goes on internal cooling at this time; the ground coolant units remain powered on until lift-off as a contingency for an aborted launch. The orbiter will redistribute heat within the orbiter until approximately 125 seconds after lift-off, when the orbiter flash evaporators will be turned on.
00:00:09.5	The SSME engine chill-down sequence is complete and the onboard computers command the three MPS liquid hydrogen prevalves to open. (The MPSs three liquid oxygen prevalves were opened during ET tank loading to permit engine chill-down.) These valves allow liquid hydrogen and oxygen flow to the SSME turbopumps.
00:00:09.5	Command decoders are powered off. The command decoders are units that allow ground control of some onboard components. These units are not needed during flight.
00:00:06.6	The main fuel and oxidizer valves in each engine are commanded open by the onboard computers, permitting fuel and oxidizer flow into each SSME for SSME start. All three SSMEs are started at 120-millisecond intervals (SSME 3, 2, then 1) and throttle up to 100-percent thrust levels in 3 seconds under control of the SSME controller on each SSME.
00:00:04.6	All three SSMEs are verified to be at 100-percent thrust and the SSMEs are gimbaled to the lift-off position. If one or more of the three SSMEs does not reach 100-percent thrust at this time, all SSMEs are shut down, the SRBs are not ignited, and an RSLS pad abort occurs. The GLS RSLS will perform shuttle and ground systems safing. Vehicle bending loads caused by SSME thrust buildup are allowed to initialize before SRB ignition. The vehicle moves towards ET including ET approximately 25.5 inches.
00:00:00	The two SRBs are ignited under command of the four onboard PASS computers, the four hold-down explosive bolts on each SRB are initiated (each bolt is 28 inches long and 3.5 inches in diameter), and the two T-0 umbilicals on each side of the spacecraft are retracted. The onboard timers are started and the ground launch sequence is terminated. All three SSMEs are at 104-percent thrust. Boost guidance in attitude hold.
00:00	Lift-off.

STS-40 MISSION HIGHLIGHTS TIMELINE

Editor's Note: The following timeline lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-40 Flight Plan, Ascent Checklist, Post Insertion Checklist, Deorbit Prep Checklist, and Entry Checklist.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY ZERO	
0/00:00:08	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:10	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down (astronauts), wings level.
0/00:00:18	Roll maneuver ends.
0/00:00:21	All three SSMEs throttle down from 104 to 98 percent for maximum aerodynamic load (max q).
0/00:00:32	All three SSMEs throttle down from 98 to 67 percent for max q.
0/00:00:53	Max q occurs.
0/00:01:04	All three SSMEs throttle to 104 percent.
0/00:02:05	SRBs separate.
	When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. 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.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:04:02	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:06:54	Single engine press to main engine cutoff (MECO).
0/00:07:29	All three SSMEs throttle down from 104 percent--vehicle acceleration capability no greater than 3g's.
0/00:08:24	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:31	MECO occurs at approximate velocity 25,793 feet per second, 155 by 40 nautical miles (178 by 46 statute miles).
0/00:08:50	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	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.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	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.
0/00:44	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 3 seconds in duration, at 196.7 fps, 160 by 150 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS)/payload specialist (PS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.
0/00:59	MS configures aft flight station.
0/01:00	MS unstows, sets up, and activates SPOC.
0/01:07	Pilot activates payload bus (panel R1).
0/01:10	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive Y velocity vector attitude.
0/01:15	Metabolic operations begin.
0/01:15	Urine monitoring system installation.
0/01:18	Commander activates radiators.
0/01:19	PS2 unstows MBI-OP kit.
0/01:20	If go for payload bay door operations, MS configures for payload bay door operations.
0/01:23	Orbit 2 begins.
0/01:29	Pilot opens payload bay doors.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:30	Central venous pressure measurements (Exp. 294).
0/01:35	Commander switches star tracker (ST) power 2 (panel 06) to ON.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	Commander and pilot seat egress.
0/01:38	Commander and pilot clothing configuration.
0/01:39	MS/PS clothing configuration.
0/01:50	Pilot initiates fuel cell auto purge.
0/01:52	Commander starts post-payload bay door operations and radiator configuration.
0/01:56	Commander starts ST self-test and opens door.
0/01:58	Pilot closes main B supply water dump isolation circuit breaker, panel ML86B, opens supply water dump isolation valve, panel R12L, talkback barber pole.
0/02:00	Pilot activates auxilary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:00	Urine monitoring system void.
0/02:05	MS/PS seat removal/stowage.
0/02:07	MCC-H informs crew to go for Spacelab activation; MS/PS begin Spacelab activation procedures.
0/02:10	MS1/MS3 reconfigure orbiter main bus.
0/02:10	Commander configures for RCS vernier control.
0/02:12	MS2 assembles cabin TV equipment required for initial Spacelab ingress.
0/02:12	Commander and pilot configure controls for on-orbit operations.
0/02:20	MS1/MS3 perform Spacelab telemetry format load.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/02:20	Central venous pressure measurements (Exp. 294).
0/02:20	Commander maneuvers vehicle to IMU align attitude.
0/02:21	Pilot enables hydraulic thermal conditioning.
0/02:24	MS resets caution/warning (C/W).
0/02:25	MS2 performs TV setup.
0/02:27	MS1/MS3 perform SS command and data management system (CDMS) initial activation.
0/02:27	Pilot switches APU coolant system (panel R2), APU fuel pump/valve cool, A to OFF and B to AUTO.
0/02:29	Pilot plots fuel cell performance.
0/02:30	Leg volume measurement (Exp. 294).
0/02:30	Pressure control system (PCS) configuration.
0/02:30	Metabolic operations.
0/02:35	MS1/MS3 activate data display system 2.
0/02:35	IMU alignment: ST.
0/02:39	MS3 configures high-rate multiplexer (HRM)/audio.
0/02:40	MS3 configures Spacelab atmosphere.
0/02:40	Ku-band antenna deployment.
0/02:40	Maneuver vehicle to biased -YLV, -ZVV attitude.
0/02:50	Ku-band antenna activation.
0/02:50	MS3 enables fault detection and annunciation (FDA) limits.
0/02:53	Orbit 3 begins.
0/02:55	MS3 performs experiment CDMS initial activation.
0/02:56	MS 2 activates TV.
0/03:00	Systems management checkpoint.
0/03:00	Unstow cabin.
0/03:05	Group B powerdown.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:10	MS3 configures experiment power and control for ingress TV.
0/03:15	MS1 performs airlock/tunnel ingress and activation.
0/03:18	P/TV 01 activation.
0/03:18	CVP measurements (Exp. 294).
0/03:23	Metabolic operations.
0/03:30	MS1 module ingress.
0/03:31	MS1 transfers PFDF slant box and Spacelab data kit from middeck lockers to module.
0/03:37	MS1 activates and checks out intercom.
0/03:40	APU heater deactivation.
0/03:50	MS1/MS3 perform PYCB verification; Spacelab fire/smoke test.
0/04:04	MS1 activates atmosphere storage and control system (ASCS).
0/04:05	APU cool B.
0/04:11	MS1 configures rack cooling valves.
0/04:20	Cryo oxygen sensor check.
0/04:20	MS1 performs environmental control system (ECS) power switching unit fuse check.
0/04:23	Orbit 4 begins.
0/04:25	MS1/MS3 configure data display system.
0/04:25	CVP measurements (Exp. 294).
0/04:31	MS1 activates experiment remote acquisition units/ checks control center rack valve.
0/04:32	PS performs Research Animal Holding facility servicing.
0/04:35	MS1 performs ventline activation.
0/04:35	Experiment transfer.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/04:35	Cardiovascular setup.
0/04:35	Metabolic operations.
0/04:37	MS1 configures experiment power switching panel (EPSP).
0/04:39	PS sets up CCU and refrigerator/incubator module.
0/04:40	CRT 4 powerdown.
0/04:45	Air-to-ground 1 check.
0/04:45	MS2 sets up TVC-2.
0/04:55	Echocardiograph operations (Exp. 294).
0/05:00	Lymphocyte activation (Exp. 240).
0/05:20	CVP measurements (Exp. 294).
0/05:30	Metabolic operations.
0/05:53	Orbit 5 begins.
0/06:15	Cardiovascular setup.
0/06:20	CVP measurements (Exp. 294).
0/06:30	Cardiovascular calibration (Exp. 66).
0/06:30	APU heater reconfiguration.
0/06:50	Shuttle particulate monitor.
0/06:58	Resting cardiovascular set (Exp. 66/294).
0/07:15	Body mass measurement.
0/07:23	Orbit 6 begins.
0/07:38	CVP measurements (Exp. 294).
0/07:45	Meal.
0/08:40	P/TV 108 setup.
0/08:40	Echocardiograph operations (Exp. 294).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/08:53	Orbit 7 begins.
0/08:55	DTO 623--cabin air monitoring.
0/09:05	Resting cardiovascular set (Exp. 66/294).
0/09:13	Echocardiograph operations (Exp. 294).
0/09:30	Getaway Special APC unstow/setup.
0/09:35	Jellyfish operations.
0/09:40	CVP measurements (Exp. 294).
0/09:45	Echocardiograph operations (Exp. 294).
0/09:55	Crew begins presleep activities.
0/10:05	Body mass measurement.
0/10:10	P/TV 113.
0/10:20	CVP measurements (Exp. 294).
0/10:20	Body mass measurement.
0/10:23	Orbit 8 begins.
0/10:35	P/TV 104 setup.
0/10:45	Cardiovascular stow.
0/10:45	Daily planning.
0/10:50	End of FD1 Spacelab operations.
0/11:05	Private medical conference.
0/11:25	Maneuver vehicle to IMU align attitude.
0/11:40	IMU alignment: ST.
0/11:45	Maneuver vehicle to -ZLV, -YVV attitude.
0/11:53	Orbit 9 begins.
0/12:00	Group A Getaway Special activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/12:45	Maneuver vehicle to +XLV, -YVV attitude.
0/13:00	Crew begins sleep period.
0/13:23	Orbit 10 begins.
0/14:53	Orbit 11 begins.
0/16:23	Orbit 12 begins.
0/17:53	Orbit 13 begins.
0/19:23	Orbit 14 begins.
0/20:54	Orbit 15 begins.
0/21:15	Saliva collection.
0/21:20	Begin FD2 Spacelab operations.
0/21:20	Maneuver vehicle to -ZLV, +YVV attitude.
0/21:20	Body mass measurement.
0/21:20	Metabolic operations.
0/21:20	Urine monitoring system void.
0/21:35	Postsleep activities.
0/21:45	Body mass measurement.
0/21:50	Urine monitoring system void.
0/22:05	Saliva collection.
0/22:10	P/TV 102 setup.
0/22:10	Urine monitoring system void.
0/22:15	Initiate supply water dump.
0/22:15	Pulmonary test (Exp. 198).
0/22:15	Saliva collection.
0/22:20	Body mass measurement.
0/22:20	Postsleep activities.
0/22:25	Metabolic operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/22:25	Orbit 16 begins.
0/23:18	Supply dump termination.
0/23:28	Maneuver vehicle to IMU/COAS attitude.
0/23:43	IMU alignment: ST.
0/23:50	COAS calibration--aft station.
0/23:53	Maneuver vehicle to biased -YLV, -ZVV attitude.
0/23:55	Orbit 17 begins.
MET DAY ONE	
1/00:20	Daily planning.
1/00:50	Teleprinter activation.
1/00:50	Body mass measurement.
1/00:50	Metabolic operations.
1/01:05	Space Acceleration Measurement System (SAMS) operations.
1/01:15	Saliva collection.
1/01:15	Baroreflex test (Exp. 022).
1/01:17	Pulmonary test (Exp. 198).
1/01:20	DSO 611--air monitoring instrument evaluation.
1/01:25	Orbit 18 begins.
1/01:35	Saliva collection.
1/01:45	Spacelab module air sample.
1/01:45	P/TV 103 setup.
1/01:45	Saliva collection.
1/01:55	DSO 904 setup.
1/02:00	Saliva collection.
1/02:05	Body mass measurement.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/02:10	DSO 904--noise measurement, Location 0.
1/02:10	STS particulate sampler.
1/02:20	DSO 476 exercise (MS2).
1/02:30	DSO 904--noise measurement, Location 5.
1/02:55	Orbit 19 begins.
1/03:00	P/TV 102 setup.
1/03:20	CCU powerup.
1/03:20	Baroreflex test (Exp. 022).
1/03:30	DSO 476 exercise.
1/03:30	Saliva collection.
1/03:45	P/TV 102 setup.
1/03:45	Baroreflex test (Exp. 022).
1/04:20	Metabolic operations.
1/04:25	Orbit 20 begins.
1/04:30	Baroreflex test (Exp. 022).
1/04:35	DSO 469 setup--radiation dose distribution.
1/04:35	Metabolic operations.
1/04:55	P/TV 02 setup.
1/05:05	P/TV 108 setup.
1/05:25	Meal.
1/05:55	Orbit 21 begins.
1/06:25	Cardiovascular setup.
1/06:25	Echocardiograph operations (Exp. 294).
1/06:30	P/TV 02 activation.
1/06:35	Cardiovascular calibration (Exp. 66).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/06:50	DTO 623--cabin air monitoring.
1/07:10	Galley water sample.
1/07:15	P/TV 107 setup.
1/07:25	Group B Getaway Special activities.
1/07:25	Orbit 22 begins.
1/07:25	Cardiovascular/sub maximum exercise (Exp. 66/294).
1/07:30	Urine monitoring system void/saliva collection.
1/07:45	DSO 611--air monitoring instrument evaluation.
1/08:00	DSO 904--inflight questionnaire.
1/08:20	DSO 476 exercise.
1/08:25	Echocardiograph operations (Exp. 294).
1/08:40	Resting cardiovascular set (Exp. 66/294).
1/08:50	Filter cleaning.
1/08:55	Orbit 23 begins.
1/09:15	Cardiovascular/sub maximum exercise (Exp. 66/294).
1/09:25	Urine monitoring system calibration.
1/09:50	Maneuver vehicle to +ZLV, +YVV attitude.
1/10:00	Supply water dump initiation.
1/10:05	ARC rat health check.
1/10:20	Resting cardiovascular set (Exp. 66/294).
1/10:20	Group C Getaway Special activities.
1/10:20	Crew begins presleep activities.
1/10:26	Orbit 24 begins.
1/10:40	Private medical conference.
1/10:50	End of FD2 Spacelab operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/10:50	P/TV 104 setup.
1/10:55	Cardiovascular stow.
1/11:00	Supply dump termination.
1/11:05	Daily planning.
1/11:10	Maneuver vehicle to IMU alignment attitude.
1/11:25	IMU alignment: ST.
1/11:30	DTO 785--Heads-up display backup to crew optical alignment sight.
1/11:50	Maneuver vehicle to -ZLV, -YVV attitude.
1/11:56	Orbit 25 begins.
1/13:05	Maneuver vehicle to +XLV, -YVV attitude.
1/13:20	Crew begins sleep period.
1/13:26	Orbit 26 begins.
1/14:56	Orbit 27 begins.
1/16:26	Orbit 28 begins.
1/17:56	Orbit 29 begins.
1/19:27	Orbit 30 begins.
1/20:56	Orbit 31 begins.
1/21:20	Begin FD3 Spacelab operations.
1/21:20	Postsleep activities.
1/21:20	Leg volume measurements (Exp. 294).
1/21:20	Maneuver vehicle to -ZLV, +YVV attitude.
1/21:25	Body mass measurement.
1/21:30	Urine monitoring system void.
1/21:33	Metabolic operations.
1/22:05	Body mass measurement.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/22:10	P/TV 118 setup.
1/22:15	Supply dump initiation.
1/22:27	Orbit 32 begins.
1/23:15	Supply dump termination.
1/23:25	Maneuver vehicle to IMU alignment attitude.
1/23:40	IMU alignment: ST.
1/23:45	Maneuver vehicle to COAS attitude.
1/23:50	COAS calibration: forward station.
1/23:57	Orbit 33 begins.
MET DAY TWO	
2/00:00	Maneuver vehicle to biased -YLV, -ZVV attitude.
2/00:20	Daily planning.
2/00:50	Metabolic operations.
2/00:50	Body mass measurement.
2/00:55	Group D Getaway Special activities.
2/00:55	ARC activity--Particulate Containment Demonstration Test 2.
2/01:00	DSO 476 exercise.
2/01:05	Body mass measurement.
2/01:15	Maneuver vehicle to -ZSI attitude.
2/01:27	Orbit 34 begins.
2/01:30	Group E Getaway Special activities.
2/01:40	STS particulate sampler.
2/01:55	Intravenous pump verification.
2/02:00	DSO 476 exercise.
2/02:20	ARC activity--small mass measurement instrument calculation.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/02:25	Position awareness test.
2/02:40	CCU powerup.
2/02:40	P/TV 121 setup.
2/02:55	Intravenous pump verification.
2/02:55	ARC activity--Particulate Containment Demonstration Test 1.
2/02:57	Orbit 35 begins.
2/03:00	P/TV 03 setup.
2/03:30	P/TV 03 activation.
2/03:30	DSO 476 exercise (MS2).
2/04:00	Group E Getaway Special activities.
2/04:10	Maneuver vehicle to biased -YLV, -ZVV attitude.
2/04:15	Cardiovascular setup.
2/04:20	P/TV 108 setup.
2/04:27	Orbit 36 begins.
2/04:30	Meal.
2/05:30	Body mass calculation.
2/05:30	Echocardiograph operations (Exp. 294).
2/05:30	DTO 647 filter installation.
2/05:45	Lymphocyte fixation (Exp. 240).
2/05:57	Orbit 37 begins.
2/06:05	Cardiovascular calibration (Exp. 66).
2/06:20	Jellyfish operations.
2/06:30	Cardiovascular/sub maximum exercise (Exp. 66/294).
2/06:40	Echocardiograph operations (Exp. 294).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/07:25	DTO 647 performance evaluation.
2/07:25	Maneuver vehicle to +YLV, -XVV attitude.
2/07:28	Orbit 38 begins.
2/07:35	P/TV 107 setup.
2/07:40	Condensate tank dump.
2/07:45	Echocardiograph operations (Exp. 294).
2/07:50	Lymphocyte fixation (Exp. 240).
2/08:05	DTO 647 performance evaluation.
2/08:10	DTO 623--cabin air monitoring.
2/08:45	DTO 647 performance evaluation.
2/08:45	Maneuver vehicle to -ZSI attitude.
2/08:45	Echocardiograph operations (Exp. 294).
2/08:50	P/TV 119.
2/08:50	ARC rat health check.
2/08:57	Orbit 39 begins.
2/09:00	Group F Getaway Special activities.
2/09:25	DTO 647 performance evaluation.
2/09:30	ARC video.
2/09:50	Group G Getaway Special activities.
2/09:50	P/TV 105 setup.
2/10:10	Maneuver vehicle to +ZLV, +YVV attitude.
2/10:20	Crew begins presleep activities.
2/10:25	Supply dump initiation.
2/10:28	Orbit 40 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/10:40	Private medical conference.
2/10:50	End of FD3 Spacelab operations.
2/10:55	Cardiovascular stow.
2/11:05	Daily planning.
2/11:25	Supply dump termination.
2/11:35	Maneuver vehicle to IMU alignment attitude.
2/11:50	IMU alignment: ST.
2/11:55	Maneuver vehicle to -ZLV, -YVV attitude.
2/11:57	Orbit 41 begins.
2/13:05	Maneuver vehicle to +XLV, -YVV attitude.
2/13:20	Crew begins sleep period.
2/13:27	Orbit 42 begins.
2/14:58	Orbit 43 begins.
2/16:28	Orbit 44 begins.
2/17:58	Orbit 45 begins.
2/19:28	Orbit 46 begins.
2/20:58	Orbit 47 begins.
2/21:20	Begin FD4 Spacelab operations.
2/21:20	Postsleep activities.
2/21:20	Maneuver vehicle to -ZLV, -YVV attitude.
2/21:20	Metabolic operations.
2/21:20	Body mass measurement.
2/21:35	Body mass measurement.
2/21:35	Pulmonary test (Exp. 198).
2/22:05	Maneuver vehicle to IMU alignment attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/22:05	P/TV 103 setup.
2/22:20	IMU alignment: ST.
2/22:25	Maneuver vehicle to +ZLV, +YVV attitude.
2/22:28	Orbit 48 begins.
2/22:40	Supply dump initiation.
2/23:35	Supply dump termination.
2/23:45	Maneuver vehicle to biased -YLV, -ZVV attitude.
2/23:58	Orbit 49 begins.
MET DAY THREE	
3/00:20	Daily planning.
3/00:50	Lymphocyte fixation (Exp. 240).
3/00:50	Pulmonary test (Exp. 198).
3/00:50	DTO 647 filter evaluation.
3/00:55	Metabolic operations.
3/01:00	Baroreflex test (Exp. 022).
3/01:20	DSO 611--air monitoring instrument evaluation.
3/01:28	Orbit 50 begins.
3/01:30	Baroreflex test (Exp. 022).
3/01:35	DSO 476 exercise (MS2).
3/02:10	Baroreflex test (Exp. 022).
3/02:35	Baroreflex test (Exp. 022).
3/02:35	Solid surface combustion experiment.
3/02:40	P/TV 04 setup.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/02:40	P/TV 115 setup/activation.
3/02:50	Lymphocyte fixation (Exp. 240).
3/02:58	Orbit 51 begins.
3/03:05	Lymphocyte multigravity (Exp. 240).
3/03:15	Conference audio/video check.
3/03:15	P/TV 04 activation.
3/04:05	DSO 904--noise measurement, Location 0-2.
3/04:28	Orbit 52 begins.
3/04:55	Crew press conference.
3/04:55	P/TV 04 activation.
3/05:20	DSO 904--noise measurement, Location 8.
3/05:40	Meal.
3/05:58	Orbit 53 begins.
3/06:40	DTO 623--cabin air monitoring.
3/06:45	P/TV 04 setup.
3/06:45	ARC activity--Particulate Containment Demonstration Test 3.
3/06:50	Exercise.
3/07:00	P/TV 109 setup.
3/07:05	P/TV 04 activation.
3/07:20	ARC rat health check.
3/07:20	Medical restraint system test.
3/07:29	Orbit 54 begins.
3/07:55	ARC activity--small mass measurement instrument test.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/08:00	DSO 476 exercise.
3/08:05	ARC activity--Particulate Containment Demonstration Test 4.
3/08:50	P/TV 120.
3/08:55	P/TV 118 setup.
3/08:59	Orbit 55 begins.
3/09:05	DTO 647 filter evaluation.
3/09:10	P/TV 120.
3/09:20	DSO 476 exercise.
3/09:20	ARC activity--Particulate Containment Demonstration Test 5.
3/09:50	End of FD4 Spacelab operations.
3/09:50	P/TV 105 setup.
3/10:05	Daily planning.
3/10:20	Crew begins presleep activities.
3/10:20	Maneuver vehicle to +ZLV, +YVV attitude.
3/10:30	Orbit 56 begins.
3/10:35	Supply dump initiation.
3/10:50	Private medical conference.
3/11:30	Supply dump termination.
3/11:40	Maneuver vehicle to IMU alignment attitude.
3/11:55	IMU alignment: ST.
3/11:59	Orbit 57 begins.
3/12:00	Maneuver vehicle to -ZLV, -YVV attitude.
3/13:05	Maneuver vehicle to +XLV, -YVV attitude.
3/13:20	Crew begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/13:30	Orbit 58 begins.
3/15:00	Orbit 59 begins.
3/16:30	Orbit 60 begins.
3/18:00	Orbit 61 begins.
3/19:30	Orbit 62 begins.
3/21:00	Orbit 63 begins.
3/21:20	Maneuver vehicle to -ZLV, -YVV attitude.
3/21:20	Begin FD5 Spacelab operations.
3/21:20	Postsleep activities.
3/21:20	Body mass measurement.
3/21:25	Body mass measurement.
3/21:45	Pulmonary test (Exp. 198).
3/22:00	Maneuver vehicle to IMU alignment attitude.
3/22:15	IMU alignment: ST.
3/22:20	Maneuver vehicle to +ZLV, +YVV attitude.
3/22:30	Orbit 64 begins.
3/22:35	Supply dump initiation.
3/23:25	Supply dump termination.
3/23:35	Maneuver vehicle to biased -YLV, -ZVV attitude.
3/23:50	Daily planning.

MET DAY FOUR

4/00:00	Orbit 65 begins.
4/00:10	RCS regulator reconfiguration.
4/00:20	CCU powerup.
4/00:20	Pulmonary test (Exp. 198).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/00:20	Body mass measurement.
4/00:30	DTO 647 filter evaluation.
4/00:30	STS particulate monitor.
4/00:50	Heater reconfiguration.
4/00:50	P/TV 103 setup.
4/00:55	Group H Getaway Special activities.
4/01:00	DSO 476 exercise (MS2).
4/01:05	Research animal holding facility service.
4/01:15	ECLSS checkout.
4/01:25	Atmosphere storage and control system reconfiguration.
4/01:30	Orbit 66 begins.
4/01:35	Cabin temperature control reconfiguration.
4/01:50	P/TV 04 setup.
4/02:00	Cardiovascular setup.
4/02:05	P/TV 103 setup.
4/02:20	P/TV 04 activation--Spacelab tour.
4/02:20	Echocardiograph operations (Exp. 294).
4/02:20	P/TV 110 setup.
4/03:01	Orbit 67 begins.
4/03:15	Venous compliance (Exp. 294).
4/03:20	P/TV 03 setup.
4/03:25	Cardiovascular calibration (Exp. 66).
4/03:55	P/TV 117 setup.
4/03:55	Meal.
4/04:31	Orbit 68 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/04:55	P/TV 03 activation.
4/04:55	Echocardiograph operations (Exp. 294).
4/05:00	Jellyfish operations.
4/05:20	Cardiovascular/sub maximum exercise (Exp. 66/294).
4/05:30	P/TV 117 setup.
4/05:50	DSO 904--noise measurement (Locations 6 and 7).
4/05:50	Venous compliance (Exp. 294).
4/06:01	Orbit 69 begins.
4/06:25	P/TV 110 setup.
4/06:25	Group I Getaway Special activities.
4/06:30	Echocardiograph operations (Exp. 294).
4/06:45	P/TV 107 setup.
4/06:45	DTO 623--cabin air monitoring.
4/06:50	Cardiovascular/maximum exercise (Exp. 294/66).
4/06:50	DSO 476 exercise.
4/07:25	Venous compliance (Exp. 294).
4/07:31	Orbit 70 begins.
4/07:50	DSO 476 exercise.
4/08:05	Echocardiograph operations (Exp. 294).
4/08:05	Filter cleaning.
4/08:20	P/TV 112.
4/08:30	Cardiovascular/maximum exercise (Exp. 294/66).
4/09:00	DSO 904--noise measurement (Location 9).
4/09:00	Venous compliance (Exp. 294).
4/09:01	Orbit 71 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/09:25	DTO 647 filter evaluation.
4/09:30	ARC rat health check.
4/09:35	DTO 637 on-orbit cabin air cleaner (OCAC) setup.
4/09:45	P/TV 119.
4/09:50	Cardiovascular/sub maximum exercise (Exp. 66/294).
4/09:55	Maneuver vehicle to +ZLV, +YVV attitude.
4/10:10	Supply dump initiation.
4/10:20	Presleep activities.
4/10:32	Orbit 72 begins.
4/10:45	Supply dump termination.
4/10:55	DTO 637--OCAC notes.
4/10:55	Cardiovascular stow.
4/10:55	End of FD5 Spacelab operations.
4/10:55	Waste dump initiation.
4/11:05	Daily planning.
4/11:20	Private medical conference.
4/11:30	Waste dump termination.
4/11:40	Maneuver vehicle to IMU alignment attitude.
4/11:55	IMU alignment: ST.
4/12:00	Maneuver vehicle to -ZLV, -YVV attitude.
4/12:01	Orbit 73 begins.
4/13:05	Maneuver vehicle to +XLV, -YVV attitude.
4/13:20	Crew begins sleep period.
4/13:31	Orbit 74 begins.
4/15:02	Orbit 75 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/16:32	Orbit 76 begins.
4/18:02	Orbit 77 begins.
4/19:32	Orbit 78 begins.
4/21:02	Orbit 79 begins.
4/21:20	Begin FD6 Spacelab operations.
4/21:20	Body mass measurement.
4/21:20	Leg volume measurement (Exp. 294).
4/21:20	Maneuver vehicle to -ZLV, -YVV attitude.
4/21:20	Postsleep activities.
4/21:30	CCU powerup.
4/22:10	Maneuver vehicle to IMU alignment attitude.
4/22:25	IMU alignment: ST.
4/22:30	Maneuver vehicle to +ZLV, +YVV attitude.
4/22:32	Orbit 80 begins.
4/22:45	Supply dump initiation.
4/23:35	Supply dump termination.
4/23:45	Maneuver vehicle to biased -YLV, -ZVV attitude.

MET DAY FIVE

5/00:02	Orbit 81 begins.
5/00:08	Daily planning.
5/00:20	Body mass measurement.
5/00:30	DTO 647 filter evaluation.
5/00:40	DTO 637 OCAC stow.
5/00:40	Baroreflex test (Exp. 022).
5/00:40	Rotating dome experiment.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/00:45	P/TV 114.
5/01:20	DSO 611--air monitoring instrument evaluation.
5/01:25	P/TV 114.
5/01:32	Orbit 82 begins.
5/01:50	Cardiovascular setup.
5/01:55	Baroreflex test (Exp. 022).
5/02:00	P/TV 110 setup.
5/02:10	Echocardiograph operations (Exp. 294).
5/02:15	DSO 476 exercise (MS2)
5/03:00	Baroreflex test (Exp. 022).
5/03:02	Orbit 83 begins.
5/03:08	Venous compliance (Exp. 294).
5/03:20	Cardiovascular calibration (Exp. 66).
5/03:30	Spacelab module air sample.
5/03:50	Meal.
5/04:32	Orbit 84 begins.
5/04:50	P/TV 107 setup.
5/04:50	Echocardiograph operations (Exp. 294).
5/04:55	Jellyfish operations.
5/05:15	Cardiovascular/maximum exercise (Exp. 294/66).
5/05:45	Venous compliance (Exp. 294).
5/05:50	DSO 611--air monitoring instrument evaluation.
5/06:00	DTO 647 filter removal.
5/06:00	P/TV 02 setup.
5/06:03	Orbit 85 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/06:30	Echocardiograph operations (Exp. 294).
5/06:30	P/TV 02 activation.
5/06:45	P/TV 108 setup.
5/06:50	Cardiovascular/sub maximum exercise (Exp. 66/294).
5/07:15	OEX equipment on.
5/07:20	Venous compliance (Exp. 294).
5/07:30	DTO 623--cabin air monitoring.
5/07:30	DSO 476 exercise.
5/07:33	Orbit 86 begins.
5/07:55	DSO 904--noise measurement (Location 3).
5/08:10	Echocardiograph operations (Exp. 294).
5/08:20	Cardiovascular/sub maximum exercise (Exp. 66/294).
5/08:30	DSO 476 exercise.
5/08:50	Venous compliance (Exp. 294).
5/09:03	Orbit 87 begins.
5/09:10	DTO 637 OCAC setup.
5/09:30	Group J Getaway Special activities.
5/09:35	ARC rat health check.
5/09:40	Cardiovascular/maximum exercise (Exp. 294/66).
5/09:45	P/TV 119.
5/09:55	Maneuver vehicle to IMU alignment attitude.
5/10:00	ARC activity.
5/10:10	IMU alignment: ST.
5/10:15	DTO 785--HUD backup to COAS
5/10:20	Crew begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/10:33	Orbit 88 begins.
5/10:35	Maneuver vehicle to -ZLV, +YVV attitude.
5/10:45	Small mass measurement instrument test.
5/10:50	DTO 637 OCAC notes.
5/10:50	Supply dump initiation.
5/10:55	Cardiovascular stow.
5/10:55	End of FD6 Spacelab operations.
5/11:05	Daily planning.
5/11:20	Spacelab deactivation--exit configuration.
5/11:30	Private medical conference.
5/11:50	Supply dump termination.
5/12:00	Maneuver vehicle to +XLV, +YVV attitude.
5/12:03	Orbit 89 begins.
5/12:35	OARE activation.
5/13:20	Crew begins sleep period.
5/13:33	Orbit 90 begins.
5/15:03	Orbit 91 begins.
5/16:33	Orbit 92 begins.
5/18:03	Orbit 93 begins.
5/19:33	Orbit 94 begins.
5/21:03	Orbit 95 begins.
5/21:20	Postsleep activities.
5/22:15	Maneuver vehicle to IMU alignment attitude.
5/22:30	IMU alignment: ST.
5/22:33	Orbit 96 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/22:35	Maneuver vehicle to -ZLV, +YVV attitude.
5/22:50	Supply dump initiation.
5/23:30	OEX equipment on.
5/23:50	Supply dump termination.
MET DAY SIX	
6/00:00	Maneuver vehicle to -ZLV, +XVV attitude.
6/00:00	Daily planning.
6/00:03	Orbit 97 begins.
6/00:20	OARE/1 pitch maneuver.
6/00:35	OARE/2 yaw maneuver.
6/00:50	OARE/3 roll maneuver.
6/01:05	Maneuver vehicle to biased -ZLV, +XVV attitude.
6/01:20	OARE drag test.
6/01:33	Orbit 98 begins.
6/01:50	Maneuver vehicle to -ZLV, +YVV attitude.
6/02:05	DTO 637 OCAC stow with filter checkout.
6/02:05	DSO 476 exercise (MS2).
6/03:00	Maneuver and initiate gravity gradient free drift.
6/03:03	Orbit 99 begins.
6/03:10	Ku-band power to standby.
6/03:20	OARE calibration.
6/03:50	Terminate gravity gradient free drift.
6/03:50	Lymphocyte multigravity (Exp. 240).
6/04:00	Ku-band power to on.
6/04:10	Maneuver vehicle to +XLV, +ZVV attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/04:25	OARE maximum drag test.
6/04:25	Meal.
6/04:33	Orbit 100 begins.
6/05:25	Maneuver vehicle to -ZLV, -YVV attitude.
6/05:50	P/TV 02 setup.
6/06:04	Orbit 101 begins.
6/06:15	OARE deactivation.
6/06:25	P/TV 02 activation.
6/07:10	MODE-0 experiment operations.
6/07:33	Orbit 102 begins.
6/08:20	DSO 476 exercise.
6/08:35	DTO 623--cabin air monitoring.
6/08:40	DTO 637 OCAC setup.
6/09:03	Orbit 103 begins.
6/09:20	DSO 476 exercise.
6/09:50	DTO 637 OCAC notes.
6/09:55	Maneuver vehicle to IMU/COAS attitude.
6/10:10	IMU alignment.
6/10:10	Lymphocyte multigravity (Exp. 240).
6/10:15	COAS calibration--forward station.
6/10:20	Presleep activities.
6/10:20	DTO 785--HUD backup to COAS.
6/10:33	Orbit 104 begins.
6/10:40	Maneuver vehicle to -ZLV, +YVV attitude.
6/10:55	Supply dump initiation.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/11:05	Daily planning.
6/11:20	Private medical conference.
6/11:55	Supply dump termination.
6/12:03	Orbit 105 begins.
6/13:05	Maneuver vehicle to +XLV, +YVV attitude.
6/13:20	Crew begins sleep period.
6/13:33	Orbit 106 begins.
6/15:04	Orbit 107 begins.
6/16:34	Orbit 108 begins.
6/18:04	Orbit 109 begins.
6/19:34	Orbit 110 begins.
6/21:04	Orbit 111 begins.
6/21:20	Maneuver vehicle to -ZLV, +YVV attitude.
6/21:20	Postsleep activities.
6/21:20	Void/saliva collection.
6/21:20	Metabolic operations.
6/21:20	Body mass measurement.
6/21:35	P/TV 102 setup.
6/21:50	Body mass measurement.
6/22:05	CCU powerup.
6/22:15	Metabolic operations.
6/22:15	Maneuver vehicle to IMU alignment attitude.
6/22:30	IMU alignment: ST.
6/22:34	Orbit 112 begins.
6/22:35	Maneuver vehicle to +ZLV, +YVV attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/22:50	Supply dump initiation.
6/23:30	Spacelab activation--ingress configuration.
6/23:50	Supply dump termination.

MET DAY SEVEN

7/00:00	Maneuver vehicle to biased -YLV, -ZVV attitude.
7/00:04	Orbit 113 begins.
7/00:10	Daily planning.
7/00:30	DTO 637 OCAC stow.
7/00:40	Metabolic operations.
7/00:50	Baroreflex test (Exp. 022).
7/01:00	Cardiovascular setup.
7/01:10	Body mass measurement.
7/01:10	Saliva collection.
7/01:20	DSO 611--air monitoring instrument evaluation.
7/01:25	Metabolic operations.
7/01:34	Orbit 114 begins.
7/01:35	STS particulate sample.
7/01:50	DSO 904--noise measurement (location 4).
7/02:00	Baroreflex test (Exp. 022).
7/02:00	DSO 904--noise measurement.
7/02:05	SLM deactivation.
7/02:05	DSO 476 exercise (MS2).
7/02:10	Metabolic operations.
7/02:25	Cardiovascular setup.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/02:35	Baroreflex test (Exp. 022).
7/02:40	Cardiovascular calibration (Exp. 66).
7/02:55	Cardiovascular calibration (Exp. 66).
7/03:04	Orbit 115 begins.
7/03:10	Saliva collection.
7/03:15	P/TV 104 setup.
7/03:35	P/TV 03 setup.
7/03:55	P/TV 108 setup.
7/04:05	Meal.
7/04:34	Orbit 116 begins.
7/05:05	Galley water sample.
7/05:05	P/TV 03 activation.
7/05:10	Echocardiograph operations (Exp. 294).
7/05:10	Body mass calibration.
7/05:15	Metabolic operations.
7/05:20	Research animal holding facility servicing.
7/05:25	P/TV 108 setup.
7/05:40	Metabolic operations.
7/05:55	DSO 611--air monitoring instrument evaluation.
7/06:00	Jellyfish operations.
7/06:05	Orbit 117 begins.
7/06:10	Cardiovascular/sub maximum exercise (Exp. 66/294).
7/06:20	Echocardiograph operations (Exp. 294).
7/06:50	DTO 623--cabin air monitoring.
7/07:15	Echocardiograph operations (Exp. 294).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/07:20	DSO 476 exercise.
7/07:25	Void/saliva collection.
7/07:34	Orbit 118 begins.
7/08:20	DSO 476 exercise.
7/08:30	DTO 637 OCAC setup.
7/08:35	Cardiovascular/sub maximum exercise (Exp. 66/294).
7/08:45	Echocardiograph operations (Exp. 294).
7/08:45	ARC rat health check.
7/08:55	P/TV 119.
7/09:04	Orbit 119 begins.
7/09:25	ARC video.
7/09:40	P/TV 119.
7/09:50	DTO 637--OCAC notes.
7/09:55	P/TV 105 setup.
7/09:58	Maneuver vehicle to IMU/COAS attitude.
7/10:13	IMU alignment: ST.
7/10:20	Presleep activities.
7/10:20	COAS calibration--forward station
7/10:23	DTO 785--HUD backup to COAS.
7/10:34	Orbit 120 begins.
7/10:43	Maneuver vehicle to -ZLV, +YVV attitude.
7/10:50	End of FD8 Spacelab operations.
7/11:00	Supply dump initiation.
7/11:00	Cardiovascular stow.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/11:05	Daily planning.
7/11:20	Private medical conference.
7/12:00	Supply dump termination.
7/12:04	Orbit 121 begins.
7/13:05	Maneuver vehicle to +XLV, +YVV attitude.
7/13:20	Crew begins sleep period.
7/13:34	Orbit 122 begins.
7/15:05	Orbit 123 begins.
7/16:34	Orbit 124 begins.
7/18:05	Orbit 125 begins.
7/19:35	Orbit 126 begins.
7/21:05	Orbit 127 begins.
7/21:20	Begin FD9 Spacelab operations.
7/21:20	Postsleep activities.
7/21:20	Maneuver vehicle to -ZLV, +YVV attitude.
7/21:20	Body mass measurement.
7/21:20	Metabolic operations.
7/21:30	Body mass measurement.
7/21:45	CCU powerup.
7/21:50	Pulmonary test (Exp. 198).
7/22:00	Supply dump initiation.
7/22:35	Orbit 128 begins.
7/22:35	Supply dump termination.
7/22:45	Waste dump initiation.
7/23:40	Waste dump termination.
7/23:50	Maneuver vehicle to IMU alignment attitude.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/23:50	Daily planning.

MET DAY EIGHT

8/00:00	IMU alignment: ST.
8/00:05	Orbit 129 begins.
8/00:05	Maneuver vehicle to biased -YLV, +ZVV attitude.
8/00:20	Pulmonary test (Exp. 198).
8/00:20	Metabolic operations.
8/00:20	Cardiovascular setup.
8/00:25	DTO 637--OCAC stow.
8/00:30	Echocardiograph operations (Exp. 294).
8/00:35	P/TV 104 setup.
8/00:55	APU steam vent heater activation.
8/00:55	Body mass measurement.
8/01:00	Body mass measurement.
8/01:15	FCS checkout.
8/01:20	Body mass measurement.
8/01:20	P/TV 105 setup.
8/01:25	P/TV 108 setup.
8/01:35	Orbit 130 begins.
8/01:35	STS particulate sample.
8/02:30	Echocardiograph operations (Exp. 294).
8/02:35	RCS hot fire test.
8/02:50	DSO 476 exercise (MS2).
8/03:00	APU heater reconfiguration.
8/03:05	Orbit 131 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/03:05	Cardiovascular calibration (Exp. 66).
8/03:05	Spacelab module air sample.
8/03:05	APU heater reconfiguration.
8/03:20	APU cool A.
8/03:30	Resting cardiovascular set (Exp. 66/294).
8/03:50	Space acceleration measurement system.
8/04:05	Meal.
8/04:35	Orbit 132 begins.
8/05:05	Resting cardiovascular set (Exp. 66/294).
8/05:05	DSO 904 questionnaire.
8/05:05	Exercise.
8/05:25	Group K Getaway Special activities.
8/05:30	P/TV 116 setup.
8/05:35	Echocardiograph operations (Exp. 294).
8/05:40	Resting cardiovascular set (Exp. 66/294).
8/05:45	GAS APC stow.
8/05:55	P/TV 02 setup.
8/06:05	Orbit 133 begins.
8/06:05	Exercise.
8/06:05	Begin Spacelab cabin stow.
8/06:25	P/TV 02 activation.
8/06:25	Resting cardiovascular set (Exp. 66/294).
8/06:50	Cardiovascular stow.
8/07:05	DSO 476 exercise.
8/07:05	DSO 476 exercise.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/07:15	Resting cardiovascular set (Exp. 66/294).
8/07:25	DTO 902 maneuver, biased +XLV, -ZVV attitude.
8/07:35	Orbit 134 begins.
8/07:40	DTO 902 OEX shuttle upper atmosphere mass spectrometer.
8/07:40	Shuttle particulate monitor.
8/07:55	Space acceleration measurement system.
8/08:05	Maneuver vehicle to biased -YLV, +ZVV attitude.
8/08:05	DSO 476 exercise.
8/08:20	Exercise.
8/08:20	Cabin stow.
8/08:20	DTO 623--cabin air monitoring.
8/08:55	CRT 4 powerup.
8/09:00	Spacelab partial deactivation.
8/09:01	MS3 checks Spacelab configuration.
8/09:05	DSO 469 radiation dose distribution stow.
8/09:05	Orbit 135 begins.
8/09:05	Daily planning.
8/09:05	PS reconfigures research animal holding facility for entry.
8/09:07	MS3 deactivates experiment remote acquisition units.
8/09:12	PS deactivates refrigerator/incubator module.
8/09:14	MS3 deactivates high rate multiplexer.
8/09:16	PS deactivates EPSP.
8/09:19	MS3 performs initial experiment bus powerdown.
8/09:20	Jellyfish operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/09:33	MS3 inhibits cabin fan delta P limit.
8/09:36	MS1 transfers PFDF slant box and SL data kit to middeck lockers except Spacelab operations checklist.
8/09:38	MS3 deactivates data display system 1.
8/09:46	MS3 configures Spacelab rack for deactivation.
8/09:51	MS3 deactivates ventline.
8/09:52	MS3 configures for orbiter PCS.
8/10:00	MS3 checks cabin depressurization valve.
8/10:00	IMU recovery.
8/10:05	Entry planning.
8/10:05	CRT 4 powerdown.
8/10:20	Presleep activities.
8/10:20	Maneuver vehicle to IMU alignment attitude.
8/10:35	Orbit 136 begins.
8/10:35	IMU alignment: ST.
8/10:40	Maneuver vehicle to -ZLV, +YVV attitude.
8/11:00	Private medical conference.
8/11:30	Ku-band antenna stow.
8/12:05	Orbit 137 begins.
8/12:35	Maneuver vehicle to +XLV, +YVV attitude.
8/12:50	Orbiter crew begins seven-hour sleep period.
8/13:20	Payload crew begins sleep period.
8/13:35	Orbit 138 begins.
8/15:05	Orbit 139 begins.
8/16:35	Orbit 140 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/18:05	Orbit 141 begins.
8/19:35	Orbit 142 begins.
8/19:50	Orbiter crew postsleep activities.
8/20:35	CRT 4 powerup.
8/20:50	Spacelab total deactivation begins.
8/20:50	Maneuver vehicle to IMU alignment attitude.
8/21:05	Orbit 143 begins.
8/21:05	IMU alignment: ST.
8/21:10	Maneuver vehicle to -XSI attitude.
8/21:20	Payload crew postsleep activities.
8/21:52	MS3 configures ICMS/ICRS headset for deactivation.
8/21:56	MS3 deactivates module lighting.
8/22:02	MS3, PS egress tunnel/airlock and deactivate.
8/22:16	MS3 configures Spacelab cabin fan for deactivation and performs cabin depressurization valve check.
8/22:21	MS3 informs MS2 to perform additional deactivation procedure.
8/22:23	MS3 performs additional deactivation procedures.
8/22:25	DTO 623--cabin air monitoring.
8/22:28	MS3 deactivates temperature controller.
8/22:29	MS3 deactivates experiment computer.
8/22:35	Orbit 144 begins.
8/22:35	Group B powerup.
8/22:35	MS3 deactivates CNDS separators.
8/22:40	MS3 deactivates SS command and data management system.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/22:44	MS3 configures Spacelab entry.
8/22:47	MS3 loads pulse code modulation master unit orbit formats.
8/22:50	OARE activation.
8/22:50	Begin deorbit preparation.
8/22:50	CRT timer setup.
8/22:54	Commander initiates coldsoak.
8/22:54	Stow radiators, if required.
8/23:05	Cardiovascular entry.
8/23:12	Commander configures DPS for deorbit preparation.
8/23:15	Mission Control Center updates IMU star pad, if required.
8/23:24	MS configures for payload bay door closure.
8/23:40	Maneuver vehicle to IMU alignment attitude.
8/23:52	MCC-H gives "go/no-go" command for payload bay door closure.

MET DAY NINE

9/00:00	Pilot and MS close payload bay doors.
9/00:05	Orbit 145 begins.
9/00:10	IMU alignment: ST/payload bay door operations.
9/00:20	Commander and pilot configure dedicated displays for entry.
9/00:33	MCC gives the crew the go for OPS 3.
9/00:36	Maneuver vehicle to deorbit burn attitude.
9/00:40	Pilot starts repressurization of SSME systems.
9/00:45	Commander and pilot perform DPS entry configuration.
9/00:54	MS deactivates ST and closes ST doors.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/00:56	All crew members verify entry payload switch list.
9/01:11	All crew members perform entry review.
9/01:13	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
9/01:26	Commander and pilot configure clothing.
9/01:35	Orbit 146 begins.
9/01:41	MS configure clothing.
9/01:51	Commander and pilot seat ingress.
9/01:53	Commander and pilot set up heads-up display (HUD).
9/01:55	Commander and pilot adjust seat, exercise brake pedals.
9/02:03	Final entry deorbit update/uplink.
9/02:09	OMS thrust vector control gimbal check is performed.
9/02:10	APU prestart.
9/02:25	Close vent doors.
9/02:29	MCC-H gives "go" for deorbit thrusting period.
9/02:35	Maneuver vehicle to deorbit thrusting attitude.
9/02:36	MS ingress seats.
9/02:44	First APU is activated.
9/02:50	Deorbit thrusting period.
9/02:55	Initiate post-deorbit thrusting period attitude.
9/02:59	Terminate post-deorbit thrusting attitude.
9/03:07	Dump forward RCS, if required.
9/03:15	Activate remaining APUs.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/03:19	Entry interface, 400,000 feet altitude.
9/03:22	Enter communication blackout.
9/03:23	Automatically deactivate RCS roll thrusters.
9/03:31	Initiate preprogrammed test inputs.
9/03:31	Automatically deactivate RCS pitch thrusters.
9/03:32	Initiate first roll reversal.
9/03:34	Exit communications blackout.
9/03:38	Initiate second roll reversal.
9/03:39	Initiate ammonia boilers.
9/03:41	Initiate air data system (ADS) probe deploy.
9/03:42	Initiate third roll reversal.
9/03:44	Begin entry/terminal area energy management (TAEM).
9/03:44	Initiate payload bay venting.
9/03:46	Automatically deactivate RCS yaw thrusters.
9/03:48	Begin TAEM/approach/landing (A/L) interface.
9/03:49	Initiate landing gear deployment.
9/03:50	Vehicle has weight on main landing gear.
9/03:50	Vehicle has weight on nose landing gear.
9/03:50	Initiate main landing gear braking.
9/03:51	Wheel stop.

GLOSSARY

AA	accelerometer assembly
ADS	air data system
AEM	animal enclosure module
A/L	approach and landing
APC	adaptive payload carrier
APU	auxiliary power unit
ASCS	atmosphere storage and control system
BFS	backup flight control system
CDMS	command and data management system
COAS	crewman optical alignment sight
CRT	cathode ray tube
CTV	crew transport vehicle
CVP	central venous pressure
C/W	caution/warning
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECS	environmental control system
ECLSS	environmental control and life support system
EDO	extended duration orbiter
EOM	end of mission
EPS	electrical power system
EPSP	experiment power switching panel
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FCS	flight control system
FDA	fault detection and annuciation
FES	flash evaporator system
FDF	flight data file
FPS	feet per second
GAS	getaway special
GBA	gas bridge assembly
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GPTU	general-purpose transfer unit
GPWS	general-purpose work station
GSFC	Goddard Space Flight Center

HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
IV	intravehicular
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
LSLE	life-sciences laboratory equipment
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
MODE	middeck zero-gravity dynamics experiment
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NMI	nautical miles
NOR	Northrup Strip
O&C	operations and checkout
OAA	orbiter access arm
OARE	orbiter acceleration research experiment
OCAC	on-orbit air cleaner
OEX	orbiter experiments
OMS	orbital maneuvering system
OSE	orbiter stability experiment
OTC	orbiter test conductor
PASS	primary avionics software system
PCS	pressure control system
PIC	pyro initiator controller
PMS	physiological monitoring system
POCC	payload operations control center
PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV

RAHF	research animal holding facility
RCS	reaction control system
RGA	rate gyro assembly
R/IM	refrigerator/incubator module
RMS	remote manipulator system
RSLS	redundant-set launch sequencer
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SAMS	space acceleration measurement system
SLS	Spacelab Life Sciences
SM	statute miles
SMIDEX	Spacelab middeck experiments
SMMI	small mass measurement instrument
SPOC	shuttle portable on-board computer
SRB	solid rocket booster
SSCE	solid surface combustion experiment
SRSS	shuttle range safety system
SSF	Space Station Freedom
SSME	space shuttle main engine
ST	star tracker
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAL	transatlantic landing
TCD	timing control distributor
TDRS	tracking data relay satellite
TI	thermal phase initiation
TIG	time of ignition
TPS	thermal protection system
TSM	tail service mast
TV	television
UMS	urine monitoring system
VTR	videotape recorder
WCS	waste collection system