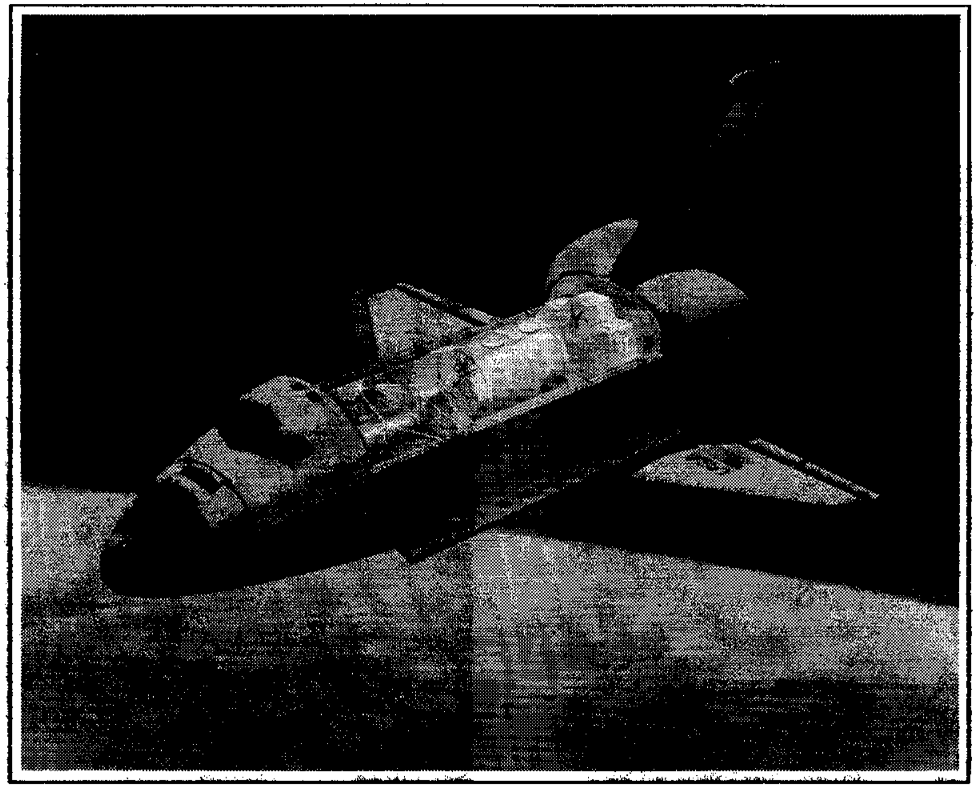


STS-50

PRESS INFORMATION

June 1992

Rockwell International
Space Systems Division

Office of External Communications & Media Relations

PUB 3546-V Rev 6-92

CONTENTS

MISSION OVERVIEW

This is the 12th flight of Columbia and the 48th for the space shuttle.

The flight crew for the 13-day STS-50 mission is commander Richard (Dick) N. Richards; pilot Kenneth (Ken) D. Bowersox; payload commander (lead mission specialist) Bonnie J. Dunbar; mission specialists Carl J. Meade and Ellen S. Baker; and payload specialists Lawrence (Larry) J. DeLucas and Eugene (Gene) H. Trinh. The crew will be divided into a blue team, consisting of Baker, Meade, and Trinh, and a red team, comprised of Richards, Bowersox, Dunbar, and DeLucas. Each team will work consecutive 12-hour shifts, providing for around-the-clock operations.

The primary objective of STS-50, the first dedicated extended duration flight in the history of the shuttle program, is to successfully perform the planned operations of the United States Microgravity Laboratory (USML)-1 payload, the first in a series of space shuttle Spacelab missions dedicated to studying microgravity materials processing technology and other science and research requiring the low-gravity environment of Earth orbit. Designed to help the U.S. maintain world leadership in microgravity research and development, the USML mission series will bring together representatives from academia, industry, and government (10 universities, 5 NASA centers, and 3 commercial interests on USML-1) to study basic scientific questions and gain new knowledge in materials science, biotechnology, combustion science, the physics of fluids, and the way energy and mass are transported within them. The USML missions will continue development and testing of experimental flight equipment for space station Freedom and will be laying the scientific foundation for microgravity research conducted over extended time periods.

USML-1 consists of 31 scientific experiments and associated hardware housed in a Spacelab long module–made up of a core segment and an experiment segment in the payload bay–and on the orbiter middeck. A long Spacelab transfer tunnel connects the Spacelab module with the orbiter crew module. Laboratory hardware includes new equipment, such as the crystal growth furnace, and some equipment that has flown previously, such as the solid surface combustion experiment. The experiments include the following:

The **Astroculture-l** hydroponic experiment is designed to validate a concept that was developed for supplying water and nutrients to plants growing in a microgravity environment.

The **crystal growth furnace** will grow crystals of materials (primarily semiconducting material, metal, and alloys) that form the basis of electronic devices in a microgravity environment. A directional solidification process will be used. The experiment consists of a large structure that has three furnaces (high temperature, low temperature, and adiabatic) and a carousel mechanism that places material samples into the processing mechanism. The CGF dictates the orbiter's attitude, since it requires that the long axis of the furnace be pointed along the velocity vector. Four different samples (HgCdTe, GaAs, CdTe, and HgZnTe) will be processed with run durations of 1,2,4, and 6 days.

The **drop physics module** is an instrument for conducting containerless material properties and materials processing experiments in space. The module uses acoustic waves to hold a drop of a particular material in the middle of the container. The experiment complement on USML-1 includes an investigation of surface-controlled phenomena (high-purity water), a study of rotating, oscillating drops (water, glycerine, and silicone oil), and an investigation of the kinetics of compound drops (water, silicone oil). In addition, instrument calibration and capability demonstrations are planned. Basic physics experiments such as these may provide new insights into processes such as cell encapsulation, which involves surrounding living cells with a membrane to protect them from harmful antibodies. This method could have tremendous potential in the treatment of several diseases.

The **extended duration orbiter medical project** consists of three major components: the in-flight lower body negative pressure experiment (LBNP), the heart rate and blood pressure variability during space flight experiment, and the air monitoring instrument evaluation and atmosphere characterization experiment. The LBNP experiment is used to evaluate the effectiveness of the combination of fluid loading (ingestion of salt tablets and water) during application of negative pressure to the lower body in reversing space flight-incurred cardiovascular changes. The objective of the study is to evaluate the effectiveness of fluid loading during LBNP in improving tolerance of an LBNP stress protocol. The heart rate and blood pressure variability during space flight experiment will determine if heart rate and arterial blood pressure exhibit less variability in a microgravity environment than on Earth. The air monitoring instrument evaluation and atmosphere characterization experiment will evaluate and verify the microbial air sampler to ensure proper function and operations in orbit. In addition, data will be collected on microbial contaminant levels during missions of various durations. The data will be used to establish baseline levels and to evaluate potential risks to crew health and safety. LBNP has flown before on STS-32, -43, and -44; heart rate and blood pressure variability during space flight has flown before on STS-41,-35, -39, -43, and -48; and the microbial air sampler has flown previously on STS-1 and -42.

The **generic bioprocessing apparatus** payload is designed as a self-contained mixing and heating module used to process biological fluid samples in a microgravity environment. It will support up to 132 individual experiments on small quantities of samples ranging from molecules to small organisms. The experiment hardware is located in the SMIDEX rack in the module, and refrigerated samples (4 degrees Celsius) will be kept in the GBA refrigerator/incubator module located in the middeck.

The **glovebox** facility will house 16 experiments to be conducted in a closed environment. These will include complementary experiments in fluid dynamics, protein crystal growth, and combustion science, as well as technology demonstrations. It is an enclosed working area that will be used for all specimen manipulations to prevent materials from entering the Spacelab module atmosphere and to prevent contamination of the materials when its containment has to be opened for observations, microscopy, photography, etc.

The primary objective of the **protein crystal growth** experiments is to produce large, high quality crystals of selected proteins under controlled conditions in microgravity. The results are applicable to the development of new/improved medicines and foods with improved nutritional value. There will be two refrigerator/incubator modules on the orbiter middeck, one at 22 degrees Celsius and one at 4 degrees Celsius. PCG has flown previously on STS-26, -29, -31, -32, -37, -42, -43, -48, and -49.

The **space acceleration measurement system** is a microprocessor-driven data acquisition system used to measure and record the Spacelab microgravity acceleration environment. Acceleration information will help scientists better understand their flight experiments by comparing results with vibration levels encountered in the shuttle. This information will also assist engineers as they design equipment and plan the placement of sensitive experiments on future missions. SAMS has flown before on STS-40, -42, and -43.

The primary objective of the **solid surface combustion experiment** is to measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds of polymethylacrylate or ashless filter paper in the reduced-gravity environment of space. SSCE has flown before on STS-40 and -41.

The purpose of the **surface tension-driven convection experiment** is to measure, by video photography and subsequent digital analysis, how thermocapillary flow (the fluid motion generated by surface tension variations due to a temperature difference along the interface of a fluid) affects containerless materials processing in the microgravity environment. The knowledge gained may assist in improving production of glasses and ceramics, semiconductor and protein crystals, metals, and alloys. In the experiment, a 4- in. diameter by 2-in. deep container of silicone oil is heated and data are collected on the velocity profile of the cross section of the oil. Two different methods of heating are used: surface heating by a carbon dioxide laser and internal heating by a heater cartridge. The effects of both are studied.

The objective of the **zeolite crystal growth** experiment is to evaluate the synthesis of large zeolite crystals in microgravity. Zeolites are complex arrangements of silica and alumina that occur naturally as well as synthetically. Because of their molecular sieve characteristics, zeolites are used as highly selective catalysts, absorbents, and ion exchange materials.

USML-1 experiments are sponsored by NASA and are managed by NASA's Marshall Space Flight Center, Huntsville, Ala.

Three secondary objectives will be flown on STS-50: Investigations Into Polymer Membrane Processing, Shuttle Amateur Radio Experiment II, and the Ultraviolet Plume Instrument.

The objective of the IPMP payload, sponsored by the Battelle Advanced Materials Center, a NASA center for the commercial development of space, is to investigate the formation of polymer membranes in microgravity. IPMP research could lead to possible advances in filtering technologies.

SAREX-II, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, will establish crew voice communication with amateur radio stations within the line of sight of the orbiter.

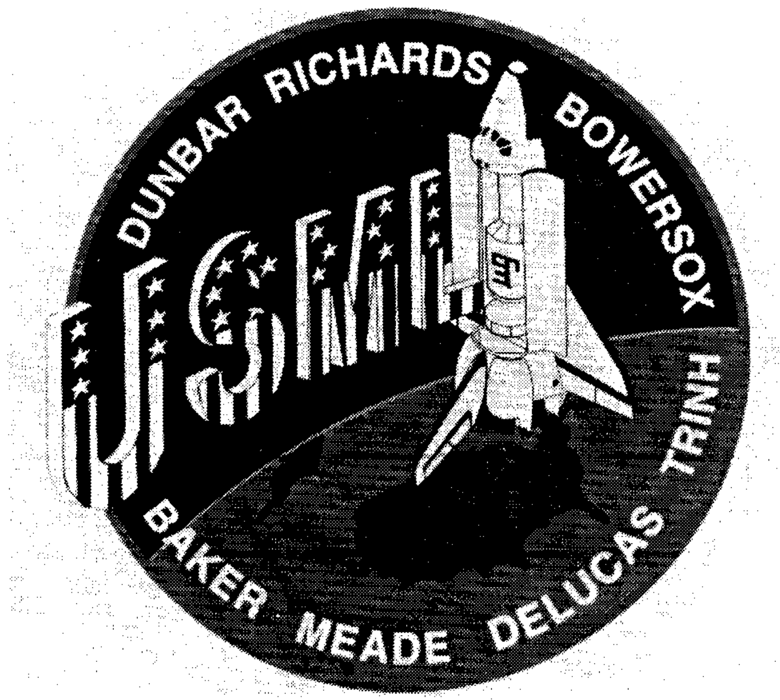
The UVPI is a payload of opportunity that will be conducted if time permits. It does not require any on-board hardware. It is a Department of Defense payload located on the Low-Power Atmospheric Compensation Experiment satellite, a Strategic Defense Initiative Organization satellite in low Earth orbit. UVPI's sensors will be trained on the orbiter to obtain imagery and/or signature data to calibrate the sensors and to observe jet firings during cooperative encounters of the orbiter with the LACE satellite.

At 12 days, 20 hours, 28 minutes, STS-50 will be the longest shuttle mission to date. The extended duration is made possible through conversion of Columbia into an extended duration orbiter capable of flights of up to 16 days in length. Under a 1988 NASA amendment to an existing Rockwell shuttle orbiter contract, Rockwell International Corporation's Space Systems Division (SSD) designed, developed, certified, and produced an extended duration orbiter (EDO) mission kit that will allow a shuttle to remain in orbit for up to 16 days, plus a two-day contingency capability. The EDO modification program is designed to reduce the number of flights required to accomplish tasks; lower risks, costs, and vehicle wear; and substantially increase the volume of data that can be collected on a mission.

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

In addition to conversion into the shuttle fleet's first extended duration orbiter, Columbia underwent a complete structural inspection, installation of a drag chute, calibration of its wing strain gauges, and nearly 50 other avionics, subsystems, and structures/ thermal protection system upgrades to improve vehicle performance during its six-month modification period at Rockwell's Palmdale facility. The changes were designed to maintain Columbia's structural integrity, keep the fleet uniform and technologically up-to-date and enhance vehicle turnaround time.

Fifteen detailed test objectives and twenty detailed supplementary objectives are scheduled to be flown on STS-50.



MTD 920610-3599

STS-50 Crew Insignia

MISSION STATISTICS

Vehicle: Columbia (OV-102), 12th flight

Launch Date/Time:

6/25/92	12:07 p.m., EDT
	11:07 a.m., CDT
	9:07 p.m., PDT

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

Launch Window: 3 hours, 7 minutes (2 hours, 30 minutes crew on back constraint)

Mission Duration: 12 days, 20 hours, 28 minutes

Landing: Nominal end-of-mission landing on orbit 206

7/8/92	8:35 a.m., EDT
	7:35 a.m., CDT
	5:35 a.m., PDT

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

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

Return to Launch Site: KSC

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

Inclination: 28.45 degrees

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

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 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 nautical miles (184 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2019
No. 2 position: Engine 2031
No. 3 position: Engine 2011

External Tank: ET-50

Solid Rocket Boosters: BI-051

Editor's Note: The following weight data are current as of June 16,1992.

Total Lift-off Weight: Approximately 4,519,680 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 257,265 pounds

Orbiter (Columbia) Empty, and 3 SSMEs: Approximately 180,784 pounds

Payload Weight Up: Approximately 24,589 pounds

Payload Weight Down: Approximately 24,589 pounds

Orbiter Weight at Landing: Approximately 228,003 pounds

Payloads–Payload Bay (*denotes primary payload): United States Microgravity Laboratory 1*, Orbital Acceleration Research Experiment

Payloads–Middeck: Investigations Into Polymer Membrane Processing; Shuttle Student Amateur Radio Experiment II; Zeolite Crystal Growth, Generic Bioprocessing Apparatus, Astroculture, Protein Crystal Growth (all part of USML-1)

Other Mission Objective–No Flight Hardware: Ultraviolet Plume Instrument (UVPI)

Flight Crew Members:

Red Team:

Commander: Richard (Dick) N. Richards, third space shuttle flight
Pilot: Kenneth (Ken) D. Bowersox, first space shuttle flight
Payload Commander (MS1): Bonnie J. Dunbar, third space shuttle flight
Payload Specialist 1: Lawrence (Larry) J. DeLucas, first space shuttle flight

Blue Team:

Mission Specialist 2: Ellen S. Baker, second space shuttle flight
Mission Specialist 3: Carl J. Meade, second space shuttle flight
Payload Specialist 2: Eugene (Gene) H. Trinh, first space shuttle flight

Richards, Bowersox, and Baker make up the orbiter crew, which operates the shuttle and Spacelab systems monitored by the Mission Control Center at NASA's Johnson Space Center, Houston, Texas. DeLucas, Trinh, Dunbar, and Meade form the science crew, which will operate the USML-1 experiments monitored by the Payload Operations Control Center at NASA's Marshall Space Flight Center in Huntsville, Ala.

Ascent Seating:

Flight deck, front left seat, commander Richard (Dick) N. Richards
Flight deck, front right seat, pilot Kenneth (Ken) D. Bowersox
Flight deck, aft center seat, mission specialist Ellen S. Baker
Flight deck, aft right seat, payload commander Bonnie J. Dunbar
Middeck, mission specialist Carl J. Meade
Middeck, payload specialist Lawrence J. DeLucas
Middeck, payload specialist Eugene H. Trinh

Entry Seating:

Flight deck, front left seat, commander Richard (Dick) N. Richards
Flight deck, front right seat, pilot Kenneth (Ken) D. Bowersox
Flight deck, aft center seat, mission specialist Ellen S. Baker
Flight deck, aft right seat, mission specialist Carl J. Meade
Middeck, payload commander Bonnie J. Dunbar
Middeck, payload specialist Lawrence J. DeLucas

Middeck, payload specialist Eugene H. Trinh

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: Ellen S. Baker
EV-2: Carl J. Meade

Intravehicular Astronaut: Kenneth (Ken) D. Bowersox

STS-50 Flight Directors:

Orbit 2/Lead: Bob Castle
Orbit 1: Rich Jackson
Orbit 4: Rob Kelso
Orbit 3: Gary Coen
Ascent/Entry/Orbit 3: Jeff Bantle

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 is installed in Columbia's middeck

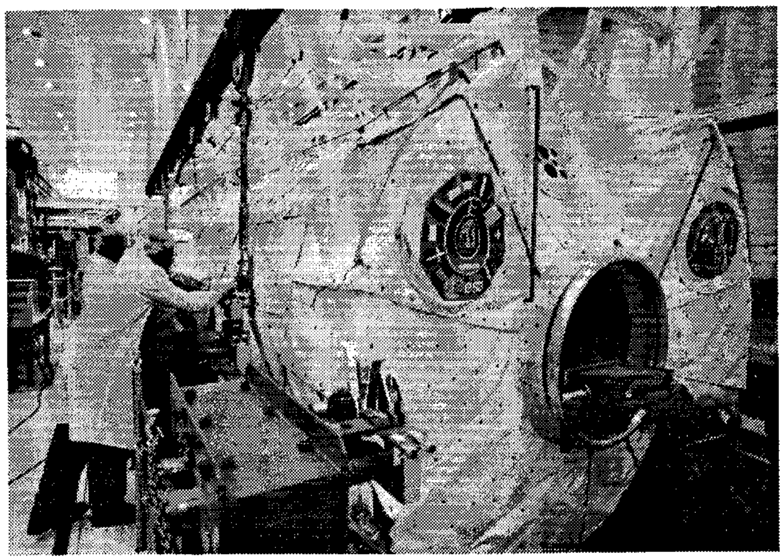
- Four flight control teams will be used instead of the usual three due to the length of the mission

- Landing is planned at EAFB concrete runway 22/04 because of Columbia's heavier landing weight (approximately 228,000 pounds at X-cg of 1080.8 in.) and vehicle mass movement (approximately 1 .72E06 ft-pounds). The STS-50 nominal end-of-mission landing weight is the second heaviest in the history of the program to date (STS-32 nominal end-of-mission weight was 228,400 pounds at X-cg of 1080.5).

- STS-50 is the first flight of carbon brakes on Columbia and will use the lighter braking profile, if possible, for the end of the mission. Given the wind conditions of the day combined with the heavy weight of the vehicle and use of the 300-knot outer glide slope, performance of the light braking DTO may not be done if the drag chute is not deployed. A real-time evaluation of braking requirements will be performed to determine whether the light braking profile is acceptable with/without the drag chute deployment. For those cases where the light braking profile is not acceptable (rollout margin of less than 2,000 feet) the standard braking profile will be used.

MISSION OBJECTIVES

- Primary Objective
  - — United States Microgravity Laboratory (USML)-1
- Secondary Objectives
  - — Middeck
    - Investigations Into Polymer Membrane Processing (IPMP)
    - Shuttle Amateur Radio Experiment (SAREX)-II
  - — Payload Bay
    - Orbital Acceleration Research Experiment (OARE)
- Ultraviolet Plume Instrument (payload of opportunity—no flight hardware)
- Development Test Objectives/Detailed Supplementary Objectives



MTD 920610-3599

USML-1 Is Readied for Transfer to Orbiter Processing Facility at KSC

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Unstow cabin
Spacelab activation
Payload activation

Flight Days 2–12

USML-1 operations

Flight Day 13

Crew press conference
RCS hot-fire test
FCS checkout

Flight Day 14

Spacelab deactivation
Deorbit preparation
Deorbit burn
Landing

Notes:

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

STS-50 CREW ASSIGNMENTS

*Denotes primary responsibility

Commander (Richard N. Richards):

Overall mission decisions
Payload—IPMP, SAREX*
DTOs/DSOs—DTOs 251*, 312*, 519*, 521*, 666, 805*, and 910; DSOs 605, 621, and 904
Other—medic

Pilot (Kenneth D. Bowersox):

Orbiter—IFM*
Payload—IPMP*
DTOs/DSOs—DTOs 251, 519, 521, 623*, 645, 658*, 663, 665*, 666, and 805; DSOs 605, 614, 617, 618, and 904
Other—intravehicular astronaut*, Earth observations, photo/TV,

Payload Commander (MS1) (Bonnie J. Dunbar):

Payload—IFM (Spacelab), USML*
DTOs/DSOs—DTO 655*; DSOs 314*, 478, 611, 613, 617, and 904

Mission Specialist 2 (Ellen S. Baker):

Orbiter—IFM
Payload—SAREX
DTOs/DSOs—DTOs 645*, 658, 663*, 665, and 910*; DSOs 472*, 484*, 614, 617, 620 (setup), 621, 802*, and 904
Other—EVA 1, medic*, Earth observations*, photo/TV*

Mission Specialist 3 (Carl J. Meade):

Payload—IFM (Spacelab), USML
DTOs/DSOs—DTOs 312 and 655; DSOs 472, 474, 484, 601, 603*, 611, 618 (control), and 904
Other—EVA 2

Payload Specialist 1 (Lawrence J. DeLucas):

DTOs/DSOs—DSOs 472, 474, 478, 603, 605, 611, 613, 620 (spotter), and 904

Payload Specialist 2 (Eugene H. Trinh):

DTOs/DSOs—DSOs 472, 474, 484, 601, 603, 611, 620, 621, and 904

STS-50 crew members are, from left, mission specialist Ellen S. Baker, pilot Kenneth D. Bowersox, payload commander Bonnie J. Dunbar, mission commander Richard N. Richards, mission specialist Carl J. Meade, and payload specialists Eugene H. Trinh and Lawrence J. DeLucas

MTD 920610-3599

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

*Indicates part of USML-1 payload

DTOs

- Ascent aerodynamic distributed loads verification on Columbia (DTO 236)
- Entry aerodynamic control surfaces test—alternate elevon schedule, part 1 (DTO 251)
- Ascent wing structural capability evaluation (DTO 301 D)
- Entry structural capability evaluation (DTO 307D)
- ET TPS performance--methods 1 and 2 (DTO 312)
- On-orbit PRSD cryo hydrogen boil-off (DTO 413)
- Carbon brake system test, condition 5 (DTO 519)
- Orbiter drag chute system, test 0 (DTO 521)
- Cabin air monitoring (DTO 623)
- Foot restraint evaluation (DTO 655)
- Evaluation of the ergometer vibration isolation system (DTO 658)
- Acoustical noise dosimeter data (DTO 663)
- Acoustical noise sound level data (DTO 665)
- Modify ECLSS supply air ducting to provide chilled air to suited crew members (DTO 666)
- Orbiter experiment (OEX) orbital acceleration research experiment (OARE) (DTO 910)

DSOs

- Columbia accelerations data collection to support micorgravity disturbances experiment (DSO 314)
- Intraocular pressure (DSO 472)
- In-flight retinal vascular changes detected by digital image analysis and correlation with space adaptation syndrome (DSO 474)
- In-flight lower body negative pressure (DSO 478)*
- Assessment of circadian shifting by bright light in astronauts (DSO 484)
- Heart rate and blood pressure variability during space flight (DSO 602)*
- Orthostatic function during entry, landing, and egress (DSO 603B)
- Postural equilibrium control during landing/egress (DSO 605)
- Air monitoring instrument evaluation and atmosphere characterization, microbial air sampler, configuration 2 (DSO 611)*
- Changes in the endocrine regulation of orthostatic tolerance during space flight (DSO 613)

- The effect of prolonged space flight on head and gaze stability during locomotion (DSO 614)

- Evaluation of functional skeletal muscle performance following space flight, group 1 (DSO 617)

- Effects of intense exercise during space flight on aerobic capacity and orthostatic function (DSO 618)

- Physiological evaluation of astronaut seat egress ability at wheel stop (DSO 620)

- In-flight use of Florinef to improve orthostatic intolerance post-flight (DSO 621)

- Educational activities, objective 1 (DSO 802)

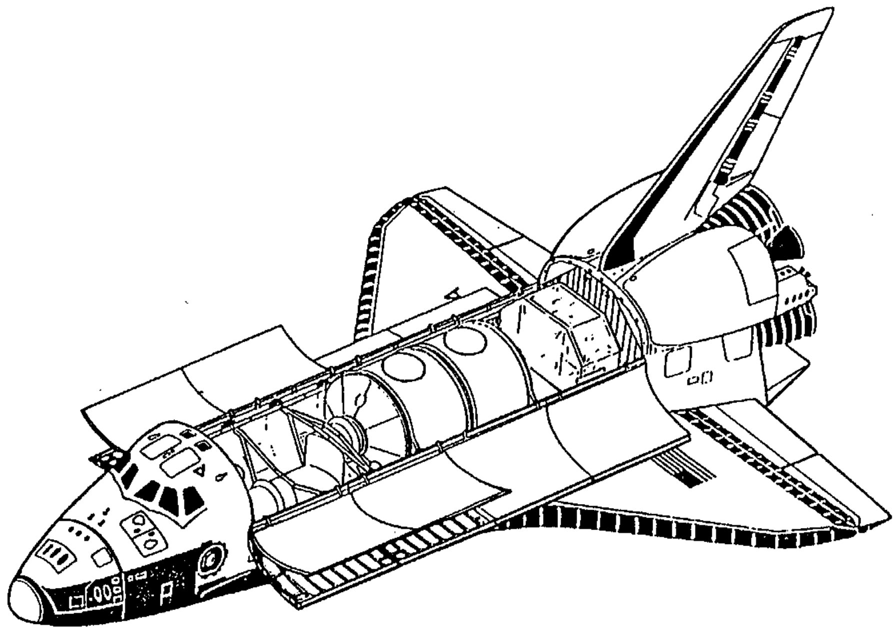
- Documentary television (DSO 901)

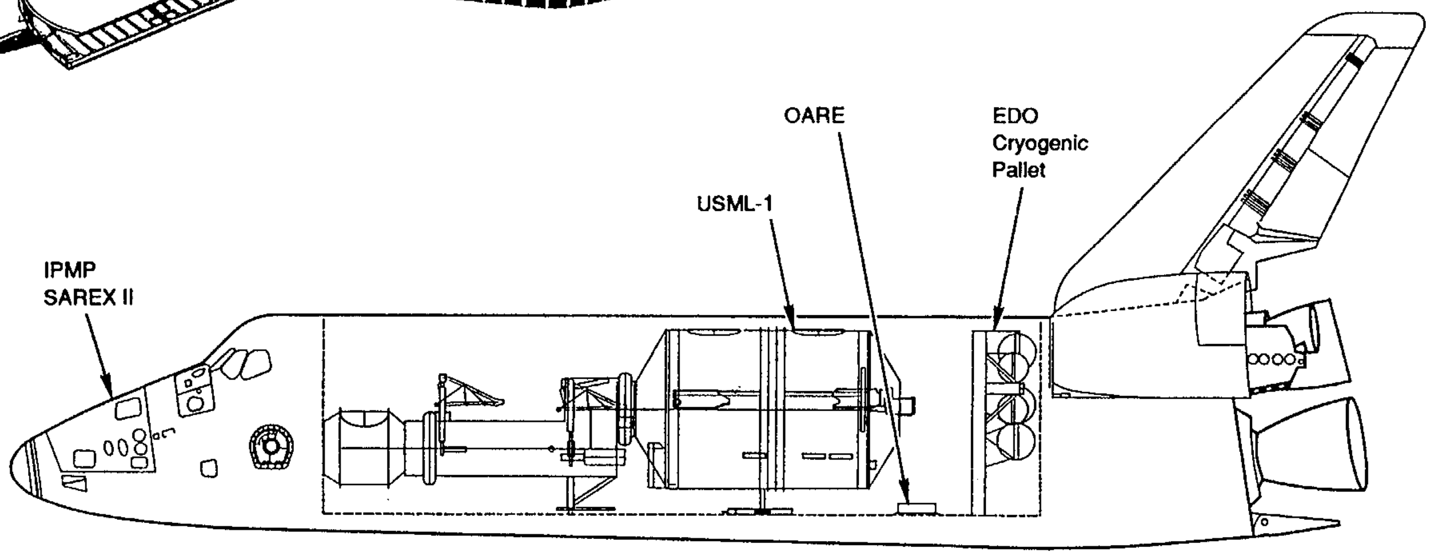
- Documentary motion picture photography (DSO 902)

- Documentary still photography (DSO 903)

- Assessment of human factors (DSO 904)

STS-50 PAYLOAD CONFIGURATION





MTD 920515-3581

UNITED STATES MICROGRAVITY LABORATORY

Since the beginning of the U.S. space program, microgravity has been the subject of exhaustive research that has often produced valuable insights into physical processes. NASA's United States Microgravity Laboratory Program, a cooperative venture of NASA's Office of Space Science and Applications and the Office of Commercial Programs, is the next step in microgravity research involving NASA, researchers in fundamental and engineering sciences, and private industry.

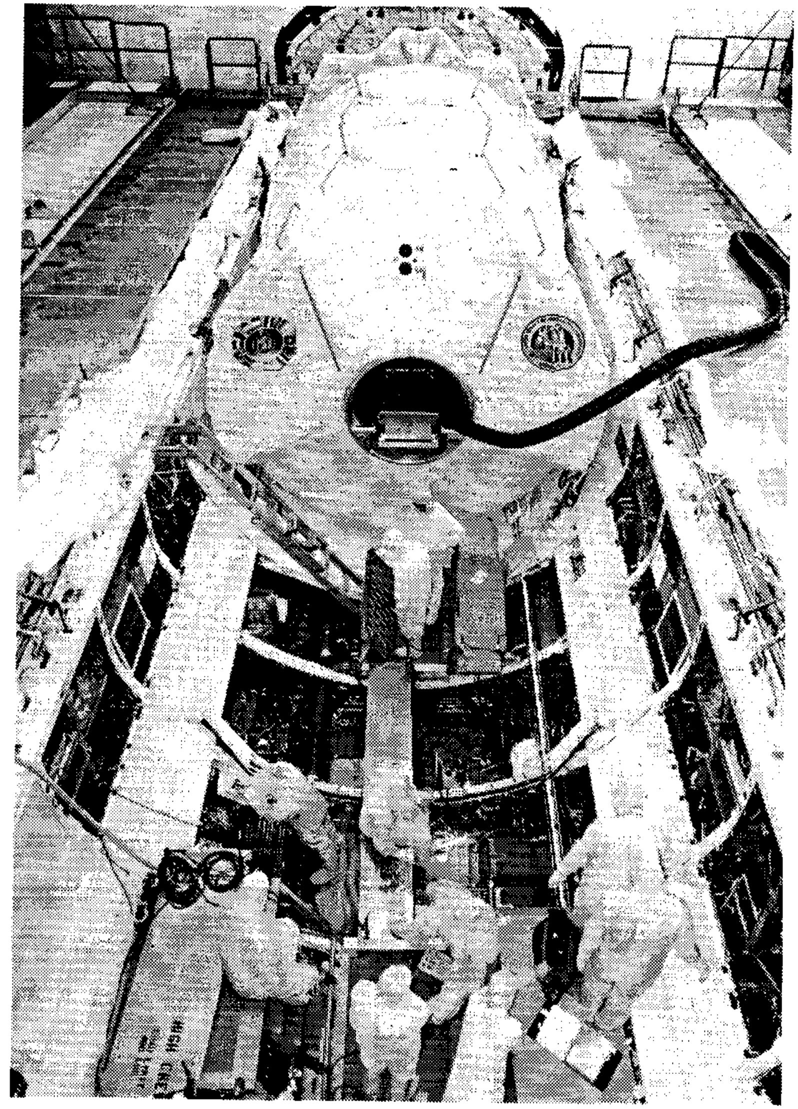
The USML is a key component in the preparations for a new age of space exploration. Flying in orbit on the space shuttle for extended periods of time, the laboratory will provide researchers greater opportunities to conduct investigations of material sciences, fluid dynamics, biotechnology, and combustion science. USML-1, the first mission in NASA's vital space exploration initiative, will pave the way for future USML flights and help prepare for advanced microgravity research and processing on board space station Freedom.

USML-1 is housed in the European Space Agency's Spacelab, a pressurized module in Columbia's payload bay that provides astronauts a shirt-sleeve environment for conducting experiments.

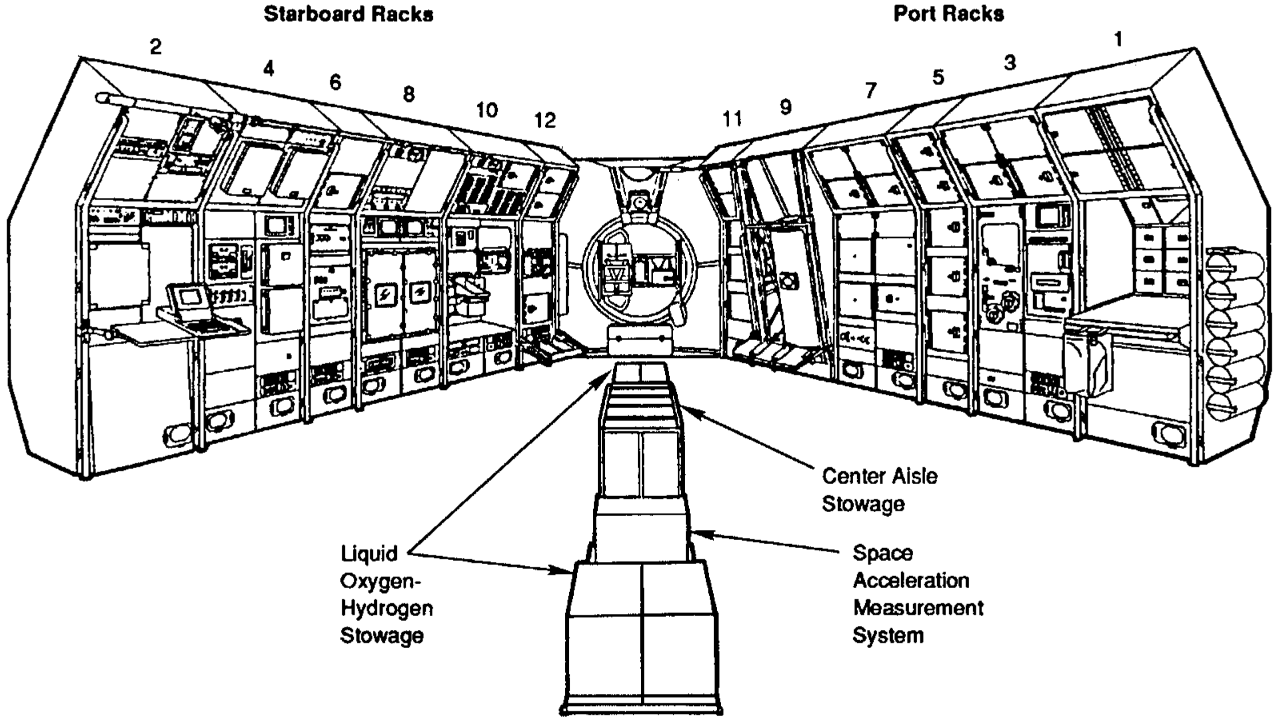
AREAS OF INVESTIGATION

The USML-1 payload comprises 31 investigations in five basic areas: fluid dynamics (how liquids and gases respond to the presence or absence of different forces), the production of organic and inorganic crystals, the study of the processes and phenomena of combustion, the study of plant and animal life, and technology demonstrations.

The fluid dynamics experiments will examine several basic fluid phenomena that cannot be studied on Earth because of the



Workers Establish Mechanical Interfaces Between Space Shuttle Columbia and USML-1



Rack 2:	Control Center
Rack 4:	Subsystems (TV/Video)
Rack 6:	Drop Physics Module Control Systems, Rack Stowage Container
Rack 8:	Drop Physics Module Mechanical Assembly
Rack 10:	Solid Surface Combustion Experiment, Generic Bioprocessing Apparatus, Extended-Duration Orbiter Medical Program
Rack 12:	Glovebox

Rack 1:	Workbench
Rack 3:	Surface-Tension-Driven Convection Experiment
Rack 5:	Stowage
Rack 7:	Crystal Growth Furnace
Rack 9:	Crystal Growth Furnace Integrated Furnace Assembly
Rack 11:	Stowage

MTD 920610-3578

USML-1 Interior Layout

effects of gravity. Knowing how and why these phenomena occur will enable scientists to understand how they influence material science processes and will help them develop methods of reducing or eliminating their undesirable effects in Earth-based experiments and processing.

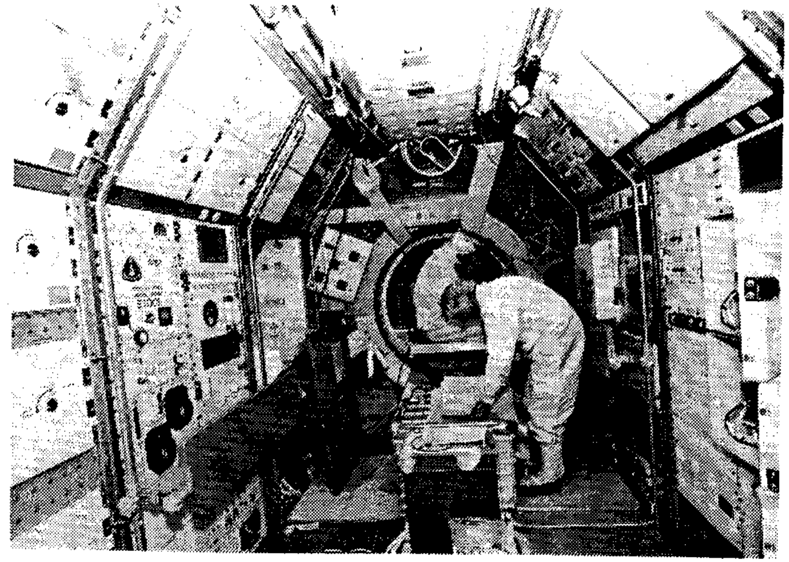
USML-1 will grow both organic and inorganic crystals so that scientists can learn more about growing crystals in microgravity and about the crystals themselves. Crystals play major roles in our lives, from the formation of the proteins in our bodies and to their use in semiconductors in electrical appliances. The microgravity of space allows scientists to grow the nearly perfect samples they need to be able to study crystals and their uses.

On this mission, scientists will observe combustion phenomena that are not normally observable on Earth because of the influence of gravity. They will study the different shapes of flames and how flames spread in microgravity compared to gravity.

In the biological experiments, researchers will investigate the production of various products and monitor the effects of extended exposure to microgravity on human physiology.

The technology demonstrations are opportunities to try out new procedures and facilities for future space missions.

These investigations will be conducted around the clock during Columbia's 13-day mission, which is the longest to date in the shuttle program. Scientists require longer periods in microgravity for their experiments to prepare for long-term microgravity research on the space station. Columbia can remain in orbit longer because it has been outfitted with additional oxygen and hydrogen tanks for propulsion, extra middeck lockers, extra nitrogen tanks for cabin air, and a system for removing carbon dioxide from the cabin air. Eventually, orbiters with extended-duration kits could stay in orbit for up to 90 days.



MTD 920610-3599

USML-1 Takes Shape at KSC

USML-1 SCIENCE EXPERIMENTS

Crystal Growth Furnace (CGF)

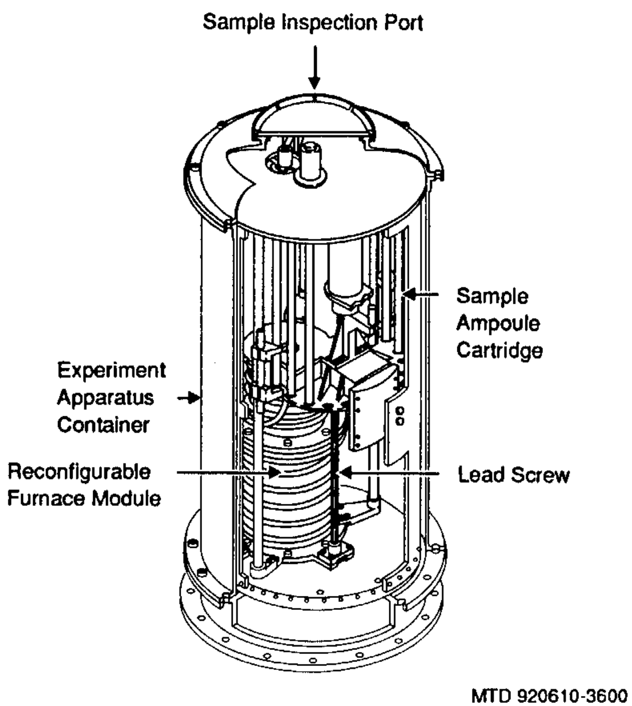
The CGF is a reusable device that can use either the directional solidification or vapor transport method to produce crystals on this and future USML missions. It is one of the first furnaces produced by the United States that is capable of producing many large crystals at temperatures above 1,000°C.

Three of the CGF experiments will use the directional solidification method to grow crystals. In this process, the CGF melts all but one end of a sample, and a crystal grows in a particular direction as the furnace moves and the melted sample resolidifies.

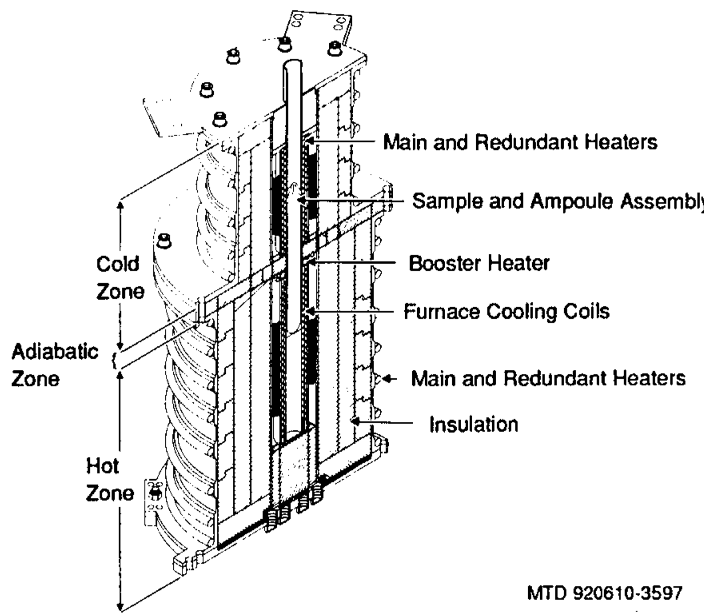
In the vapor transport process, crystals are formed as vaporized material is deposited on a substrate, or base, in a cooler section of the CGF.

The CGF is mounted in the integrated furnace experiment assembly. Part of this assembly is the reconfigurable furnace module, which contains five heating zones—three hot and two cold. The heating zones pass over the experiment samples, melting them in a controlled manner and promoting optimal crystal growth. The heating levels and gradients of the module can be modified, which permits the furnace to be used on several missions to process different types of crystals.

As many as six samples can be processed automatically by the CGF. On orbit, a crew member loads the sample cartridges in a rotary carousel, which positions the sample cartridges so the furnace



The Crystal Growth Furnance



The Reconfigurable Furnance Module

unit can move over them. Computer instructions in the flight software control the sample processing, but investigators on the ground can modify the processing by transmitting new commands to the onboard computer.

Orbital Processing of High-Quality CdTe Compound Semiconductors. This experiment studies the effects of gravity on the growth and quality of alloyed compound semiconductors.

Researchers will grow a crystal of cadmium zinc telluride (CdZnTe) in the CGF for comparison with a crystal produced by the same growth method on Earth. CdZnTe crystals are used as substrates in a variety of mercury cadmium telluride (HgCdTe) infrared detectors. Investigators would like to know if processing the CdZnTe crystals in microgravity will improve the chemical homogeneity of the detector substrates, which would minimize strain where the substrate and active HgCdTe layers join and reduce defects caused by gravitationally dependent phenomena.

The seeded Bridgman-Stockbarger method will be used to process the sample of CdZnTe in the CGF. After the sample is inserted in the unit, the hot-zone temperature will be ramped to 1,175°C and the cold-zone temperature to 980°C. (The melting point of CdZnTe is 1,095°C.) After the furnace melts the bulk of the sample, the melted material will be allowed to come into contact with the high-quality seed crystal in the unmelted portion of the sample. With the melt now seeded, the translation of the furnace will be reversed and it will travel over the stationary sample, directionally solidifying the sample.

Researchers will examine the CdZnTe crystal after the mission with infrared and optical microscopy and other characterization techniques to quantitatively map the chemical, physical, mechanical, and electrical properties of the crystal. They will also compare its properties to those of a crystal processed identically on Earth. They will quantitatively compare thermal, compositional, and stress models to the experimental results for the space- and Earth-grown crystals.

The principal investigator for this experiment is Dr. David J. Larson, Jr., of the Grumman Corporate Research Center.

Crystal Growth of Selected II-VI Semiconducting Alloys by Directional Solidification. The purpose of this experiment is to determine how growing mercury zinc telluride (HgZnTe) II-VI semiconductor crystals in a low-gravity environment affects their structural, electrical, and optical properties. HgZnTe is being investigated for use in infrared radiation detection. Crystals of HgZnTe are classified as II-VI because of the position of their constituent atoms in the vertical columns of the periodic table.

It is nearly impossible to grow homogeneous, high-quality bulk crystals of HgZnTe on Earth because of gravity-induced fluid flows and compositional segregation. It is expected that more even mixing of the components of the crystal can be obtained in microgravity processing.

Besides evaluating the effect of gravitationally driven fluid flows on the HgZnTe crystal's composition and microstructure and determining the possible role of irregular fluid flows and hydrostatic pressure effects in causing crystal defects, the scientists hope to produce enough high-quality HgZnTe crystals to be able to conduct bulk crystal property characterizations and fabricate detectors that can be used to establish ultimate material performance limits.

The directional solidification method will be used to process samples of HgZnTe in the CGF. After melting the sample in the 800°C hot zone, the furnace will move very slowly over the sample (3.5 mm per day) to resolidify the material. This slow rate is necessary to prevent constitutional supercooling ahead of the solidification interface.

After the mission, investigators will use an array of characterization techniques to examine the chemical homogeneity and microstructural perfection of the crystals. Detectors will be fabricated from the crystals and evaluated.

Dr. Sandor L. Lehoczky of the Marshall Space Flight Center is the principal investigator for this experiment.

The Study of Dopant Segregation Behavior During the Growth of GaAs in Microgravity. This experiment investigates ways of obtaining complete uniformity of selenium dopant in gallium arsenide (GaAs) crystals.

GaAs has electronic properties that make it almost as popular as silicon as a material for semiconductors. However, the distribution of the impurities, or dopants, added to GaAs in minute amounts (10 parts per million) to determine its material properties cannot be precisely controlled during the formation of the crystals on Earth because of the effects of gravity. In this experiment, scientists will investigate whether uniform distribution of the selenium dopant can be achieved in microgravity.

Time constraints of the mission permit only one sample to be processed. Scientists will study the sample after the mission to characterize its properties. They will compare their data to analytical and computer model theories of crystal growth.

The principal investigator is Dr. David Matthiesen of GTE Laboratories.

Vapor Transport Crystal Growth of Mercury Cadmium Telluride in Microgravity. This experiment establishes the relationship between convective flow, mass flux, and crystal morphology and examines the effects of microgravity on the properties of HgCdTe crystals.

During the processing of the HgCdTe sample, researchers will observe temperature profiles, how the shape of the sample ampoule affects mass transport and crystal growth, and other phenomena to get a better understanding of the factors that influence the growth of the crystal in microgravity. The goal of such research is to improve the performance of infrared detectors in which crystals of HgCdTe are used by producing crystals that have no large structural defects and more evenly dispersed constituent elements.

The vapor transport process will be used in this experiment to grow HgCdTe crystals.

Scientists will use microscopy, spectroscopy, and other techniques to evaluate the morphology, structural perfection, and properties of the crystals after the mission. An infrared detector may be fabricated from the crystals to study their performance.

Dr. Heribert Wiedemeier of the Rensselaer Polytechnic Institute is the principal investigator.

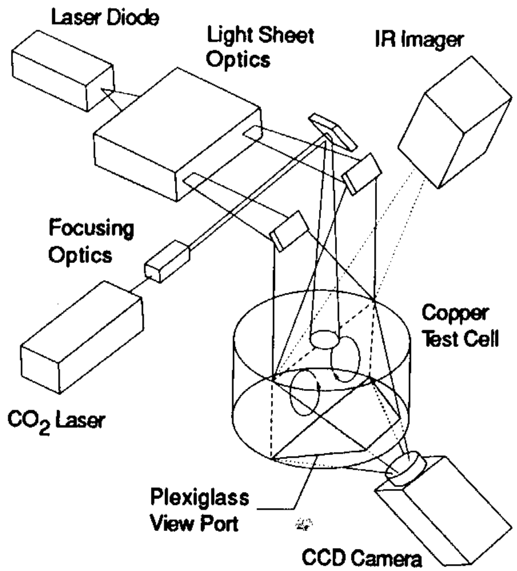
Surface-Tension-Driven Convection Experiment (STDCE)

This experiment studies the basic fluid mechanics and heat transfer of thermocapillary flows in microgravity. Thermocapillary flow is the motion of fluids created by variations in temperature along the free surfaces of liquids. Thermocapillary flow and other types of unwanted flows, such as buoyancy-driven flows, that occur during processing cause defects in crystals, metals, and alloys produced from gases and liquids. Buoyancy-driven flows and convection are overcome by processing materials in microgravity, but thermocapillary flows remain a problem. Free from the effects of gravity, thermocapillary flows are much easier to study in space, and scientists can examine how these flows are influenced by different imposed surface temperature distributions (thermal signatures), interface shapes, and other controllable factors.

Scientists will use state-of-the-art equipment to obtain quantitative data on steady and unsteady flows for a variety of conditions and experiment configurations. They will also try to determine the conditions that cause oscillations in the flows. The data will be useful in predicting thermocapillary flows.

This experiment will be performed in two parts. In the first part, the free surface of silicone oil contained in a cylinder 10 cm in diameter by 5 cm high will be heated to generate thermocapillary flows. Two heaters will be used: a CO_2 laser that produces various temperature distributions along the surface of the oil and a submerged heater that imposes a range of temperature differences. From the detailed data obtained on flow velocity, temperature fields, and surface temperatures, scientists will define the nature and extent of thermocapillary flows in microgravity.

Temperature and flow field measurements will be taken by a sophisticated data acquisition system connected to the experiment



Schematic View of the Test Cell and Associated Hardware

container. Fluid flows can be observed by illuminating aluminum oxide particles suspended in the oil with a laser and recording particle motion with a video camera attached to a view port below the experiment container. Surface temperatures of the oil, which determine the driving force of the flow, will be measured by a scanning infrared imager, and bulk oil temperatures will be measured by thermistors inside the container.

Data from the first series of experiments will be transmitted to researchers in the Spacelab Mission Operations Control Center at the Marshall Space Flight Center. After analyzing the data, they will send new test parameters for the next series of tests to the experiment computer in Spacelab.

The data they obtain will allow scientists to develop mathematical models of thermocapillary flow, which is currently believed to result from interaction among driving force, fluid flow, and surface shape.

Dr. Simon Ostrach of Case Western Reserve University is the principal investigator for this experiment.

Drop Physics Module (DPM)

The DPM, in which drops of material are suspended by relatively weak sound waves, enables scientists to test basic theories of fluid physics that cannot be proved on Earth because of gravity. The DPM used in USML-1 is an advanced version of the module that was flown on Spacelab 3 in 1985.

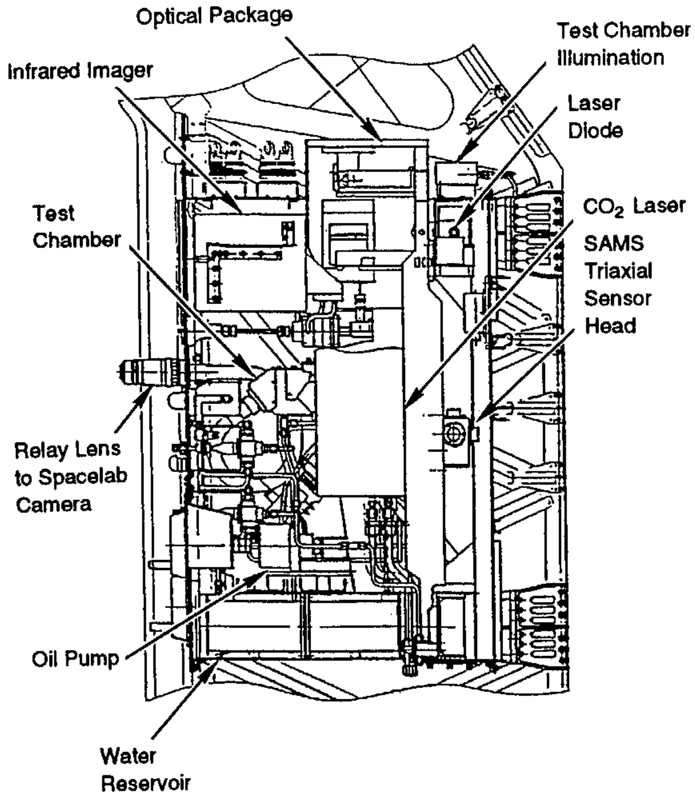
The DPM is used for studying the dynamics of drops in detail, but it also demonstrates containerless processing, a technique that may prove valuable in the future because of the way the module, in conjunction with microgravity, isolates the sample being studied from the container and its potentially harmful effects. In the future, scientists plan to melt solids in the DPM, study the fluid, and resolidify the material, all without touching the sample.

Film and video cameras record the behavior of drops positioned in the DPM by sound waves. Crew members can view the drop's response on a video display and manipulate the drop by modulating the sound waves.

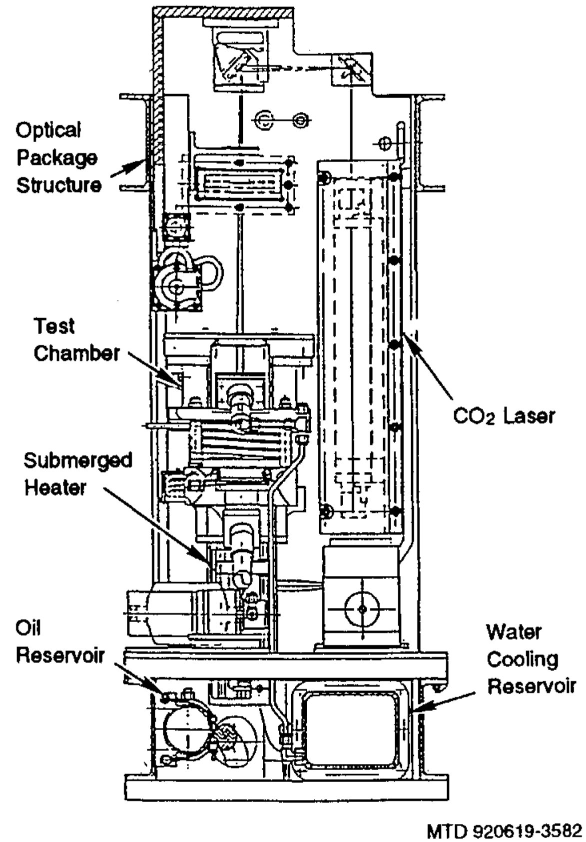
When real-time video is available, scientists on the ground can observe the experiment, discuss it with the astronaut operator, analyze the video images, and suggest things the operator could do to increase the experiment's scientific return.

Drop Dynamics Experiment. This experiment gathers data on the behavior of drops in microgravity.

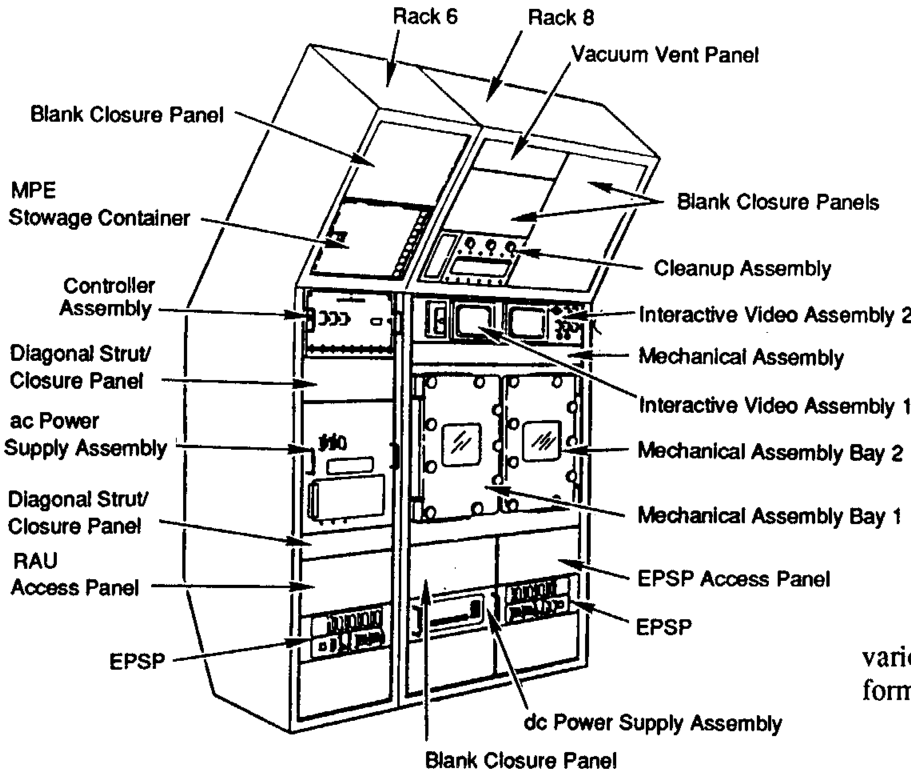
Some of the investigations were conducted in the Spacelab 3 DPM and produced unexpected results. Scientists hope the



STDCE Experiment Package, Side View



STDCE Experiment Package, Front View

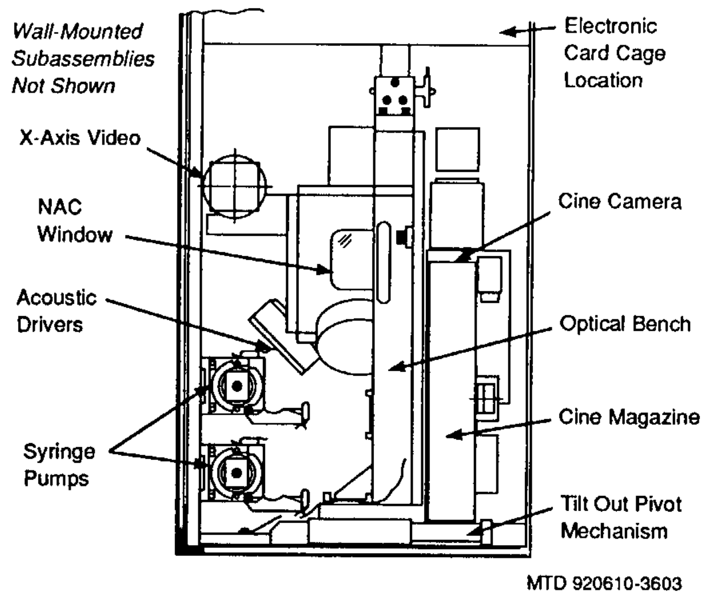


Drop Physics Module

advanced DPM being used on the USML-1 mission will resolve the differences between theory and experiment.

Researchers will also investigate for the first time methods of encapsulating cells in a drop. This could prove beneficial in treating diseases such as diabetes through cell transplantation.

In this experiment, researchers will determine the equilibrium shapes of rotating drops of water, water and glycerin, and silicone oil and the shape oscillation frequency of simple and compound drops. In the encapsulation study, researchers will subject a drop of calcium chloride into which a drop of sodium alginate has been injected to



The Drop Physics Module

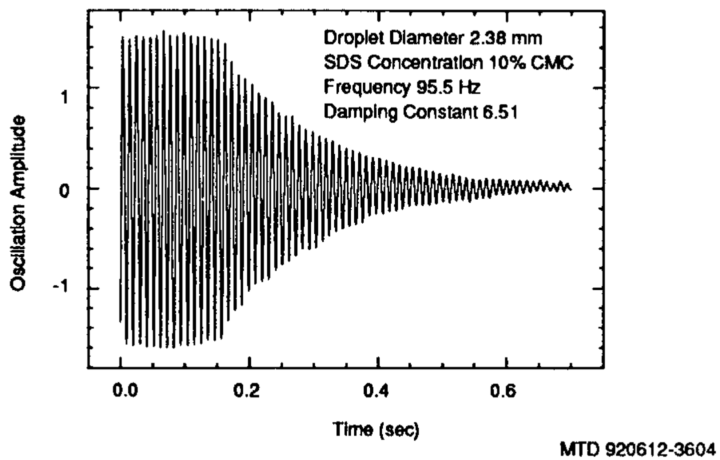
various acoustic conditions to find the best method of forming uniform concentric spherical membranes.

The principal investigator for this experiment is Dr. Taylor Wang of Vanderbilt University.

Science and Technology of Surface-Controlled Phenomena. This experiment determines the surface properties of drops coated with surfactants (materials that migrate toward free surfaces or the interface between two liquids) and examines the coalescence of surfactant-coated drops.

The results of the two sets of experiments planned should help scientists to better understand what is going on in the surface layer of a drop of water and provide better information for the application of surfactants in industry.

In one set of experiments, water drops that contain a variety of surfactants in different concentrations will be oscillated in the DPM by being "squeezed" acoustically and released. Researchers will relate the measured frequencies and damping of the oscillations to surface properties, such as shear and dilatational viscosities, with the help of theoretical expressions.

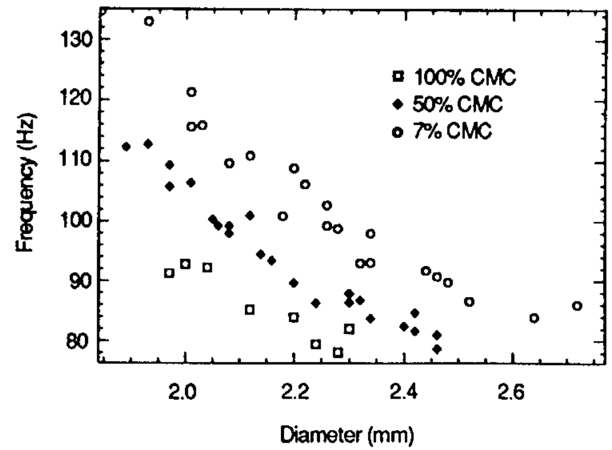


Time History of Damped Guadrupole Shape Oscillations of a Water Droplet With Small Concentration of Surfactant

In the second set of experiments, two drops of water will be positioned in the DPM and forced toward each other until they coalesce. The size of the water drops and the concentrations of surfactants in the drops will vary. The drops containing heavier concentrations of surfactants should not coalesce spontaneously; they will be forced to combine. Researchers will try to characterize the critical parameters that cause the drops to rupture and coalesce.

Dr. Robert E. Apfel of Yale University is the principal investigator.

Measurement of Liquid-Liquid Interfacial Tension and the Role of Gravity in Phase Separation Kinetics of Fluid Glass Melts.

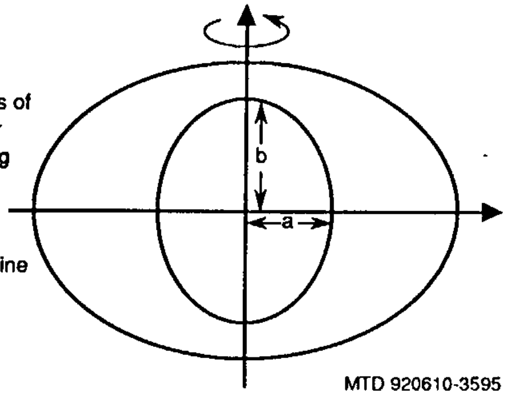


Guadrupole Resonance Frequency of Water Droplets as a Function of Droplet Diameter and Surfactant Concentration

This experiment assesses the effect of gravity on phase separation in liquids and the geometrical structure of a two-phase glass and investigates a unique method for measuring the tension between the interfaces of drops and other materials.

Many liquid solutions and glasses separate into phases when they are held in appropriate temperature ranges. In glass, this process is referred to as liquid-liquid phase separation. In this experiment, the interfacial tension of a compound drop comprising two immiscible liquids will be measured by the spinning-drop technique. Interfacial tension is one of the key parameters governing the rate of phase separation.

As the compound drop is rotated in the DPM, the shapes of the inner and outer drops will be distorted. Scientists will study photographs of the drops' distorted geometries and, with the help of theoretical models, will calculate the interfacial tension of the compound drop's components. Several compound drops with different properties and surface interactions will be measured.



Interfacial Tension Measurement Methodology

If this experiment is successful, the technique could be used to measure the interfacial tension of high-temperature glasses in microgravity. It is not possible to make such measurements on Earth.

The principal investigator is Dr. Michael C. Weinberg of the University of Arizona.

Astroculture

This experiment evaluates the effectiveness of the Astroculture plant watering system in microgravity. The Astroculture unit is designed to support the growth of plants in microgravity through precise watering and delivery of nutrients.

Astronauts will have to grow plants during lengthy space missions to reduce the costs of providing food, oxygen, and pure water and removing carbon dioxide from the air supply. The Astroculture unit is capable of operating in weightlessness or the partial gravity of the moon or Mars.

The Astroculture system consists of pumps, porous stainless steel tubes for delivering and recovering a nutrient solution, and a rooting matrix. The delivery tube carries nutrients under negative pressure to the rooting matrix of baked montmorillinitic clay. The recovery tube, operating at a greater negative pressure than the delivery tube, removes water from the rooting matrix, simulating the action of plant roots.

On this mission, researchers will use a computer system to determine how fast the nutrient solution passes through the root matrix at different combinations of pressure levels. The information they gather will tell them how well the Astroculture unit replaces the water and nutrients used by growing plants in microgravity.

Other plant growth subsystems, such as lighting and atmosphere control, will be tested on future missions before plants are grown.

The principal investigator for this experiment is Dr. Theodore W. Tibbitts of the Wisconsin Center for Space Automation and Robotics at the University of Wisconsin.

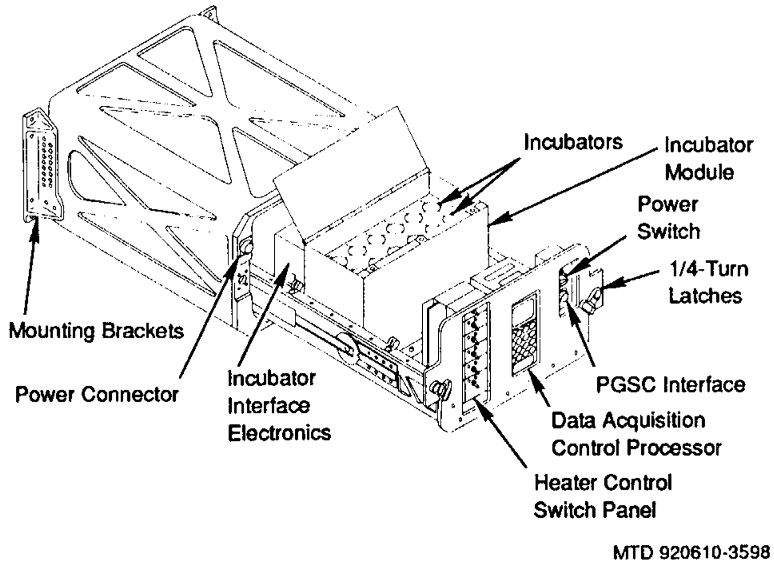
Generic Bioprocessing Apparatus

This multipurpose facility, which supports up to 132 individual experiments, is used to research the relationship between gravity and biology in molecules and small organisms.

On this mission, one experiment will study how macromolecules of collagen form fibers. If the absence of gravity changes the fiber assembly, collagen could find more use as artificial skin, blood vessels, and other body parts.

Another experiment will see if the microstructural assembly of liposomes and virus capsids can be formed in a manner that would allow them to target drugs to selected body tissues for treatment. An examination of the process of mineralization and its effect on the embryonic bone tissue of rodents will help explain why astronauts experience loss of bone material during weightlessness in space and possibly shed light on medical problems like osteoporosis.

Tests on microorganisms will yield information useful in the design of waste treatment and water recovery systems for lengthy



The Generic Bioprocessing Apparatus

space missions. It will also help scientists better understand the influence of gravity on cells and whether bacteria and other microorganisms could mutate during a long planetary space trip, posing a health hazard to the crew.

Other experiments involve whole organisms (brine shrimp and wasp eggs) to determine the effect of gravity on development and aging, seed germination and growth to learn more about growing plants in space and on Earth, and studies of the immune system's response (lymphocytes and macrophages) to microgravity.

A crew member will place a group of 12 specimens in the self-contained apparatus and then initiate fluid mixing and incubation processes. Multistep mixing sequences are available for phased processing. After a computer records information and ends the programmed sequence, the samples will be removed and stored in a refrigerator, and the next batch loaded for testing. Some experiments require periodic monitoring during processing. Data will be gathered in space and from the samples returned to Earth for analysis.

Dr. Michael C. Robinson of the Center for Bioserve Space Technologies at the University of Colorado is the principal investigator.

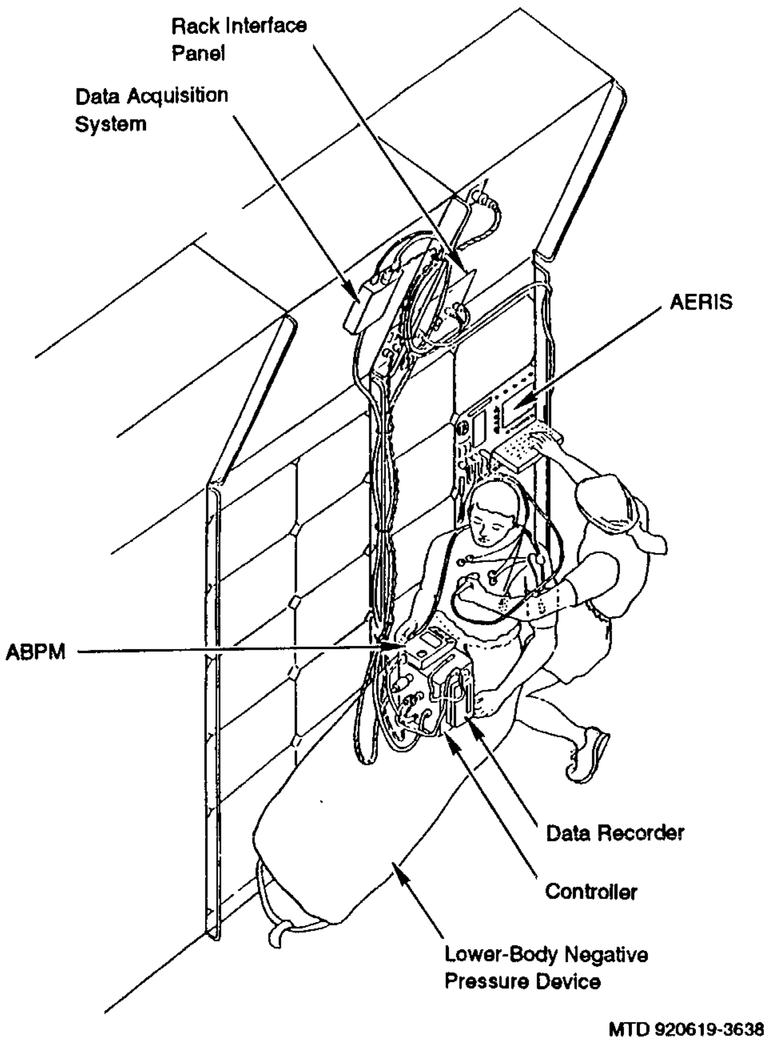
Extended-Duration-Orbiter Medical Project

During space missions, the crew experiences numerous effects of the body's adaptation to microgravity. This medical project investigates these changes in preparation for extended-duration shuttle missions of 13 to 16 days, which could pose problems for the crew when the flights are over. Three experiments will be conducted on USML-1.

The first has to do with the shift in fluids from the lower body to the head, which has troubled some crew members with lightheadedness and fainting spells when they return to Earth. Investigators want to see if negative pressure on the lower body, applied by a vacuum within a shroud that seals around the waist, can redistribute the fluids and mitigate the downstream effects. During this 4-hour treatment, pressure will be automatically increased and reduced; heart functions and blood pressure will be recorded, and leg volume will be measured before and after each sequence.

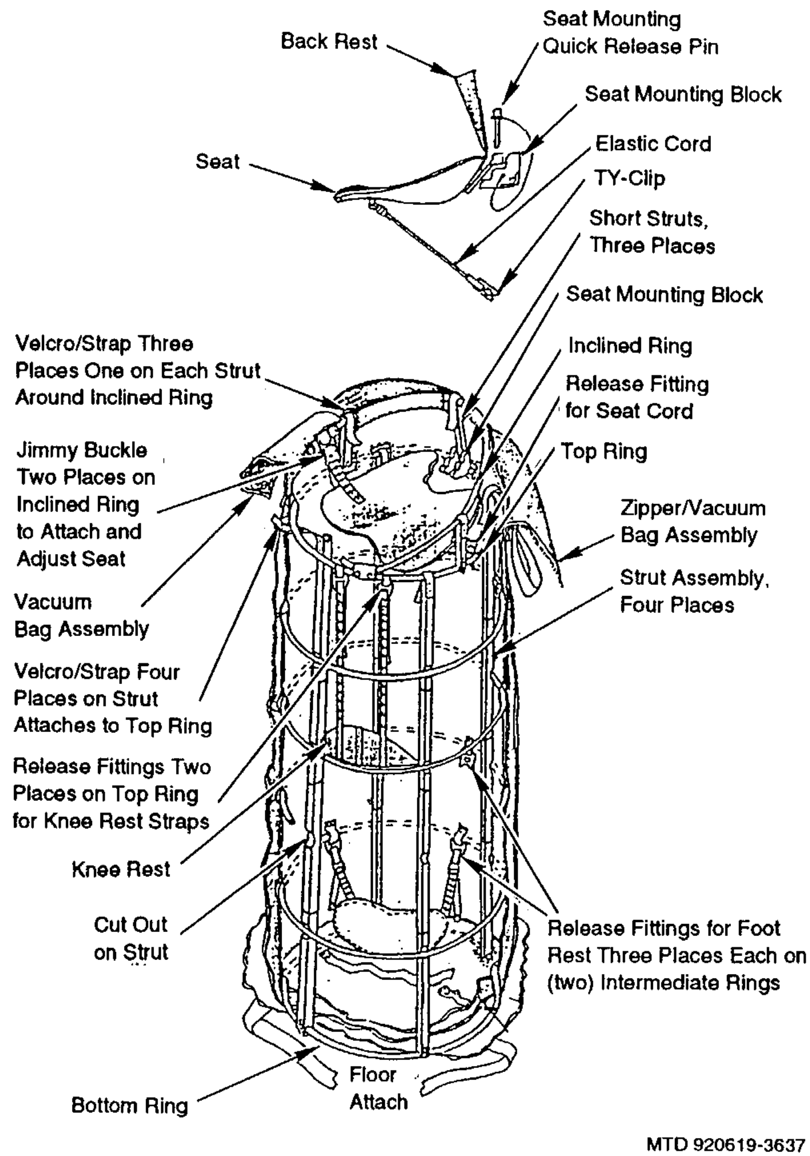
Since many factors on Earth cause our blood pressure and heart rate to fluctuate, the second experiment seeks to determine if the microgravity of space induces more or less variability. It will also look for any changes related to the sensitivity of baroreceptors in the carotid artery running through the neck, which are one of the regulators of blood pressure and heart rate. Crew members will wear portable automatic blood pressure monitors that periodically take measurements from the arm and Holter monitors that continuously record heart activity. The data will be studied after the mission.

On shuttle missions of 6 to 10 days, small growths of bacteria and fungi have been found in the spacecraft. To find out if longer

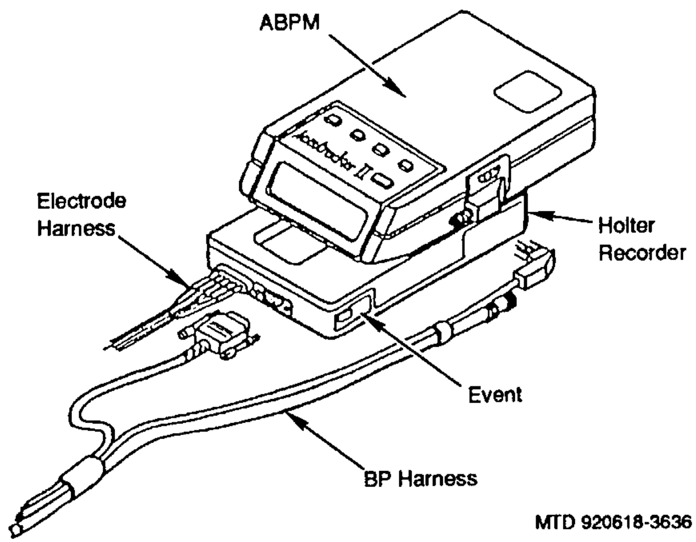


EDOMP Experiment Configuration

missions run the risk of microbial contamination, which could jeopardize crew health, air samplers will be placed in several Spacelab locations. A small fan will blow air across agar strips inserted in the sampler, which will be analyzed after the 13-day flight is over.



LBNPD, Expanded View



ABPM

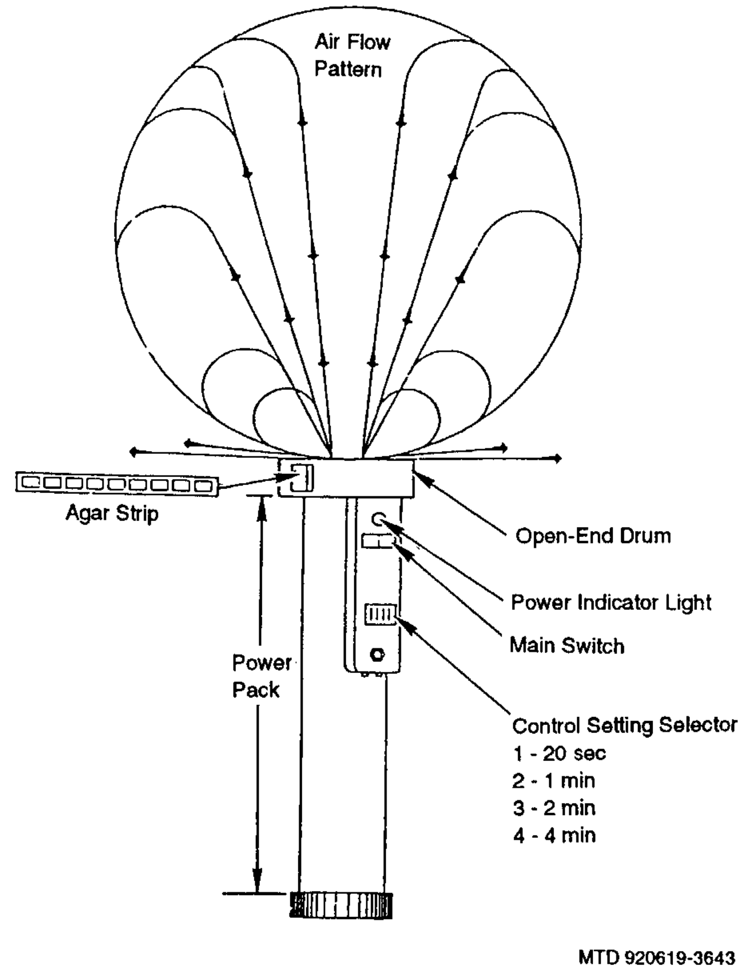
The project manager is J. Travis Brown of NASA's Johnson Space Center.

Protein Crystal Growth

Scientists want to know what specific proteins do and how their structures determine their function. But the protein crystals grown on Earth that are large enough to study are too flawed to be useful. The Protein Crystal Growth experiment, a veteran of previous shuttle missions, takes advantage of microgravity to produce larger, more uniformly structured crystals that are much better suited to X-ray diffraction analysis.

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

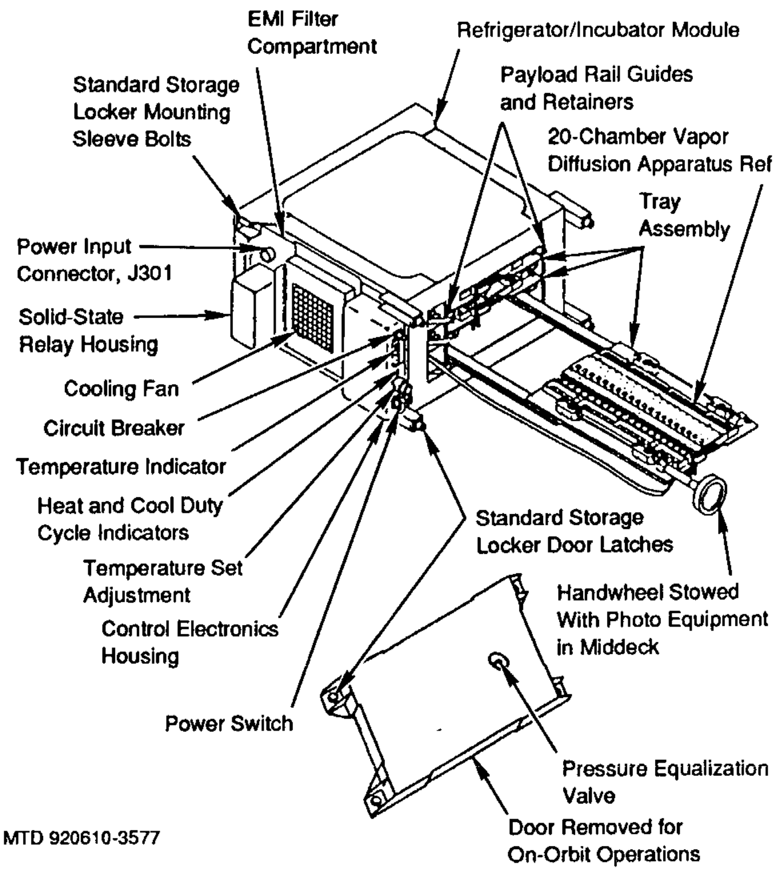
If these proteins reveal their secrets, we will know more about biological processes (e.g., what enables viruses like influenza and



Microbial Air Sampler

AIDS to spread and replicate), nutritional content of foods, crop improvement, and drug effectiveness.

Three middeck refrigerator/incubator modules will be used to conduct the experiments; two contain three vapor diffusion apparatuses apiece that hold 20 separate crystal growth chambers each. Syringes of protein solution are injected into a precipitant solution



PCG Flight Hardware

that begins the crystal growth. By turning a handwheel back and forth, a crew member activates the process and mixes the two solutions. The crew will also photograph crystal growth periodically throughout the flight. After the process is finished, the drops of solution containing the crystals will be drawn back into the syringes for postflight analysis.

The principal investigator is Dr. Charles E. Bugg of the Center for Macromolecular Crystallography at the University of Alabama, Birmingham.

Space Acceleration Measurement System

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

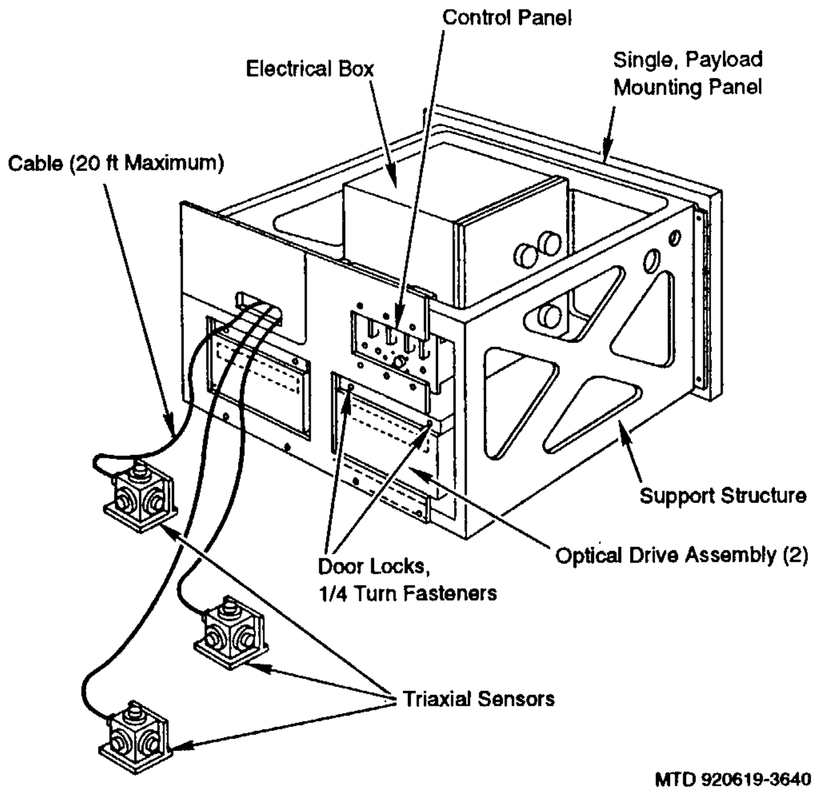
Returning for its fourth flight under the Orbiter Experiments Program, this measurement system will record vibrations in three crucial Spacelab areas: the Surface-Tension-Driven Convection experiment, the Crystal Growth experiment, and the glovebox below the work space. Its three triaxial sensor heads, placed at the three experiment locations, measure accelerations along three orthogonal axes. Three inertial sensors on each sensor head monitor both positive and negative accelerations in a preset frequency range. Each head, which also measures local temperature, filters and amplifies the signals from the sensors.

Data taken at each location will be sent to a central unit for conversion and storage on optical disks. Analysis of these various accelerations will enhance the understanding of other USML-1 experiment results and enable designers to improve future experiments and space structures.

Richard DeLombard of NASA's Lewis Research Center is the project manager.

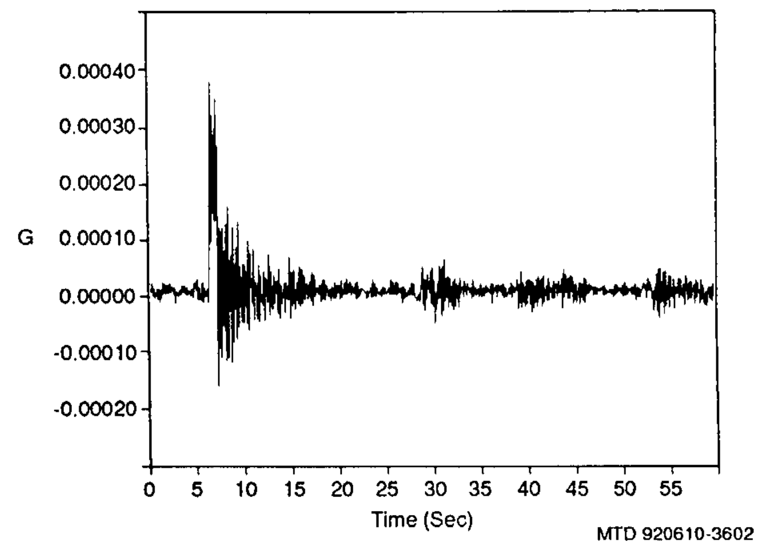
Solid Surface Combustion Experiment

Although the physical and chemical factors that make fires spread on Earth are well known, little is known about how fires spread in the microgravity environment of a space vehicle. This information is needed for assessments of fire hazards aboard spacecraft.



SAMS Hardware

A piece of ashless filter paper, sealed in a chamber whose atmosphere is conducive to combustion, will be ignited by a hot filament wire. Through windows in the chamber, two 16-mm cameras will film the event from the top and side so that the flame spread rate can be studied. Measurements from a temperature sensor, pressure transducer, and thermocouples will help determine the rate of heat transfer from the flame to the fuel. Hopefully, this information will tell scientists how flames propagate in a microgravity environment.



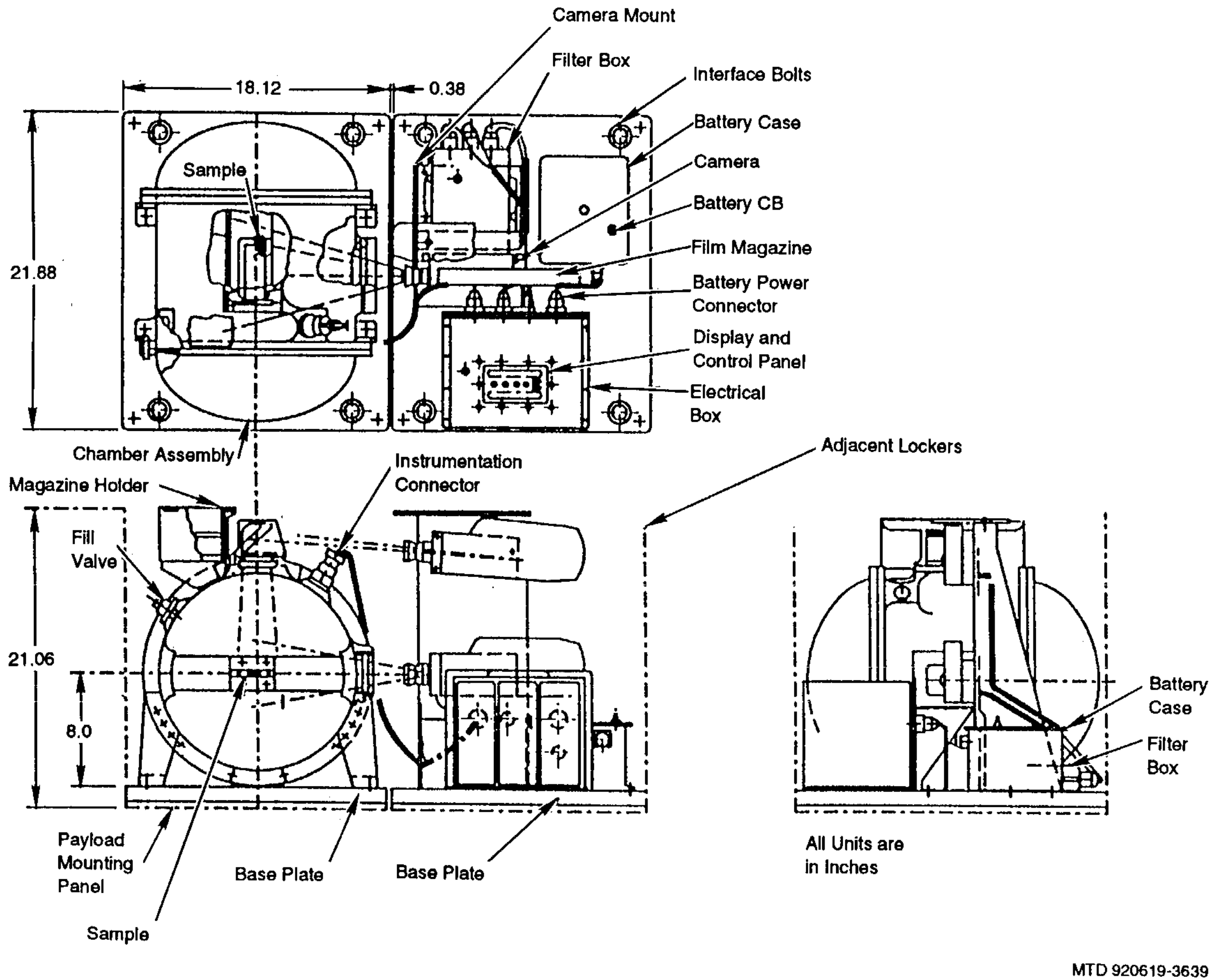
Typical Space Acceleration Measurement System Data Plot, Showing Portion of the X-Axis Acceleration Data From a Triaxial Sensor Head Mounted to the Solid Surface Combustion Experiment on STS-40

Principal investigator for this experiment is Dr. Robert A. Altenkirch of Mississippi State University.

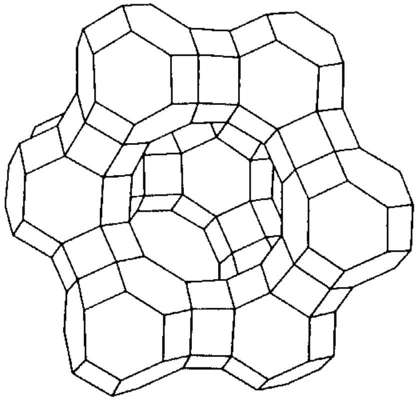
Zeolite Crystal Growth

Zeolite is used in chemical processes as a catalyst and filter because of its three-dimensional crystal structure. If investigators can grow crystals in space that are 500 to 1,000 times larger than those grown on Earth, they can learn much more about the zeolite crystalline structure and the chemical process industry can reap the benefits of a nearly perfect separation membrane.

The USML-1 experiment will seek the optimum hardware and mixtures for growing the crystals. Before the shuttle is launched, 38 separate cylindrical autoclaves will be loaded with solution. During



SSCE Configuration

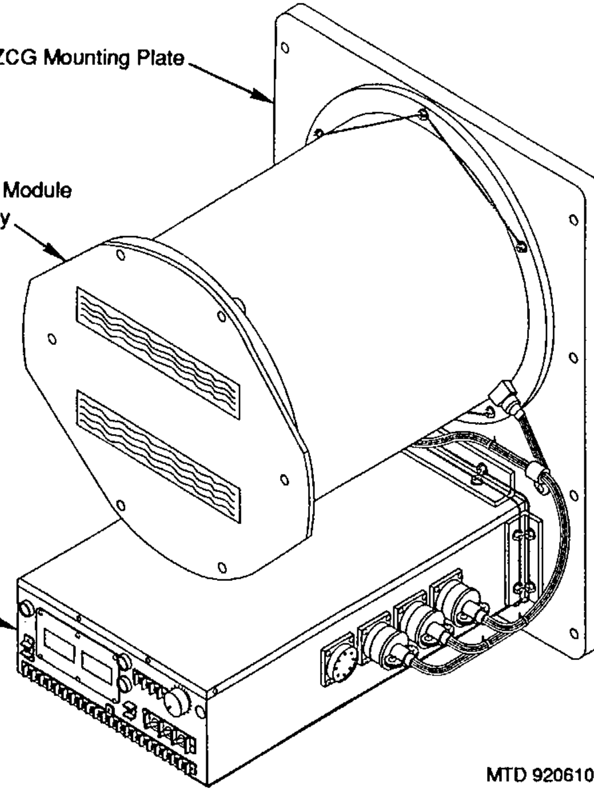

MTD 920610-3601

Drawing of a Typical Zeolite Crystal

the mission, a crew member will mix the two elements of the solution by turning a screw on the autoclaves back and forth and then place them in a furnace assembly that takes up two middeck lockers. When all the autoclaves have been activated and installed, the furnace will automatically process the multiple samples in three independently controlled temperature zones.

A crew member will check the furnace every 2 hours to make sure the experiment is operating properly. When the time is up, the autoclaves will be removed and stored for postmission analysis by scientists.

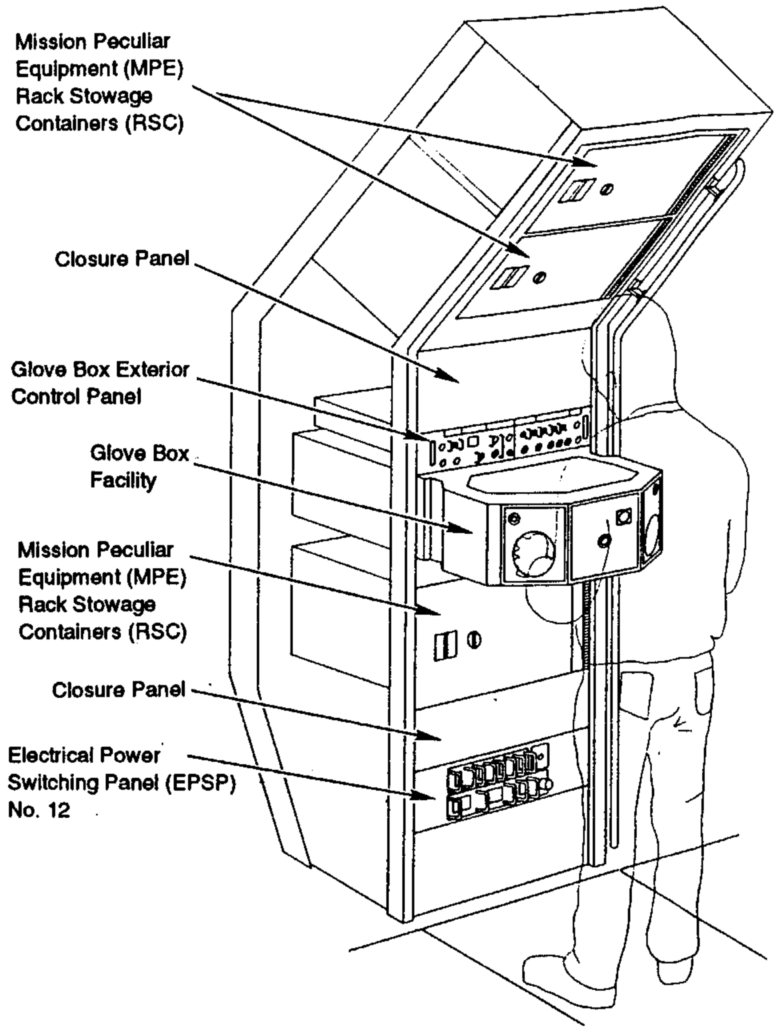
The principal investigator is Dr. Albert Sacco, Jr., of Worcester Polytechnic Institute. Because of the interest in zeolite's potential, two commercial development centers—Battelle Advanced Materials Center and Clarkson Center for Commercial Crystal Growth in Space—have combined, along with their industry partners, to sponsor the experiment.



ZCG Flight Configuration

Glovebox Experiments

Supplied by the European Space Agency, the glovebox is an enclosure for isolating experiments that would be impractical in the open Spacelab, either because they could contaminate or endanger the laboratory or the laboratory could contaminate them. This miniature "clean room" features a large viewing window on top, equipment to secure experiments, real-time video downlink, electrical power, lighting, partial temperature control, and cleaning supplies. It has six video camera heads to record experiments, a 35-mm camera, and a stereomicroscope.

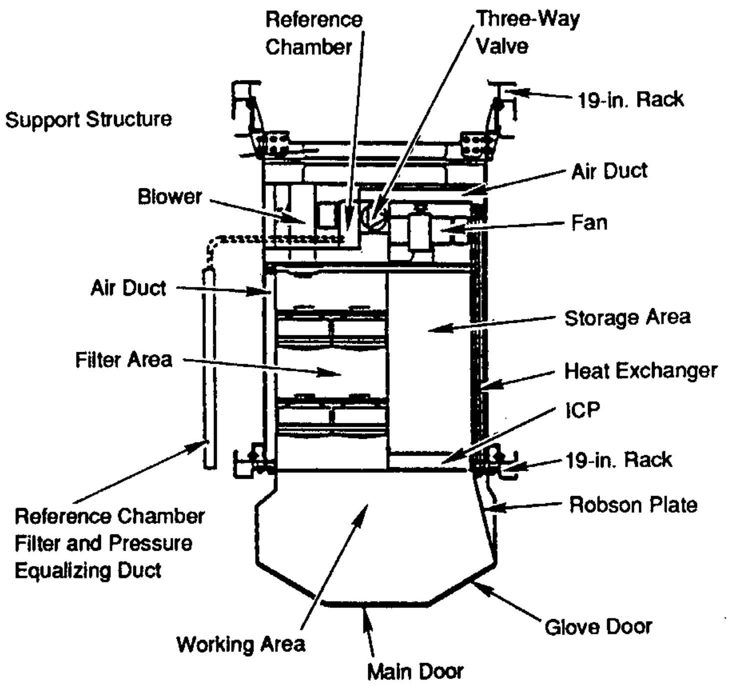


Glovebox

The crew can reach into the glovebox through a central port or the two glovedoors on either side of it. For experiments that require an airtight seal, crew members put their hands into a pair of gloves attached to the glovedoors. If these gloves are too cumbersome for the experiment at hand, crew members can wear a pair of surgical gloves and insert their arms through a set of adjustable cuffs.

In general, the procedure for using the glovebox is to take experiment modules and samples out of stowage, put them in the glovebox, conduct the experiment, clean up any spills or leaks, and restow the experiment components for postflight examination.

The 16 experiments to be conducted by crew members in the glovebox investigate 4 main areas of microgravity research: 7 fluid dynamics tests, 3 combustion science tests, 3 crystal growth tests, and 3 technology demonstrations. Some of these supplement the other previously described USML experiments, whose investigators will use glovebox results for immediate refinement or alteration of their tests and demonstrations.



Glovebox Components

Experiment	Investigator	Purpose
Passive Accelerometer System	Dr. J.Iwan D. Alexander, University of Alabama, Huntsville	Measure low-level accelerations from atmospheric drag and shuttle's gravity-gradient attitude
Interface Configuration Experiment	Dr. Paul Concus, University of California, Berkeley, and Lawrence Berkeley Laboratory	Investigate how containers influence the shape of fluid surfaces in microgravity

Protein Crystal Growth Glovebox Experiment	Dr. Lawrence J. DeLucas, University of Alabama, Birmingham	Identify optimum conditions for nucleating and growing protein crystals from solution in space
Solid Surface Wetting Experiment	Dr. Eugene H. Trinh, NASA Jet Propulsion Laboratory	Determine best shape and surface treatment for injector tips used to release drops in the drop physics module
Marangoni Convection in Closed Containers	Dr. Robert J. Naumann, University of Alabama, Huntsville	Determine whether surface-tension-driven convection can occur in closed containers, and under what conditions, in microgravity
Smoldering Combustion in Microgravity	Dr. A. Carlos Fernandez-Pello, University of California, Berkeley	Observe characteristics of smoldering polyurethane in microgravity
Wire Insulation Flammability Experiment	Paul S. Greenberg, NASA Lewis Research Center	Examine ignition and combustion of electrical wire insulation in microgravity
Candle Flames in Microgravity	Dr. Howard D. Ross, NASA Lewis Research Center	Determine whether candle flames can be sustained in space; study the interaction and properties of diffusion flames
Fiber Pulling in Microgravity	Dr. Robert J. Naumann, University of Alabama, Huntsville	Investigate advantages of pulling optical fibers in space
Nucleation of Crystals From Solutions in a Low-g Environment	Dr. Roger L. Kroes, NASA Marshall Space Flight Center	Demonstrate and evaluate a new technique for initiating and controlling crystal nucleation in a solution
Oscillatory Dynamics of Single Bubbles and Agglomeration in an Ultrasonic Sound Field in Microgravity	Dr. Philip L. Marston, Washington State University	Explore how large and small bubbles respond to an ultrasound stimulus in space
Stability of a Double Float Zone	Dr. Robert J. Naumann, University of Alabama, Huntsville	Determine if a solid cylinder can be supported by two liquid columns and remain stable in space

Oscillatory Thermocapillary Flow Experiment	Dr. Simon Ostrach, Case Western Reserve University	Determine conditions for onset of oscillations in thermocapillary flows in silicone oils
Particle Dispersion Experiment	Dr. John R. Marshall, NASA Ames Research Center	Investigate how fine particles aggregate in air; evaluate technique for dispersing particles uniformly to begin aggregation experiments
Directed Orientation of Polymerizing Collagen Fibers	Dr. Louis S. Stodieck, Center for Bioserve Space Technologies	Demonstrate the ability to direct the orientation of collagen fiber polymers in microgravity without fluid mixing effects
Zeolite Glovebox Experiment	Dr. Albert Sacco, Jr., Worcester Polytechnic Institute	Examine and evaluate mixing procedures and nozzle designs to enhance the middeck crystal growth experiment; observe when and where the crystal nucleates

SPACELAB

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

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

Spacelab is developed on a modular basis and can be varied to meet specific mission requirements. Its four principal components are the pressurized module, which contains a laboratory with a shirt-sleeve working environment; one or more open pallets that expose materials and equipment to space; a tunnel to gain access to the module; and an instrument pointing subsystem. Spacelab is not deployed free of the orbiter. The pressurized module will be used on STS-50.

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

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

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

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

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

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

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

NASA astronauts called mission specialists, as well as non-career astronauts called payload specialists, fly aboard Spacelab to operate experiments. Payload specialists are nominated by the scientists sponsoring the experiments aboard Spacelab. They are accepted, trained, and certified for flight by NASA. Their training includes familiarization with experiments and payloads as well as information and procedures to fly aboard the space shuttle. From one to four payload specialists can be accommodated for a Spacelab flight. These specialists ride into space and return to Earth in the orbiter crew compartment cabin, but they work with Spacelab on orbit. Because Spacelab missions, once on orbit, may operate on a 24-hour basis, the flight crew is usually divided into two teams. The STS-50 crew will work two 12-hour shifts.

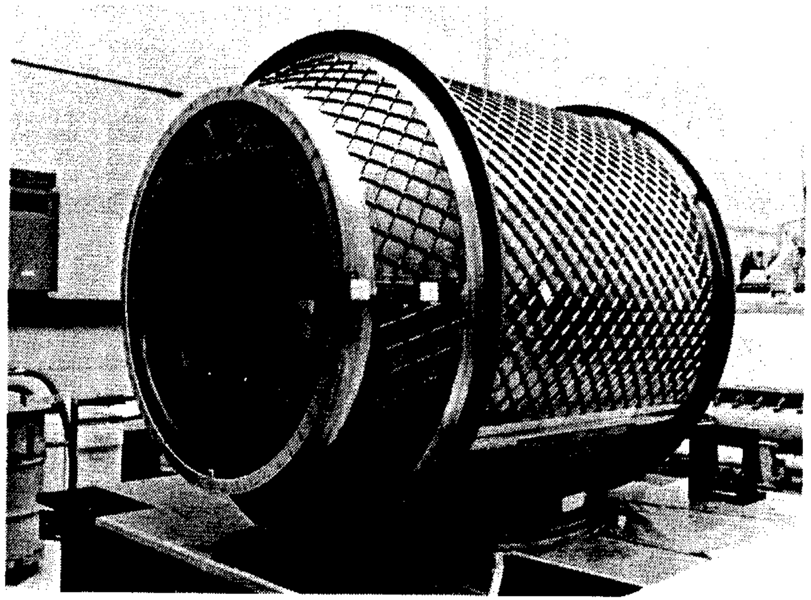
PRESSURIZED MODULE. The pressurized module, or laboratory, is available in two segments. One, called the core segment, contains supporting systems, such as data processing equipment and utilities for the pressurized modules and pallets (if pallets are used in conjunction with the pressurized modules).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

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

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

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

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



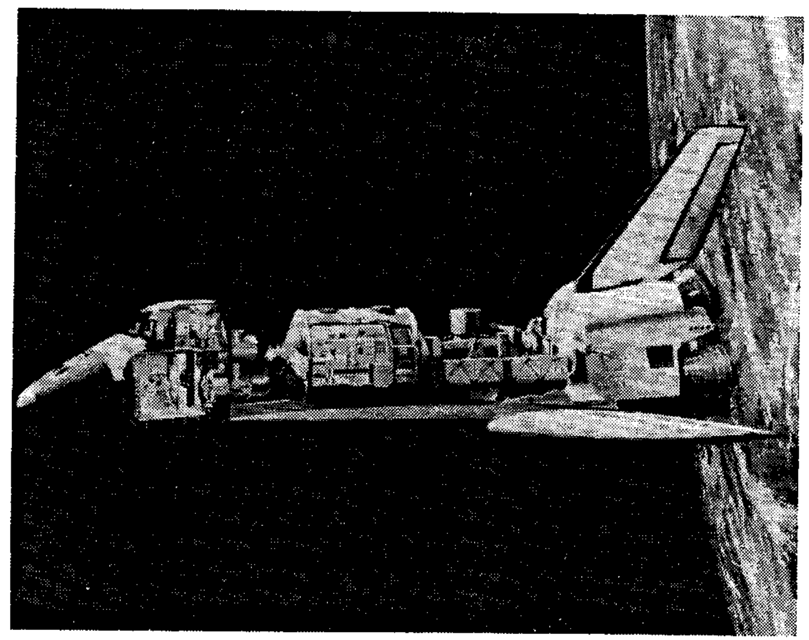
Tunnel Adapter

surized module's 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.

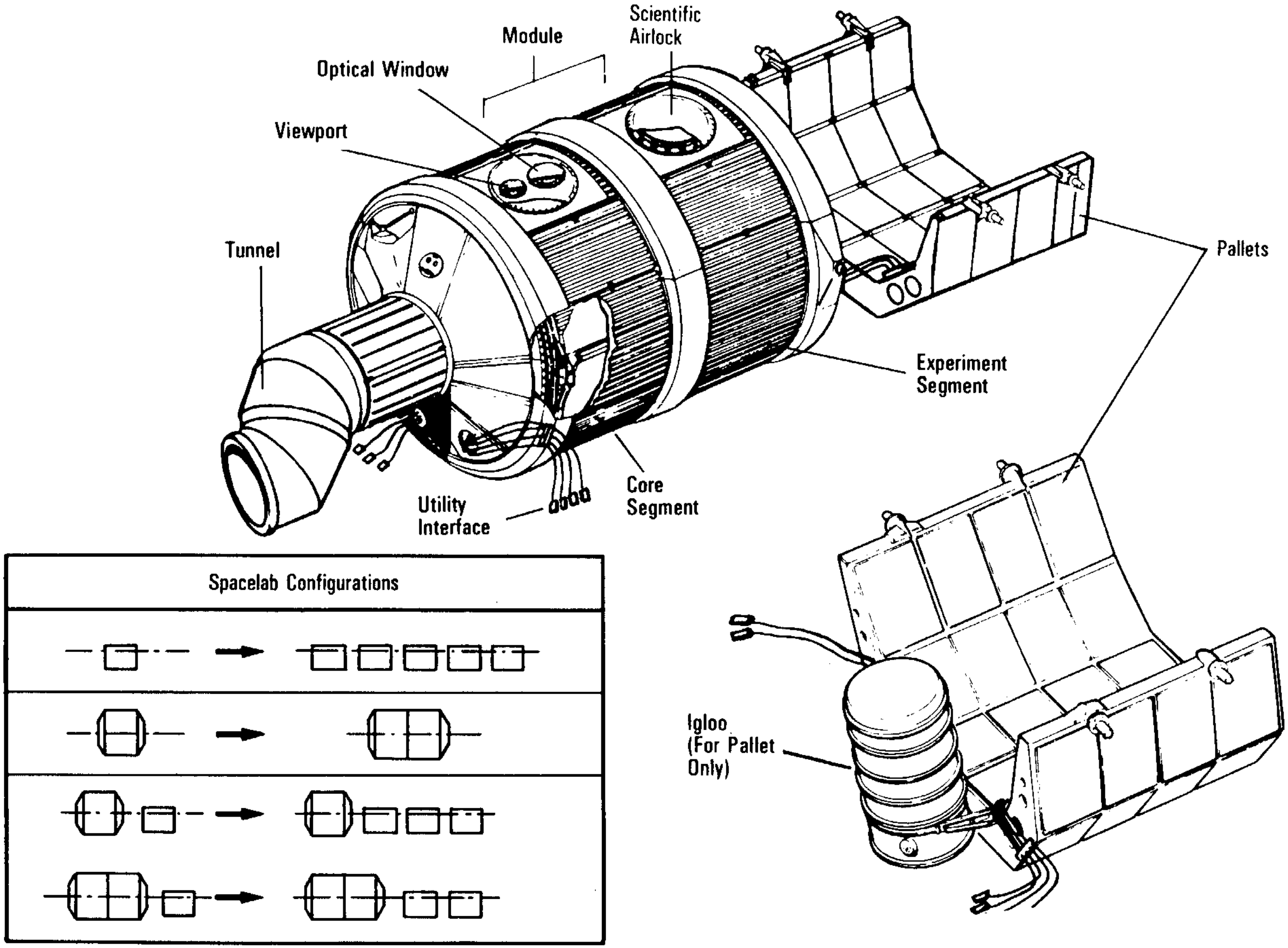
The airlock in the middeck of the orbiter, the tunnel adapter, hatches, the tunnel extension, and the tunnel itself permit the flight crew members to transfer from the orbiter middeck to the Spacelab pressurized module or modules in a pressurized shirt-sleeve environment. The airlock, tunnel adapter,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

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

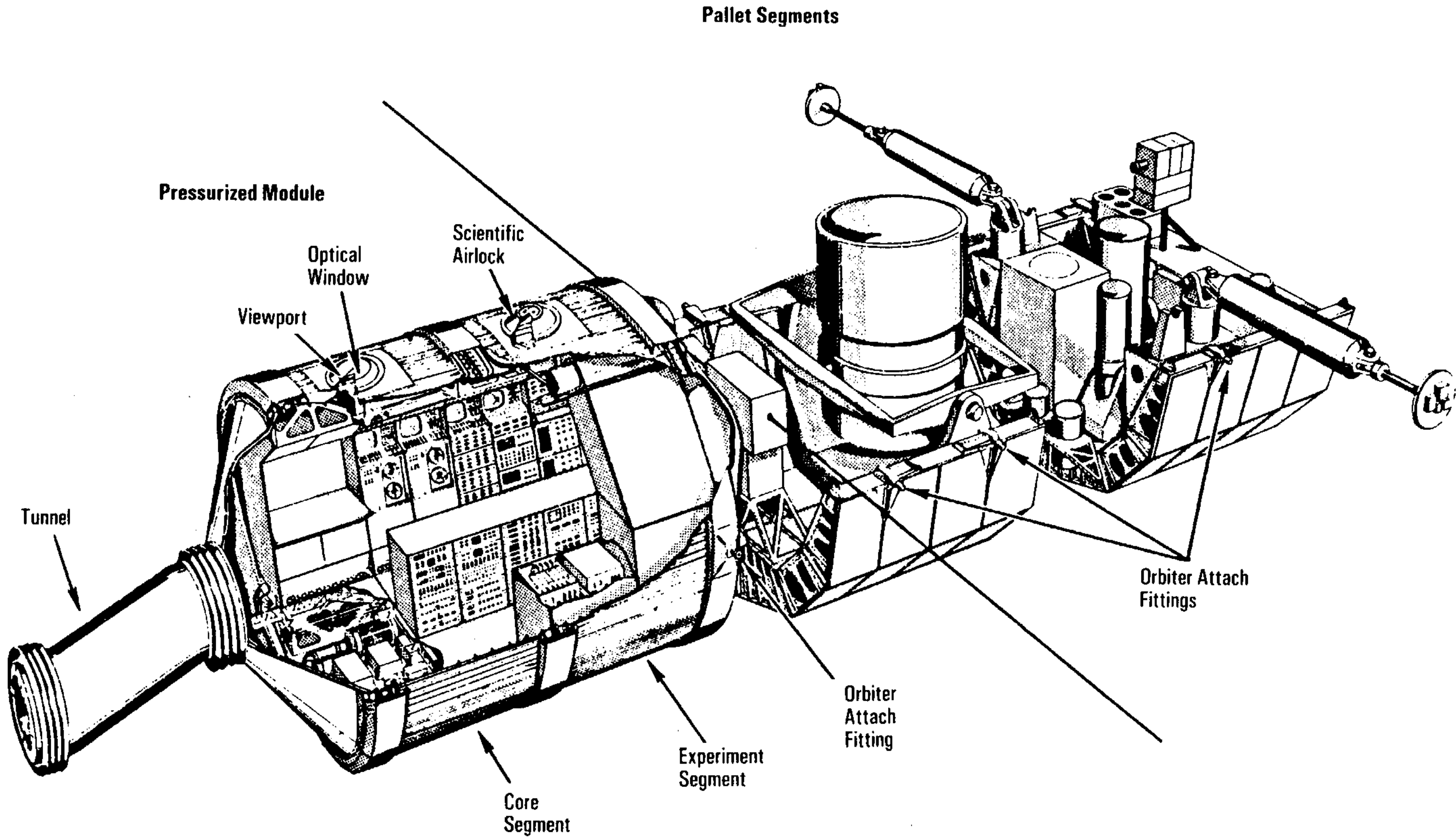
The IPS consists of a three-axis gimbal system mounted on a gimbal support structure connected to the pallet at one end and to the aft end of a payload at the other, a payload clamping system to support the mounted experiment elements during launch and landing,



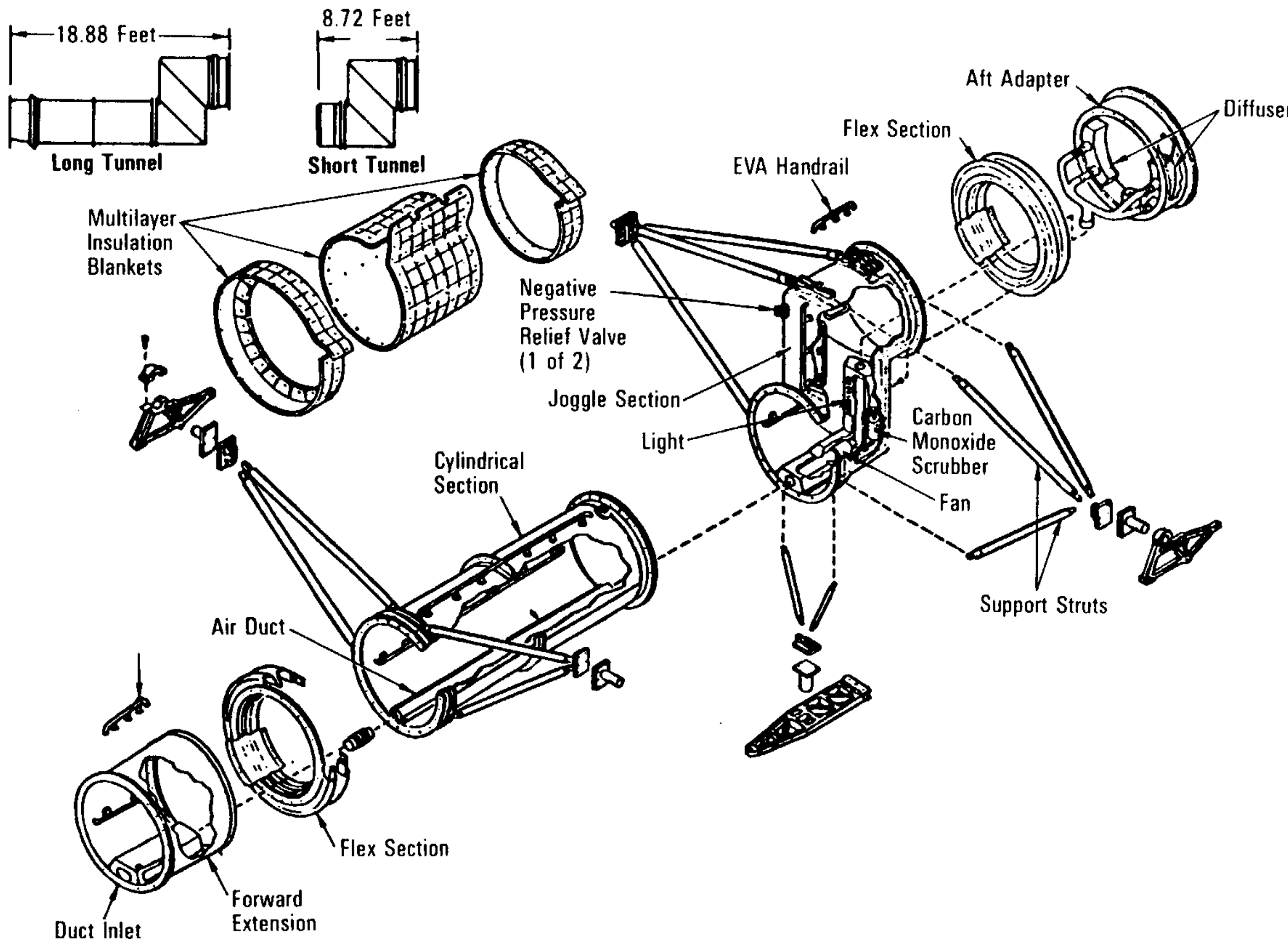
Spacelab



Spacelab External Design Features



European Space Agency's Spacelab

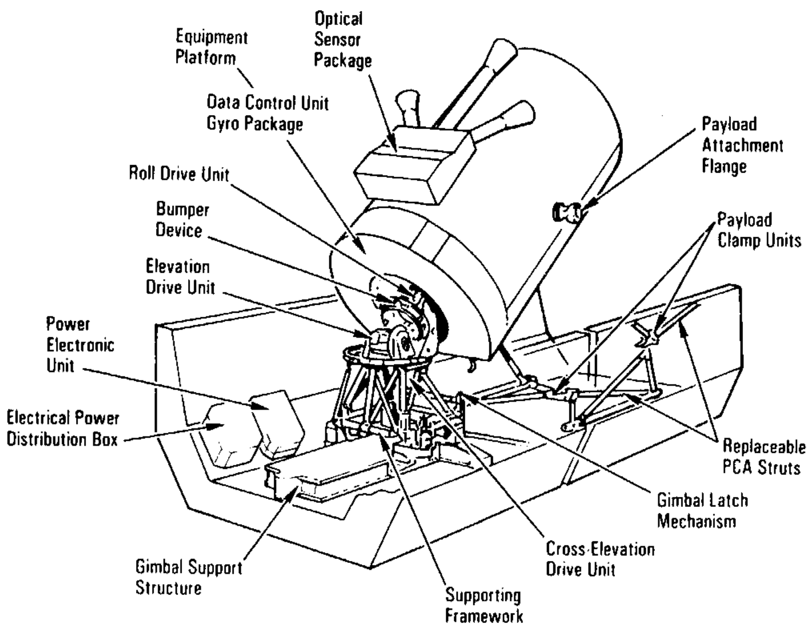


Spacelab Transfer Tunnel

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

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

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



Instrument Pointing Subsystem

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

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

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

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

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

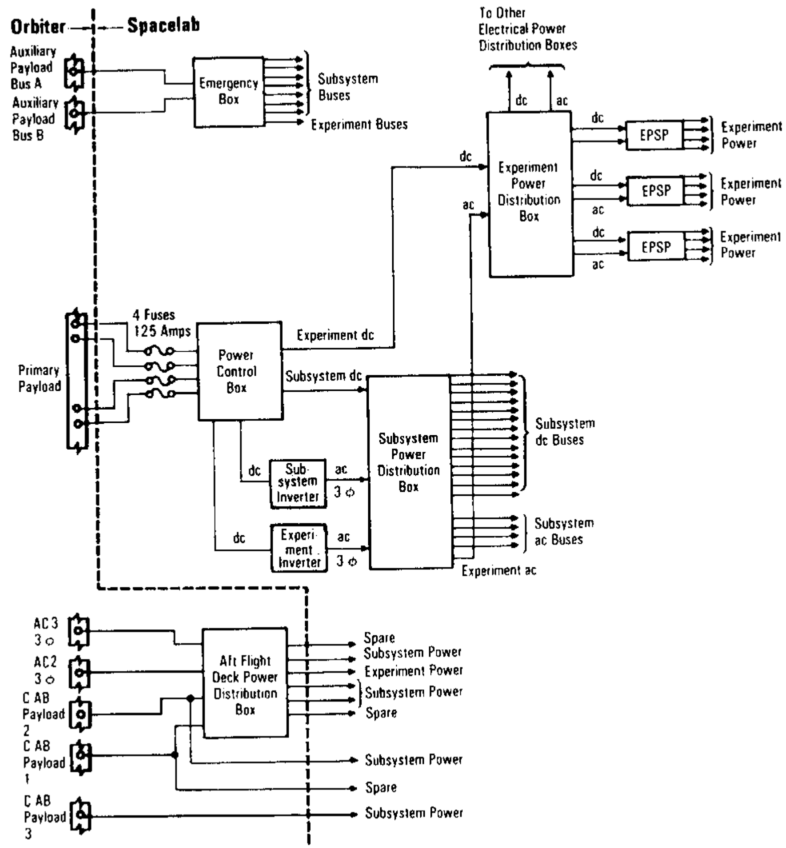
The pallets are uniform. Each is a U-shaped aluminum frame and panel platform 13.1 feet wide and 10 feet long.

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

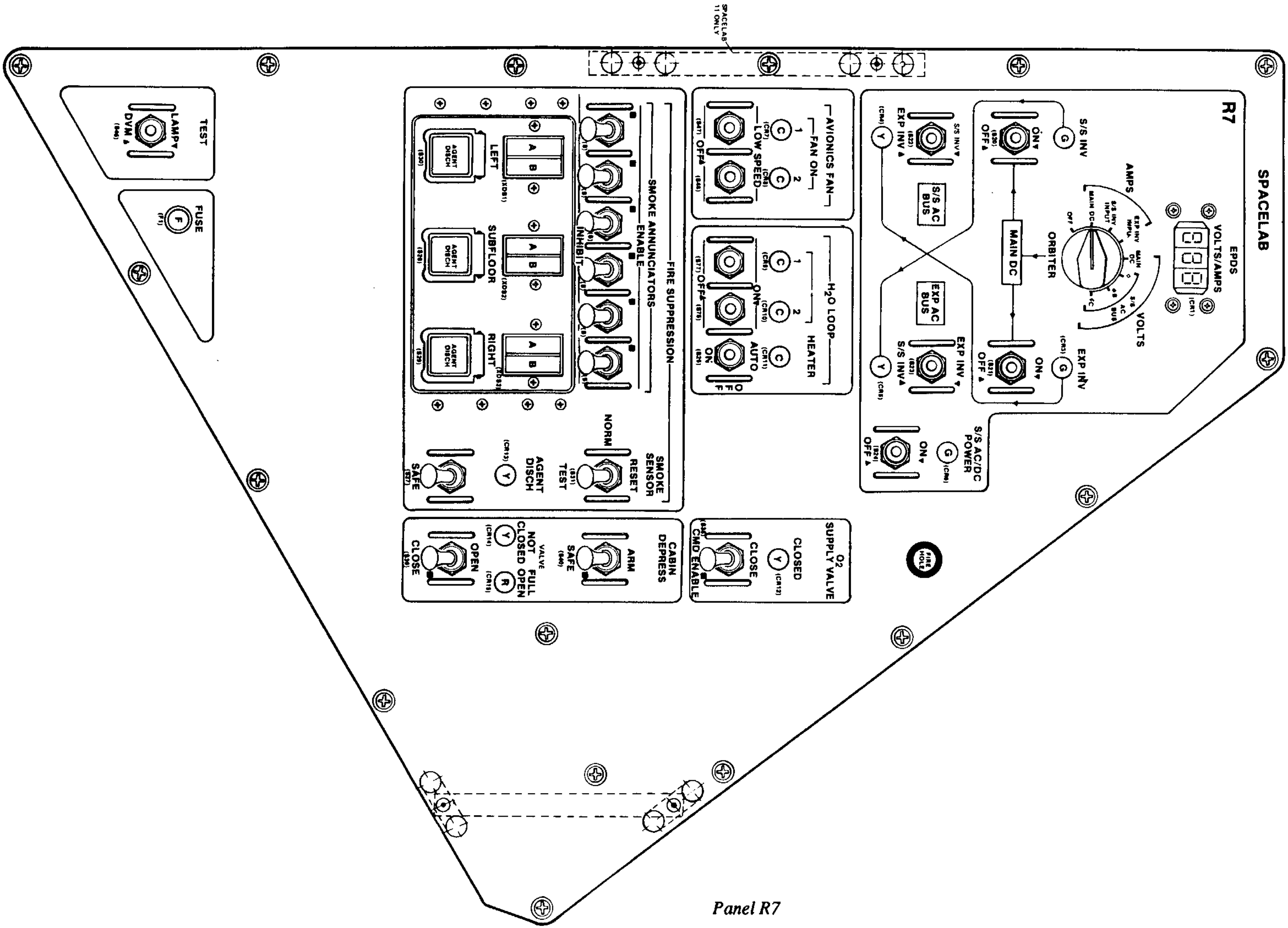
The igloo is attached vertically to the forward end frame of the first pallet. Its outer dimensions are approximately 7.9 feet in height and 3.6 feet in diameter. The igloo is a closed cylindrical shell made of aluminum alloy. A removable cover allows full access to the interior. The igloo houses subsystems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

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

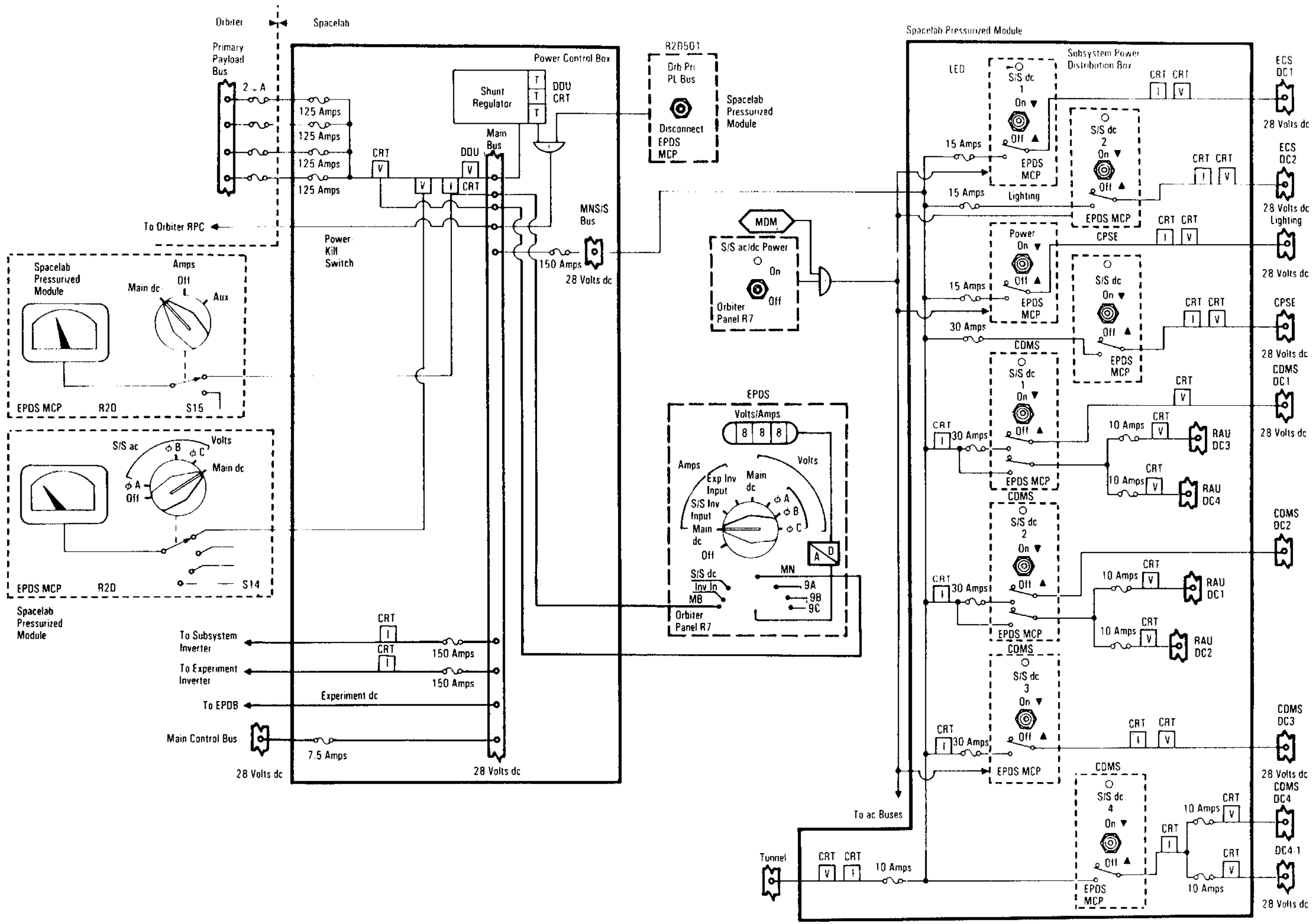
The primary dc power received in the Spacelab from the orbiter primary payload bus is nominally 28 volts, a maximum of 32 volts, and a worst-case minimum of 23 volts. The four redundant power



Orbiter Spacelab Electrical Power Distribution


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

Panel R7



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

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

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

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

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

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

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

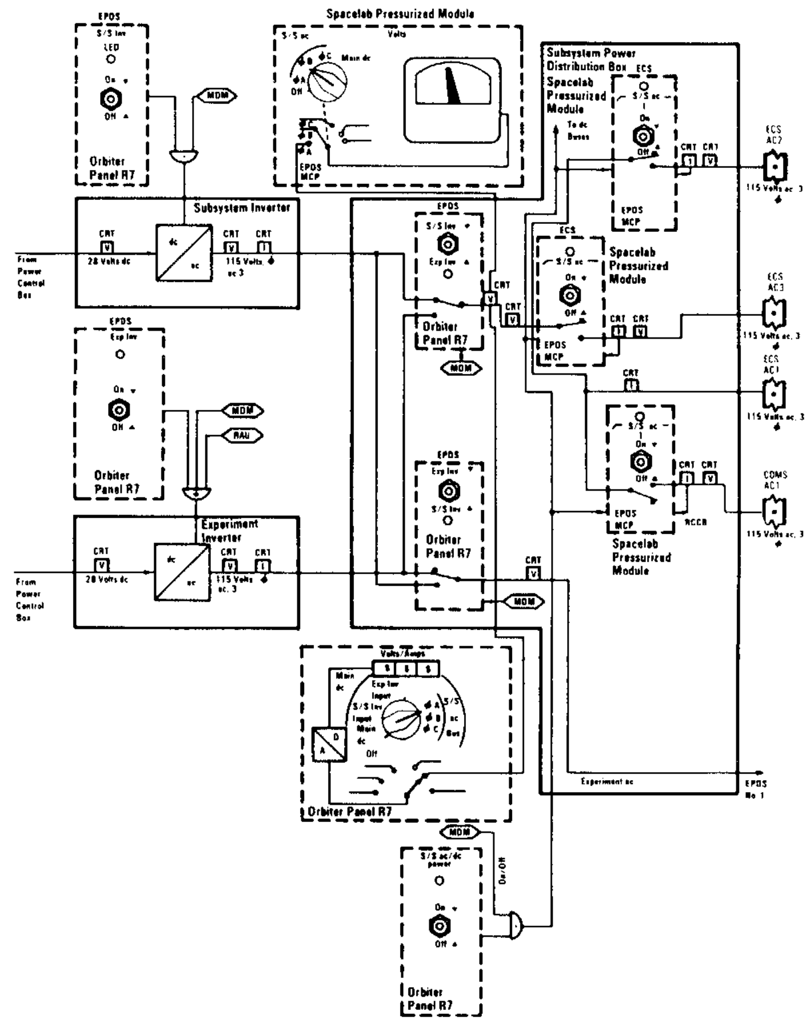
The Spacelab subsystem inverter is activated by the *S/S inv on/off* switch on panel R7 or by orbiter Spacelab CRT command. Positioning the switch to *on* activates the subsystem inverter, and a green LED above the switch on panel R7 is illuminated, indicating the inverter is operating. Positioning the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

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

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

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

In the pressurized module configuration, the subsystem power distribution box ac bus feeds several Spacelab subsystem power buses controlled by switches on the Spacelab EPDS MCP. All func-



Spacelab Electric Power Distribution—
Subsystem ac Power Distribution

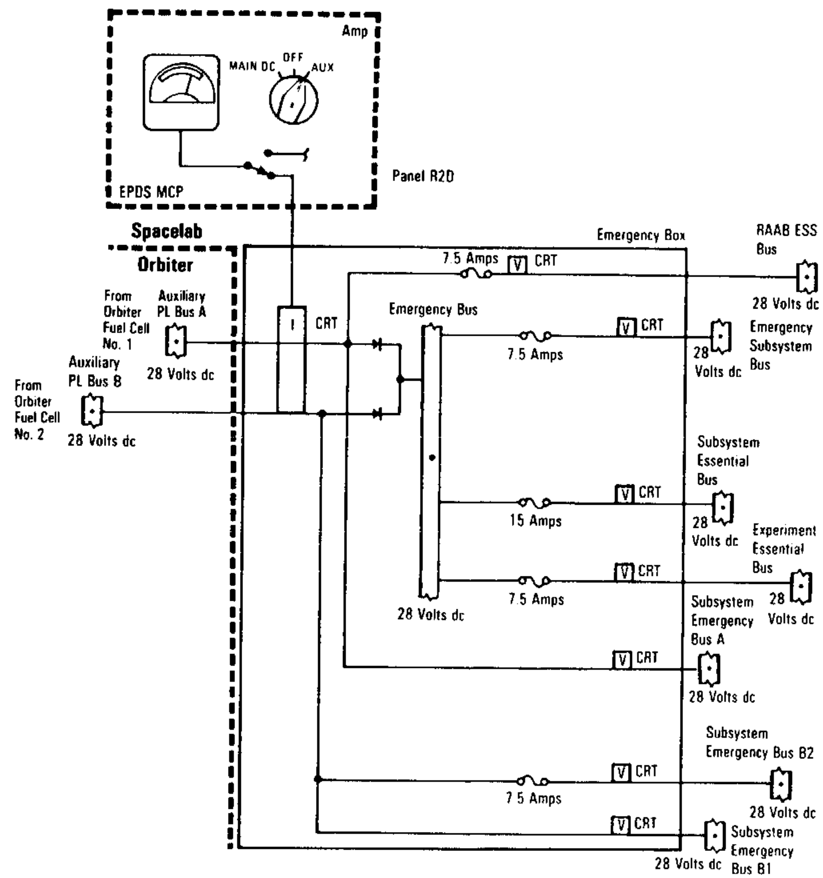
tions on this panel can be initiated simultaneously by the *S/S ac/dc power on/off* switch on orbiter panel R7 or by item commands from the orbiter CRT Spacelab displays. The status of the commanded relays is available via orbiter CRT Spacelab displays and indicated by the green LED light above the respective 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.

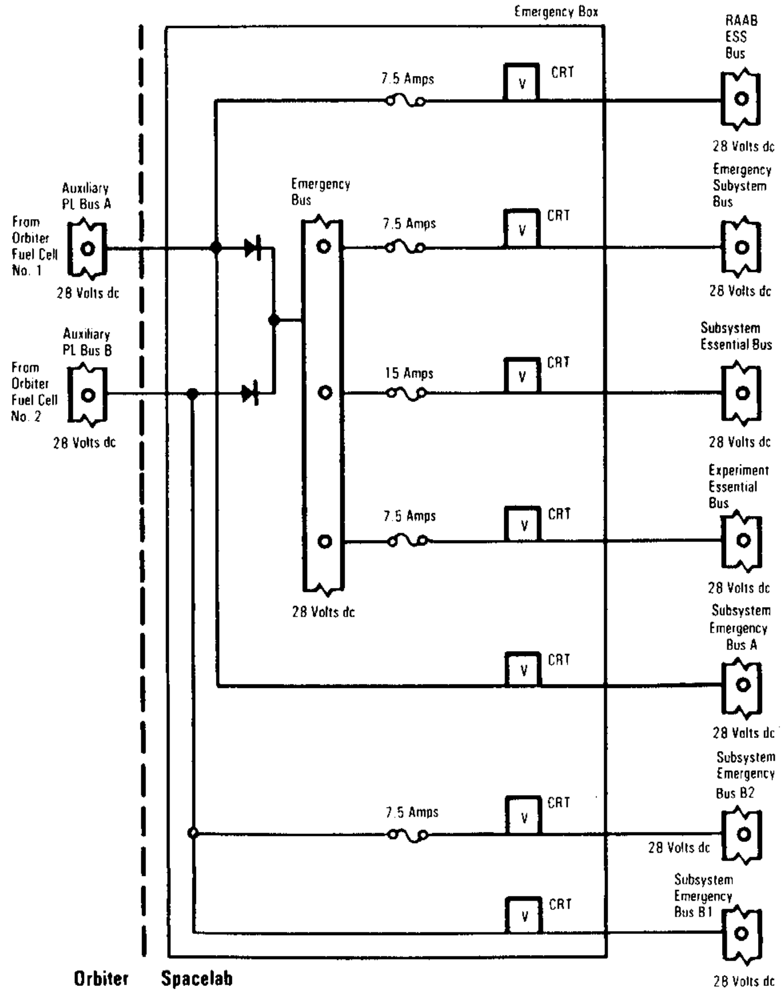
Emergency and essential dc power for the pallet-only configuration is also provided by orbiter auxiliary payload buses A and B, which send dc power to the Spacelab emergency box located in the igloo. The Spacelab emergency box provides emergency or essential power to Spacelab subsystem equipment. The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



Spacelab Pressurized Module Emergency and Essential Power Distribution blies with an adapter plate on a cold plate that is fitted on a support structure and attached to the pallet.

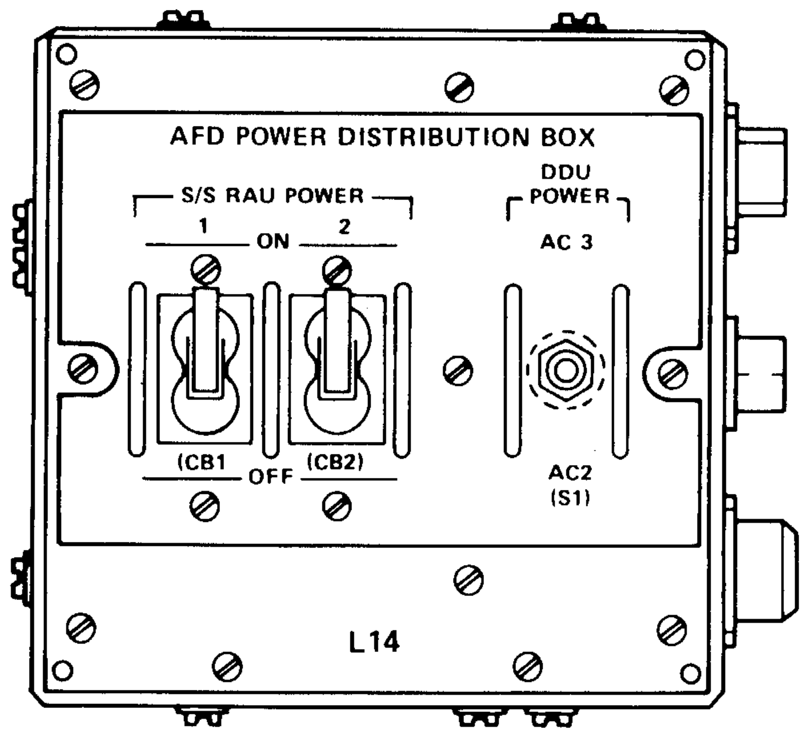
The orbiter pressurized module CRT Spacelab displays present emergency and essential bus current, voltages for auxiliary buses A



Spacelab Pallet Emergency and Essential Power Distribution

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

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



Panel L14

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

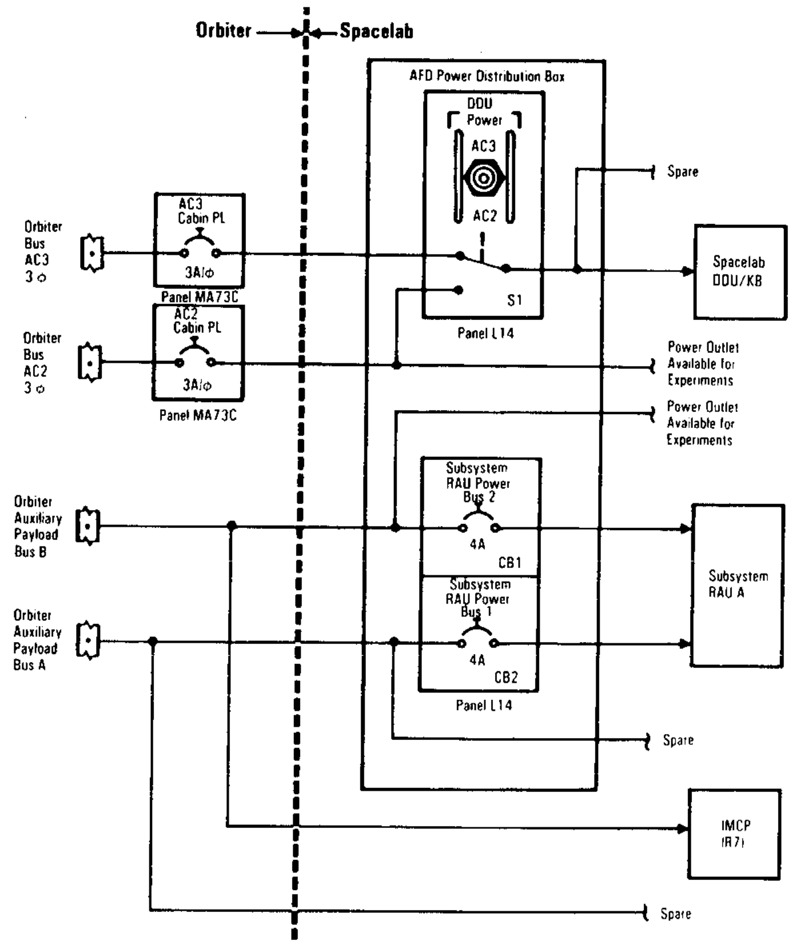
The Spacelab power distribution box at the orbiter aft flight deck payload station distributes dc and ac power to the Spacelab subsystem remote acquisition unit and the Spacelab data display system (a data display unit and keyboard). When a Spacelab data display system is installed at the mission station,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

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

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

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

In the Spacelab module, the experiment power switching panel provides facilities for branching and switching dc and ac power delivered by a dedicated experiment power control box. The dc and ac output is distributed to experiments and experiment-supporting



Pressurized Module Configuration—Orbiter Aft Flight Deck Power Distribution

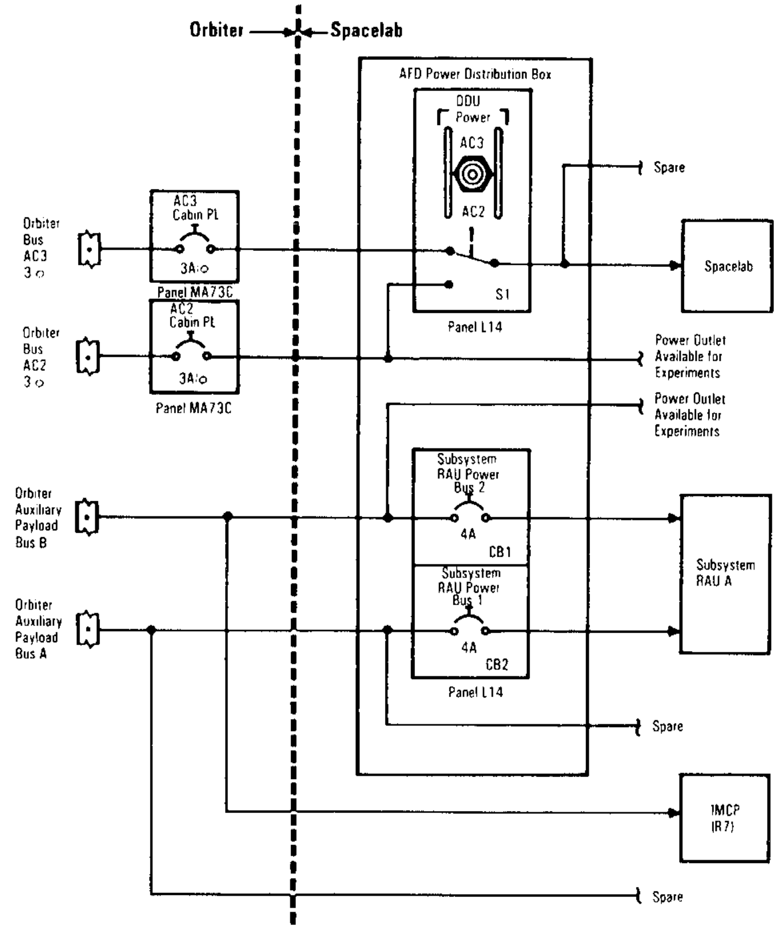
RAUs (dc only). The number of switching panels and their locations depend on the mission configuration.

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.

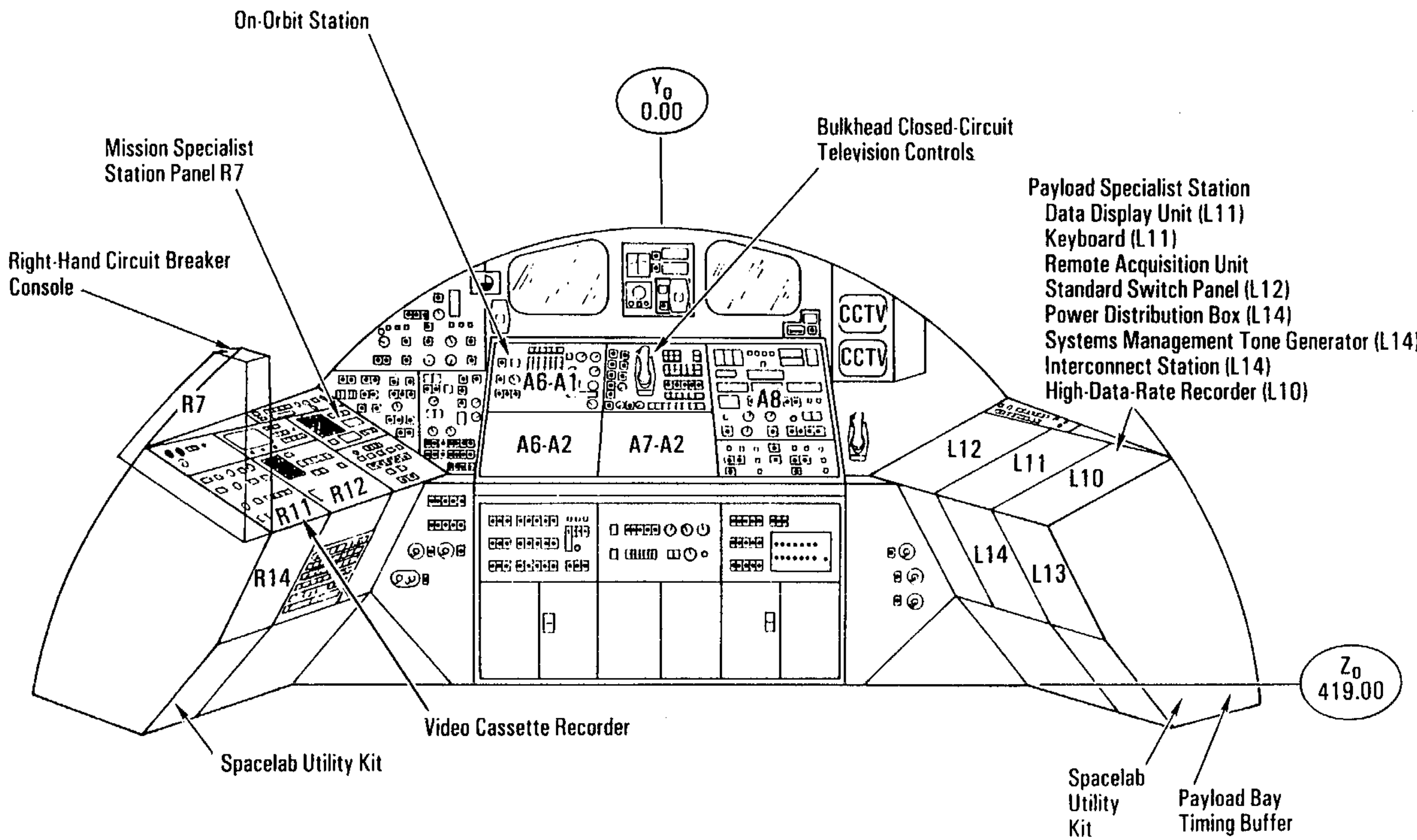
COMMAND AND DATA MANAGEMENT SYSTEM. The Spacelab command and data management system provides a variety of services to Spacelab experiments and subsystems. Most of the CDMS commands are carried out through the use of the computerized system aboard Spacelab, called the data processing assembly. The DPA 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 payload experiments through data display and keyboard units. The pre-

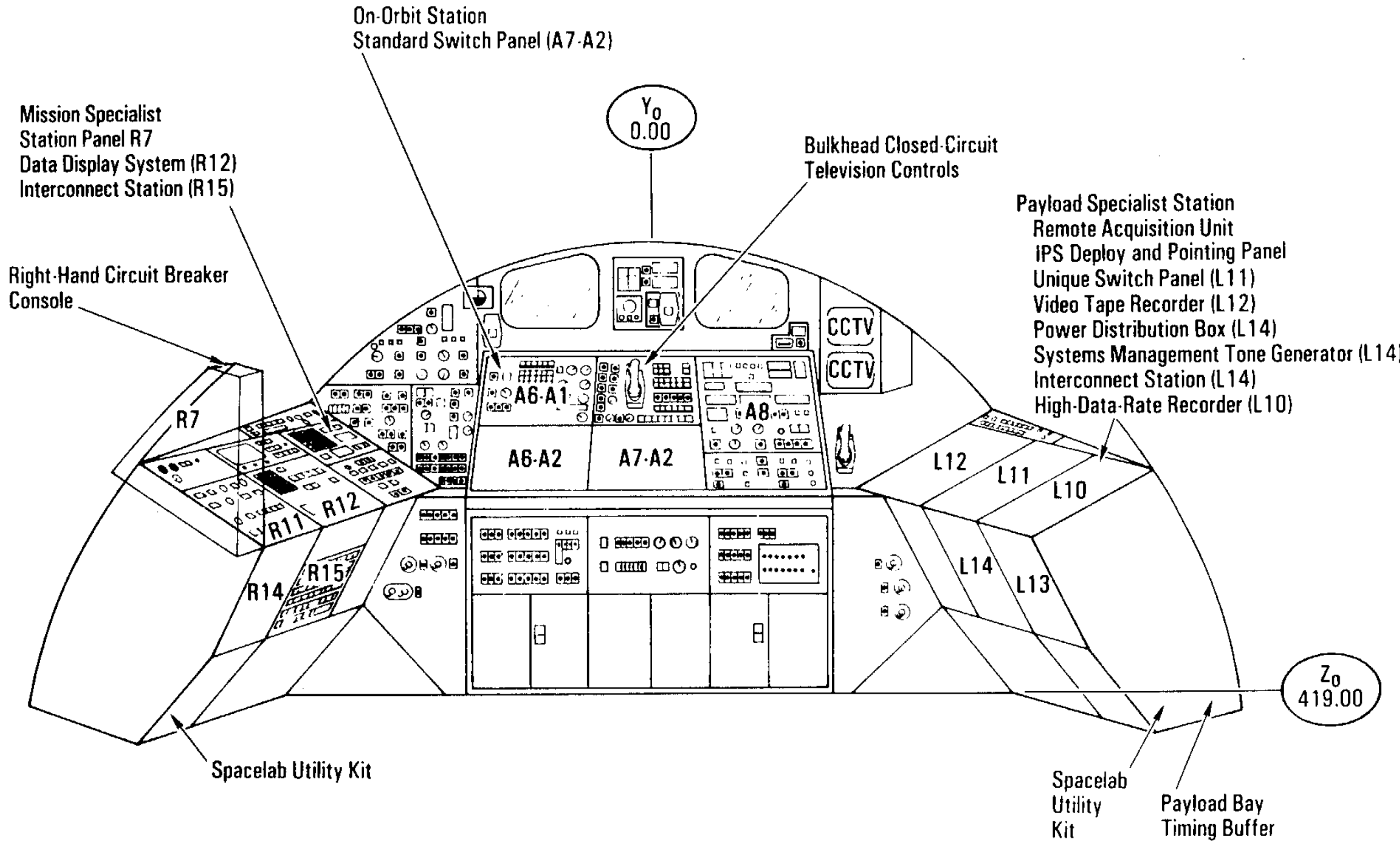


Pallet-Only Configuration—Orbiter Aft Flight Deck Power Distribution

viously used three identical MATRA 125/MS computers have been changed to the upgraded AP-101SL orbiter computers. The experiment computer activates, controls, and monitors payload operations and provides experiment data acquisition and handling. The subsystem computer provides control and data management for basic Spacelab services that are available to support experiments, such as electrical power distribution, equipment cooling, and scientific air-



Example of a Spacelab Pressurized Module Aft Flight Deck Panel Configuration



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

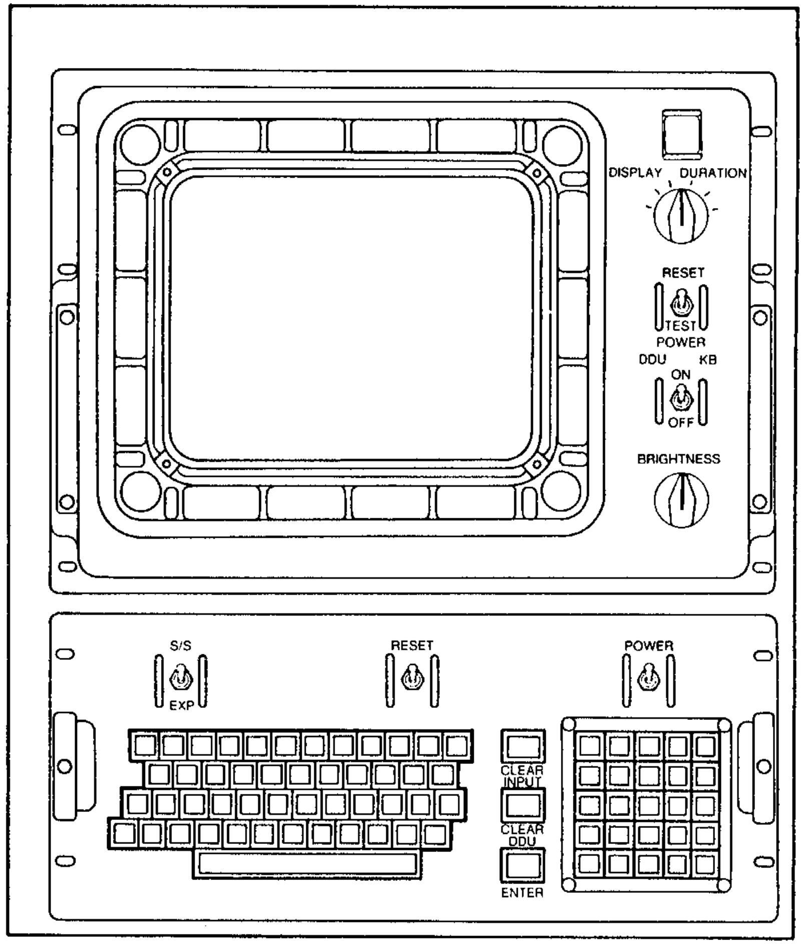
An input/output unit buffers all communications between the computer and the rest of the subsystem. The experiment computer also has at least one RAU (and as many as eight, depending on the payload) for interfacing between experiments and the subsystem. The subsystem computer may have as many as nine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

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

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

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

The keyboard consists of 25 function keys and 43 alphabet, numeral, punctuation, and symbol keys of the familiar standard typewriter keyboard as well as the standard typewriter action keys, such as space and backspace. The data display unit is a 12-inch diagonal CRT screen providing a 22-line display (47 characters per line) in three colors (green, yellow, and red). In addition to 128 alphanumeric symbols, the unit can also display vector graphics (1,024 dif-



Data Display Unit and Keyboard

ferent lengths and 4,096 angles). A high-intensity green flashing mode is also provided.

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

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

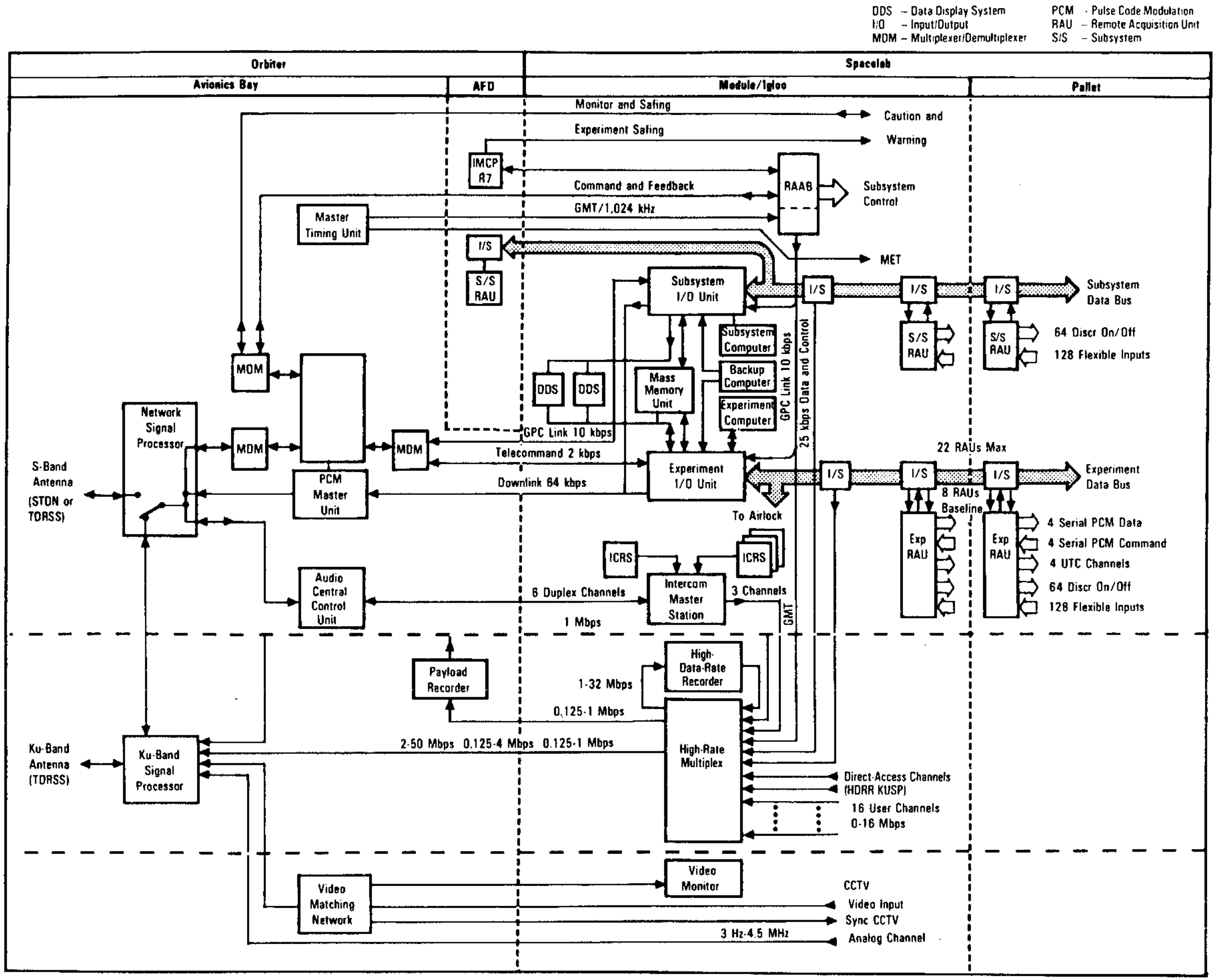
The subsystem computer functions mainly to monitor and control other Spacelab subsystems and equipment, such as the electrical power distribution subsystem and the environmental control subsystem. These functions are performed by the subsystem computer operating software.

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

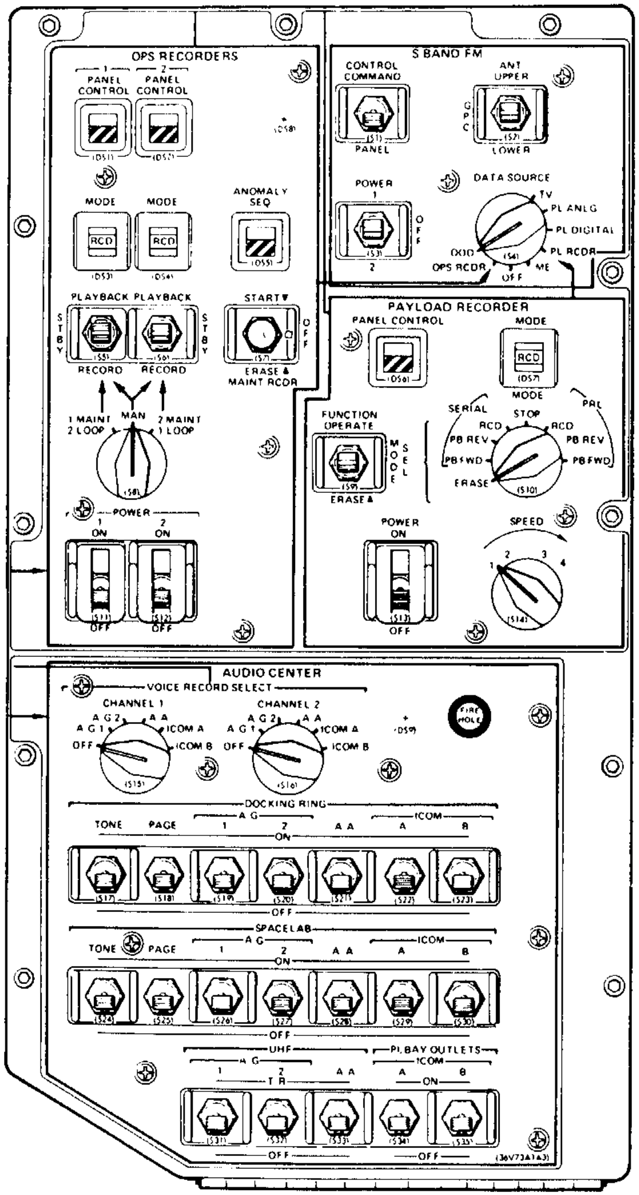
The Spacelab experiment computer interfaces with two telemetry systems. The orbiter PCMMU allows the orbiter to acquire data for on-board monitoring of systems and provides the Mission Control Center in Houston with system performance data for real-time display and recording through the orbiter network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

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

In the pressurized module, the high-data-rate recorder is located at the control center rack next to the data display system; in the pallet-only configuration, it is at the aft flight deck panel L10. It records real-time, multiplexed data or data from two direct-access channels and stores the information at rates from 1 to 32 Mbps during mission periods with no downlink capability or degraded downlink capability for playback when the capability is available. The HDRR dumps



Spacelab Command and Data Management System Interfaces With the Orbiter



Panel A1A3

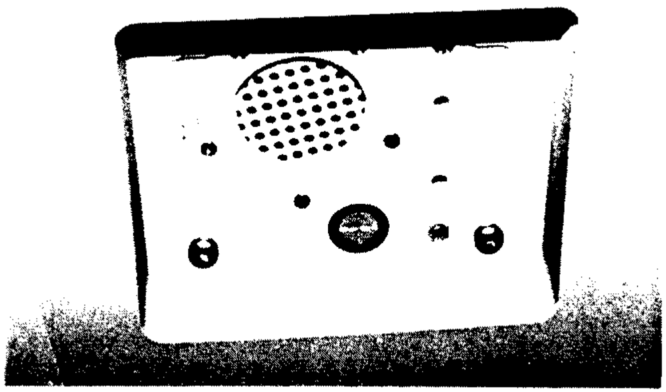
in reverse order at 2, 4, 8, 12, 16, 24, or 32 Mbps. At a rate of 32 Mbps, a tape runs for 20 minutes. The recorder can be changed manually by the flight crew; however, no tape changes are planned because the time required to change tapes is very long and it is much more efficient to dump the tape.

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

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

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

Pressurized Module Intercom. The Spacelab intercom master station interfaces with the orbiter audio central control unit and the orbiter EVA/ATC transceiver for communications through orbiter duplex (simultaneous talk and listen) audio channels. Audio chan-



Spacelab Pressurized Module Aural Annunciator
Located Below Panel L14

nel 1 is air-to-ground 2, channel 2 is intercom B, and channel 3 is air-to-ground 1.

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

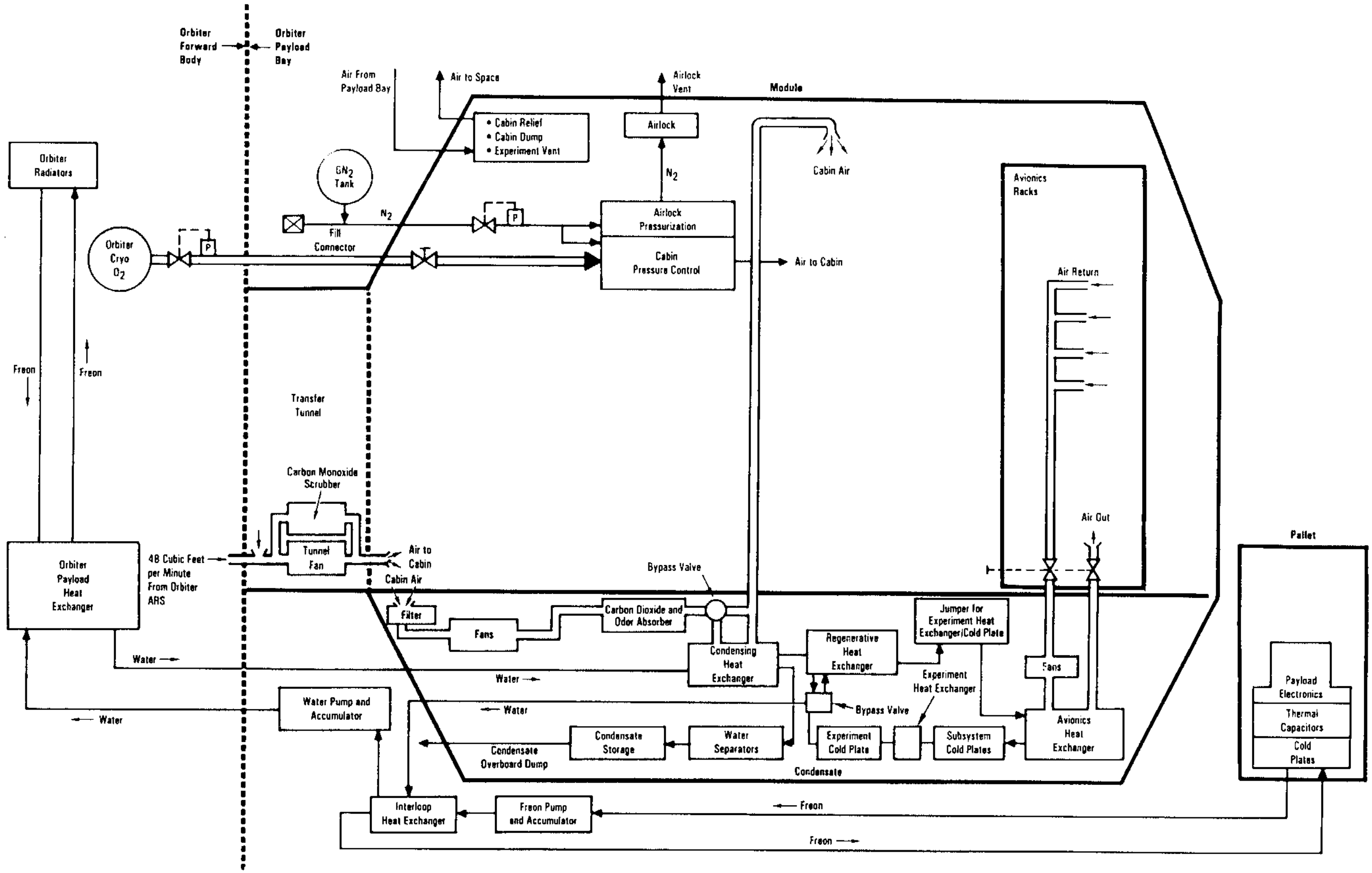
Access to orbiter channels is controlled within the orbiter. Normal voice recordings are made on the orbiter operations recorders. The Spacelab talk and listen lines are combined for distribution to the Spacelab voice digitizer in the Spacelab high-rate multiplexer for all three Spacelab channels.

PRESSURIZED MODULE ENVIRONMENTAL CONTROL SUBSYSTEM AND LIFE SUPPORT. The Spacelab environmental control subsystem consists of the atmosphere storage and control subsystem and the atmosphere revitalization system.

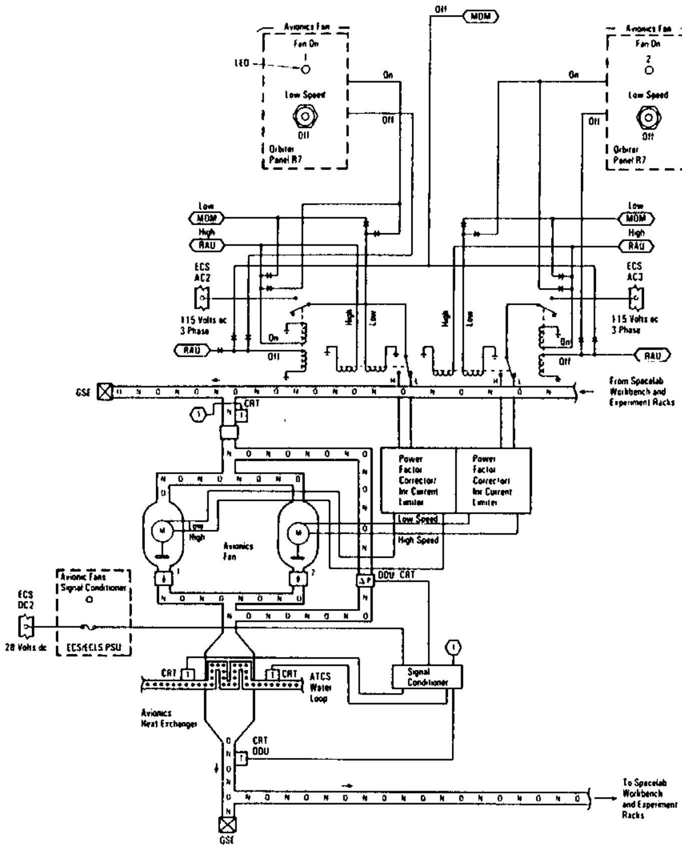
The atmosphere storage and control subsystem receives gaseous oxygen from the orbiter power reactant storage and distribution system and gaseous nitrogen from a tank located on the Spacelab module's exterior. The Spacelab ASCS regulates the gaseous oxygen and nitrogen pressure and flow rates to provide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

Gaseous oxygen from the orbiter PRSD enters the Spacelab module through the upper feedthrough in the Spacelab forward end cone at 100 psi and a maximum flow rate of 14 pounds per hour. A motor-controlled valve in the Spacelab module controls the flow of gaseous oxygen. This valve, operated by Spacelab RAU commands, opens when the *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 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



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



Spacelab Avionics Loop

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.

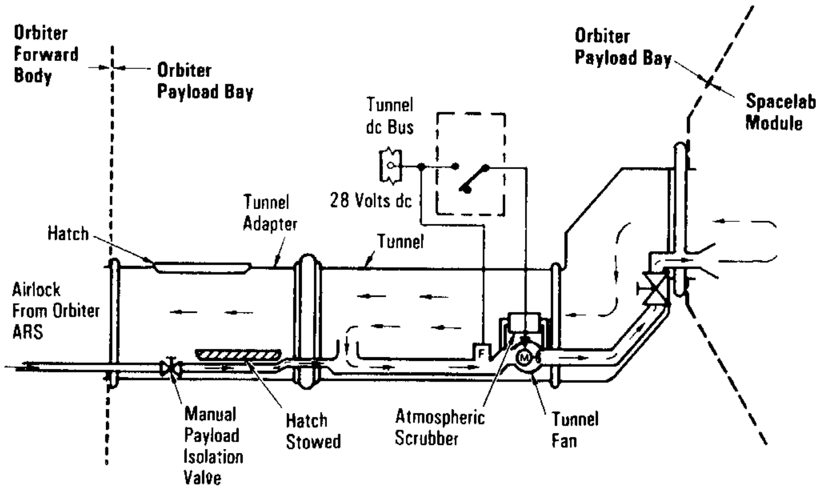
Air in the Spacelab avionics air loop is circulated by one of two dual-redundant fans, with check valves to prevent recirculation through the inactive fan and a filter upstream to protect both fans. For ascent and descent flight phases, as well as low-power modes on orbit, the avionics fans operate when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

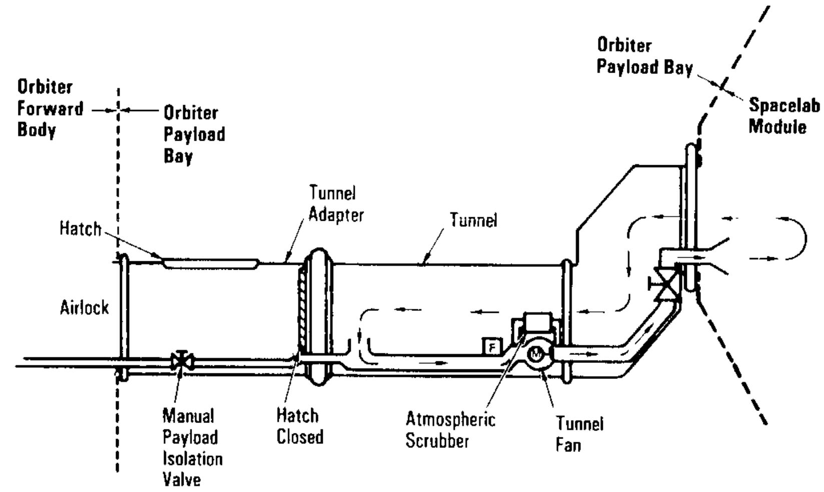
The Spacelab avionics fans can also be activated in the low-speed mode by commands from the orbiter CRT keyboard. The fans are activated in the high-speed mode (four-pole) by commands from the orbiter CRT keyboards. The orbiter MDM deactivation command deactivates both fans simultaneously, and the Spacelab 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 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



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



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

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.

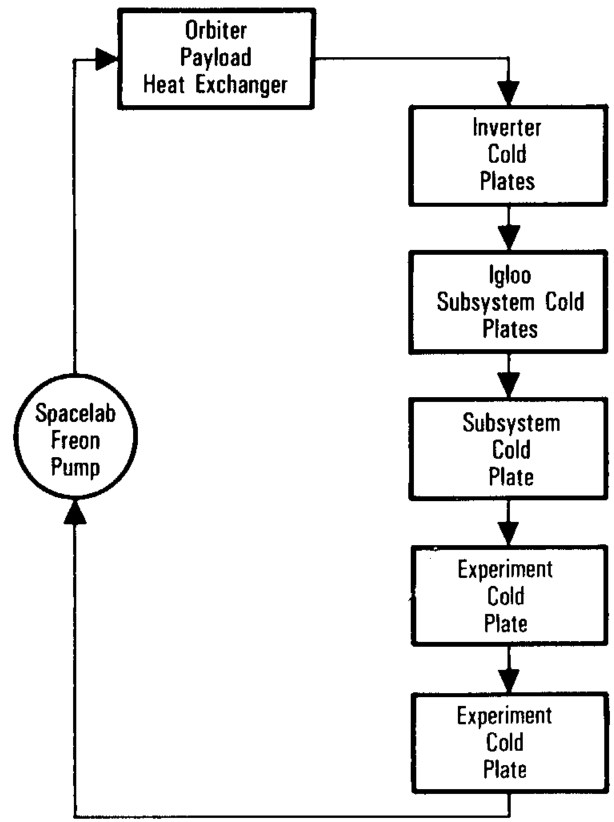
When a Spacelab fire/smoke signal is detected, an emergency tone (siren) generated by the orbiter caution and warning circuitry is transmitted by the orbiter audio central control unit and announced in the Spacelab module by the loudspeaker, and the Spacelab *master alarm* light is illuminated. The six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

INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING

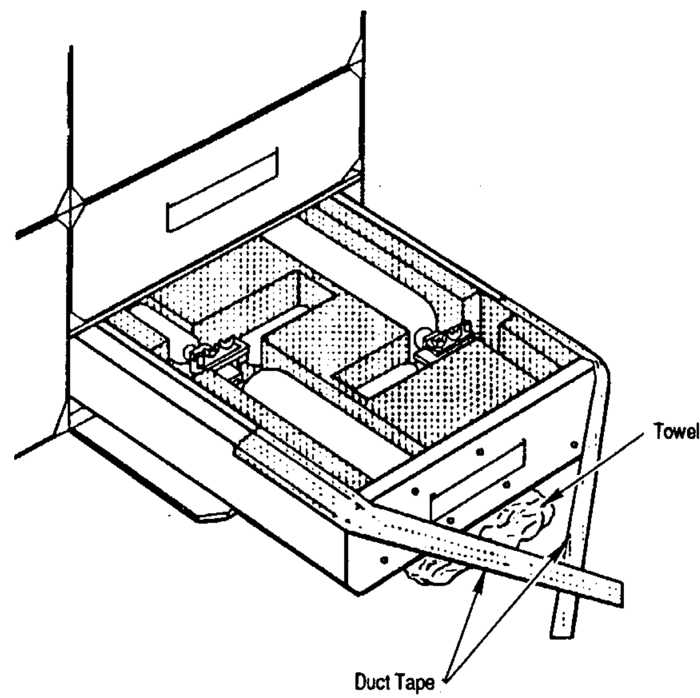
Investigations Into Polymer Membrane Processing will make its seventh space shuttle flight for the Office of Commercial Programs-sponsored Battelle Advanced Materials Center for the Commercial Development of Space in Columbus, Ohio. IPMP flew previously on STS-31, -41, -43, -48, -42, and -45. The objective of the IPMP is to investigate the physical and chemical processes that occur during the formation of polymer membranes in microgravity so that the improved knowledge base can be applied to commercial membrane-processing techniques. Supporting the overall program objective, the STS-50 mission will provide additional data on the polymer precipitation process.

Polymer membranes have been used in the separation industry for many years for such applications as desalination of water, filtration during the processing of food products, atmospheric purification, purification of medicines, and dialysis of kidneys and blood.

Polymer membranes frequently are made using a two-step process. A sample mixture of polymer and solvents is applied to a casting surface. The first step involves the evaporation of solvents from the mixture. In the second step, the remaining sample is immersed in a fluid bath (typically water) to precipitate the membrane, form the solution and complete the process. Previous flights of IPMP have involved the complete process (STS-41, -43, -48, and -42) the evaporation step alone (STS-31), and the precipitation step alone (STS-45). On the STS-50 mission, the complete process will be performed.

The IPMP payload on STS-50 consists of two experimental units containing different solvent solutions that occupy a single small stowage tray (half of a middeck locker). Each unit consists of two 304L stainless steel sample cylinders measuring 4 inches and 2 inches in diameter. The cylinders are connected to each other by a stainless steel packless valve with an aluminum cap. The IPMP payload weighs approximately 17 pounds.

Before the mission, a thin-film polymer membrane is swollen in a solvent solution, rolled, and inserted into the smaller canisters and then sealed at ambient pressure (approximately 14.7 psia). The valve is sealed with Teflon tape. The larger canister is evacuated and sealed with threaded stainless steel plugs using a Teflon tape threading compound.



IPMP Configuration

An STS-50 crew member will activate the IPMP experiment by sliding the stowage tray which contains two IPMP units to the edge of the locker. When the valve on each unit is turned, water vapor is infused into the sample container, initiating the evaporation process. The evaporation process will last five minutes for one unit and one hour for the other. The units' valves will then be turned to a second position, initiating a 15-minute precipitation process that includes quenching the membrane with water. The stowage tray containing the two units is then restowed for the duration of the flight.

Following the flight, the samples will be retrieved and returned to Battelle for testing. Portions of the samples will be sent to the CCDS's industry partners for quantitative evaluation consisting of comparisons of the membranes' permeability and selectivity characteristics with those of laboratory-produced membranes.

The principal investigator for the IPMP is Dr. Vince McGinness of Battelle. Lisa A. McCauley, associate director of the Battelle CCDS, is program manager.

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

SAREX has been flown on missions STS-9, -51F, -35, -37, and -45 in different configurations. STS-50 SAREX hardware consists of a low-power hand-held FM transceiver, a spare battery set, an interface module, a headset assembly, an equipment assembly cabinet, and an antenna that will be mounted in a forward flight deck side window. The equipment complement is stowed in one and a half middeck lockers.

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

During the mission, SAREX-II will be operated at the discretion of two licensed amateur radio operators who are members of the STS-50 crew: commander Richard N. Richards (call sign KB5SIW) and mission specialist Ellen S. Baker (call sign KB5SIX).

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

SAREX Insignia

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

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

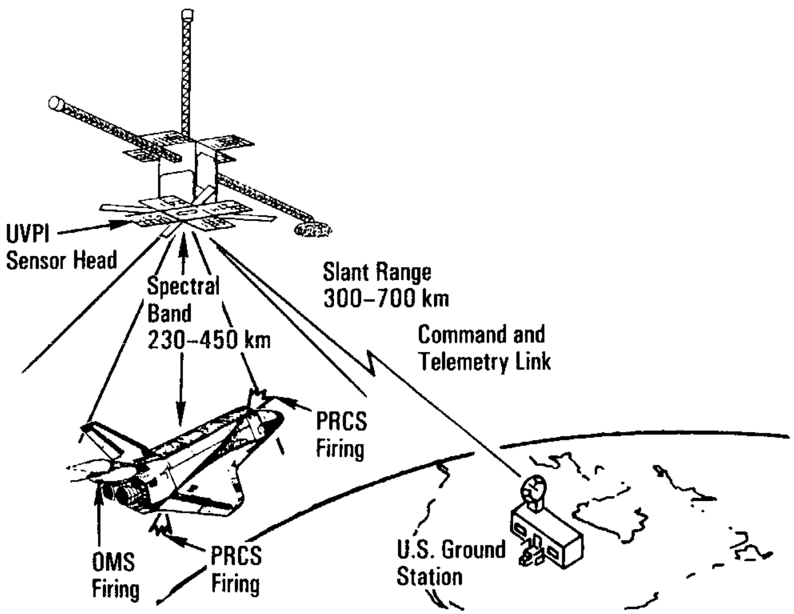
The primary pair of frequencies intended for use during the missions is 145.55 MHz for downlink from Columbia and 144.95 MHz for uplink. A spacing of 600 kHz was deliberately chosen for this primary pair to accommodate those whose split-frequency capability is limited to the customary repeater offset. Digital packet and slow scan television will operate on the same frequencies, while the television uplink will be limited to the UHF ham band at 450 MHz.

ULTRAVIOLET PLUME INSTRUMENT

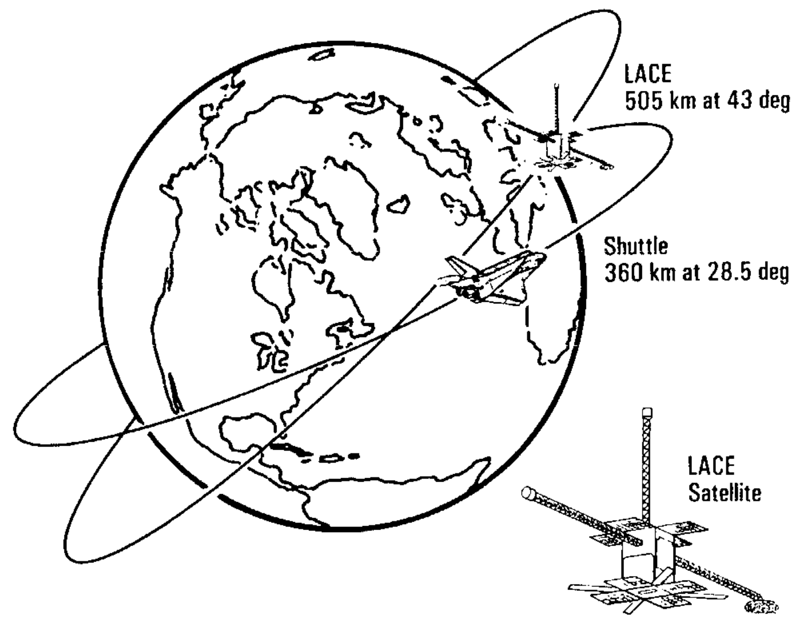
The Ultraviolet Plume Instrument is located on the Low-Power Atmospheric Compensation Experiment satellite, a Strategic Defense Initiative Organization satellite in low Earth orbit at an inclination of 43 degrees and an altitude of approximately 290 nautical miles. The UVPI's sensors will be trained on the orbiter to obtain imagery and/or signature data to calibrate the sensors and to observe orbiter jet firings during cooperative encounters of the orbiter with the LACE satellite. Orbiter maneuvers will include, in order of priority, an OMS burn test, primary reaction control system burn test, vernier reaction control system burn test, orbiter hardbody, and payload bay lighting test.

UVPI is a payload of opportunity. A UVPI test will be scheduled late in the mission if an orbiter encounter with the satellite fits within the crew's scheduling constraints and the orbiter has enough propellant. UVPI requires no flight hardware to be carried on the orbiter.

UVPI is sponsored by the Strategic Defense Initiative Organization.



LACE/Shuttle UVPI Encounter



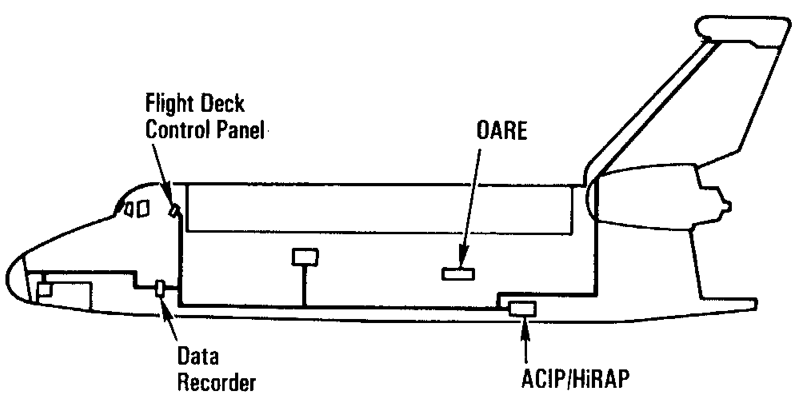
LACE (UVPI)/Shuttle Encounter

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.

Three OEX experiments will be flown on STS-50: Aerodynamic Coefficient Identification Package (ACIP), High-Resolution Accelerometer Package (HiRAP), and Orbital Acceleration Research Experiment (OARE).



Orbiter Experiments Program STS-50 Configuration

Orbiter Experiments Support Systems for OV-102 (Columbia). The support system for the orbiter experiments was developed to record data obtained and to provide time correlation for the recorded data. The information obtained through the sensors of the OEX instruments must be recorded during the orbiter mission because there is no real-time or delayed downlink of OEX data. In addition, the analog data produced by certain instruments must be digitized for recording.

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

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.

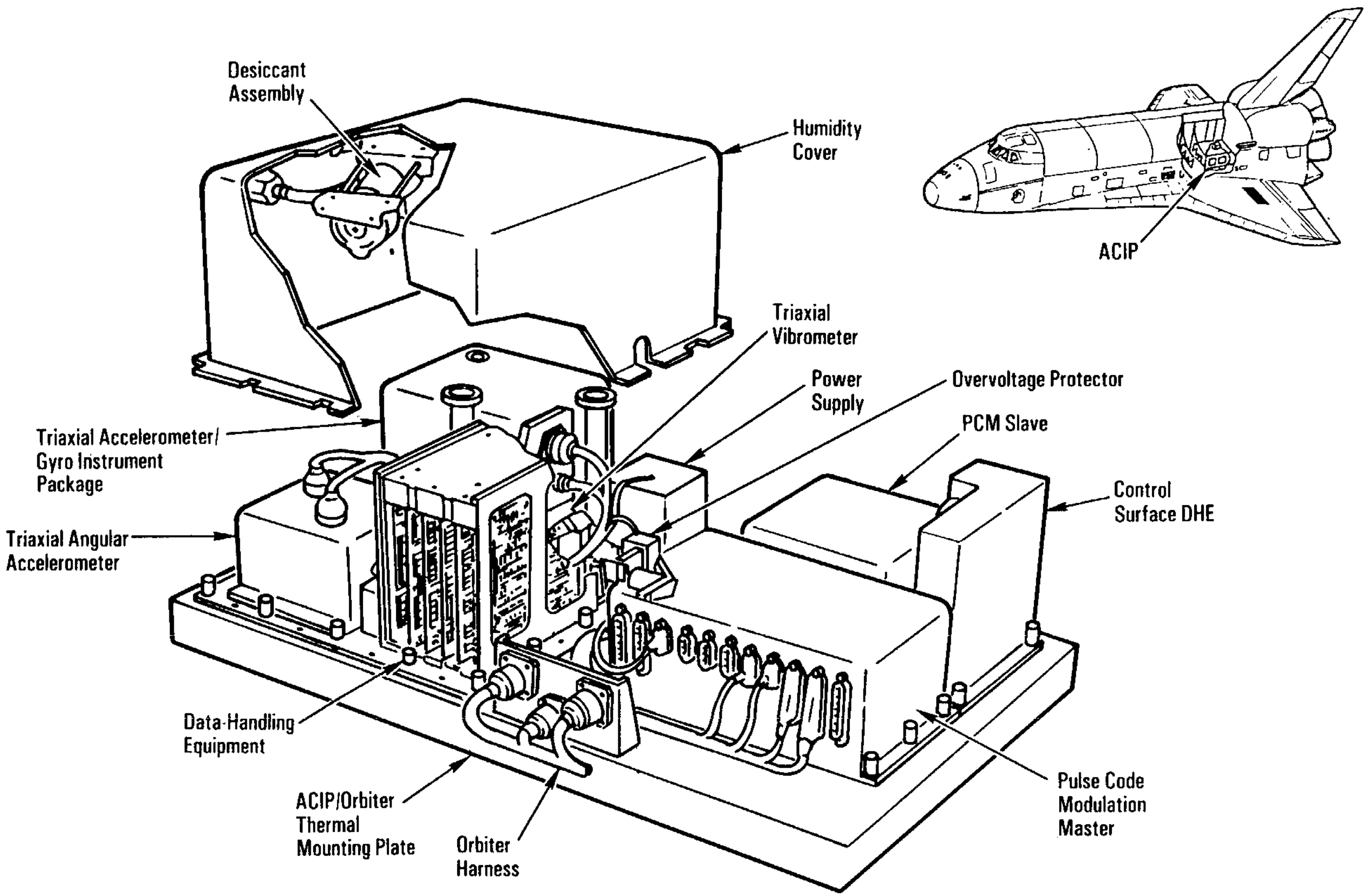
Implementing the ACIP program will benefit the space shuttle because the more precise data obtained through the ACIP will enable earlier attainment of the spacecraft's full operational capability. Currently installed instrumentation provides sufficiently precise data for orbiter operations, but not for 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.

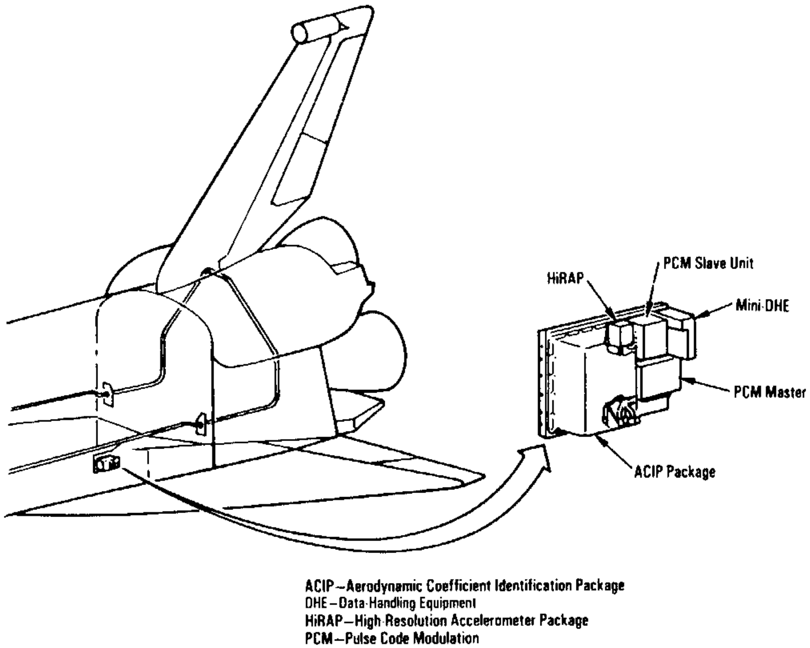
The ACIP has flown on all flights of orbiters Columbia and Challenger. David B. Kanipe, Johnson Space Center, Houston, is the ACIP principal investigator.

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.

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



Aerodynamic Coefficient Identification Package advances, these techniques depend on actual flight data to serve as benchmarks, particularly in the transition regime between free molecular flow and continuum flow.



High-Resolution Accelerometer Package

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.

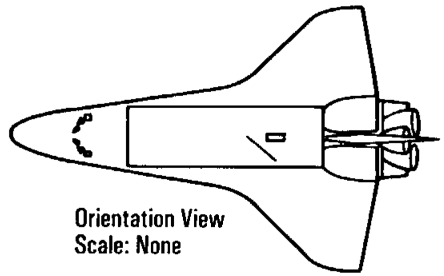
HiRAP has been flown on 13 previous missions of the orbiters Columbia and Challenger. Robert C. Blanchard, Langley Research Center, is the HiRAP principal investigator.

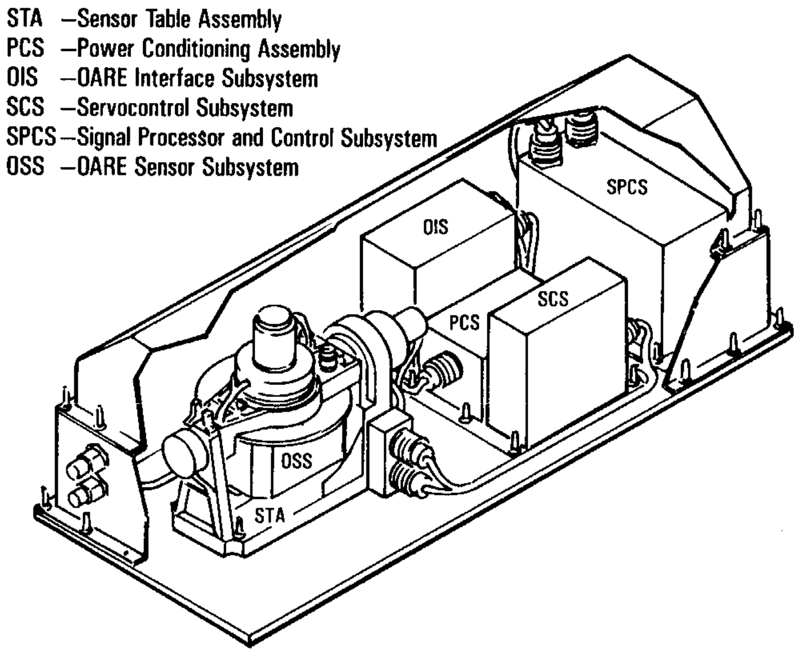
ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

The Orbital Acceleration Research Experiment (OARE) complements the Aerodynamic Coefficient Identification Package (ACIP) and High-Resolution Accelerometer Package (HiRAP) instruments by extending the altitude range over which vehicle acceleration data can be obtained to orbital altitudes. Aerodynamic data are acquired on-orbit and during the high-altitude portion of atmospheric entry. 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, capable of measuring acceleration levels as small as one part per billion of Earth's gravity.

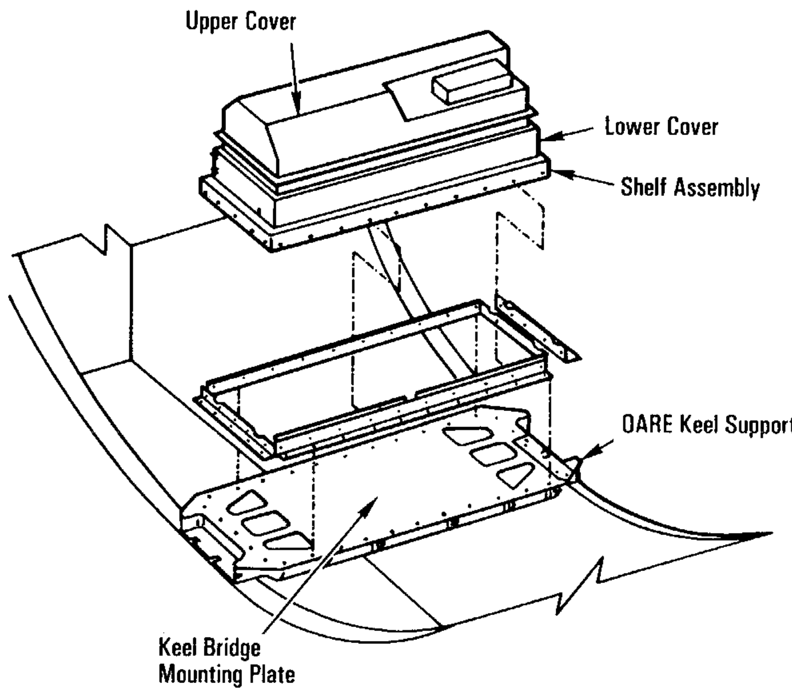
Because of their extreme measurement sensitivity, the OARE sensors cannot be adequately calibrated on the ground (in a 1-g environment). Consequently, the sensors are mounted on a rotary calibration table which enables an accurate instrument calibration to be performed on orbit.

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 and within the OARE's own solid-state memory for post-flight analysis. This is the second flight for the OARE instrument. Principal investigator is Robert C. Blanchard of Langley Research Center.





OARE Experiment



OARE Installation

Ascent aerodynamic distributed loads verification on Columbia (DTO 236). This DTO will collect data on wing aerodynamic distributed loads to allow verification of the aerodynamic database. A less negative alpha will be flown on STS–50.

Entry aero control surfaces test—alternate elevon schedule, part 1 (DTO 251). The purpose of this DTO is to perform PTI maneuvers, and one body flap maneuver, during entry and TAEM to obtain aerodynamic response data for use to evaluate effectivity of aerodynamic control surfaces. Analysis may enhance vehicle performance and safety. This DTO uses the alternate forward elevon schedule and contains six parts. Part 1 contains a BF maneuver between Mach 16 and Mach 14.

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

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

ET TPS performance—method 2 (DTO 312). This DTO will photograph the external tank after separation to document overall thermal protection system performance.

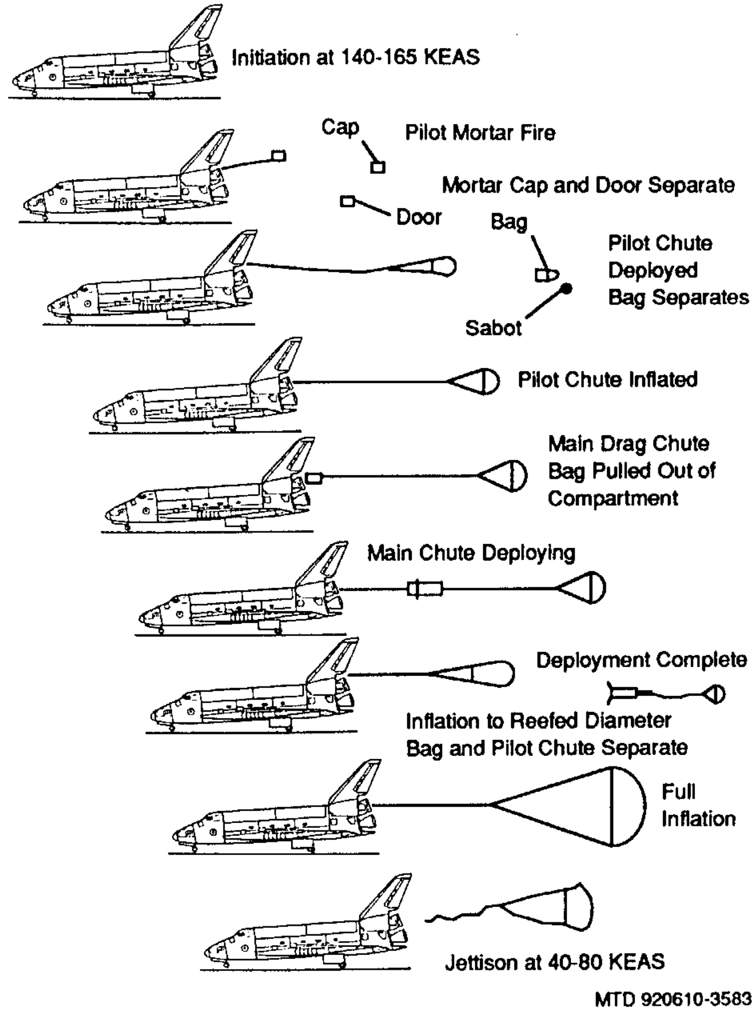
On-orbit PRSD cryo hydrogen boil-off (DTO 413). The objective of this DTO is to measure residual heat leaks into cryo tanks. The data will be applicable to the long stay times required by orbiters during space station Freedom operations.

Carbon brake system test (DTO 519). The objective of this DTO is to evaluate the orbiter carbon brake system performance through a series of landing rollout brake tests on lakebed and concrete surfaces. Test conditions must be performed using the following vehicles: Discovery for 1, 2, and 3; Atlantis for 4; Columbia for 5; and Endeavour for 6.

Orbiter drag chute system (DTO 521). This DTO will evaluate the orbiter drag chute system performance through a series of landings with increasing deployment speeds. The DTO will be performed on vehicles equipped to measure drag forces imposed by the drag chute system. This DTO consists of two phases: Phase I will consist of three flights, with first flight drag chute deployment at or subsequent to nose gear touchdown, second flight will be nose gear touchdown incorporating delayed load relief, and the third flight with initiation at derotation. Upon completion of Phase I, the deceleration parachute will be operational for all vehicles. Phase II will consist of seven additional flights gradually increasing in speed from initiation at derotation 185 knots equivalent air speed (KEAS) to initiation at 205 KEAS.

Cabin air monitoring (DTO 623). This DTO will use the solid sorbent sampler to continuously sample the orbiter atmosphere throughout the flight. The sampler collects trace levels of volatile contaminants which are used to determine spacecraft air quality and the effectiveness of the ECLSS in removing these compounds from the air. The solid sorbent sampler is to be flown on all Spacelab manned module flights. For STS-50, the solid sorbent sampler will alternate readings between the middeck and the Spacelab module.

Foot restraint evaluation (DTO 655). The purpose of this DTO is to evaluate a new conceptual design for foot restraints. The crew will comment on ease of ingress/egress, if pitch is required in



Sequence of Drag Chute Deployment and Inflation

design, foot loop size and spacing, fit and comfort, as well as base plate size. The foot restraints will be used in the Spacelab module during Spacelab experiment operations.

Evaluation of the ergometer vibration isolation system (DTO 658). The purpose of this DTO is to measure the magnitude and frequency of the vibration generated in the Spacelab and orbiter middeck by the cycle ergometer with the ergometer vibration isolation system (EVIS) on specific areas of the Spacelab and the middeck. The crew will also comment on ease of setup and stowage, impact on exercise activities, as well as activities in the middeck. The experiment is applicable to future microgravity research on the space shuttle and space station Freedom.

Acoustical noise dosimeter data (DTO 663). This DTO will gather baseline data on the time-averaged acoustical noise levels for the middeck (crew sleep station, airlock) and the module (location OH7) during daytime and nighttime operations using an audio dosimeter. The CPCG, CRIM, ergometer, and new galley may negatively influence the overall cabin noise levels. This data will provide information to help determine new specification levels for intermittent noises as well as a maximum 24–hour exposure level.

Acoustical noise sound level data (DTO 665). This DTO will obtain baseline data of octave band acoustical noise levels for the middeck and flight deck, exercise equipment, inside the four-tier sleep station, on the new regenerable carbon dioxide removal system, the new galley, new waste collection system, and manned laboratory data when labs are flown. A Spacelab analog sound level meter will be used. The Spacelab sound level meter will also be used to record eight sound level readings for the USML-1 payload.

Modify ECLSS supply air ducting to provide chilled air to suited crewmembers (DTO 666). This DTO will evaluate hardware modifications that direct cool ARS supply air to the crew during the launch, entry, and landing orbital phases.

Orbiter experiment (OEX) orbital acceleration research experiment (OARE) (DTO 910). OARE will acquire accurate measurement data on low–level aerodynamic acceleration on the orbiter principal axes during orbit and reentry. Its instruments have "nano-g" measurement capability, and are therefore more sensitive than SAMS (see Orbiter Experiments section).

Columbia accelerations data collection to support microgravity disturbances experiment (DSO 314). This DSO will collect and record accelerometer data from the high resolution accelerometer package (HiRAP) during specific mission events to characterize the induced disturbances in the acceleration environment that result from thruster firings, satellite deploys, crew treadmill activity, and other disturbances. The aerodynamic coefficients identification package (ACIP) is required and the orbiter acceleration research experiment (OARE) is desired.

Intraocular pressure (DSO 472). This DSO will gather data on headward fluid shifts in zero gravity, which can be used to evaluate crew health. Pressure measurements 20 to 25 percent above normal preflight levels were observed in bedrest studies, during zero gravity on the KC-135 aircraft and on the STS 61-A shuttle mission. The deleterious effects of sustained deviations in intraocular pressure are difficult to predict since no statistically valid in-flight data exists. Even though a few days or weeks of elevated intraocular pressure would be harmless, months or years of sustained pressures, due to microgravity, could cause ocular disturbances. Significant baseline data is needed to define normal intraocular pressure ranges in microgravity and to determine the magnitude of pressure rises to be expected in crew members. A hand-held tonometer will be validated as a tool for diagnostic and scientific data collection on orbit.

In-flight retinal vascular changes detected by digital image analysis and correlation with space adaptation syndrome (DSO 474). Retinal photography is a noninvasive method of detecting changes in intracranial pressure through changes in the retinal blood vessels and elevation of the optic disc. The purpose of this DSO is to analyze retinal photography taken on orbit and determine if microgravity induced cephalad fluid shifts elevate intracranial pressure. It will also certify equipment to provide retinal images for diagnostic and investigative purposes.

In-flight lower body negative pressure (DSO 478). Fluid loading through ingesting salt tablets and water in association with lower body negative pressure treatment will protect tolerance to orthostasis (simulated in flight by LBNP). The objective of this study is to evaluate the effectiveness of fluid loading during LBNP in improving tolerance of an LBNP stress protocol.

Assessment of circadian shifting in astronauts by bright light (DSO 484). This DSO will determine the efficacy of bright light in facilitating preflight circadian shifting in astronauts requiring atypical work-rest cycles during space flight. A total of 12 crewmembers from varying flights are required. The activity is all scheduled for pre- and postflight periods. There is no in-flight activity.

Heart rate and blood pressure variability during space flight (DSO 602). The objective of this DSO is to determine whether arterial blood pressure and heart rate exhibit less variability in a microgravity environment than on Earth. The data will be used to investigate whether reduced blood pressure variability in flight, if any, is correlated with the extend of baroreflex attenuation that has been measured postflight. Integrity of the baroreceptor function is required for the appropriate blood pressure responses to the orthostatic stresses imposed by entry, landing, and egress. The crewmember will wear blood pressure and electrocardiograph equipment for two flight days on orbit.

Orthostatic function during entry, landing, and egress (DSO 603B). Heart rate and rhythm, blood pressure, cardiac output, and peripheral resistance will be monitored during entry, landing, seat egress, and orbiter egress in order to develop and assess countermeasures designed to improve orthostatic tolerance upon return to Earth. Crewmembers will don equipment prior to donning the LES during deorbit preparation. Equipment consists of a blood pressure monitor, accelerometers, an impedance cardiograph, and transcranial Doppler hardware. The crewmember wears the equipment and records verbal comments throughout entry.

Postural equilibrium control during landing/egress (DSO 605). Postural control as a function of mission duration will be assessed using a posture platform test performed pre- and postflight only. Results from this study will be used to develop countermeasures to assure postural stability during landing and egress.

Air monitoring instrument evaluation and atmosphere characterization (DSO 611). This DSO will evaluate and verify the archival organic sampler (AOS) 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.

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

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

Evaluation of functional skeletal muscle performance following space flight (DSO 617). The purpose of this DSO is to determine the physiological effects of long duration space flight on skeletal muscle strength, endurance, and power by evaluating concentric and eccentric functional changes from pre- to postflight for the trunk and lower limbs. Additionally, neuromuscular dysfunction as measured by EMG will be determined. It will provide knowledge necessary to support the development of future countermeasure prescriptions essential for nominal muscle performance. On-orbit activities consist of maintaining an exercise log.

Effects of intense exercise during space flight on aerobic capacity and orthostatic function (DSO 618). The purpose of this DSO is to evaluate the effects of cycle ergometer exercise 18-24 hours before landing with similar exercise performed immediately postflight, to quantify deconditioning that occurs over the duration of the flight, and to compare preflight, inflight, and postflight heart rate responses to cycle ergometry.

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

In-flight use of Florinef to improve orthostatic intolerance postflight (DSO 621). The purpose of this DSO is to evaluate the efficacy of mineralocorticoid, commonly known as Florinef, to enhance postflight orthostatic capacity as determined by heart rate, blood pressure, stroke volume, and other cardiovascular responses to orthostatic stress. Florinef, a plasma expander, has been effective in restoring or maintaining plasma volume and orthostatic tolerances during postbedrest tests. A cardiovascular profile will be determined both pre- and postflight for the participating crew member.

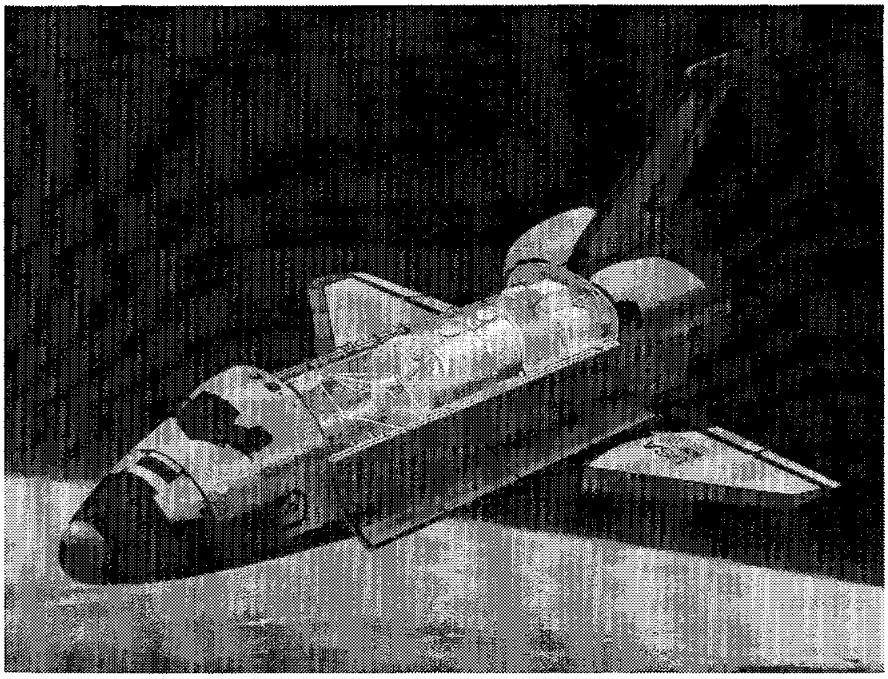
Educational activities (DSO 802). The objective of this DSO is to use the attraction of spaceflight to motivate students toward careers in science, engineering, and mathematics. This will be accomplished by live downlink of educational activities performed by the crew and production of video lessons with scenes recorded both on orbit and on the ground.

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

Documentary motion picture photography (DSO 902). This DSO requires documentary and public affairs motion picture photography of significant activities that best depict the basic capabilities of the space shuttle and key flight objectives. This DSO includes motion picture photography of Spacelab module activities, flight deck activities, middeck activities, and any unscheduled motion picture photography.

Documentary still photography (DSO 903). This DSO requires still photography of crew activities in the orbiter, Spacelab, and mission related scenes of general public and historical interest. Still photography with 70mm format for exterior photography and 35mm format for interior photography is required.

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.). It will also record in-flight comments on how and why task productivity is affected, contribute to future space environmental designs, and aid the principal investigators in designing investigations with better quantifications of time and requirements for in-flight tasks.



STS-50

MISSION STATISTICS

PRELAUNCH COUNTDOWN TIMELINE

MISSION TIMELINE

June 1992

Rockwell International
Space Systems Division

Office of Media Relations

CONTENTS

MISSION OVERVIEW

This is the 12th flight of Columbia and the 48th for the space shuttle.

The flight crew for the 13-day STS-50 mission is commander Richard (Dick) N. Richards; pilot Kenneth (Ken) D. Bowersox; payload commander (lead mission specialist) Bonnie J. Dunbar; mission specialists Carl J. Meade and Ellen S. Baker; and payload specialists Lawrence (Larry) J. DeLucas and Eugene (Gene) H. Trinh. The crew will be divided into a blue team, consisting of Baker, Meade, and Trinh, and a red team, comprised of Richards, Bowersox, Dunbar, and DeLucas. Each team will work consecutive 12-hour shifts, providing for around-the-clock operations.

The primary objective of STS-50, the first dedicated extended duration flight in the history of the shuttle program, is to successfully perform the planned operations of the United States Microgravity Laboratory (USML)-1 payload, the first in a series of space shuttle Spacelab missions dedicated to studying microgravity materials processing technology and other science and research requiring the low-gravity environment of Earth orbit. Designed to help the U.S. maintain world leadership in microgravity research and development, the USML mission series will bring together representatives from academia, industry, and government (10 universities, 5 NASA centers, and 3 commercial interests on USML-1) to study basic scientific questions and gain new knowledge in materials science, biotechnology, combustion science, the physics of fluids, and the way energy and mass are transported within them. The USML missions will continue development and testing of experimental flight equipment for space station Freedom and will be laying the scientific foundation for microgravity research conducted over extended time periods.

USML-1 consists of 31 scientific experiments and associated hardware housed in a Spacelab long module--made up of a core segment and an experiment segment in the payload bay--and on the orbiter middeck. A long Spacelab transfer tunnel connects the Spacelab module with the orbiter middeck. Laboratory hardware includes new equipment, such as the crystal growth furnace, and some equipment that has flown previously, such as the solid surface combustion experiment. The experiments include the following:

The **Astroculture-1** hydroponic experiment is designed to validate a concept that was developed for supplying water and nutrients to plants growing in a microgravity environment.

The **crystal growth furnace** will grow crystals of materials (primarily semiconducting material, metal, and alloys) that form the basis of electronic devices in a microgravity environment. A directional solidification process will be used. The experiment consists of a large structure that has three furnaces (high temperature, low temperature, and adiabatic) and a carousel mechanism that places material samples into the processing mechanism. The CGF dictates the orbiter's attitude, since it requires that the long axis of the furnace be pointed along the velocity vector. Four different samples (HgCdTe, GaAs, CdTe, and HgZnTe) will be processed with run durations of 1, 2, 4, and 6 days.

The **drop physics module** is an instrument for conducting containerless material properties and materials processing experiments in space. The module uses acoustic waves to hold a drop of a particular material in the middle of the container. The experiment complement on USML-1 includes an investigation of surface-controlled phenomena (high-purity water), a study of rotating, oscillating drops (water, glycerine, and silicone oil), and an investigation of the kinetics of compound drops (water, silicone oil). In addition, instrument calibration and capability demonstrations are planned. Basic physics experiments such as these may provide new insights into processes such as cell encapsulation, which involves surrounding living cells with a membrane to protect them from harmful antibodies. This method could have tremendous potential in the treatment of several diseases.

The **extended duration orbiter medical project** consists of three major components: the in-flight lower body negative pressure experiment (LBNP), the heart rate and blood pressure variability during space flight experiment, and the air monitoring instrument evaluation and atmosphere characterization experiment. The LBNP experiment is used to evaluate the effectiveness of the combination of fluid loading (ingestion of salt tablets and water) during application of negative pressure to the lower body in reversing space flight-incurred cardiovascular changes. The objective of the study is to evaluate the effectiveness of fluid loading during LBNP in improving tolerance of an LBNP stress protocol. The heart rate and blood pressure variability during space flight experiment will determine if heart rate and arterial blood pressure exhibit less variability in a microgravity environment than on Earth. The air monitoring instrument evaluation and atmosphere characterization experiment will evaluate and verify the microbial air sampler to ensure proper function and operations in orbit. In addition, data will be collected on microbial contaminant levels during missions of various durations. The data will be used to establish baseline levels and to evaluate potential risks to crew health and safety. LBNP has flown before on STS-32, -43, and -44; heart rate and blood pressure variability during space flight has flown before on STS-41, -35, -39, -43, and -48; and the microbial air sampler has flown previously on STS-1 and -42.

The **generic bioprocessing apparatus** payload is designed as a self-contained mixing and heating module used to process biological fluid samples in a microgravity environment. It will support up to 132 individual experiments on small quantities of samples ranging from molecules to small organisms. The experiment hardware is located in the SMIDEX rack in the module, and refrigerated samples (4 degrees Celsius) will be kept in the GBA refrigerator/incubator module located in the middeck.

The **glovebox** facility will house 16 experiments to be conducted in a closed environment. These will include complementary experiments in fluid dynamics, protein crystal growth, and combustion science, as well as technology demonstrations. It is an enclosed working area that will be used for all specimen manipulations to prevent materials from entering the Spacelab module atmosphere and to prevent contamination of the materials when its containment has to be opened for observations, microscopy, photography, etc.

The primary objective of the **protein crystal growth** experiments is to produce large,high quality crystals of selected proteins under controlled conditions in microgravity. The results are applicable to the development of new/improved medicines and foods with improved nutritional value. There will be two refrigerator/incubator modules on the orbiter middeck, one at 22 degrees Celsius and one at 4 degrees Celsius. PCG has flown previously on STS-26, -29, -31, -32, -37, -42, -43, -48, and -49.

The **space acceleration measurement system** is a microprocessor-driven data acquisition system used to measure and record the Spacelab microgravity acceleration environment. Acceleration information will help scientists better understand their flight experiments by comparing results with vibration levels encountered in the shuttle. This information will also assist engineers as they design equipment and plan the placement of sensitive experiments on future missions. SAMS has flown before on STS-40, -42, and -43.

The primary objective of the **solid surface combustion experiment** is to measure flame spread rate, solid-phase temperature, and gas-phase temperature for flames spreading over rectangular fuel beds of polymethylacrylate or ashless filter paper in the reduced-gravity environment of space. SSCE has flown before on STS-40 and -41.

The purpose of the **surface tension driven convection experiment** is to measure, by video photography and subsequent digital analysis, how thermocapillary flow (the fluid motion generated by surface tension variations due to a temperature difference along the interface of a fluid) affects containerless materials processing in the microgravity environment. The knowledge gained may assist in improving production of glasses and ceramics, semiconductor and protein crystals, metals, and alloys. In the experiment, a 4-in. diameter by 2-in. deep container of silicone oil is heated and data is collected on the velocity profile of the cross section of the oil. Two different methods of heating are used: surface heating by a carbon dioxide laser and internal heating by a heater cartridge. The effects of both are studied.

The objective of the **zeolite crystal growth** experiment is to evaluate the synthesis of large zeolite crystals in microgravity. Zeolites are complex arrangements of silica and alumina that occur naturally as well as synthetically. Because of their molecular sieve characteristics, zeolites are used as highly selective catalysts, absorbents, and ion exchange materials.

USML-1 experiments are sponsored by NASA and are managed by NASA's Marshall Space Flight Center, Huntsville, Ala.

Three secondary objectives will be flown on STS-50: Investigations Into Polymer Membrane Processing, Shuttle Amateur Radio Experiment II, and the Ultraviolet Plume Instrument.

The objective of the IPMP payload, sponsored by the Battelle Advanced Materials Center, a NASA center for the commercial development of space, is to investigate the formation of polymer membranes in microgravity. IPMP research could lead to possible advances in filtering technologies.

SAREX-II, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, will establish crew voice communication with amateur radio stations within the line of sight of the orbiter.

The UVPI is a payload of opportunity that will be conducted if time permits. It does not require any on-board hardware. It is a Department of Defense payload located on the Low-Power Atmospheric Compensation Experiment satellite, a Strategic Defense Initiative Organization satellite in low Earth orbit. UVPI's sensors will be trained on the orbiter to obtain imagery and/or signature data to calibrate the sensors and to observe jet firings during cooperative encounters of the orbiter with the LACE satellite.

At 12 days, 20 hours, 28 minutes, STS-50 will be the longest shuttle mission to date. The extended duration is made possible through conversion of Columbia into an extended duration orbiter capable of flights of up to 16 days in length. Under a 1988 NASA amendment to an existing Rockwell shuttle orbiter contract, Rockwell International Corporation's Space Systems Division (SSD) designed, developed, certified, and produced an extended duration orbiter (EDO) mission kit that will allow a shuttle to remain in orbit for up to 16 days, plus a two-day contingency capability. The EDO modification program is designed to reduce the number of flights required to accomplish tasks; lower risks, costs, and vehicle wear; and substantially increase the volume of data that can be collected on a mission.

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

In addition to conversion into the shuttle fleet's first extended duration orbiter, Columbia underwent a complete structural inspection, installation of a drag chute, calibration of its wing strain gauges, and nearly 50 other avionics, subsystems, and structures/thermal protection system upgrades to improve vehicle performance during its six-month modification period at Rockwell's Palmdale facility. The changes were designed to maintain Columbia's structural integrity, keep the fleet uniform and technologically up-to-date and enhance vehicle turnaround time.

Fifteen detailed test objectives and twenty detailed supplementary objectives are scheduled to be flown on STS-50.

MISSION STATISTICS

Vehicle: Columbia (OV-102), 12th flight

Launch Date/Time:

6/25/92	12:07 p.m., EDT
	11:07 a.m., CDT
	9:07 a.m., PDT

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

Launch Window: 3 hours, 7 minutes (2 hours, 30 minutes crew on back constraint)

Mission Duration: 12 days, 20 hours, 28 minutes

Landing: Nominal end-of-mission landing on orbit 206

7/8/92	8:35 a.m., EDT
	7:35 a.m., CDT
	5:35 a.m., PDT

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

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

Return to Launch Site: KSC

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

Inclination: 28.45 degrees

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

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 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 nautical miles (184 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2019
No. 2 position: Engine 2031
No. 3 position: Engine 2011

External Tank: : ET-50

Solid Rocket Boosters: BI-051

Editor's Note: The following weight data are current as of June 16, 1992.

Total Lift-off Weight: Approximately 4,519,680 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 257,265 pounds

Orbiter (Columbia) Empty, and 3 SSMEs: Approximately 180,784 pounds

Payload Weight Up: Approximately 24,589 pounds

Payload Weight Down: Approximately 24,589 pounds

Orbiter Weight at Landing: Approximately 228,003 pounds

Payloads--Payload Bay (* denotes primary payload): United States Microgravity Laboratory 1*, Orbital Acceleration Research Experiment

Payloads--Middeck: Investigations Into Polymer Membrane Processing; Shuttle Student Amateur Radio Experiment II; Zeolite Crystal Growth, Generic Bioprocessing Apparatus, Astroculture, Protein Crystal Growth (all part of USML-1)

Other Mission Objective--No Flight Hardware: Ultraviolet Plume Instrument (UVPI)

Flight Crew Members:

Red Team:

Commander: Richard (Dick) N. Richards, third space shuttle flight
Pilot: Kenneth (Ken) D. Bowersox, first space shuttle flight
Payload Commander (MS1): Bonnie J. Dunbar, third space shuttle flight
Payload Specialist 1: Lawrence (Larry) J. DeLucas, first space shuttle flight

Blue Team:

Mission Specialist 2: Ellen S. Baker, second space shuttle flight
Mission Specialist 3: Carl J. Meade, second space shuttle flight
Payload Specialist 2: Eugene (Gene) H. Trinh, first space shuttle flight

Richards, Bowersox, and Baker make up the orbiter crew, which operates the Shuttle and Spacelab systems monitored by the Mission Control Center at NASA's Johnson Space Center, Houston, Texas. DeLucas, Trinh, Dunbar, and Meade form the science crew, which will operate the USML-1 experiments monitored by the Payload Operations Control Center at NASA's Marshall Space Flight Center in Huntsville, Ala.

Ascent Seating:

Flight deck, front left seat, commander Richard (Dick) N. Richards
Flight deck, front right seat, pilot Kenneth (Ken) D. Bowersox
Flight deck, aft center seat, mission specialist Ellen S. Baker
Flight deck, aft right seat, payload commander Bonnie J. Dunbar
Middeck, mission specialist Carl J. Meade
Middeck, payload specialist Lawrence J. DeLucas
Middeck, payload specialist Eugene H. Trinh

Entry Seating:

Flight deck, front left seat, commander Richard (Dick) N. Richards
Flight deck, front right seat, pilot Kenneth (Ken) D. Bowersox
Flight deck, aft center seat, mission specialist Ellen S. Baker
Flight deck, aft right seat, mission specialist Carl J. Meade
Middeck, payload commander Bonnie J. Dunbar
Middeck, payload specialist Lawrence J. DeLucas
Middeck, payload specialist Eugene H. Trinh

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: Ellen S. Baker
EV-2: Carl J. Meade

Intravehicular Astronaut: Kenneth (Ken) D. Bowersox

STS-50 Flight Directors:

Orbit 2/Lead: Bob Castle
Orbit 1: Rich Jackson
Orbit 4: Rob Kelso
Orbit 3: Gary Coen
Ascent/Entry/Orbit 3: Jeff Bantle

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 is installed in Columbia's middeck

. Four flight control teams will be used instead of the usual three due to the length of the mission

. Landing is planned at EAFB concrete runway 22/04 because of Columbia's heavier landing weight (approximately 228,000 pounds at x-cg of 1080.8 in.) and vehicle mass movement (approximately 1.72E06 ft-pounds). The STS-50 nominal end-of-mission landing weight is the second heaviest in the history of the program to date (STS-32 nominal end-of-mission weight was 228,400 pounds at x-cg of 1080.5).

. STS-50 is the first flight of carbon brakes on Columbia and will use the lighter braking profile, if possible, for the end of the mission. Given the wind conditions of the day combined with the heavy weight of the vehicle and use of the 300-knot outer glide slope, performance of the light braking DTO may not be done if the drag chute is not deployed. A real-time evaluation of braking requirements will be performed to determine whether the light braking profile is acceptable with/without the drag chute deployment. For those cases where the light braking profile is not acceptable (rollout margin of less than 2,000 feet) the standard braking profile will be used.

MISSION OBJECTIVES

. Primary Objective
  - United States Microgravity Laboratory (USML)-1
. Secondary Objectives
  - Middeck
    . Investigations Into Polymer Membrane Processing (IPMP)
    . Shuttle Amateur Radio Experiment (SAREX)-II
  - Payload Bay
    . Orbital Acceleration Research Experiment (OARE)
. Ultraviolet Plume Instrument (UVPI) (payload of opportunity--no flight hardware)
. Development Test Objectives/Detailed Supplementary Objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2
Unstow cabin
Spacelab activation
Payload activation

Flight Days 2 - 12

USML-1 operations

Flight Day 13

Crew press conference
RCS hot-fire test
FCS checkout

Flight Day 14

Spacelab deactivation
Deorbit preparation
Deorbit burn
Landing

Notes:

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

STS-50 CREW ASSIGNMENTS

* Denotes primary responsibility

Commander (Richard N. Richards):

Overall mission decisions

Payload--IPMP, SAREX*

DTOs/DSOs--DTOs 251*, 312*, 519*, 521*, 666, 805*, and 910; DSOs 605, 621, and 904

Other--medic

Pilot (Kenneth D. Bowersox):

Orbiter--IFM*

Payload--IPMP*

DTOs/DSOs--DTOs 251, 519, 521, 623*, 645, 658*, 663, 665*, 666, and 805; DSOs 605, 614, 617, 618, and 904

Other--intravehicular astronaut*, Earth observations, photo/TV

Payload Commander (MS1) (Bonnie J. Dunbar):

Payload--IFM (Spacelab), USML*

DTOs/DSOs--DTO 655*; DSOs 314*, 478, 611, 613, 617, and 904

Mission Specialist 2 (Ellen S. Baker):

Orbiter--IFM

Payload--SAREX

DTOs/DSOs--DTOs 645*, 658, 663*, 665, and 910*; DSOs 472*, 484*, 614, 617, 620 (setup), 621, 802*, and 904

Other--EVA 1, medic*, Earth observations*, photo/TV*

Mission Specialist 3 (Carl J. Meade):

Payload--IFM (Spacelab), USML

DTOs/DSOs--DTOs 312 and 655; DSOs 472, 474, 484, 601, 603*, 611, 618 (control), and 904

Other--EVA 2

Payload Specialist 1 (Lawrence J. DeLucas):

DTOs/DSOs--DSOs 472, 474, 478, 603, 605, 611, 613, 620 (spotter), and 904

Payload Specialist 2 (Eugene H. Trinh):

DTOs/DSOs--DSOs 472, 474, 484, 601, 603, 611, 620, 621, and 904

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

* indicates part of USML-1 payload

DTOs

. Ascent aerodynamic distributed loads verification on Columbia (DTO 236)
. Entry aerodynamic control surfaces test -- alternate elevon schedule, part 1(DTO 251)
. Ascent wing structural capability evaluation (DTO 301D)
. Entry structural capability evaluation (DTO 307D)
. ET TPS performance--methods 1 and 2 (DTO 312)
. On-orbit PRSD cryo hydrogen boil-off (DTO 413)
. Carbon brake system test, condition 5 (DTO 519)
. Orbiter drag chute system, test 0 (DTO 521)
. Cabin air monitoring (DTO 623)
. Foot restraint evaluation (DTO 655)
. Evaluation of the ergometer vibration isolation system (DTO 658)
. Acoustical noise dosimeter data (DTO 663)
. Acoustical noise sound level data (DTO 665)
. Modify ECLSS supply air ducting to provide chilled air to suited crew members (DTO 666)
. Orbiter experiment (OEX) orbital acceleration research experiment (OARE) (DTO 910)

DSOs

. Columbia accelerations data collection to support microgravity disturbances experiment (DSO 314)
. Intraocular pressure (DSO 472)
. In-flight retinal vascular changes detected by digital image analysis and correlation with space adaptation syndrome (DSO 474)
. In-flight lower body negative pressure (DSO 478)*
. Assessment of circadian shifting in astronauts by bright light (DSO 484)
. Heart rate and blood pressure variability during space flight (DSO 602)*
. Orthostatic function during entry, landing, and egress (DSO 603B)
. Postural equilibrium control during landing/egress (DSO 605)
. Air monitoring instrument evaluation and atmosphere characterization, microbial air sampler, configuration 2 (DSO 611)*
. Changes in the endocrine regulation of orthostatic tolerance following space flight (DSO 613)
. The effect of prolonged space flight on head and gaze stability during locomotion (DSO 614)

. Evaluation of functional skeletal muscle performance following space flight, group 1 (DSO 617)
. Effects of intense exercise during space flight on aerobic capacity and orthostatic function (DSO 618)
. Physiological evaluation of astronaut seat egress ability at wheel stop (DSO 620)
. In-flight use of Florinef to improve orthostatic intolerance postflight (DSO 621)
. Educational activities, objective 1 (DSO 802)
. Documentary television (DSO 901)
. Documentary motion picture photography (DSO 902)
. Documentary still photography (DSO 903)
. Assessment of human factors (DSO 904)

STS-50 PRELAUNCH COUNTDOWN

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

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

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

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

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

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

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

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

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

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

STS-50 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-50 Flight Plan, Ascent Checklist, Post Insertion Checklist, Spacelab Activation/Deactivation Checklist, Deorbit Prep Checklist, and Entry Checklist.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
DAY ZERO	
0/00:00:07	Tower is cleared (SRBs above lightning-rod tower).
0/00:00:10	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down (astronauts), wings level.
0/00:00:18	Roll maneuver ends.
0/00:00:32	All three SSMEs throttle down from 104 to 72 percent for maximum aerodynamic load (max q).
0/00:01:00	All three SSMEs throttle to 104 percent.
0/00:01:04	Max q occurs.
0/00:02:06	SRBs separate.
	When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:03:56	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:06:52	Single engine press to main engine cutoff (MECO).
0/00:08:26	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:29	MECO occurs at approximate velocity 25,795 feet per second, 36 by 161 nautical miles (41 by 185 statute miles).
0/00:08:47	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs.
	--Remaining residual propellants are vented to space vacuum, inerting the MPS.
	--Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads.
	--MPS vacuum inerting terminates.
0/00:40	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 21 seconds in duration, at 221 fps, 162 by 160 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS)/payload specialist (PS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:59	MS configures aft flight station.
0/01:02	MS unstows, sets up, and activates PGSC.
0/01:06	Pilot activates payload bus (panel R1).
0/01:08	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, negative Y velocity vector attitude.
0/01:15	Orbit 2 begins.
0/01:17	Commander activates radiators.
0/01:19	If go for payload bay door operations, MS configures for payload bay door operations.
0/01:28	Pilot opens payload bay doors, manual/fit test procedures.
0/01:33	Commander switches star tracker (ST) power 2 (panel 06) to ON.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	MS deploys Ku-band antenna.
0/01:38	Commander and pilot seat egress.
0/01:39	Commander and pilot clothing configuration.
0/01:40	MS/PS clothing configuration.
0/01:47	MS activates Ku-band antenna.
0/01:50	Pilot initiates fuel cell auto purge.
0/01:51	MS activates teleprinter (if flown).

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:53	Commander begins post-payload bay door operations and radiator configuration.
0/01:55	MS/PS remove and stow seats.
0/01:56	Commander starts ST self-test and opens door.
0/01:57	MS configures middeck.
0/01:58	Pilot closes main B supply water dump isolation circuit breaker, panel ML86B, opens supply water dump isolation valve, panel R12L.
0/02:01	Pilot activates auxiliary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:07	MCC informs crew to "go for Spacelab activation."
0/02:07	MS, PS begin Spacelab activation.
0/02:10	Commander, pilot configure controls for on-orbit.
0/02:10	DSO 472--intraocular pressure, and DSO 474--retinal photography
0/02:14	Commander configures vernier drivers.
0/02:20	Pilot enables hydraulic thermal conditioning.
0/02:26	MS resets caution/warning (C/W).
0/02:28	Pilot plots fuel cell performance.
0/02:30	Blue team begins presleep activities.
0/02:43	Orbit 3 begins.
0/03:20	Ingress Spacelab.
0/03:30	Priority Group B powerdown.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:30	Blue team begins sleep period.
0/03:45	USML protein crystal growth (PCG) activation.
0/04:13	Orbit 4 begins.
0/04:40	Payload activation.
0/04:55	Maneuver to IMU alignment/COAS calibration attitude.
0/05:05	USML space acceleration measurement system (SAMS) operations.
0/05:35	Maneuver vehicle to biased -XLV, -ZVV attitude.
0/05:43	Orbit 5 begins.
0/05:55	SAMS operations.
0/06:00	USML crystal growth facility (CGF) activation.
0/06:05	USML glovebox check.
0/06:25	CGF operations.
0/07:05	Glovebox (GBX) operations.
0/07:14	Orbit 6 begins.
0/08:15	DTO 623--cabin air monitoring.
0/08:45	Orbit 7 begins.
0/09:00	Red team begins presleep activities.
0/09:10	CGF operations.
0/09:30	Blue team begins postsleep activities.
0/10:15	Red team handover to blue team.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/10:15	Orbit 8 begins.
0/10:35	DSOs 472 and 474.
0/11:00	Red team begins sleep period.
0/11:15	USML generic bioprocessing apparatus (GBA) undisconnect.
0/11:15	USML drop physics module (DPM) operations.
0/11:30	GBA activation.
0/11:45	Orbit 9 begins.
0/11:55	GBA load.
0/12:00	Shuttle amateur radio experiment (SAREX) setup.
0/12:15	GBA operations.
0/13:15	Orbit 10 begins.
0/14:46	Orbit 11 begins.
0/15:25	DPM operations.
0/15:30	GBX operations.
0/16:16	Orbit 12 begins.
0/16:30	DTO 658 initial setup--ergometer vibration isolation system evaluation.
0/17:47	Orbit 13 begins.
0/18:15	DSO 904 setup--human factors.
0/18:30	DSO 904.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
0/19:00	Red team begins postsleep activities.
0/19:00	DPM operations.
0/19:17	Orbit 14 begins.
0/20:15	DTO 663 setup--acoustical noise dosimeter data.
0/20:40	DSOs 472 and 474.
0/20:47	Orbit 15 begins.
0/21:00	Blue team handover to red team.
0/21:30	DSOs 472 and 474.
0/21:30	DPM operations.
0/21:30	GBX operations.
0/21:30	Blue team begins presleep activities.
0/22:15	PCG operations.
0/22:17	Orbit 16 begins.
0/22:50	DPM operations.
0/23:00	DTO 658.
0/23:30	GBX operations.
0/23:35	DSO 904.
0/23:48	Orbit 17 begins.

MET DAY ONE

1/00:00	Blue team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:30	GBX operations.
1/00:40	USML zeolite crystal growth (ZCG) activation.
1/01:18	Orbit 18 begins.
1/02:25	ZCG operations.
1/02:48	Orbit 19 begins.
1/02:55	CGF operations.
1/03:00	DSO 314--acceleration data collection.
1/03:05	GBX operations.
1/03:30	ZCG operations.
1/03:40	DPM operations.
1/04:19	Orbit 20 begins.
1/04:30	DSO 802--educational activities.
1/04:45	DPM operations.
1/05:30	ZCG operations.
1/05:45	DPM operations.
1/05:49	Orbit 21 begins.
1/06:10	ZCG operations.
1/07:19	Orbit 22 begins.
1/07:30	DTO 658.
1/07:45	DPM operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/07:50	DSO 904.
1/08:00	Blue team begins postsleep activities.
1/08:10	ZCG operations.
1/08:45	SAMS operations.
1/08:50	Orbit 23 begins.
1/08:55	DSOs 472 and 474.
1/09:15	Red team handover to blue team.
1/09:30	Red team begins presleep activities.
1/09:45	DTO 663--acoustical noise dosimeter data.
1/09:45	DPM operations.
1/10:10	ZCG operations.
1/10:20	GBA operations.
1/10:20	Orbit 24 begins.
1/10:40	DTO 658.
1/11:00	Red team begins sleep period.
1/11:05	GBX operations.
1/11:25	SAREX operations--Ohio Boy Scouts.
1/11:50	Orbit 25 begins.
1/12:10	ZCG operations.
1/12:30	DTO 665--acoustic noise sound level data.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/13:21	Orbit 26 begins.
1/14:30	ZCG operations.
1/14:30	GBX operations.
1/14:30	DPM operations.
1/14:51	Orbit 27 begins.
1/15:00	DTO 665.
1/16:10	ZCG operations.
1/16:22	Orbit 28 begins.
1/16:50	DPM operations.
1/17:52	Orbit 29 begins.
1/18:00	Lower body negative pressure (LBNP) setup.
1/18:10	ZCG operations.
1/18:50	DTO 658.
1/19:00	Red team begins postsleep activities.
1/19:20	SAMS operations.
1/19:22	Orbit 30 begins.
1/20:10	ZCG operations.
1/20:15	DTO 663.
1/20:30	Blue team handover to red team.
1/20:45	Blue team begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
1/20:52	Orbit 31 begins.
1/21:00	DTO 665.
1/21:00	USML surface tension driven convection experiment (STDCE) operations.
1/21:00	GBX operations.
1/21:30	DSO 618--effects of intense exercise.
1/22:23	Orbit 32 begins.
1/22:25	DPM operations.
1/22:45	ZCG operations.
1/23:00	DTO 658.
1/23:00	GBX operations.
1/23:00	Blue team begins sleep period.
1/23:15	LBNP operations.
1/23:53	Orbit 33 begins.

MET DAY TWO

2/00:00	Investigations into polymer membrane processing (IPMP) activation.
2/00:15	ZCG operations.
2/00:30	DTO 623--cabin air monitoring.
2/01:05	IPMP deactivation.
2/01:23	Orbit 34 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/02:00	ZCG operations.
2/02:53	Orbit 35 begins.
2/03:05	SAMS operations.
2/03:05	PCG operations.
2/04:10	ZCG operations.
2/04:15	LBNP operations.
2/04:23	Orbit 36 begins.
2/05:54	Orbit 37 begins.
2/06:10	ZCG operations.
2/07:00	DTO 658.
2/07:00	GBX operations.
2/07:00	Blue team begins postsleep activities.
2/07:24	Orbit 38 begins.
2/08:05	DTO 658.
2/08:10	SAMS operations.
2/08:15	Red team handover to blue team.
2/08:30	Red team begins presleep activities.
2/08:30	ZCG operations.
2/08:40	DTO 663.
2/08:45	DSO 602--heart rate and blood pressure variability during space flight.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/08:55	Orbit 39 begins.
2/09:10	GBX operations.
2/09:15	DPM operations.
2/10:00	Red team begins sleep period.
2/10:10	ZCG operations.
2/10:25	Orbit 40 begins.
2/10:30	DSO 802.
2/11:55	Orbit 41 begins.
2/12:10	ZCG operations.
2/13:20	GBX operations.
2/13:25	Orbit 42 begins.
2/13:45	DPM operations.
2/14:10	ZCG operations.
2/14:30	DTO 665.
2/14:55	Orbit 43 begins.
2/15:10	GBA operations.
2/15:10	DPM operations.
2/16:10	ZCG operations.
2/16:26	Orbit 44 begins.
2/16:30	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/17:30	DPM operations.
2/17:45	DTO 658.
2/17:55	ZCG operations.
2/17:56	Orbit 45 begins.
2/18:00	Red team begins postsleep activities.
2/19:15	DTO 663.
2/19:25	SAMS operations.
2/19:27	Orbit 46 begins.
2/19:30	Blue team handover to red team.
2/19:45	Blue team begins presleep activities.
2/20:00	DPM operations.
2/20:10	ZCG operations.
2/20:15	DSO 904.
2/20:56	Orbit 47 begins.
2/21:00	GBX operations.
2/21:30	DTO 665.
2/22:00	DTO 658.
2/22:00	Blue team begins sleep period.
2/22:10	ZCG operations.
2/22:27	Orbit 48 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
2/22:40	SAREX operations--Laporte, Texas.
2/23:57	Orbit 49 begins.

MET DAY THREE

3/00:00	SAREX operations--U.S. school.
3/00:10	ZCG operations.
3/00:40	DSO 904.
3/01:28	Orbit 50 begins.
3/02:00	DPM operations.
3/02:00	GBX operations.
3/02:10	ZCG operations.
3/02:58	Orbit 51 begins.
3/04:10	ZCG operations.
3/04:28	Orbit 52 begins.
3/05:30	DTO 658.
3/05:58	Orbit 53 begins.
3/06:00	Blue team begins postsleep activities.
3/06:10	ZCG operations.
3/06:10	DPM operations.
3/06:20	DTO 665.
3/07:05	DTO 658.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/07:10	SAMS operations.
3/07:15	Red team handover to blue team.
3/07:29	Orbit 54 begins.
3/07:30	DTO 663.
3/07:30	Red team begins presleep activities.
3/07:45	DSO 602.
3/07:55	GBA operations.
3/07:55	DPM operations.
3/08:10	ZCG operations.
3/08:59	Orbit 55 begins.
3/09:00	Red team begins sleep period.
3/09:05	GBX operations.
3/09:55	ZCG operations.
3/10:00	SAREX operations--Ohio Boy Scouts.
3/10:30	Orbit 56 begins.
3/11:59	Orbit 57 begins.
3/12:10	ZCG operations.
3/12:45	DPM operations.
3/12:55	GBX operations.
3/13:30	Orbit 58 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/14:10	ZCG operations.
3/15:00	GBX operations.
3/15:01	Orbit 59 begins.
3/16:10	ZCG operations.
3/16:30	Orbit 60 begins.
3/16:40	DTO 658.
3/16:45	DPM operations.
3/17:00	Red team begins postsleep activities.
3/18:00	DTO 663.
3/18:02	Orbit 61 begins.
3/18:10	SAMS operations.
3/18:15	Blue team handover to red team.
3/18:30	ZCG operations.
3/18:30	DSOs 472 and 474.
3/18:45	DTO 623.
3/18:50	Blue team begins presleep activities.
3/18:55	LBNP operations.
3/19:28	Orbit 62 begins.
3/20:10	ZCG operations.
3/20:30	Blue team begins sleep period.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
3/20:45	DTO 658.
3/21:02	Orbit 63 begins.
3/21:40	SAMS operations.
3/21:45	GBX operations.
3/22:10	ZCG operations.
3/22:32	Orbit 64 begins.
3/23:55	DPM operations.

MET DAY FOUR

4/00:00	GBX operations.
4/00:02	Orbit 65 begins.
4/00:05	SAREX operations--U.S. school.
4/00:10	ZCG operations.
4/01:32	Orbit 66 begins.
4/02:10	ZCG operations.
4/02:15	LBNP operations.
4/02:30	DSO 904.
4/03:03	Orbit 67 begins.
4/04:10	ZCG operations.
4/04:30	Blue team begins postsleep activities.
4/04:33	Orbit 68 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/04:50	DTO 658.
4/05:55	SAMS operations.
4/06:00	Red team handover to blue team.
4/06:03	Orbit 69 begins.
4/06:15	Red team begins presleep activities.
4/06:15	ZCG operations.
4/06:20	DTO 663.
4/06:30	STDCE operations.
4/07:30	DTO 658.
4/07:30	DPM operations.
4/07:33	Orbit 70 begins.
4/08:05	ZCG operations.
4/08:30	Red team begins sleep period.
4/09:03	Orbit 71 begins.
4/10:10	ZCG operations.
4/10:34	Orbit 72 begins.
4/11:55	DPM operations.
4/11:55	STDCE operations.
4/12:04	Orbit 73 begins.
4/12:10	ZCG operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/13:15	GBA operations.
4/13:30	GBX operations.
4/13:34	Orbit 74 begins.
4/14:10	ZCG operations.
4/14:45	GBX operations.
4/15:00	ZCG operations.
4/15:00	DPM operations.
4/15:05	Orbit 75 begins.
4/15:45	STDCE operations.
4/16:10	ZCG operations.
4/16:20	DTO 658.
4/16:30	Red team begins postsleep activities.
4/16:34	Orbit 76 begins.
4/17:45	DSOs 472 and 474.
4/17:55	SAMS operations.
4/18:00	Blue team handover to red team.
4/18:05	Orbit 77 begins.
4/18:15	ZCG operations.
4/18:15	DTO 663.
4/18:15	Blue team begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
4/18:30	DPM operations.
4/18:30	GBX operations.
4/19:35	Orbit 78 begins.
4/19:50	DTO 658.
4/20:10	ZCG operations.
4/20:30	Blue team begins sleep period.
4/21:05	Orbit 79 begins.
4/22:10	ZCG operations.
4/22:35	Orbit 80 begins.
4/23:30	DPM operations.

MET DAY FIVE

5/00:06	Orbit 81 begins.
5/00:10	SAREX operations--U.S. school.
5/00:10	ZCG operations.
5/01:30	GBX operations.
5/01:36	Orbit 82 begins.
5/02:10	ZCG operations.
5/03:06	Orbit 83 begins.
5/03:30	GBX operations.
5/04:10	ZCG operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/04:15	DTO 658.
5/04:30	Blue team begins postsleep activities.
5/04:36	Orbit 84 begins.
5/04:40	DTO 665.
5/05:30	DTO 623.
5/05:50	DTO 658.
5/05:55	SAMS operations.
5/06:00	Red team handover to blue team.
5/06:07	Orbit 85 begins.
5/06:15	Red team begins presleep activities.
5/06:15	ZCG operations.
5/06:20	DSOs 472 and 474.
5/06:30	GBA operations.
5/06:30	DPM operations.
5/06:40	DTO 663.
5/07:37	Orbit 86 begins.
5/07:55	GBX operations.
5/08:10	ZCG operations.
5/08:30	Red team begins sleep period.
5/08:30	DPM operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/08:30	DSO 602.
5/08:30	DSO 802.
5/09:07	Orbit 87 begins.
5/09:40	GBX operations.
5/10:00	DPM operations.
5/10:10	ZCG operations.
5/10:37	Orbit 88 begins.
5/11:30	DPM operations.
5/12:08	Orbit 89 begins.
5/12:15	ZCG operations.
5/12:15	DPM operations.
5/12:45	GBX operations.
5/13:38	Orbit 90 begins.
5/14:10	ZCG operations.
5/14:15	GBX operations.
5/14:55	GBX operations.
5/15:08	Orbit 91 begins.
5/15:10	GBX operations.
5/15:15	SAMS operations.
5/15:25	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/15:35	GBX operations.
5/16:00	DTO 658.
5/16:10	ZCG operations.
5/16:30	Red team begins postsleep activities.
5/16:38	Orbit 92 begins.
5/17:45	DTO 663.
5/17:55	GBX operations.
5/17:55	SAMS operations.
5/18:00	Blue team handover to red team.
5/18:08	Orbit 93 begins.
5/18:15	ZCG operations.
5/18:15	Blue team begins presleep activities.
5/18:30	DPM operations.
5/19:38	Orbit 94 begins.
5/20:10	ZCG operations.
5/20:30	Blue team begins sleep period.
5/20:35	DTO 658.
5/21:08	Orbit 95 begins.
5/21:20	SAREX operations--Laporte, Texas.
5/21:30	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
5/21:35	DPM operations.
5/22:10	ZCG operations.
5/22:39	Orbit 96 begins.
5/22:40	SAREX operations--U.S. schools and Calif., JSC, and Fla.
5/23:05	USML astroculture (ASC) activation.
5/23:45	GBX operations.
5/23:55	GBX operations.

MET DAY SIX

6/00:09	Orbit 97 begins.
6/00:10	ASC operations.
6/00:25	ZCG operations.
6/01:39	Orbit 98 begins.
6/02:10	ZCG operations.
6/02:20	ASC operations.
6/02:40	DSO 802.
6/03:10	Orbit 99 begins.
6/04:10	ZCG operations.
6/04:30	Blue team begins postsleep activities.
6/04:40	Orbit 100 begins.
6/04:45	DTO 658.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/05:25	ASC operations.
6/05:55	SAMS operations.
6/06:00	Red team handover to blue team.
6/06:10	Orbit 101 begins.
6/06:15	Red team begins presleep activities.
6/06:15	ZCG operations.
6/06:20	DTO 663.
6/06:30	STDCE operations.
6/07:20	ASC operations.
6/07:30	DSO 602.
6/07:40	DTO 658.
6/07:40	Orbit 102 begins.
6/07:55	GBX operations.
6/08:00	ZCG operations.
6/08:15	GBX operations.
6/08:30	Red team begins sleep period.
6/09:10	Orbit 103 begins.
6/10:15	ZCG operations.
6/10:20	ASC operations.
6/10:41	Orbit 104 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/12:10	ZCG operations.
6/12:11	Orbit 105 begins.
6/12:15	ASC operations.
6/12:45	GBX operations.
6/12:50	STDCE operations.
6/13:00	DPM operations.
6/13:40	GBA operations.
6/13:41	Orbit 106 begins.
6/14:00	ZCG operations.
6/14:05	ASC operations.
6/15:11	Orbit 107 begins.
6/15:25	DTO 658.
6/15:30	GBX operations.
6/15:35	ASC operations.
6/15:50	STDCE operations.
6/16:20	ZCG operations.
6/16:30	Red team begins postsleep activities.
6/16:30	DPM operations.
6/16:41	Orbit 108 begins.
6/16:45	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/17:40	SAREX operations--Adelaide, Australia school.
6/17:55	SAMS operations.
6/18:00	Blue team handover to red team.
6/18:12	Orbit 109 begins.
6/18:15	ASC operations.
6/18:15	DTO 663.
6/18:15	Blue team begins presleep activities.
6/18:30	DPM operations.
6/18:35	ZCG operations.
6/19:15	SAREX operations.
6/19:30	GBX operations.
6/19:42	Orbit 110 begins.
6/20:00	SAREX operations.
6/20:15	ZCG operations.
6/20:25	ASC operations.
6/20:30	Blue team begins sleep period.
6/20:30	DTO 658.
6/21:12	Orbit 111 begins.
6/21:40	ASC operations.
6/22:10	ZCG operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
6/22:25	USML solid surface combustion experiment (SSCE) operations.
6/22:42	Orbit 112 begins.
6/22:50	SAREX operations--U.S. school.

MET DAY SEVEN

7/00:12	Orbit 113 begins.
7/00:15	ZCG operations.
7/00:15	DPM operations.
7/00:30	ASC operations.
7/01:00	GBX operations.
7/01:43	Orbit 114 begins.
7/02:10	ZCG operations.
7/02:20	DTO 623.
7/02:50	SAREX operations--Johannesburg, South Africa.
7/03:10	ASC operations.
7/03:13	Orbit 115 begins.
7/04:10	ZCG operations.
7/04:30	Blue team begins postsleep activities.
7/04:43	Orbit 116 begins.
7/04:50	DTO 658.
7/05:50	DTO 658.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/05:55	SAMS operations.
7/06:00	Red team handover to blue team.
7/06:13	Orbit 117 begins.
7/06:15	ZCG operations.
7/06:15	Red team begins presleep activities.
7/06:20	DTO 663.
7/06:30	DSO 602.
7/06:30	DPM operations.
7/07:30	GBX operations.
7/07:43	Orbit 118 begins.
7/08:10	ZCG operations.
7/08:20	CGF operations.
7/08:30	Red team begins sleep period.
7/09:00	DSO 314.
7/09:14	Orbit 119 begins.
7/09:20	CGF operations.
7/09:25	GBX operations.
7/10:05	ZCG operations.
7/10:43	Orbit 120 begins.
7/11:55	SAMS operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/12:00	DPM operations.
7/12:10	ZCG operations.
7/12:13	Orbit 121 begins.
7/12:30	GBA operations.
7/13:43	Orbit 122 begins.
7/14:05	DPM operations.
7/14:10	ZCG operations.
7/14:35	GBX operations.
7/15:14	Orbit 123 begins.
7/15:15	DSO 904.
7/15:50	DTO 658.
7/16:05	ZCG operations.
7/16:10	SAREX operations--Sidney, Australia school.
7/16:30	Red team begins postsleep activities.
7/16:44	Orbit 124 begins.
7/16:55	SAMS operations.
7/17:35	DTO 663.
7/17:55	ZCG operations.
7/18:00	Blue team handover to red team.
7/18:14	Orbit 125 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
7/18:15	Blue team begins presleep activities.
7/18:45	DPM operations.
7/19:30	GBX operations.
7/19:44	Orbit 126 begins.
7/20:00	ZCG operations.
7/20:30	Blue team begins sleep period.
7/20:30	DTO 658.
7/21:15	Orbit 127 begins.
7/21:15	SAREX operations.
7/21:45	GBX operations.
7/22:10	ZCG operations.
7/22:45	Orbit 128 begins.
7/23:10	GBX operations.

MET DAY EIGHT

8/00:10	ZCG operations.
8/00:10	GBX operations.
8/00:15	Orbit 129 begins.
8/00:15	ASC operations.
8/01:10	DPM operations.
8/01:20	SAREX operations--Swaziland school.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/01:20	ASC operations.
8/01:45	Orbit 130 begins.
8/02:10	ZCG operations.
8/03:15	Orbit 131 begins.
8/03:35	ASC operations.
8/04:20	ZCG operations.
8/04:30	Blue team begins postsleep activities.
8/04:45	Orbit 132 begins.
8/04:50	DTO 658.
8/05:55	SAMS operations.
8/06:00	Red team handover to blue team.
8/06:15	Red team begins presleep activities.
8/06:15	Orbit 133 begins.
8/06:15	ZCG operations.
8/06:20	DTO 663.
8/06:40	STDCE operations.
8/06:50	ASC operations.
8/07:30	DTO 658.
8/07:30	GBX operations.
8/07:45	Orbit 134 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/08:10	ZCG operations.
8/08:15	STDCE operations.
8/08:30	Red team begins sleep period.
8/09:16	Orbit 135 begins.
8/09:30	ASC operations.
8/09:35	GBX operations.
8/09:50	GBX operations.
8/10:05	GBX operations.
8/10:10	ZCG operations.
8/10:15	GBX operations.
8/10:30	GBX operations.
8/10:46	Orbit 136 begins.
8/10:50	GBX operations.
8/10:55	ASC operations.
8/11:10	GBX operations.
8/11:25	GBX operations.
8/11:40	GBX operations.
8/12:05	STDCE operations.
8/12:10	ZCG operations.
8/12:16	Orbit 137 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/12:45	GBX operations.
8/13:30	GBA operations.
8/13:35	ASC operations.
8/13:46	Orbit 138 begins.
8/14:10	ZCG operations.
8/14:30	DSO 904.
8/15:00	GBX operations.
8/15:16	Orbit 139 begins.
8/15:30	DTO 658.
8/15:30	GBX operations.
8/15:40	ASC operations.
8/16:00	STDCE operations.
8/16:15	ZCG operations.
8/16:30	Red team begins postsleep activities.
8/16:47	Orbit 140 begins.
8/17:20	ASC operations.
8/17:35	SAMS operations.
8/17:40	GBX operations.
8/17:45	STDCE operations.
8/18:00	Blue team handover to red team.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
8/18:15	Blue team begins presleep activities.
8/18:17	Orbit 141 begins.
8/18:25	SAREX operations.
8/18:30	LBNP operations.
8/18:35	DTO 663.
8/18:40	ZCG operations.
8/19:45	DTO 658.
8/19:45	ASC operations.
8/19:47	Orbit 142 begins.
8/20:10	ZCG operations.
8/20:30	Blue team begins sleep period.
8/21:17	Orbit 143 begins.
8/21:20	SAREX operations--U.S. school.
8/21:55	ASC operations.
8/22:15	ZCG operations.
8/22:30	DTO 623.
8/22:47	Orbit 144 begins.
8/23:30	ASC operations.

MET DAY NINE

9/00:15	ZCG operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/00:17	Orbit 145 begins.
9/00:50	GBX operations.
9/01:47	Orbit 146 begins.
9/02:00	ASC operations.
9/02:00	GBX operations.
9/03:10	GBX operations.
9/03:17	Orbit 147 begins.
9/03:45	SAMS operations.
9/04:00	DTO 658.
9/04:10	ZCG operations.
9/04:30	Blue team begins postsleep activities.
9/04:48	Orbit 148 begins.
9/05:20	GBX operations.
9/05:50	DTO 658.
9/05:55	SAMS operations.
9/06:00	Red team handover to blue team.
9/06:15	Red team begins presleep activities.
9/06:15	ZCG operations.
9/06:18	Orbit 149 begins.
9/06:20	DTO 663.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/06:30	GBX operations.
9/06:30	DPM operations.
9/07:35	GBX operations.
9/07:48	Orbit 150 begins.
9/08:10	ZCG operations.
9/08:20	GBX operations.
9/08:30	Red team begins sleep period.
9/08:35	GBX operations.
9/08:50	GBX operations.
9/09:05	GBX operations.
9/09:18	Orbit 151 begins.
9/09:30	GBX operations.
9/09:45	GBX operations.
9/10:00	GBX operations.
9/10:15	GBX operations.
9/10:15	ZCG operations.
9/10:20	DPM operations.
9/10:48	Orbit 152 begins.
9/10:50	GBX operations.
9/11:50	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/12:00	DPM operations.
9/12:18	Orbit 153 begins.
9/12:20	ZCG operations.
9/12:30	ZCG operations.
9/12:50	DPM operations.
9/13:25	GBX operations.
9/13:48	Orbit 154 begins.
9/14:00	GBX operations.
9/14:25	ZCG operations.
9/14:30	GBX operations.
9/15:18	Orbit 155 begins.
9/15:25	GBA operations.
9/16:20	DTO 658.
9/16:30	Red team begins postsleep activities.
9/16:48	Orbit 156 begins.
9/17:00	GBX operations.
9/17:55	SAMS operations.
9/18:00	Blue team handover to red team.
9/18:15	Blue team begins presleep activities.
9/18:15	DSO 621--Florinef.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
9/18:18	Orbit 157 begins.
9/18:35	GBX operations.
9/18:40	DSO 621.
9/19:30	LBNP operations.
9/19:45	DTO 658.
9/19:48	Orbit 158 begins.
9/20:05	SAREX operations--JSC, MSFC, Fla.
9/20:30	Blue team begins sleep period.
9/21:19	Orbit 159 begins.
9/21:25	SAREX operations--U.S. school.
9/22:49	Orbit 160 begins.
9/23:30	GBX operations.
9/23:35	LBNP operations.

MET DAY TEN

10/00:19	Orbit 161 begins.
10/01:49	Orbit 162 begins.
10/03:19	Orbit 163 begins.
10/04:30	Blue team begins postsleep activities.
10/04:30	DSO 621.
10/04:49	Orbit 164 begins.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
10/05:55	SAMS operations.
10/05:55	GBX operations.
10/06:00	Red team handover to blue team.
10/06:15	DSO 621.
10/06:15	Red team begins presleep activities.
10/06:15	DTO 658.
10/06:19	Orbit 165 begins.
10/06:30	DSOs 472 and 474.
10:06:30	DSO 602.
10/07:05	DPM operations.
10/07:30	DTO 658.
10/07:30	DSO 602.
10/07:49	Orbit 166 begins.
10/07:55	GBX operations.
10/08:00	GBA operations.
10/08:30	Red team begins sleep period.
10/09:20	Orbit 167 begins.
10/09:30	GBX operations.
10/10:50	Orbit 168 begins.
10/11:55	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
10/12:20	Orbit 169 begins.
10/13:00	DPM operations.
10/13:50	Orbit 170 begins.
10/13:50	DSO 904.
10/15:20	Orbit 171 begins.
10/16:15	SAREX operations--Carnarvon, Australia school.
10/16:25	GBX operations.
10/16:30	DSO 621.
10/16:30	Red team begins postsleep activities.
10/16:50	Orbit 172 begins.
10/17:20	DTO 658.
10/17:45	GBX operations.
10/18:20	Orbit 173 begins.
10/18:20	SAREX operations--Calif., MSFC.
10/18:25	SAMS operations.
10/18:30	Blue team handover to red team.
10/18:45	DTO 623.
10/19:00	ZCG deactivation.
10/19:00	GBX operations.
10/19:15	Blue team begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
10/19:15	DSO 621.
10/19:50	Orbit 174 begins.
10/19:55	SAREX operations--U.S. school.
10/20:15	DTO 658.
10/20:15	LBNP operations.
10/21:20	Orbit 175 begins.
10/21:30	Blue team begins sleep period.
10/22:50	Orbit 176 begins.
10/23:55	SAMS operations.
10/23:55	GBX operations.

MET DAY ELEVEN

11/00:20	Orbit 177 begins.
11/00:55	LBNP operations.
11/01:50	Orbit 178 begins.
11/03:20	Orbit 179 begins.
11/03:35	GBX operations.
11/04:51	Orbit 180 begins.
11/05:25	DTO 658.
11/05:30	DSO 621.
11/05:30	Blue team begins postsleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
11/05:50	CGF operations.
11/06:21	Orbit 181 begins.
11/06:30	SAMS operations.
11/06:40	RCS orbit adjustment 1 burn.
11/06:45	Red team handover to blue team.
11/07:00	Red team begins presleep activities.
11/07:15	DSO 602.
11/07:25	RCS orbit adjustment 2 burn.
11/07:30	GBA operations.
11/07:51	Orbit 182 begins.
11/08:05	DSO 314.
11/08:30	Red team begins sleep period.
11/08:30	GBX operations.
11/08:45	DPM operations.
11/08:50	DTO 658.
11/09:21	Orbit 183 begins.
11/10:30	DPM operations.
11/10:51	Orbit 184 begins.
11/12:21	Orbit 185 begins.
11/13:00	GBX operations.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
11/13:00	DPM operations.
11/13:51	Orbit 186 begins.
11/15:21	Orbit 187 begins.
11/16:30	Red team begins postsleep activities.
11/16:30	DSO 621.
11/16:30	GBX operations.
11/16:45	DTO 658.
11/16:51	Orbit 188 begins.
11/18:20	DSOs 472 and 474.
11/18:21	Orbit 189 begins.
11/18:40	SAMS operations.
11/18:45	Crew press conference.
11/19:00	Blue team handover to red team.
11/19:30	GBX operations.
11/19:35	GBA operations.
11/19:40	FCS checkout.
11/19:51	Orbit 190 begins.
11/19:55	DSOs 472 and 474.
11/20:15	DSO 621.
11/20:15	Blue team begins presleep activities.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
11/21:10	PCG deactivation.
11/21:22	Orbit 191 begins.
11/21:50	DSO 618.
11/22:30	Blue team begins sleep period.
11/22:52	Orbit 192 begins.
11/23:00	DTO 658--EVIS final stow.
11/23:30	LBNP operations.

MET DAY TWELVE

12/00:22	Orbit 193 begins.
12/01:15	SAREX stow.
12/01:30	DSO 904 stow.
12/01:52	Orbit 194 begins.
12/01:55	Cabin stow.
12/02:00	DTO 623.
12/02:00	LBNP deactivation/stow.
12/03:00	PCGG deactivation.
12/03:22	Orbit 195 begins.
12/04:40	GBX shutdown.
12/04:52	Orbit 196 begins.
12/05:00	DSO 621.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
12/05:00	Red team begins presleep activities.
12/05:10	SAMS operations.
12/06:22	Orbit 197 begins.
12/06:30	Blue team begins postsleep activities.
12/06:45	Red team handover to blue team.
12/07:30	Red team begins sleep period.
12/07:52	Orbit 198 begins.
12/08:00	DSO 620--seat egress at wheel stop (video calibration).
12/09:00	Terminate biased -XLV, -ZVV attitude.
12/09:22	Orbit 199 begins.
12/10:30	DSO 621.
12/10:35	Priority Group B powerup.
12/10:52	Orbit 200 begins.
12/10:55	DSO 621.
12/11:45	SAMS operations.
12/12:00	Payload deactivation.
12/12:00	CGF deactivation.
12/12:00	SAMS maneuver.
12/12:10	DTO 910--orbiter acceleration research experiment (OARE).
12/12:10	SAMS OARE calibration.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
12/12:22	Orbit 201 begins.
12/12:30	Spacelab deactivation.
12/12:35	SAMS operations.
12/12:55	OARE drag test.
12/13:15	DSO 603--orthostatic function entry preparation.
12/13:20	Egress Spacelab.
12/13:30	Red team begins postsleep activities.
12/13:30	DSO 621.
12/13:52	Orbit 202 begins.
12/14:00	Ku-band antenna stow.
12/14:30	DSO 603.
12/14:55	DSO 603.
12/15:00	RCS hot fire test.
12/15:22	Orbit 203 begins.
12/15:27	Begin deorbit preparation.
12/15:27	CRT timer setup.
12/15:32	Commander initiates coldsoak.
12/15:41	Stow radiators, if required.
12/15:59	Commander configures DPS for deorbit preparation.
12/16:02	Mission Control Center updates IMU star pad, if required.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
12/16:11	MS configures for payload bay door closure.
12/16:20	Ku-band antenna stow.
12/16:22	MCC-H gives "go/no-go" command for payload bay door closure.
12/16:25	Maneuver vehicle to IMU alignment attitude.
12/16:47	IMU alignment/payload bay door operations.
12/16:52	Orbit 204 begins.
12/17:02	Burn maneuver.
12/17:10	MCC gives the crew the go for OPS 3.
12/17:13	Maneuver vehicle to deorbit burn attitude.
12/17:17	Pilot starts repressurization of SSME systems.
12/17:21	Commander and pilot perform DPS entry configuration.
12/17:30	MS deactivates ST and closes ST doors.
12/17:32	All crew members verify entry payload switch list.
12/17:47	All crew members perform entry review.
12/17:49	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
12/18:02	Commander and pilot configure clothing.
12/18:17	MS/PS configure clothing.
12/18:22	Orbit 205 begins.
12/18:27	Commander and pilot seat ingress.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
12/18:29	Commander and pilot set up heads-up display (HUD).
12/18:31	Commander and pilot adjust seat, exercise brake pedals.
12/18:39	Final entry deorbit update/uplink.
12/18:45	OMS thrust vector control gimbal check is performed.
12/18:47	APU prestart.
12/19:02	Close vent doors.
12/19:06	MCC-H gives "go" for deorbit burn period.
12/19:12	Maneuver vehicle to deorbit burn attitude.
12/19:15	MS/PS ingress seats.
12/19:24	First APU is activated.
12/19:27	Deorbit burn.
12/19:33	Initiate post-deorbit burn period attitude.
12/19:37	Terminate post-deorbit burn attitude.
12/19:45	Dump forward RCS, if required.
12/19:52	Orbit 206 begins.
12/19:53	Activate remaining APUs.
12/19:56	Entry interface, 400,000 feet altitude.
12/19:59	Enter communication blackout.
12/20:01	Automatically deactivate RCS roll thrusters.
12/20:08	Automatically deactivate RCS pitch thrusters.

T+ (PLUS) DAY/ HR:MIN:SEC	EVENT
12/20:12	Initiate PTIs.
12/20:13	Initiate first roll reversal.
12/20:17	Exit communications blackout.
12/20:17	Initiate second roll reversal.
12/20:17	TACAN acquisition.
12/20:19	Initiate air data system (ADS) probe deploy.
12/20:20	Initiate third roll reversal.
12/20:22	Begin entry/terminal area energy management (TAEM).
12/20:22	Initiate payload bay venting.
12/20:23	Terminate PTIs.
12/20:24	Automatically deactivate RCS yaw thrusters.
12/20:27	Begin TAEM/approach/landing (A/L) interface.
12/20:27	Initiate landing gear deployment.
12/20:28	Vehicle has weight on main landing gear.
12/20:28	Vehicle has weight on nose landing gear.
12/20:28	Initiate main landing gear braking.
12/20:29	Wheel stop.

GLOSSARY

A/G	air-to-ground
AA	accelerometer assembly
ACS	active cooling system
ADS	air data system
AFB	Air Force base
A/L	approach and landing
AOS	acquisition of signal
APC	autonomous payload controller
APU	auxiliary power unit
ASC	Astroculture
ASE	airborne support equipment
BFS	backup flight control system
CCD	charge-coupled device
CDMS	command and data management subsystem
CGF	crystal growth furnace
COAS	crewman optical alignment sight
CRT	cathode ray tube
C/W	caution/warning
DAP	digital autopilot
DOD	Department of Defense
DPM	drop physics module
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
EDO	extended duration orbiter
EDOMP	extended duration orbiter medical project
EHF	extremely high frequency
ELV	expendable launch vehicle
EMU	extravehicular mobility unit
EOM	end of mission
EPS	electrical power system
ET	external tank
ETR	Eastern Test Range

EV	extravehicular
EVA	extravehicular activity
EVIS	ergometer vibration isolation system
FC	fuel cell
FCS	flight control system
FES	flash evaporator system
FES	fluids experiment system
FDF	flight data file
FPS	feet per second
FRCS	forward reaction control system
FTA	fluid test article
GBA	generic bioprocessing apparatus
GBX	glovebox
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GSFC	Goddard Space Flight Center
HAINS	high accuracy inertial navigation system
HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
IPMP	investigations into polymer membrane processing
IR	infrared
IV	intravehicular
JSC	Johnson Space Center
KSC	Kennedy Space Center
LACE	low-power atmospheric compensation experiment satellite
LBNP	lower body negative pressure
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
MCC-H	Mission Control Center--Houston
MDM	multiplexer/demultiplexer
MECO	main engine cutoff

MET	mission elapsed time
MILA	Merritt Island
MLP	mobile launcher platform
MM	major mode
MPESS	mission-peculiar equipment support structure
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NC	phase angle adjustment maneuver
NCC	corrective combination maneuver
NH	differential height adjustment
NMI	nautical miles
NOR	Northrup Strip
NPC	plane change maneuver
NSR	coelliptic maneuver
O&C	operations and checkout
OAA	orbiter access arm
OARE	orbital acceleration research experiment
OEX	orbiter experiment
OMS	orbital maneuvering system
OTC	orbiter test conductor
PASS	primary avionics software system
PCG	protein crystal growth
PCMMU	pulse code modulation master unit
PCS	pressure control system
PGSC	payload and general support computer
PI	payload interrogator
PIC	pyro initiator controller
POCC	Payload Operations Control Center
PRD	payload retention device
PRLA	payload retention latch assembly
PRSD	power reactant storage and distribution
PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV
RAAN	right ascension of the ascending node
RCS	reaction control system
RF	radio frequency
RGA	rate gyro assembly
RMS	remote manipulator system

RPM	revolutions per minute
ROEU	remotely operated electrical umbilical
RSLS	redundant-set launch sequencer
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SA	solar array
SAF	Secretary of the Air Force
SAMS	space acceleration measurement system
SAREX	shuttle amateur radio experiment
SHF	superhigh frequency
SM	statute miles
SMIDEX	spacelab middeck experiments
SRB	solid rocket booster
SRM	solid rocket motor
SRSS	shuttle range safety system
SSCE	solid surface combustion experiment
SSME	space shuttle main engine
SSP	standard switch panel
SSPP	solar/stellar pointing platform
ST	star tracker
STA	structural test article
STDCE	surface tension driven convection experiment
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	tracking and data relay satellite
TDRSS	tracking and data relay satellite system
TFL	telemetry format load
TI	thermal phase initiation
TIG	time of ignition
TPS	thermal protection system
TSM	tail service mast
TT&C	telemetry, tracking, and communications
TV	television
TVC	thrust vector control
UHF	ultrahigh frequency
USML	United States Microgravity Laboratory
UVPI	ultraviolet plume instrument

VTR	videotape recorder
WCS	waste collection system
ZCG	zeolite crystal growth