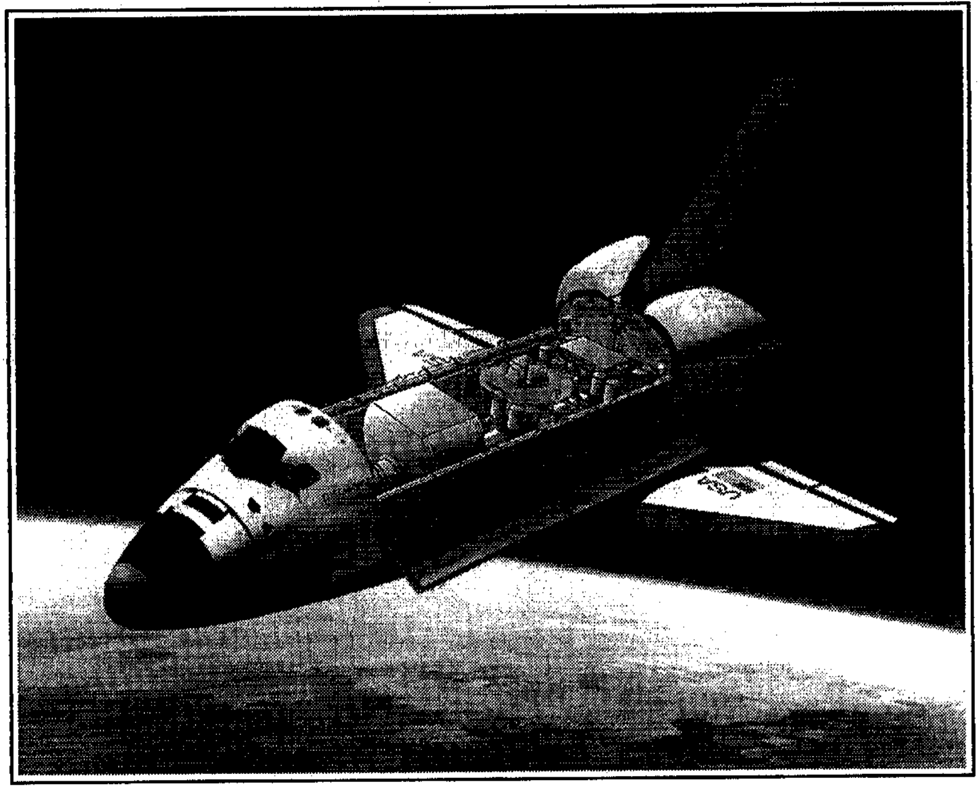

STS-60

PRESS INFORMATION AND MISSION TIME LINE

February 1994

Rockwell International
Space Systems Division

Office of Media Relations

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MISSION OVERVIEW

This is the 18th flight of Discovery and the 60th for the space shuttle.

The flight crew for the eight-day STS-60 mission is commander Charles (Charlie) F. Bolden, Jr., pilot Kenneth (Ken) S. Reightler, Jr., and mission specialists Franklin R. Chang-Diaz, N. Jan Davis, Ronald (Ron) M. Sega, and Sergei K. Krikalev of the Russian Space Agency (RSA).

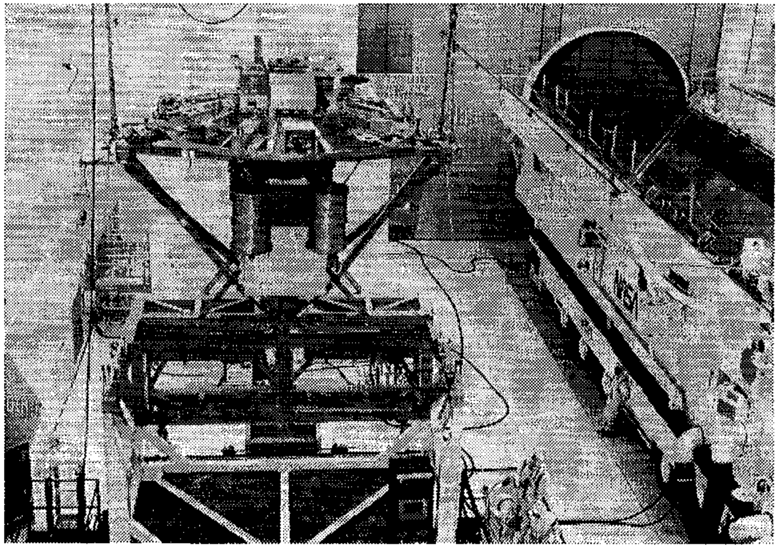
STS-60's primary mission objectives are to deploy and retrieve the Wake Shield Facility (WSF) 1 and to use the orbiter Discovery as a science platform for experiments on the SPACEHAB 2 payload.

WSF-1, built by Space Industries for the University of Houston Space Vacuum Epitaxy Center, will create a high-quality vacuum environment in which materials processing experiments can be conducted to aid in developing advanced manufacturing techniques for material processing on Earth. WSF will attempt to grow innovative thin-film materials for use in electronics, measure accelerations, and investigate plume impingement effects and pressures.

The Wake Shield Facility payload consists of a 12-foot-diameter free flyer experiment platform, a cross-bay carrier structure, and two "smart" canisters mounted on the carrier. Most of the WSF experiments are mounted on the satellite's "shield" side (the side pointing away from the direction of travel). WSF-1 can be controlled by the crew with a payload and general-support computer or the ground through the WSF-provided communications link.

Half an hour before the WSF is unberthed, Discovery will be maneuvered to a controlled free-drift attitude (i.e., tail down gravity gradient with a 60-degree deadband). It will remain in this attitude while the WSF, held by the orbiter's remote manipulater system, undergoes a cleaning process and systems checkout and for several hours after the satellite is released. Following its scheduled release on orbit 35 at a mission elapsed time of 1/03:21, the WSF free flyer will use its 2-oz. cold-gas thruster to separate from the orbiter and will fly in formation with Discovery, with its ram side into the velocity vector, at a distance of up to 46 statute miles from the orbiter (to minimize orbiter contamination) for 54 hours. During this time, the ground will control the growth of up to seven thin films via an orbiter-carrier-free flyer link.

Before the satellite is retrieved, after all WSF science is complete, a plume impingement investigation will be performed. The crew will fire the orbiter's reaction control system jets on the +Vbar and -Vbar in an effort to improve current orbiter plume models. The



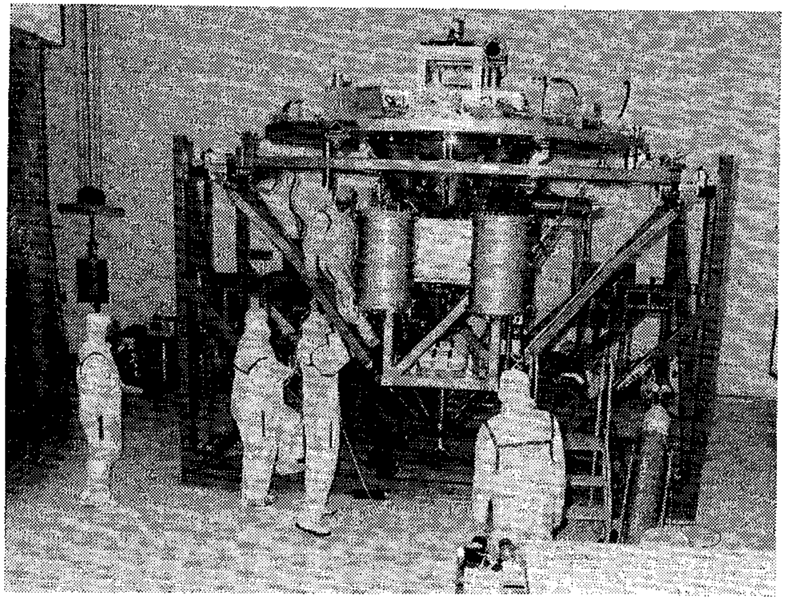
NASA Photo

Workers at KSC prepare to place Wake Shield Facility in the payload transporter.

free flyer will measure accelerations, plume pressures, and constituents. The orbiter will record free flyer data on the operations recorders and video data on the closed-circuit television system.

Following WSF's scheduled retrieval on orbit 69 at MET 3/05:49, it will be moved to an "overnight park" position designed to provide additional data for the Charge Hazards and Wake Studies (CHAWS) experiment and the Case Western University Materials Laboratory experiment. On the following flight day, the RMS will be moved to a CHAWS position, and the orbiter will be maneuvered to various attitudes relative to the velocity vector to support the study of plasma flows in Earth orbit.

Besides the plume impingement, CHAWS, and Case Western experiments, other Wake Shield experiments are the Construction Engineering Research Laboratory Containerless Coating Process (CERL CONCOP) experiment, Molecular Beam Epitaxy (MBE), and the Stand-Alone Acceleration Measurement Device (SAAMD).



NASA Photo

The Wake Shield Facility dwarfs workers performing a vacuum leak check.

Case Western's experiment is a passive experiment that will study environmental effects in low Earth orbit. It consists of several witness plates mounted on the free flyer.

CERL CONCOP, a U.S. Army-sponsored experiment, will study the effects of the space environment on vapor deposition processes. Samples of aluminum will be vented to vacuum, vaporized, and deposited on substrates.

CHAWS, a U.S. Air Force-sponsored experiment, will study WSF's wake characteristics while the satellite is still attached to the RMS. It consists of three microchannel plate detectors, several electrometers, and a microprocessor controller mounted on the ram side of the free flyer. A Langmuir probe and up to five MCPs are mounted on the wake side of the facility. The operation will take place on flight day 6 after WSF is grappled by the RMS.

The MBE experiment will grow high-purity crystalline thin films. Seven MBE source cells will be used. The experiment will be controlled from the ground through the orbiter-carrier free flyer link. The MBE substrates are housed in a carousel assembly that rotates to expose each sample to the molecular beam flux for epitaxial growth.

The plume impingement experiment will characterize the orbiter's reaction control system plume. Before the WSF retrieval, the RCS thrusters will be fired so that their plumes will impinge the satellite. The free flyer will measure accelerations, plume pressures, and constituents. The data may be used in the design of the international space station.

SAAMD will measure accelerations along three orthogonal axes. Six devices mounted on the WSF will record data on shuttle and payload responses to launch and landing loads. Data from these devices will provide new insight into orbiter launch and landing environments.

STS-60's second primary objective is the second flight of SPACEHAB (also known as the commercial middeck augmentation module [CMAM]), a commercially developed, pressurized, man-rated module that adds approximately 1,100 cubic feet of pressurized volume to the shuttle's manned work space and supports primarily orbiter middeck-type experiments. Leased to NASA by SPACEHAB, Inc. (McDonnell Douglas and Alenia), SPACEHAB has two primary objectives: (1) to support NASA's commercial development of the space program by providing additional crew-tended, middeck locker or experiment rack space for testing, demonstrating, or evaluating techniques or processes in microgravity and (2) to foster the development of a space infrastructure that can be marketed by private firms to support commercial microgravity research payloads.

SPACEHAB is installed in the forward quarter section of the orbiter payload bay. Crew members enter the module from the middeck through an airlock/tunnel adapter. Its configuration is flexible, significantly increasing its accommodation options for payload developers. Payloads are primarily mounted in middeck-type lockers (up to 60) or in a limited number of Spacelab-type racks. Experiments may also be mounted externally on the top of the module. The SPACEHAB subsystems require orbiter resources, including dc and ac electrical power, cooling via the Freon heat exchanger, atmosphere makeup (oxygen and nitrogen), humidity control, and carbon dioxide scrubbing.

SPACEHAB is expected to offer its users frequent flight opportunities with reduced lead time. SPACEHAB, Inc., may lease module space to other commercial customers on upcoming flights.

For STS-60, SPACEHAB will house 13 payloads. The cargo is primarily microgravity oriented with emphasis on materials and life science.

SPACEHAB 2 experiments are as follows:

- Three-Dimensional Microgravity Accelerometer (3-DMA) will measure the effects of deviations of microgravity on the SPACEHAB experiments.
- Astroculture (ASC-3) will supply water and nutrients to plants growing in microgravity.
- Bioserve Pilot Lab (BPL) consists of a refrigerator/incubator module and several minilabs that will conduct several biomedical and fluid studies.
- Commercial Generic Bioprocessing Apparatus (CGBA) uses a refrigerator/incubator module to process biological fluids.
- Equipment for Controlled Liquid-Phase Sintering Experiment (ECLiPSE) uses a furnace to study liquid-phase sintering of metals in microgravity.
- Organic Separation (ORSEP) will determine whether the separation process for cells and heavy molecules in microgravity results in a purer product.
- Space Acceleration Measurement System (SAMS) measures low-level shuttle accelerations with three triaxial heads and stores the data on optical disks.
- Stirling Orbiter Refrigerator/Freezer
- Commercial Protein Crystal Growth (CPCG) will reproduce large, high-quality crystals of selected proteins under controlled conditions in microgravity.
- IMMUNE-01 will measure the tissue and humoral immune responses of 12 normal rats to microgravity. The data collected will allow computer modeling of human immune system disorders.

- Penn State Biomodule (PSB) will house life science experiments that will study macromolecular assembly, protein crystallization, plant/animal cell physiology and metabolism, aging, and the regulation of gene function.

- Space Experiment Facility (SEF) will use the physical vapor transport method of growing crystals to prepare improved-quality crystals of zinc selenide, which have numerous applications in optical devices.

- Sample Return Experiment (SRE) will use two panels mounted on the outside roof of the SPACEHAB module to collect cosmic dust.

The flight crew will be required to perform various tasks in the SPACEHAB module during the mission, including activating and deactivating, monitoring, and maintaining SPACEHAB subsystems.

STS-60's secondary objectives include activating and commanding six getaway special (GAS) experiments (Capillary Pumped Loop [CAPL], Orbital Debris Radar Calibration Spheres [ODERACS], University of Bremen Satellite [BREMSAT], G-071, G-514, and G-536), as well as the Auroral Photography Experiment (APE) B and Shuttle Amateur Radio Experiment (SAREX) II.

CAPL, sponsored by the European Space Agency, is designed to provide an on-orbit demonstration of the working principle and performance of a two-phase capillary pumped loop, a two-phase vapor quality sensor, and a two-phase multichannel condenser profile. Scientists will also compare data on CAPL behavior in a low-gravity environment with analytical predictions from modeling and the performance of capillary pumped loops on Earth. The experiment equipment consists of a sealed, pressurized loop containing ammonia that can absorb and carry heat from evaporators to condensors.

NASA Johnson Space Center's ODERACS payload will eject six spheres ranging in size from 2 to 6 inches in diameter from Discovery's payload bay to test the capability to detect potentially dangerous debris in low Earth orbit from the ground. The spheres will be observed, tracked, and recorded by ground-based radars and optical telescopes, enabling end-to-end calibration of radar imaging facilities and data analysis systems. In addition, the radar signatures of the spheres will be compared to signatures detected from current orbital debris. ODERACS is scheduled to be deployed on orbit 97.

BREMSAT, constructed by the University of Bremen as part of the German national space program, is a small deployable satellite that will conduct six scientific experiments during various mission phases before and following satellite deployment. Science investigations include measurements of heat conductivity, residual acceleration forces, and the exchange of momentum and energy between the molecular flow and the rotating satellite; the study of the density distribution and dynamics of micrometeorites and dust particles in low Earth orbit; and the mapping of atomic oxygen. BREMSAT is scheduled to be deployed on orbit 100.

G-071, designed by California State University, Northridge, has a low-melting-point tin-lead-bismuth alloy that will be melted under low-gravity conditions.

G-514, sponsored by NASA's Goddard Space Flight Center, consists of two experiments: the Orbiter Stability Experiment (OSE) and a passive experiment to determine the effects of exposure to microgravity on over-the-counter medicines. OSE will evaluate the high-frequency variations in the orbiter's orientation caused by vibrations in its structure that may be present during routine in-flight operations that involve vernier or primary thruster firings. It also includes passive equipment to evaluate the fogging of photographic emulsion by energetic particles.

G-536, sponsored by NASA's Lewis Research Center, will study the effects of heat flux and liquid subcooling on nucleate pool boiling under microgravity conditions.

NASA Photo

A GAS canister holding the Pool Boiling Experiment undergoes preflight processing.

APE-B will photograph and record the spectra of aurora and airglow layer. APE-B will also be used during the night CHAWS runs to investigate shuttle glow phenomenon on the WSF Langmuir probe. APE-B equipment consists of a standard Nikon 35mm camera, 55mm and 135mm lenses, a Noctron V image intensifier, spectrometer bar, filter holder, and various lens filters. APE-B hardware can be assembled in three basic configurations to support the various experiment objectives.

SAREX-II, sponsored by NASA, the American Radio Relay League/Amateur Radio Satellite Corporation, and the Johnson Space Center Amateur Radio Club, is a middeck payload that will establish two-way communication with amateur radio stations within the line of sight of the orbiter. Configuration C is planned for this mission and is capable of operating in robot and voice modes. It consists of a suite of amateur radio equipment, including a handheld transceiver, window antenna, headset assembly, interface module, spare battery set, packet module, and personal tape recorder. SAREX-II will be operated in the robot mode for most of the flight. Intermittent voice operations will be performed by crew members as time permits.

STS-60 marks the beginning of a new era of international cooperation between NASA and the Russian Space Agency (RSA). Cosmonaut Sergei Krikalev will fly as a mission specialist on STS-60, representing one element of the Implementing Agreement on NASA/RSA Cooperation in Human Space Flight, signed by NASA and RSA on October 5,1992. Other planned elements of the agreement are the flight of a NASA astronaut on the Russian space station Mir in 1995 and a series of U.S. space shuttle dockings with Mir beginning in June 1995.

On STS-60, a series of U.S.-Russian medical experiments will be conducted. The investigations, a joint effort between NASA's Medical Sciences Division and the Russian Institute for Biomedical Problems, include three detailed supplementary objectives.

DSO 200 (radiobiological effects) will compare U.S. and Russian space flight dosimeter calibration techniques; correlate the independent, simultaneous space radiation exposure measurements and calculations made by the two space programs; and assess the radiobiological effects of high-charge, high-energy particles on actively metabolizing biological samples.

DSO 201 (sensory motor investigation) will enhance the understanding of adaptation to space flight, readaptation after flight, and correlation of the postflight recovery of postural equilibrium control, head and gaze stability, and readaptation changes in vestibular function. Scientists also intend to examine the relationship between voluntary oculomotor performance and passive vestibulo-ocular responses following space flight. On-orbit investigation protocols are voluntary head movements, optokinetic nystagmus, sensory perception performance, and electrogastrographic monitoring of autonomic gastric function.

DSO 202 (metabolic) includes ingesting bromide and/or doubly labeled water, taking blood samples and measuring peripheral venous pressure with a catheter, and collecting urine and saliva samples. The samples will indicate whether and how the fluid and electrolyte balance in the body changes in space flight.

An additional joint U.S.-Russian investigation—DSO 204—will compare visual observations from the shuttle of Earth features using remote imaging and recording from shuttle with data from previous Mir missions. The solar terminator and the stars will also be studied during this investigation.

Fourteen development test objectives and ten detailed supplementary objectives (including the four joint U.S.-Russian DSO investigations) are scheduled to be flown on STS-60.

MISSION STATISTICS

Vehicle: Discovery (OV-103), 18th flight

Launch Date/Time:

2/3/94	7:10 a.m., EST (day) 6:10 a.m., CST 4:10 a.m., PST

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

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

Launch Period: 3 hours, 48 minutes

Mission Duration: 8 days, 5 hours, 32 minutes. The capability exists for two additional days for contingency operations and weather avoidance.

Landing: Nominal end-of-mission landing on orbit 130

2/11/94	12:42 p.m., EST (day) 11:42 a.m., CST 9:42 a.m., PST

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

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

Return to Launch Site: KSC

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

Inclination: 57 degrees

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

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

Altitude: 190-nautical-mile (219-statute-mile) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2012
No. 2 position: Engine 2034
No. 3 position: Engine 2032

External Tank: ET-61

Solid Rocket Boosters: BI-062

Mobile Launcher Platform: 3

Cryo tank sets: 4 (fully loaded)

Software: OI-22 (5th flight)

Editor's Note: The following weight data are current as of January 13, 1994.

Total Lift-off Weight: Approximately 4,508,352 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 245,278 pounds

Orbiter (Discovery) Empty and 3 SSMEs: Approximately 173,509 pounds

Payload Weight Up: Approximately 28,674 pounds

Payload Weight Down: Approximately 28,499 pounds

Orbiter Weight at Landing: Approximately 214,589 pounds

Payloads—Payload Bay (* denotes primary payload): Wake Shield Facility (WSF) 1; SPACEHAB-2; getaway special (GAS) bridge assembly (GBA) with six experiments: University of Bremen Satellite (BREMSAT), Orbital Debris Radar Calibration Spheres (ODERACS), Capillary Pumped Loop (CAPL); G-071, G-514, G-536

Payloads—Middeck: Auroral Photography Experiment (APE) B; Shuttle Amateur Radio Experiment (SAREX) II

Flight Crew Members (single shift):

Commander: Charles (Charlie) F. Bolden, Jr., fourth space shuttle flight
Pilot: Kenneth (Ken) S. Reightler, Jr., second space shuttle flight
Mission Specialist 1: N. Jan Davis, second space shuttle flight
Mission Specialist 2: Ronald (Ron) M. Sega, first space shuttle flight
Mission Specialist 3: Franklin R. Chang-Diaz, fourth space shuttle flight
Mission Specialist 4: Sergei K. Krikalev, Russian Space Agency, third space flight, first space shuttle flight

Ascent and Entry Seating:

Ascent:

Flight deck, front left seat, commander Charles F. Bolden, Jr.
Flight deck, front right seat, pilot Kenneth S. Reightler, Jr.
Flight deck, aft center seat, mission specialist Ronald M. Sega
Flight deck, aft right seat, mission specialist N. Jan Davis
Middeck, mission specialist Franklin R. Chang-Diaz
Middeck, mission specialist Sergei K. Krikalev

Entry:

Flight deck, front left seat, commander Charles F. Bolden, Jr.
Flight deck, front right seat, pilot Kenneth S. Reightler, Jr.
Flight deck, aft center seat, mission specialist Ronald M. Sega
Flight deck, aft right seat, mission specialist Sergei K. Krikalev
Middeck, mission specialist N. Jan Davis
Middeck, mission specialist Franklin R. Chang-Diaz

Extravehicular Activity Crew Members, If Required:

Extravehicular (EV) astronaut 1: mission specialist Franklin R. Chang-Diaz
EV-2: mission specialist N. Jan Davis
EV-3: pilot Kenneth S. Reightler, Jr.

Entry: Automatic mode until subsonic, then control stick steering

Flight Directors:

Orbit 1 team: Al Pennington

Orbit 2 team and lead: Chuck Shaw
Planning team: Bob Castle
Ascent/entry team: Jeff Bantle

Notes:

- The remote manipulator system is installed in Discovery's payload bay for this mission.
- The shuttle orbiter repackaged galley and middeck utility panel are installed in Discovery's middeck.

MISSION OBJECTIVES

- Primary objectives
  - — Deployment and retrieval of the Wake Shield Facility (WSF) 1
  - — SPACEHAB 2 operations
- Secondary objectives
  - — Payload bay
    - Activate and command the GAS bridge assembly payloads: Capillary Pumped Loop (CAPL), Orbital Debris Radar Calibration Spheres (ODERACS), University of Bremen Satellite (BREMSAT), G-071, G-514, and G-536
  - — Middeck
    - Auroral Photography Experiment (APE) B
    - Shuttle Amateur Radio Experiment (SAREX) II
- 14 development test objectives/10 detailed supplementary objectives

CREW ASSIGNMENTS

Commander: Charles (Charlie) F. Bolden, Jr.

- Overall mission decisions
- Orbiter—DPS, ECLSS, PGSC/PADM, rendezvous, MPS,* OMS/RCS,* APU/hydraulics,* EPS*
- Payload—ODERACS, BREMSAT, ORSEP (SPACEHAB), PSB (SPACEHAB),* SAREX-II*
- DTOs/DSOs—DSO 202;* DTOs 251, 805, 623*
- Other—medic, in-flight maintenance*

Pilot: Kenneth (Ken) S. Reightler, Jr.

- Orbiter—MPS, OMS/RCS, APU/hydraulics, EPS, FDF, crew equipment,* PGSC/PADM,* rendezvous*
- Payload—ECLiPSE (SPACEHAB), ODERACS,* CGBA (SPACEHAB),* IMMUNE (SPACEHAB)*
- DTOs/DSOs—DSO 200, 201,* 202;* DTOs 700-2, 700-7, 251,* 656,* 670,* 805*
- Other—IV, EV-3

Mission Specialist: N. Jan Davis

- Orbiter—crew equipment, communications/instrumentation,* payload bay door/radiators*
- Payload—RMS, G-514, G-071, G-536, G-557, CPCG (SPACEHAB), CGBA (SPACEHAB), SPACEHAB systems,* ORSEP (SPACEHAB),* SEF (SPACEHAB)*
- DTOs/DSOs—DSO 201; DTOs 312, 664*
- Other—EV-2, photo/TV,* medic*

Mission Specialist: Franklin R. Chang-Diaz

- Orbiter—communications/instrumentation, FDF,* PGSC/PADM*
- Payload—SPACEHAB systems, SEF (SPACEHAB), ASC-3 (SPACEHAB), APE-B, WSF,* BREMSAT,* G-514,* G-071,* G-536,* G-557,* 3-DMA (SPACEHAB),* CPCG (SPACEHAB),* BPL (SPACEHAB)*
- DTOs/DSOs—DSO 202, 204;* DTOs 700-2,* 700-7*
- Other—photo/TV, Earth observations, EV-1

Mission Specialist: Ronald (Ron) M. Sega

- Orbiter—payload bay door/radiator, HP48, DPS,* ECLSS,* rendezvous*
- Payload—WSF, PSB (SPACEHAB), RMS,* CAPL/GBA,* SPACEHAB systems,* SAMS (SPACEHAB),* ECLiPSE (SPACEHAB),* SAREX-II*
- DTOs/DSOs—DSO 201; DTOs 623, 656, 664, 670, 700-2,* 700-7

Mission Specialist: Sergei K. Krikalev

- Orbiter—HP48
- Payload—CAPL/GBA, SAMS (SPACEHAB), 3-DMA (SPACEHAB), BPL (SPACEHAB), IMMUNE (SPACEHAB), SAREX-II, WSF,* RMS,* SPACEHAB systems,* ASC-3 (SPACEHAB),* APE-B*
- DTOs/DSOs—DSOs 204, 200,* 201
- Other—in-flight maintenance, Earth observations*

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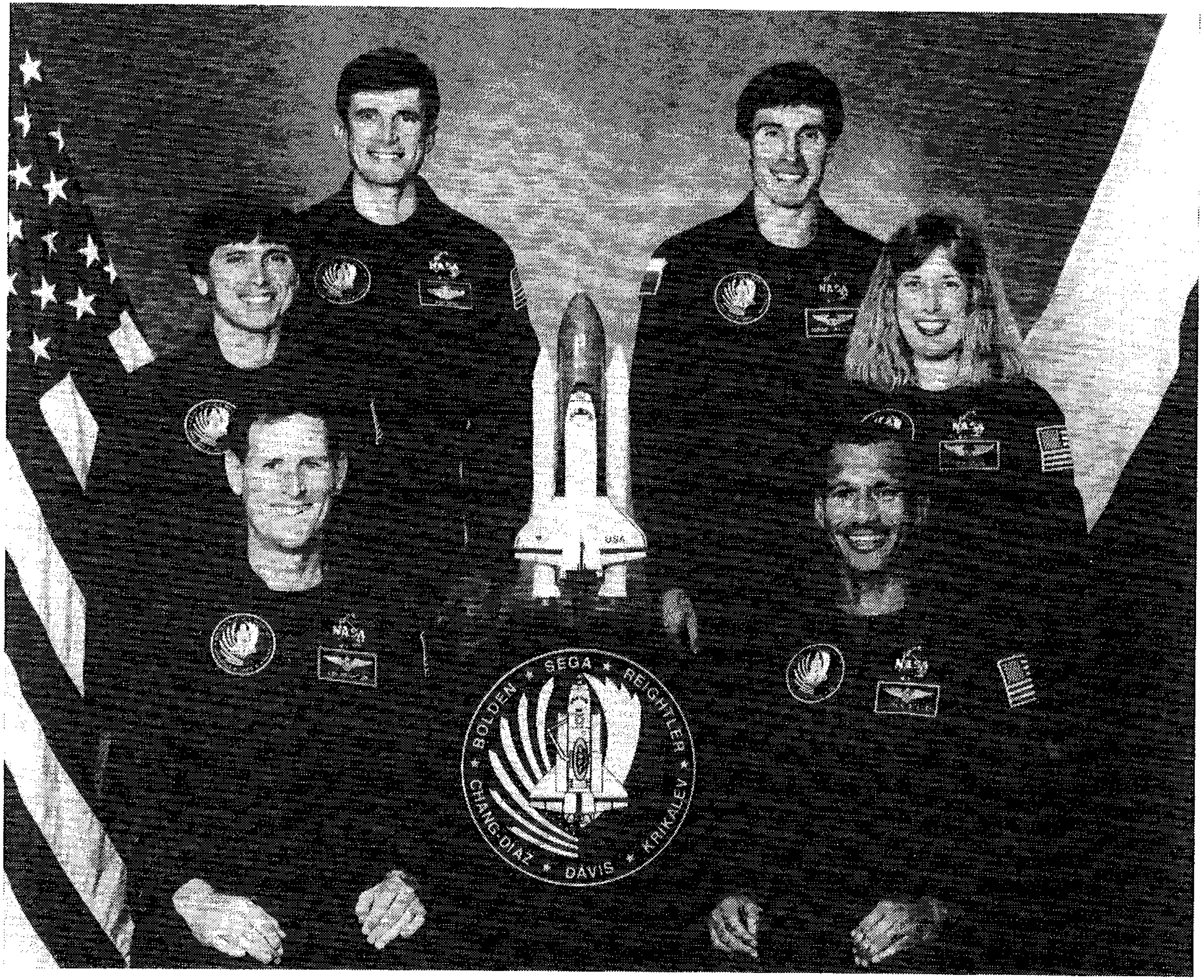
*Denotes backup responsibility



STS-60 CREW—The pilot for this mission is Ken Reightler, Jr. (seated left), and the commander is Charlie Bolden, Jr., (seated right). The mission specialists are Franklin Chang-Diaz and Jan Davis (second row) and Ron Sega and Sergei Krikalev (third row).

NASA Photo

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2 burn
Payload bay doors open
Unstow cabin
SPACEHAB activation
SPACEHAB operations
Joint U.S.-Russian science operations
CAPL activation
Group B power-down
CPCG setup

Flight Day 2

Metabolic investigations
RMS checkout
Payload bay survey
SPACEHAB operations
Vestibular experiments
SAREX setup

Flight Day 3

WSF grapple, unberth, and release
NC-1 burn
Group B power-up
Group B power-down
SPACEHAB operations

Flight Day 4

WSF free flyer operations
SPACEHAB operations
Vestibular experiments
SAREX operations

Flight Day 5

Group B power-up
NC-4 burn
TI burn
WSF rendezvous
WSF plume test operations
WSF grapple
Group B power-down
SPACEHAB operations
Overnight WSF RMS operations

Flight Day 6

SPACEHAB operations
Vestibular experiments
WSF CHAWS operations
WSF berth
Orbit adjust burn, if required

Flight Day 7

SAREX operations
SPACEHAB operations
Vestibular experiments
Group B power-up
ODERACS deployment
BREMSAT deploy
Crew press conference
Group B power-down

Flight Day 8

SPACEHAB operations
Vestibular experiments
FCS checkout
RCS hot fire
SPACEHAB stow
Cabin stow

Flight Day 9

Group B power-up
SPACEHAB deactivation
Deorbit preparations
Deorbit burn
Entry
Landing

Notes:

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

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

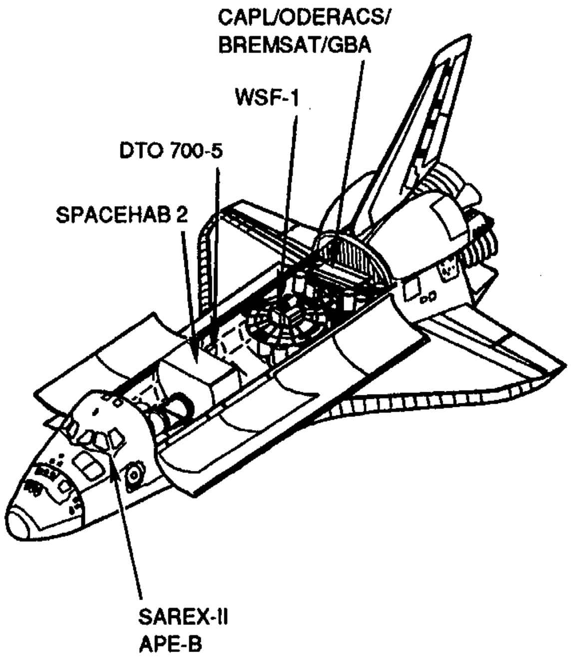
DTOs

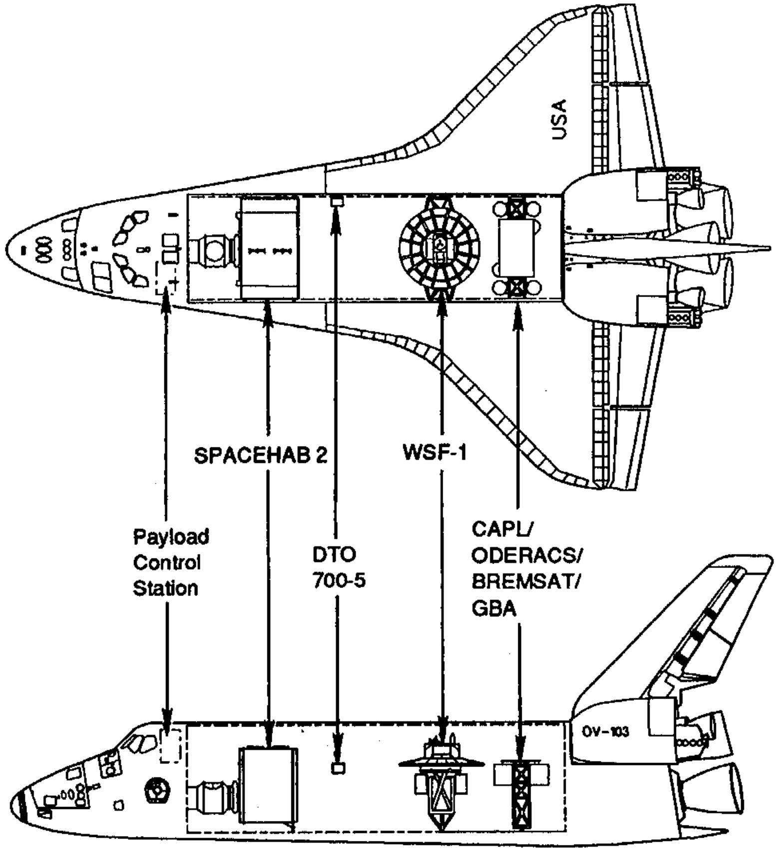
- Ascent structural capability evaluation (DTO 301D)
- Ascent compartment venting evaluation (DTO 305D)
- Entry compartment venting evaluation (DTO 306D)
- Entry structural capability evaluation (DTO 307D)
- ET TPS performance (method 3) (DTO 312)
- Shuttle/payload low-frequency environment (DTO 319D)
- APU shutdown test, sequence B (shutdown 2, then 3, then 1) (DTO 414)
- Cabin air monitoring (DTO 623)
- PGSC single-event upset monitoring (DTO 656)
- Cabin temperature survey (DTO 664)
- Evaluation of passive cycle isolation system (DTO 670)
- Laser range and range rate device (DTO 700-2)
- Orbiter data for real-time navigation evaluation (DTO 700-7)
- Crosswind landing performance (DTO 805)

DSOs

- Joint U.S.-Russian investigation: radiobiological effects (DSO 200)
- Joint U.S.-Russian investigation: sensory-motor investigations (DSO 201)
- Joint U.S.-Russian investigation: metabolic (DSO 202)
- Joint U.S.-Russian investigation: visual observations from space (DSO 204)
- Dried blood method for in-flight storage (protocol 1) (DSO 325)
- Window impact observations (DSO 326)
- Immunological assessment of crew members (DSO 487)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)

STS-60 PAYLOAD CONFIGURATION



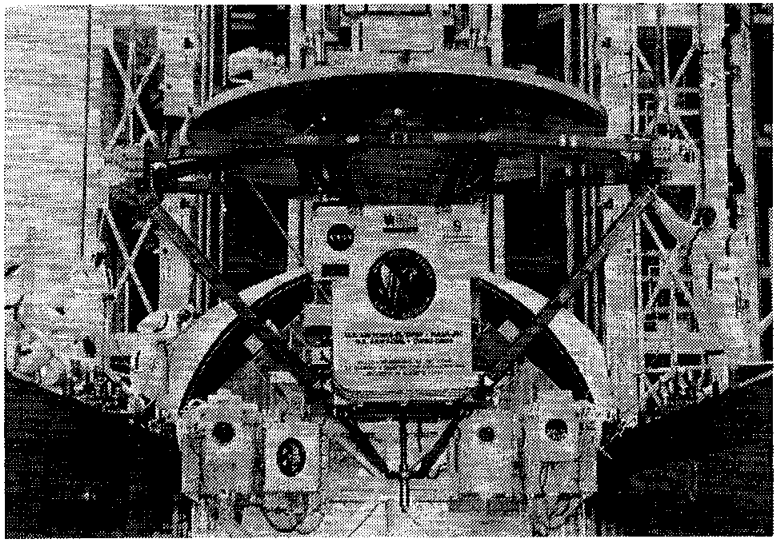


MTD-940110-4597

WAKE SHIELD FACILITY 1

The Wake Shield Facility is a small free-flying satellite that has been designed to create an ultrapure vacuum in which investigators will attempt to produce innovative crystalline thin-film semiconductors for next-generation electronics as the saucer-shaped free flyer orbits the Earth. The shield will also investigate the effects of atomic oxygen on spacecraft materials and the effects of orbiter exhaust on space objects.

This is the first of a planned series of missions for the small craft. Three more flights are called for at one-year intervals.



NASA Photo

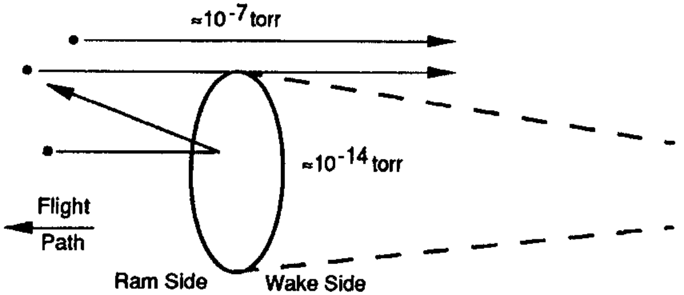
The Wake Shield Facility is being lowered into the payload transporter. The GAS bridge assembly with experiment canisters installed is in background.

The goal of the WSF program is to prove the concept of thin-film growth (known as epitaxy) and demonstrate the capability of the WSF to produce 200 to 300 thin wafers.

Most of the semiconductors used in electronic components today are made of silicon, but many other semiconductor materials have higher predicted performance than silicon. One is gallium arsenide (GaAs). Devices made from GaAs could be about 8 times faster than silicon devices and take one-tenth the power. If high-quality GaAs could be produced, the devices made from it would represent nothing less than a technological revolution.

GaAs films can be grown epitaxially in microgravity by creating a unique vacuum environment, or wake, behind an object moving in orbit. A vehicle in low Earth orbit, such as the WSF, pushes the few atoms present out of the way, leaving fewer atoms, if any, in its wake. The ultravacuum produced in space by the WSF will be 1,000 to 10,000 times better than the best vacuum environments in laboratory vacuum chambers. By capitalizing on this unique ultravacuum property of space, the WSF may spawn orbiting factories that will produce the next generation of semiconductor materials and the devices they will make possible.

Epitaxial thin-film growth is an approach to reducing the defects in semiconductor materials by growing new material on a substrate in a vacuum. In epitaxial growth, atomic or molecular beams of a material, such as arsenic (As) and gallium (Ga), formed in a vacuum are exposed to a prepared surface—or substrate. The substrate is an atomic template, or pattern, on which the atoms form thin films. The atoms grow in layers that follow the crystal structure pattern of the substrate. A thin film of new materials then grows on top of the substrate atom by atom, atomic layer by atomic layer to form a "wafer" with an ultrahigh-purity top region. This growth technique, known as molecular beam epitaxy (MBE), has been used in laboratory studies of thin-film electronic materials for the past 20



MTD-940110-4620

Ultravacuum in Space for Thin-Film Growth

years. It has been shown that the vacuum environment that the materials are grown in is critical to the quality of the thin films grown.

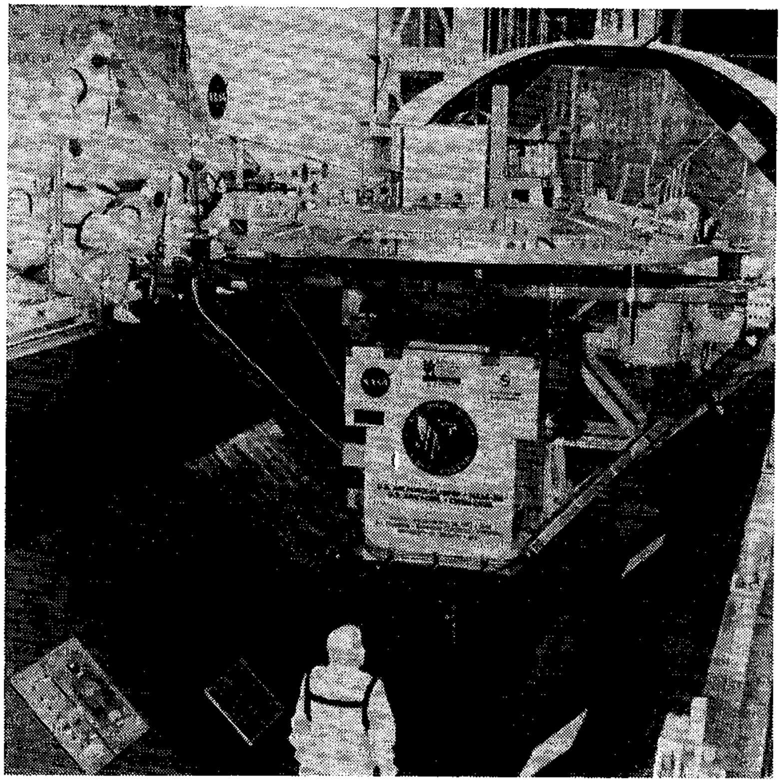
MBE is the most powerful tool for synthesizing new materials and fabricating novel microdevices. It is used to precisely fabricate atomic-scale perfect heterostructures and to synthesize artificial materials that have prescribed characteristics. However films produced on Earth by this process are contaminated and have defects because they must be fabricated in a limited vacuum.

Seven films will be grown during the mission. At least one "thick" GaAs film (~9 micrometers) will be grown to characterize ultimate defect densities. Several films will be grown to exhibit high electron mobility in GaAs and to support the Earth-based fabrication of field effect transistors. Finally, a GaAs film will be grown by chemical beam epitaxy (CBE) with arsenic and an organometallic compound containing gallium. The near-infinite vacuum pumping speed of the WSF ultravacuum environment should greatly improve the quality of the CBE GaAs film.

Unlike the flying saucers of the movies, the Wake Shield Facility will fly like a plate on its edge. The wake that forms behind the satellite as it cuts through the thin atomic oxygen in low Earth orbit will produce an extremely high vacuum that is essential to the growth of ultrapure semiconductor materials used in electronics and cannot be created in Earth-based processing facilities.

The ram side of the WSF, the side facing forward in flight, contains batteries, electrical power system packages, propulsion and attitude control systems, and data acquisition and process control electronics. The WSF's outer shield on the ram side also accommodates other payloads. On the wake side is the film-forming equipment.

The 12-foot-diameter stainless steel satellite will be deployed from Discovery's cargo bay on the third day of the mission. A crew



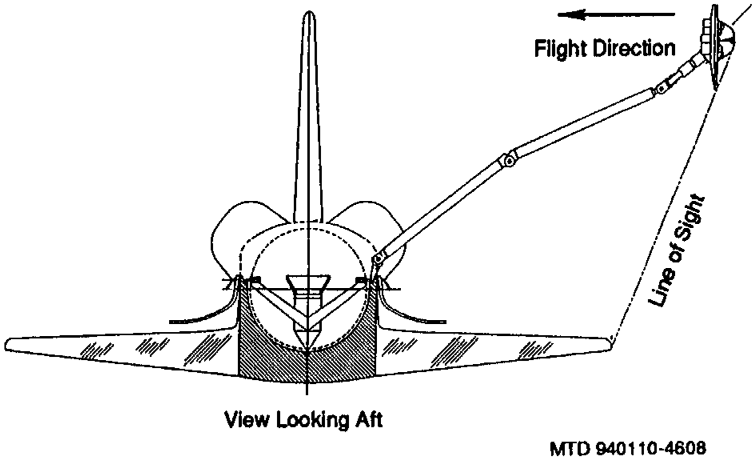
NASA Photo

Workers install Wake Shield Facility in the payload transporter.

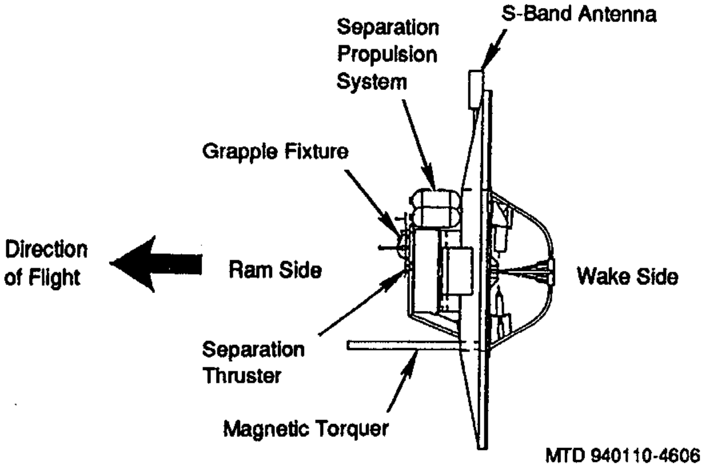
member will pluck the satellite from its special cross-bay carrier with the shuttle's remote manipulator system, but before it is released, the WSF will be exposed to atomic oxygen for five hours to ensure the cleanest possible environment for growing thin membranes.

One film will be grown while the shield is still attached to the RMS to check out the molecular beam epitaxy film-growth procedure. Because of the extreme sensitivity of the MBE process to contamination, orbiter water dumps, jet firings, and other operations that would interfere with the growth of ultrapure film will be reduced.

After it is released by the RMS, the Wake Shield Facility will use its own nitrogen thrusters to fly 60 miles away from the orbiter to avoid possible contamination of the MBE experiment by the orbiter. During 54 hours of solo flight, ground controllers will direct the WSF to produce as many as six films.



WSF/RMS Operation



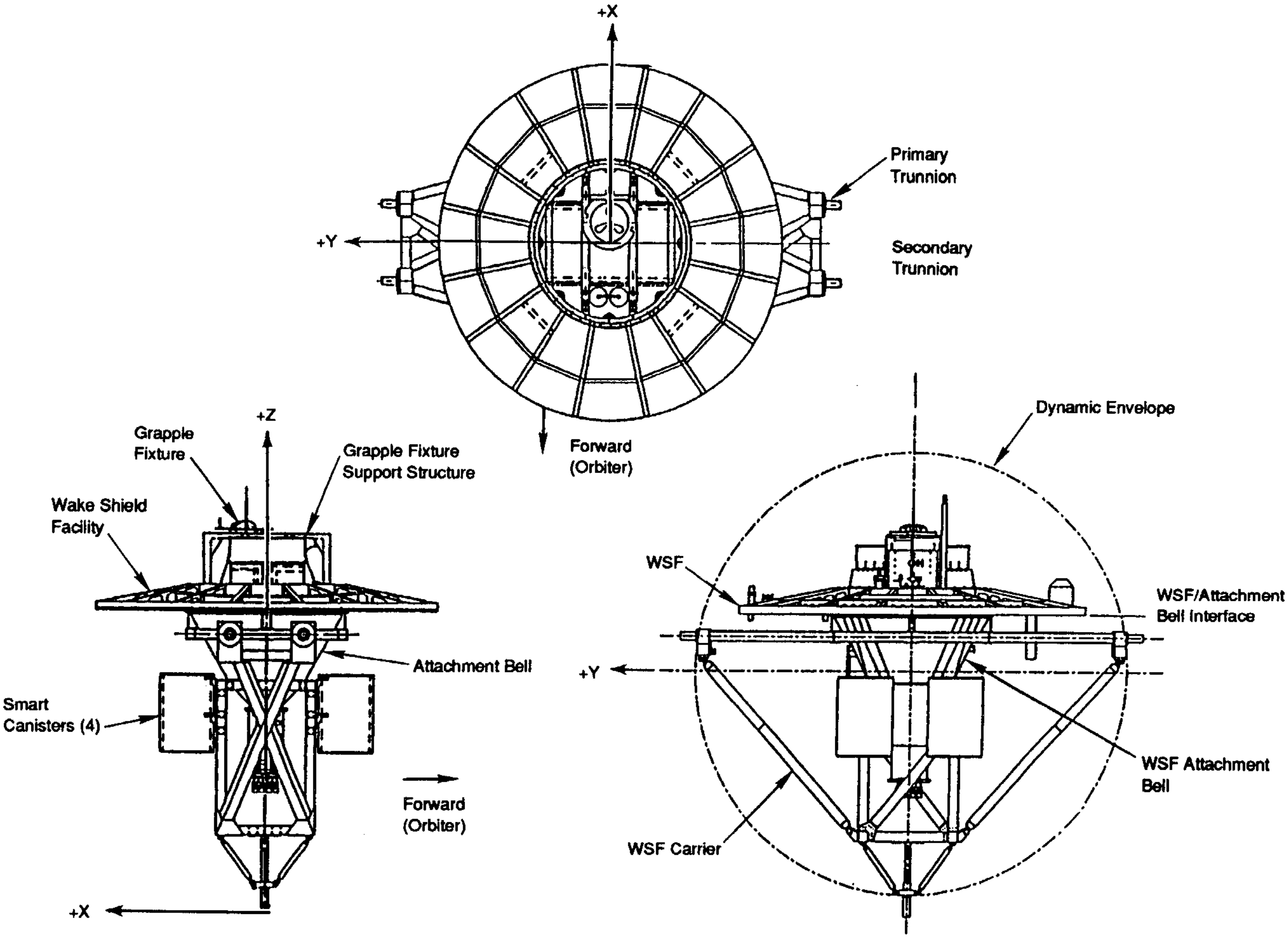
Wake Shield Facility Free Flyer

The MBE apparatus on the wake side of the shield includes seven source cells and seven target substrates with heaters. The source cells contain gallium, triethylgallium, arsenic, and silicon, which will be used to grow gallium arsenide and silicon-doped gallium arsenide membranes.

During processing, a molecular beam flux is generated by heating a source cell. The cell is pointed at a substrate, and the flux is deposited on the substrate, where a specific atomic structure is formed layer by layer. Flux levels and growth rates are controlled by monitoring data provided by a mass spectrometer and total-pressure gauge. The reflection high-energy electron diffraction system, which is also mounted on the wake side of the shield, monitors the growth of the films and the uniformity of the forming crystals' lattices.

Several other experiments are planned as part of the WSF-1 mission.

During the free-flight portion of the mission, about 75 samples of developmental materials for possible use in spacecraft will be



MTD-940110-4605

WSF/Cross-Bay Carrier Assembly

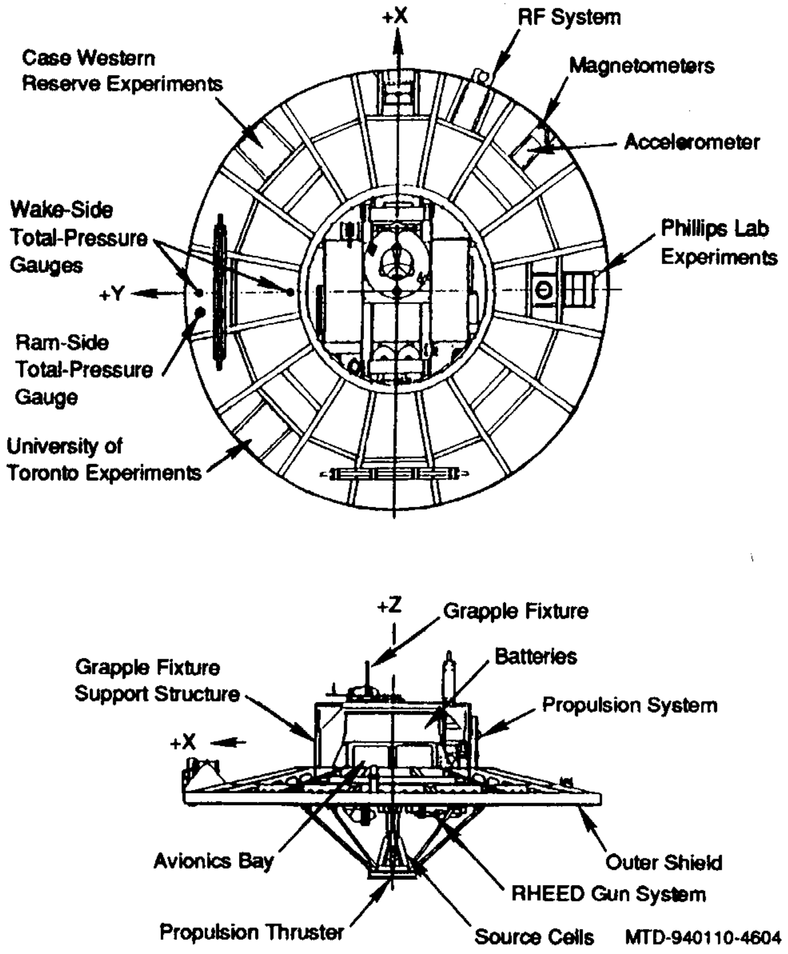
exposed to space to characterize the effects on the materials of the space environment, particularly the effects of atomic oxygen. The materials in the Case Western Reserve University MATLAB experiment are located on the ram side of the WSF to allow maximum exposure to atomic oxygen. The ram environment is also the same environment that the leading edge of a spacecraft would experience.

Before the astronauts retrieve the WSF, they will position the orbiter in front of the small spacecraft and fire the orbiter's small thrusters to gauge the effect of the jets' plume on the WSF. Instruments on the shield will measure the accelerations it experiences and the pressures and constituents of the plume.

After the shuttle's robotic arm retrieves the Wake Shield Facility on the fifth day of the flight, it will place the captured spacecraft in an overnight parking position, where the WSF will continue to collect data and conduct the MATLAB exposure experiment. On flight day 6, a crew member will command the RMS to move the WSF above the overhead windows on the orbiter's aft flight deck for the Charge Hazards and Wake Studies, or CHAWS, experiment. CHAWS, a joint effort of the U.S. Air Force Geophysics Laboratory and Phillips Laboratories, will investigate the characteristics of the WSF's wake.

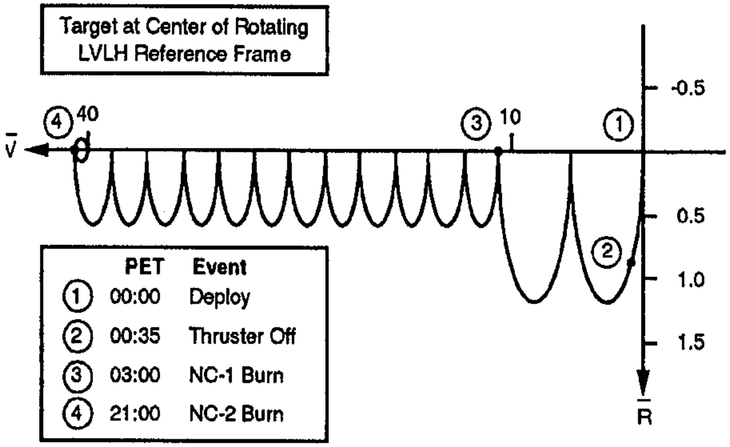
A Langmuir probe will measure the flow of ions around the shield as the orientation of the shield is changed by moving the RMS. The series of measurements will be taken with the orbiter in a tail-down attitude and will be repeated with the orbiter in a nose-down attitude. Knowledge gained from the CHAWS experiment will be used to design future space systems.

The Air Force investigation will also attempt to determine whether secondary ion effects are important to the collection of high-voltage current in a plasma wake. The Auroral Photography Experiment camera will be used to take pictures of the WSF from the aft flight deck to determine whether negative ions are present on the Langmuir probe during high-voltage operations and to observe other surface physics effects.



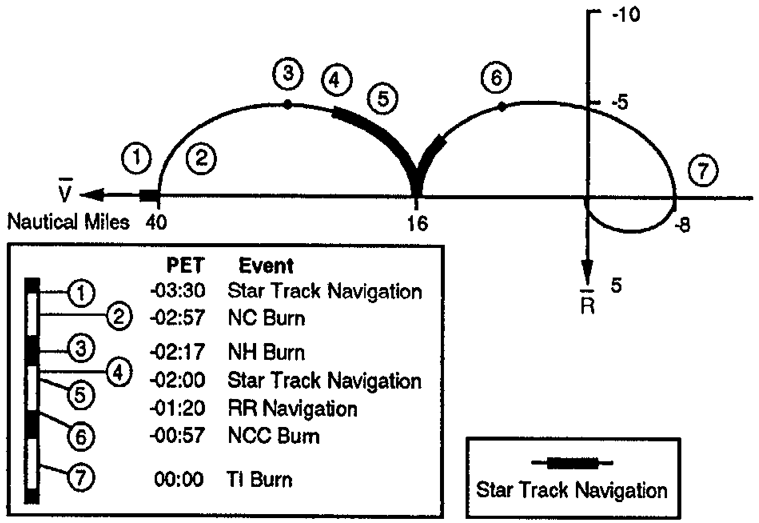
Wake Shield Facility Free Flyer

The WSF will be placed in the cross-bay carrier for the return to Earth after the completion of the CHAWS experiment.



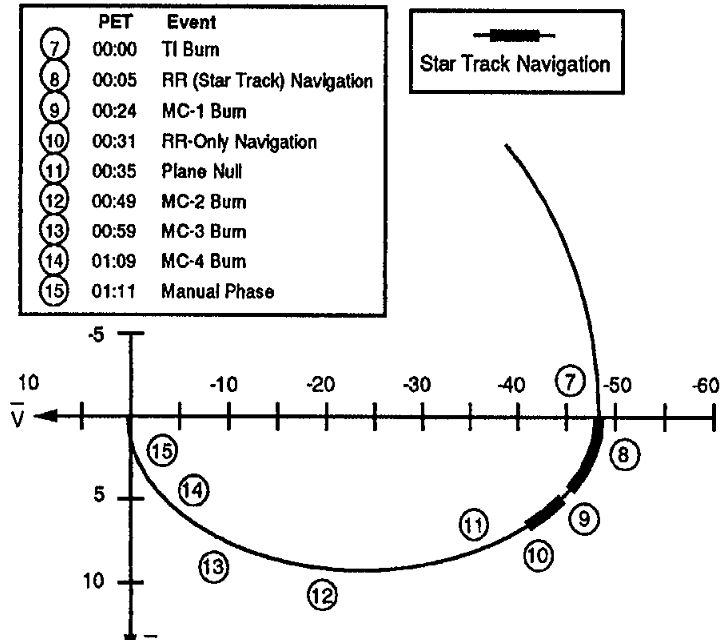
	PET	Event
①	00:00	Deploy
②	00:35	Thruster Off
③	03:00	NC-1 Burn
④	21:00	NC-2 Burn

Deployment Profile



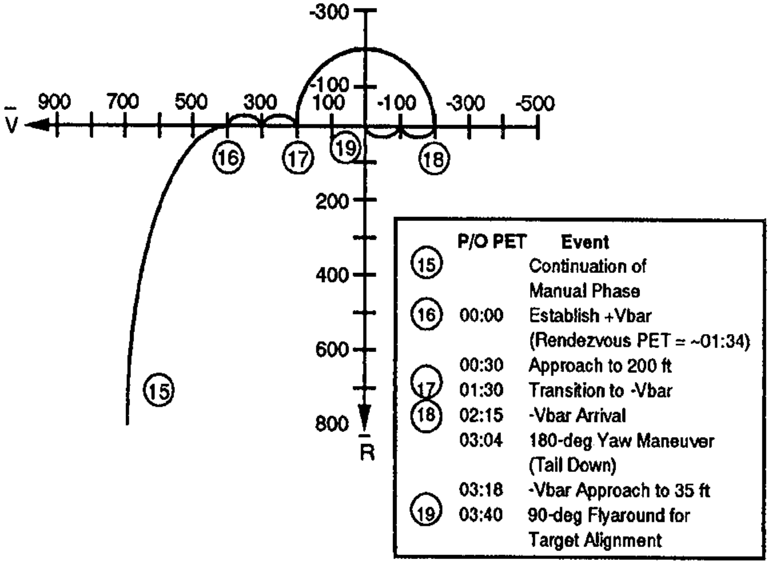
	PET	Event
①	-03:30	Star Track Navigation
②	-02:57	NC Burn
③	-02:17	NH Burn
④	-02:00	Star Track Navigation
⑤	-01:20	RR Navigation
⑥	-00:57	NCC Burn
⑦	00:00	TI Burn

Rendezvous Profile



	PET	Event
⑦	00:00	TI Burn
⑧	00:05	RR (Star Track) Navigation
⑨	00:24	MC-1 Burn
⑩	00:31	RR-Only Navigation
⑪	00:35	Plane Null
⑫	00:49	MC-2 Burn
⑬	00:59	MC-3 Burn
⑭	01:09	MC-4 Burn
⑮	01:11	Manual Phase

Post-TI Rendezvous Profile



	P/O PET	Event
⑮		Continuation of Manual Phase
⑯	00:00	Establish +Vbar (Rendezvous PET = ~01:34)
	00:30	Approach to 200 ft
⑰	01:30	Transition to -Vbar
⑱	02:15	-Vbar Arrival
	03:04	180-deg Yaw Maneuver (Tail Down)
	03:18	-Vbar Approach to 35 ft
⑲	03:40	90-deg Flyaround for Target Alignment

Rendezvous Profile, Proximity Operations

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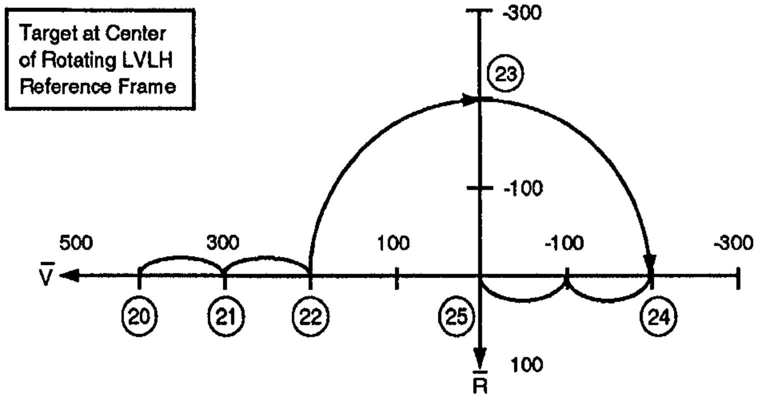

⑳ +VBAR Arrival
+400-ft Pitch Plume Test
Approach to 200 ft

㉑ +300-ft Plume Test

㉒ +200-ft Pitch Plume Test
+200-ft Yaw Plume Test
Transition to -Vbar

㉓ 200-ft Flyaround

㉔ -Vbar Arrival
-200-ft Pitch Plume Test
-200-ft Yaw Plume Test
180-deg Yaw Maneuver
(Tail Down)
Approach to 35 ft

㉕ Arrive at 35 ft
90-deg Flyaround for
Target Alignment

MTD-940110-4613

Rendezvous Profile for Plume Impingement Experiment

During the WSF mission, the U.S. Army's Central Research Labs will investigate a containerless coating process for over 100 candidate materials in the shuttle's cargo bay. The process will use aluminum vapor deposition to coat the materials in the vacuum of space. Knowledge gained from this experiment will be used to design methods of refurbishing the surfaces of large space structures that will remain in space for long periods of time, such as the U.S. space station.

The materials and experiment electronics are housed in two "smart cans" mounted on the WSF's cross-bay carrier. The carrier can hold up to four of the small canisters, which are similar to those used for getaway special payloads.

The Wake Shield Facility was built by Space Industries Inc. for the University of Houston Space Vacuum Epitaxy Center. Members of the SVEC consortium are NASA JSC, the University of Toronto, the Air Force Phillips Laboratories, the Army Construction Engineering Research Laboratory, and six corporate partners.

SPACEHAB 2

Early in the shuttle program, it became evident that the orbiter middeck is the best place to conduct crew-tended experiments in space. Each shuttle orbiter has 42 middeck lockers but most are used to stow crew gear for a typical seven-day mission, leaving only seven or eight for scientific studies. But SPACEHAB, the first crew-tended commercial payload carrier, has initiated a new era of space experimentation.

The SPACEHAB module, which takes up a quarter of the orbiter's payload bay, is like a second middeck. It adds 1,100 cubic feet of pressurized work space that can hold 61 lockers or experiment racks or a combination of the two. The lockers are sized and equipped like those in the shuttle middeck so that experiments can be moved from one location to the other. A rack, which can be single or double, takes the space of ten lockers. Double racks are similar in size and design to those planned for the space station so that they can serve as test beds for future projects.

For this second mission, the SPACEHAB interior will be arranged in the locker configuration. The astronauts will enter the module through a modified Spacelab tunnel adapter. SPACEHAB can accommodate two crew members on a continuous basis, but additional crew members can work in the module for brief periods. Power, command and data services, cooling, vacuum, and other utilities are supplied by orbiter crew cabin and payload bay resources. The lockers accommodate up to 60 pounds of experiment hardware in about 2 cubic feet. A single rack can carry 625 pounds of hardware in 22.5 cubic feet.

SPACEHAB was privately developed and is privately operated by SPACEHAB, Inc., of Arlington, Va. NASA has agreed to lease two-thirds of the module's space for the first six flights, which are expected to occur twice a year. Eight SPACEHAB missions have been listed on the shuttle manifest so far. Both SPACEHAB, Inc., and NASA hope that commercial interests will also begin to lease experiment space.

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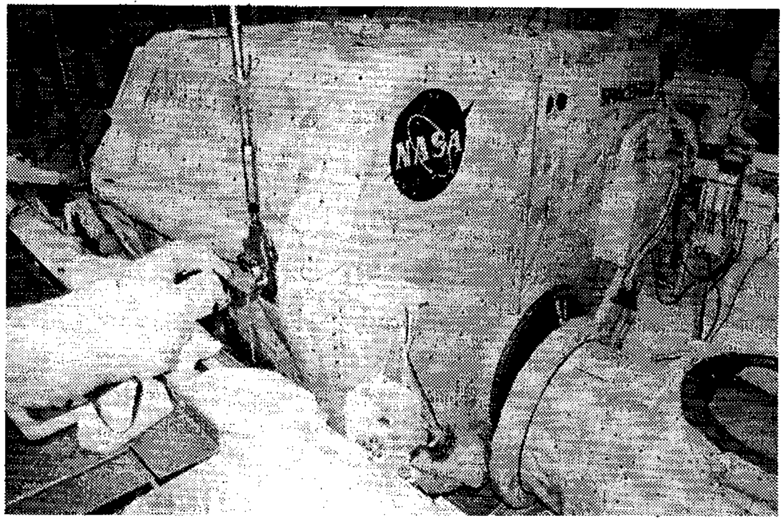
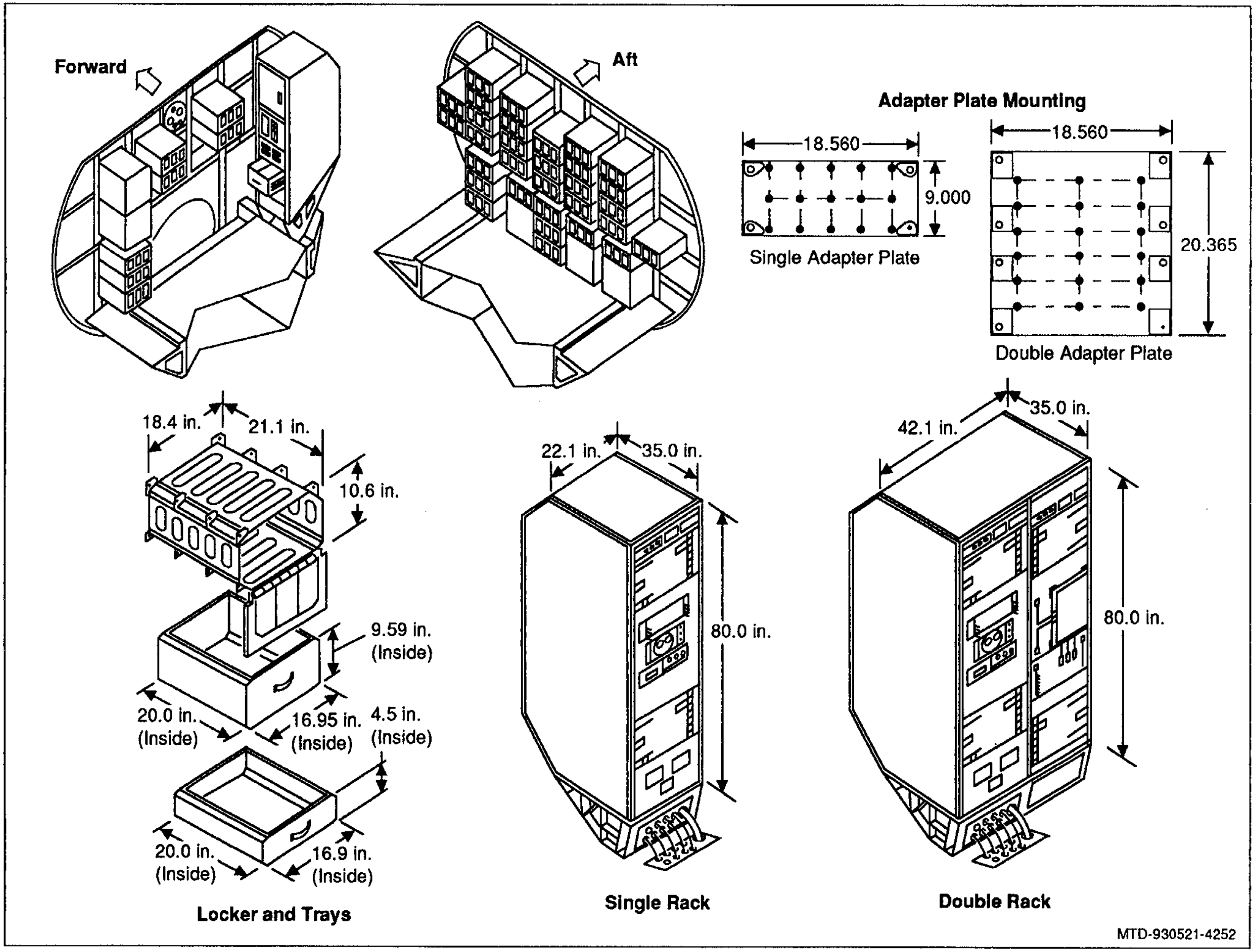


NASA Photo

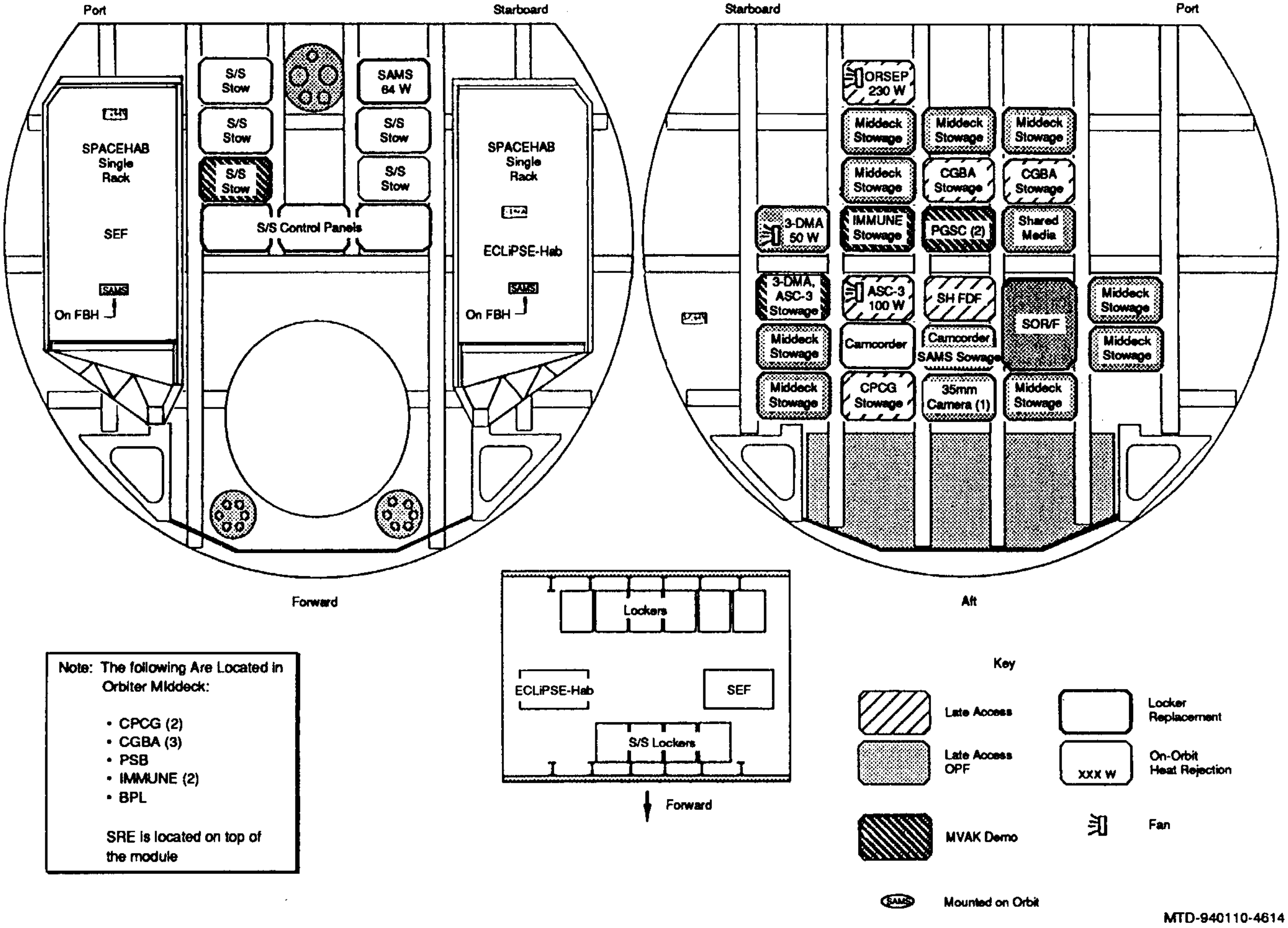
SPACEHAB module is placed in Endeavour payload bay for STS-57.

The first flight of the SPACEHAB research laboratory was on STS-57 in June 1993. All systems operated as expected, and the 21 NASA-sponsored experiments met more than 90% of the criteria for mission success. Detailed analyses of the experiment results are under way.

For STS-60, SPACEHAB will carry 13 materials processing and life sciences experiments. Six of these will be carried in the middeck because of their operational requirements. Most of the SPACEHAB payloads have been flown on the shuttle before. For them, this flight is a continuation of research to develop new or improved commercial products or processes.



Typical SPACEHAB Interior Configuration

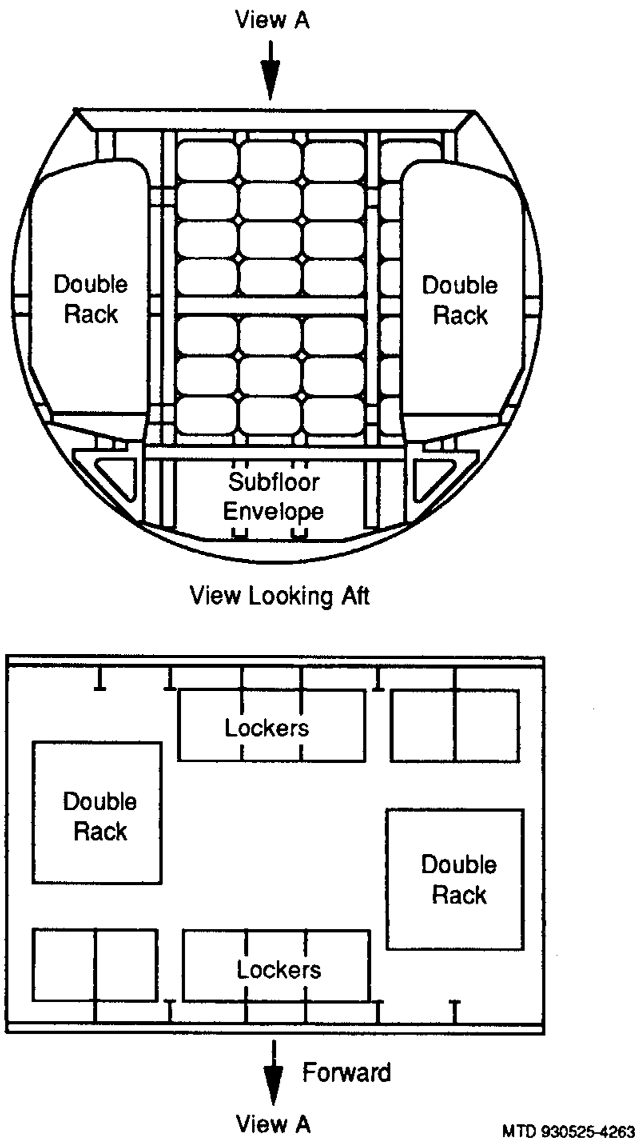


Note: The following Are Located in Orbiter Middeck:

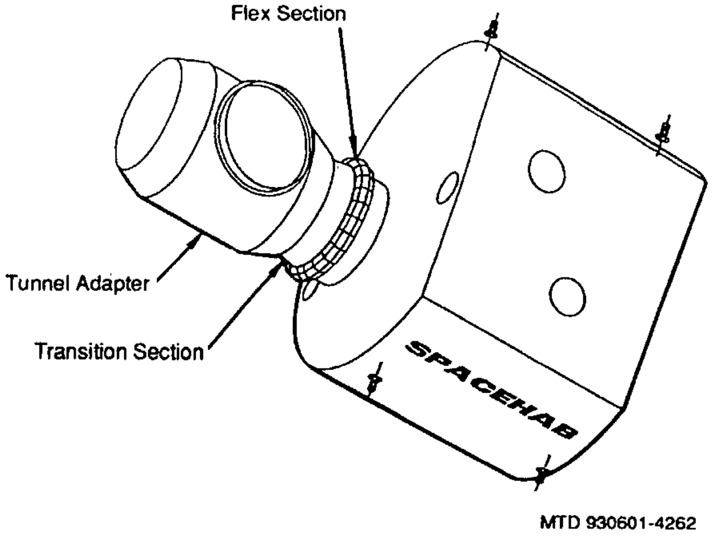
- CPCG (2)
- CGBA (3)
- PSB
- IMMUNE (2)
- BPL

SRE is located on top of the module

SPACEHAB Mission 2 Layout



SPACEHAB Rack-Plus-Locker Configuration (Reference)



SPACEHAB External View

Ten of the 13 SPACEHAB flight hardware packages were produced by Centers for the Commerical Development of Space (CCDS). The CCDS program is the cornerstone of NASA's commerical development of space effort. The nationwide network of centers is designed to increase the private sector's participation and investment in commercial space-related activities, encourage U.S. economic leadership, and stimulate advances in promising areas of research and development. The centers are based at universities and research institutions across the country and benefit from links with their industrial partners, each other, and NASA field centers.

MATERIALS PROCESSING EXPERIMENTS

Equipment for Controlled Liquid-Phase Sintering Experiments (ECLiPSE)

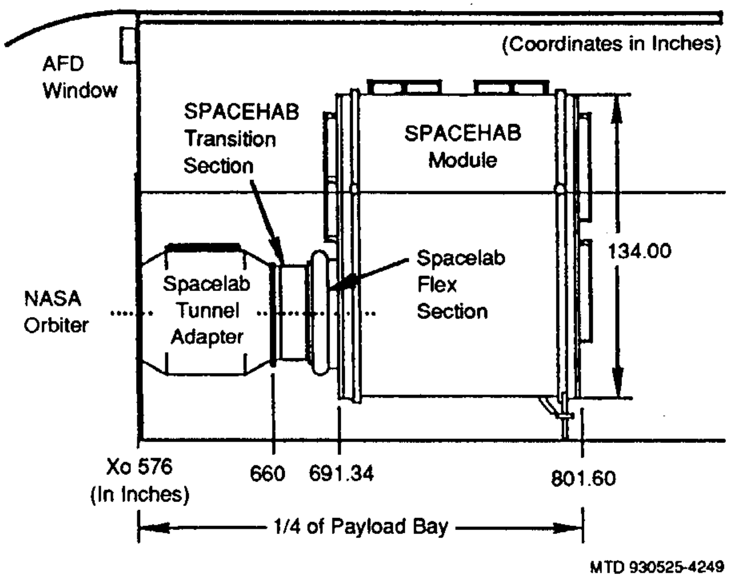
The aim of this project is to develop composites of hard metals in a tough metal matrix. The combined properties of hardness for excellent wear and toughness for strength will create highly desirable new metals that are stronger, lighter, and more durable. The applications for such a composite are numerous—e.g., bearings, cutting tools, electrical brushes, contact points, and irregularly shaped parts for high-stress duty.

ECLiPSE investigates the liquid-phase sintering (LPS) of metallic systems. Sintering is a process by which metallic powders are consolidated into a metal at temperatures 25 to 50 percent lower than those required to melt all of the constituent phases. In LPS on Earth, a liquid coexists with the solid, which can produce sedimentation, resulting in a material that lacks homogeneity and dimensional stability. To control sedimentation effects, manufacturers limit the volume of the liquid. The ECLiPSE experiment will examine metallic composites at or above the liquid volume limit to more fully understand the processes and to produce materials that are dimensionally stable and homogeneous in the absence of gravity (no sedimentation).

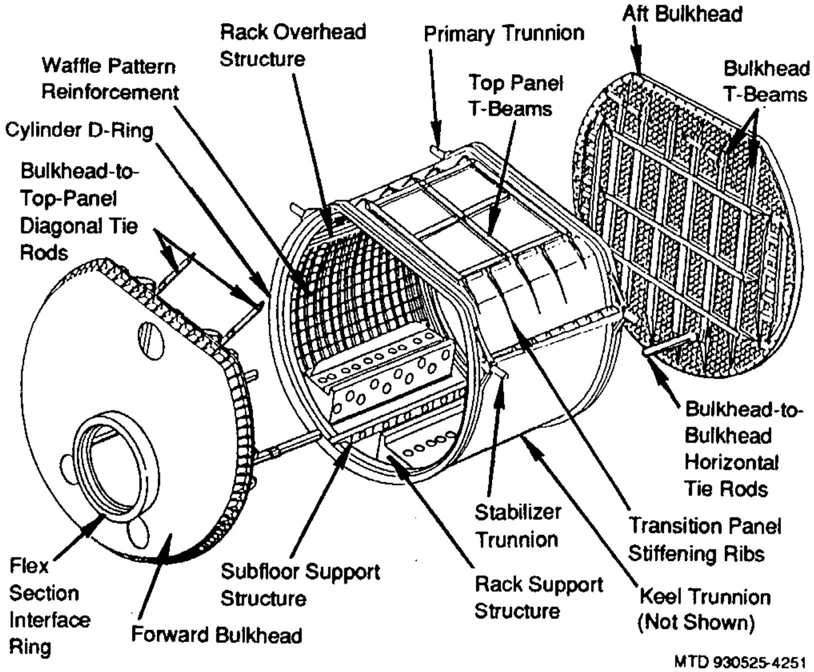
The ECLiPSE unit, which occupies about 60 percent of a single rack, consists of a processing furnace and its support equipment.

In operation, the ECLiPSE payload is first evacuated, pressurized with argon gas, and switched on by the crew. The furnace then autonomously heats to 2,000°F, which is above the melting point of one of the two or more metals in the composite samples. The samples then undergo rearrangement and reprecipitate.

During on-orbit operations, a crew member monitors the indicators on the front of the payload that show the health of the hardware and the progress of the experiment. When the experiment is complete, a crew member connects a payload and general-support com-



Orbiter/SPACEHAB Interface



Module Structure

puter to the unit, downloads the data stored in the ECLiPSE process control computer, and shuts down the experiment.

This shuttle flight builds on the experience of other ECLiPSE flights on suborbital sounding rockets, which provide only one to three minutes of sample processing time. Now the longer flight durations of the shuttle are required. Because the ECLiPSE hardware was originally designed to fly in suborbital rockets, it is very automated and requires little crew interaction.

The Consortium for Materials Development in Space (CMDS), a NASA CCDS based at the University of Alabama in Huntsville (UAH), developed the ECLiPSE equipment. It is planning more sounding rocket tests and future SPACEHAB missions as part of its sintered and alloyed materials project. Kennametal, Inc., and Wyle Laboratories are industrial partners on the project. The principal investigator is Dr. James E. Smith, Jr. of UAH.

Space Experiment Facility

The SEF will use a rack-mounted furnace to try to produce high-quality, uniform crystals of zinc selenide by the physical vapor transport process. It will also provide information on the effects of microgravity on metal liquid sintering.

The SEF has one transparent furnace that can operate at various temperatures up to approximately 900°C. Another furnace has an opaque core design that allows it to reach temperatures of 1,080°C to satisfy higher temperature requirements.

The SEF can process different types of crystals than the ECLiPSE furnace, notably crystals grown from vapor, in transparent ampoules that can be monitored by the crew and adjusted to optimize crystal growth. The ampoules can be moved around inside the furnace to control the applied temperature gradients.

Zinc selenide crystals with improved optical quality are being sought for use in light-emitting diodes, laser windows, gradient index materials, and photoconductors.

Dr. James E. Smith, Jr. of the University of Alabama, Huntsville is the principal investigator. The SEF is managed by the CMDS based at UAH. It was built by the Boeing Commercial Space Development Company.

LIFE SCIENCE EXPERIMENTS

ASTROCULTURE

Growing and tending plants in space will be necessary during long missions to reduce the cost of life support. Plants provide food, oxygen, and water, and they remove carbon dioxide from human space habitats. ASC-3 is a self-contained hydroponic system designed to supply water and nutrients to plants grown in space. STS-60 is the third in a series of test flights to evaluate the system's critical humidification/dehumidification, irrigation, and lighting units. Results are expected to reveal new information about efficient water and nutrient delivery in space and on Earth. Each shuttle flight of ASTROCULTURE adds new capabilities and complexity.

On ASC-1, the concept of supplying water and nutrients to plants was tested. ASC-2 supplied more data on the delivery of water and nutrients and evaluated the use of light-emitting diodes for plant lighting. These concepts were validated by the experiments.

ASC-3 will attempt to validate the concept of controlling temperature and humidity in a closed air loop of the plant growth chamber. The temperature and humidity control unit can humidify and dehumidify the air and recover condensed water without the use of a gas/liquid separator, which all other dehumidifiers used in space today require. The recovered water can be used for cooking and drinking.

Besides the temperature and humidity control unit, the ASC-3 hardware consists of the water and nutrient delivery unit, the LED plant lighting unit, and a microprocessor for control and data acquisition.

No plants are included. It is expected that ASC-4 will test the ability of the units to grow plants.

In orbit, the water supply and recovery systems circulate a nutrient solution through the porous tubes and into the matrix by capillary force. In the matrix, the small pores are filled with the solution and the large pores with air. The recovery system operates at several pressure levels to determine the rate at which the solution moves through the matrix and the capacity of the system to supply the matrix.

ASTROCULTURE is sponsored by the Wisconsin Center for Space Automation and Robotics, a NASA CCDS at the University of Wisconsin in Madison. The principal investigator is Dr. Raymond J. Bula of WCSAR. Industry affiliates include Automated Agriculture Association, Inc., Biotronic Technologies, Inc., Quantum Devices, Inc., and Orbital Technologies Corp.—all based in Wisconsin.

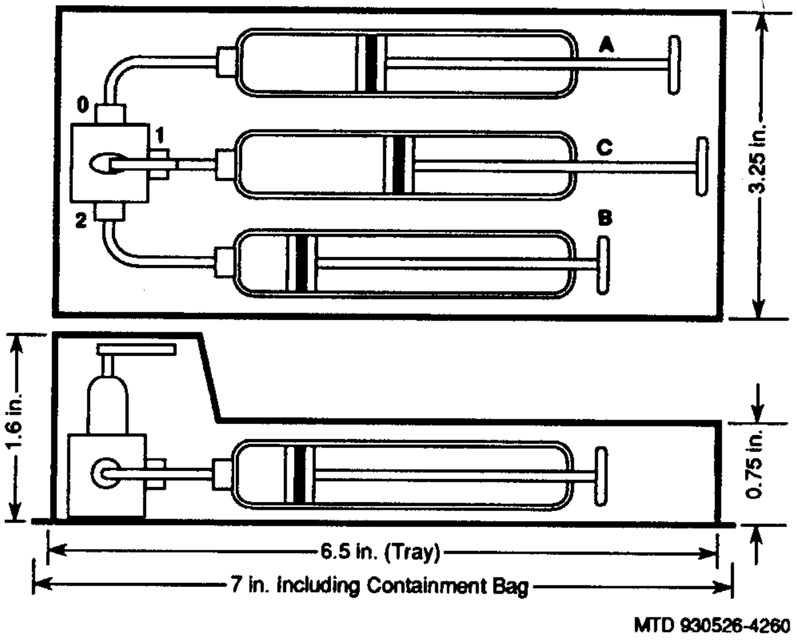
Bioserve Pilot Laboratory

The purpose of Bioserve is to give businesses and scientists affordable access to space for preliminary experimentation in material and life sciences, particularly cell studies. It enables them to prove concepts and screen processes for more complex space research and development. The experiments will study protein crystal growth, collagen polymerization, fibrin clot formation, liquid-solid diffusion, and thin-film membrane formation.

One of the Bioserve experiments will investigate the behavior of the bacterium *Rhizobium trifolii* in microgravity. Rhizobia form a symbiotic relationship with certain plants, such as alfalfa, clover, and soybeans. The bacteria derive nutrients from the plants and provide the plants with nitrogen fixed from the air. The significance is that the plants do not require synthetic fertilizers. Researchers hope to better understand the process by which *Rhizobium trifolii* infect the roots of legumes, which may enable them to manipulate the process to cause the bacteria to infect other crops, such as wheat and corn, that depend on synthetic fertilizers. The savings for fertilizers would be tremendous.

On STS-60, 40 bioprocessing modules stowed in a standard locker will contain the biological sample materials. Each module consists of an aluminum tray holding three syringes: one loaded with the cell culture and two containing fluids to start and end the process.

Controls will be run on the ground simultaneously for most of the investigations. Ground personnel using similar hardware and identical sample fluids will activate and terminate these experiments



Bioprocessing Module

in parallel with the crew, synchronizing their activities with the crew's via the orbiter-to-ground voice link.

Bioserve is sponsored by Bioserve Space Technologies, a NASA CCDS based at the University of Colorado at Boulder. Dr. Louis Stodieck and Dr. Michael Robinson are responsible for mission management.

Commercial Generic Bioprocessing Apparatus

On this, the fourth of six planned flights, the CGBA will support individual commercial studies of biological fluid samples.

Thirty-two commercial investigations will be conducted in three basic areas: biomedical testing and drug development, controlled ecological life support system development, and agricultural development of biological-based materials.

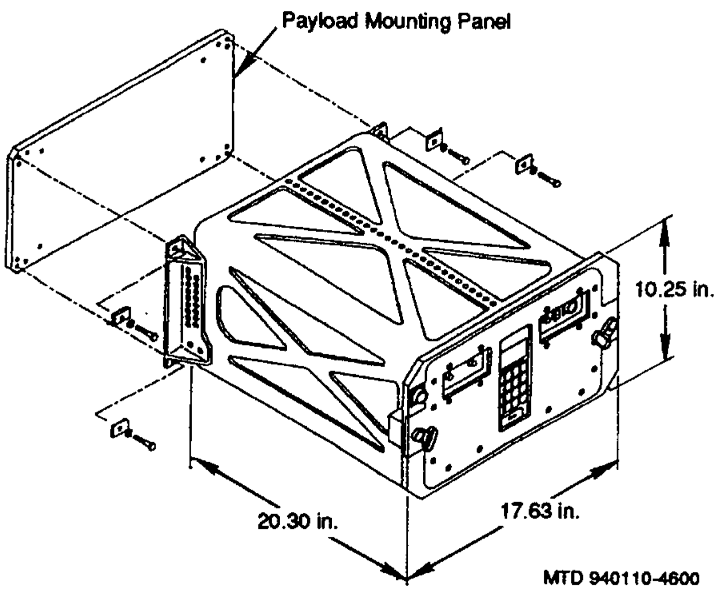
CGBA includes 12 biomedical test models that will investigate immune disorders, bone and developmental disorders, toxicological wound healing, cancer, and cellular disorders. Eleven ecological test systems will yield data on how microgravity affects micro-organisms, small animal systems, algae, and higher plant life.

The payload is sponsored by Bioserve Space Technologies and managed by those responsible for the Bioserve Pilot Laboratory.

Organic Separation

The ORSEP experiment will use a technique unavailable on Earth—phase partitioning—to separate cells, cell fragments, and heavy molecules. The experiment is expected to demonstrate that microgravity greatly enhances the separation process.

A multisample, multistep, fully automated device built by Space Hardware Optimization Technology of Indiana separates nonbiological particles as well as biological cells, particles, macromolecular assemblies, and organelles by partitioning in liquid polymer two-phase systems. The hardware is designed to perform long-duration partitioning in microgravity because two to three hours are required for each separation step.

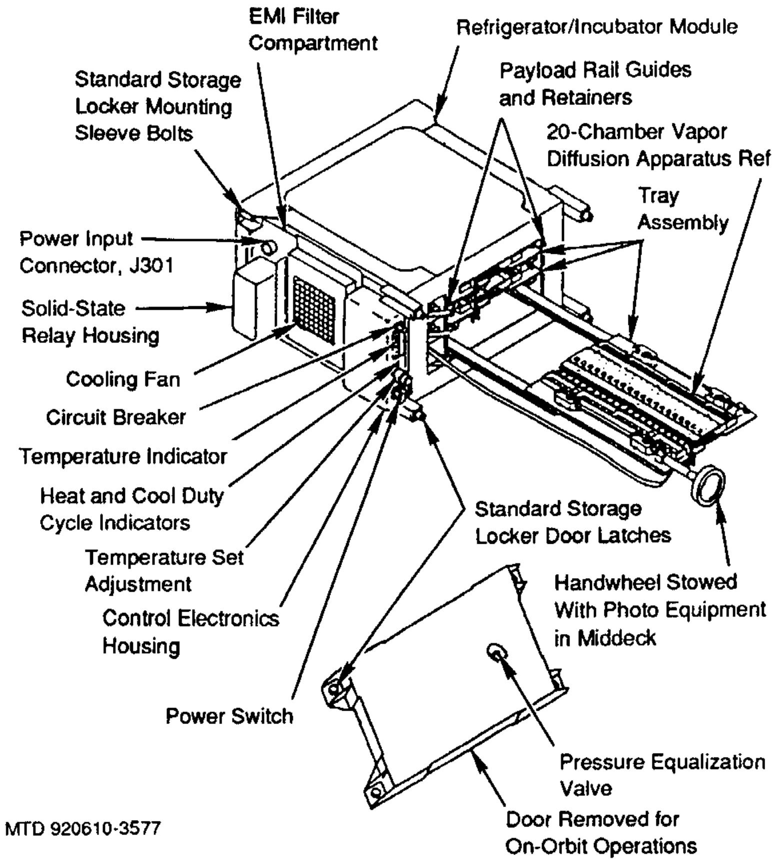


GBA Module

The Consortium for Materials Development in Space, a NASA CCDS based at the University of Alabama in Huntsville, developed the ORSEP payload. The principal investigator is Dr. Robert J. Nauman of the University of Alabama, Huntsville.

Commerical Protein Crystal Growth (CPCG)

This payload will produce large, high-quality crystals of various proteins under controlled conditions in microgravity. Crystals produced in space tend to have more highly ordered structures than crystals produced on Earth. These crystals are needed for crystallographic analysis of the molecular structure of proteins.



PCG Flight Hardware

Proteins play a vital role in areas ranging from nutrition to disease fighting, and scientists want to know how structure causes function. They also want more information to refine the growth of high-quality crystals in space. Potential applications for space-grown protein crystals are numerous: new drugs, agricultural products, and bioprocesses for use in manufacturing and waste management.

The experiment samples are stored in two thermal control enclosures called commercial refrigerator/incubator modules (CRIMs). The CRIMs contain protein crystallization facilities which use changing temperature to produce protein crystals.

A light scattering system has been added to one of the PCFs for this mission to detect crystals at the nucleation stage before they would be visible using ordinary microscopy. The astronauts will be alerted when nucleation begins, and after they know that crystals have formed, the crew members will decrease the rate at which the temperature is changing. The crystals will grow more slowly and more perfectly.

The sponsor of this experiment is the Center for Macromolecular Crystallography at the University of Alabama in Birmingham. The principal investigator is Bob Adams.

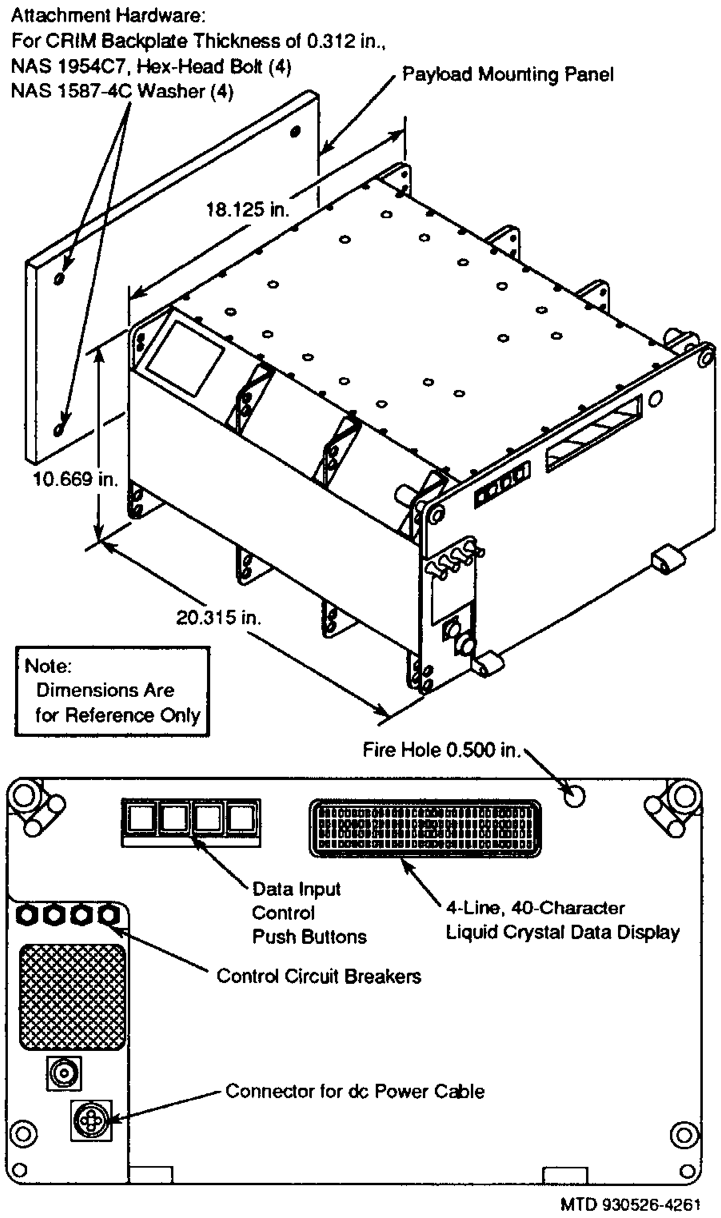
Penn State Biomodule

The PSB experiments will investigate macromolecular assembly, protein crystallization, plant and animal cell physiology and metabolism, aging, and the regulation of gene function. The studies involve biological systems and chemical reactions that require instantaneous mixing.

The PSB will test the hypothesis that exposing microbial genes to microgravity can alter them in commercially useful ways. On this mission, the investigators will study *Bacillus thuringiensis* var. tenebrionis, which is known to be an especially effective bioinsecticide against the Colorado potato beetle.

The PSB consists of eight biomodules that contain eight samples each. The biomodules are housed in a CRIM in the orbiter's middeck.

The bacteria are encapsulated in tiny (30-micron) gel beads. Researchers will use fluorescent markers and a flow cytometer to quantify bacterial growth and product formation in the individual beads. This will enable them to quickly and efficiently identify, iso-



Commercial Refrigerator/Incubator Module Configuration

late, and culture altered bacteria that overproduce or underproduce insect toxins after the flight.

Dr. Zane Smilowitz and Dr. William McCarthy of Penn State University are the principal investigators.

IMMUNE-01

This experiment will measure the immune response of tissue and body fluids of normal rats to microgravity. One group of rodents will be treated with the nontoxic compound polyethylene glycol interlenkin-2 (PEG-IL-2), and the other rats will serve as a control group. Investigators will use the data collected to develop a computer model of human immune system disorders. They also hope to learn whether PEG-IL-2 can be efficacious in preventing or reducing the suppression of immunity during space flight.

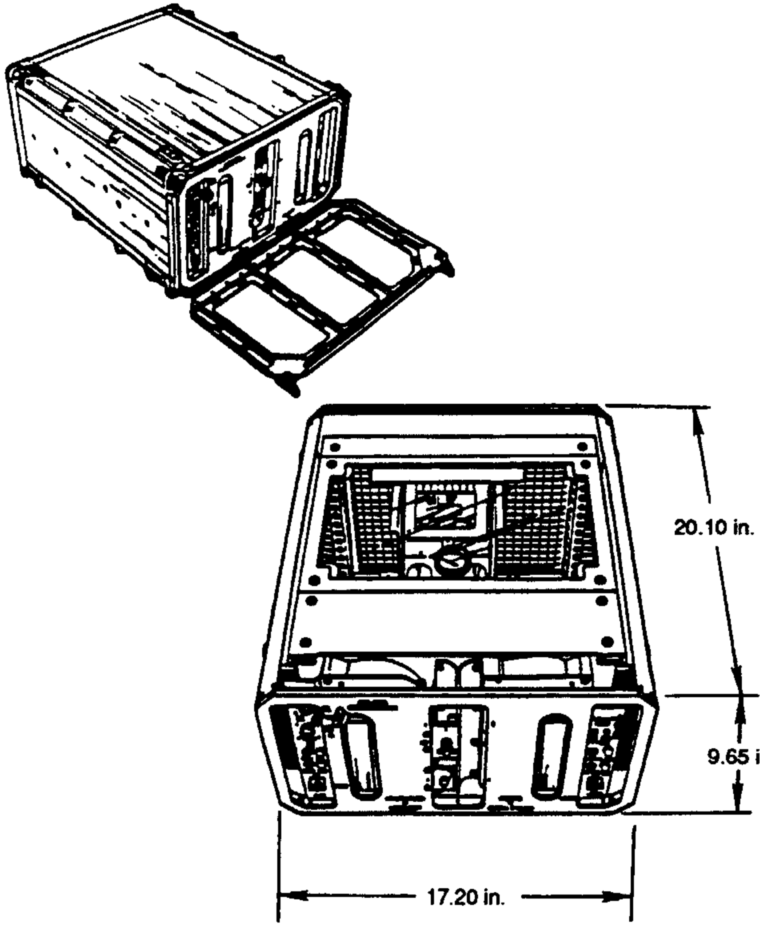
During the flight, the rats will remain in two self-contained modules that provide ventilation, lighting, food, water, and waste management. No handling of the animals is required.

The experiment is sponsored by Bioserve Space Technologies. Dr. Robert Zimmerman of Chiron Corp., the corporate affiliate leading the investigation, is the principal investigator.

MICROGRAVITY MEASUREMENTS

Three-Dimensional Microgravity Accelerometer

Three instruments will measure deviations from zero gravity in three dimensions inside SPACEHAB at different locations so that researchers can determine their effect on experiment results. Mea-



MTD 940110-4599

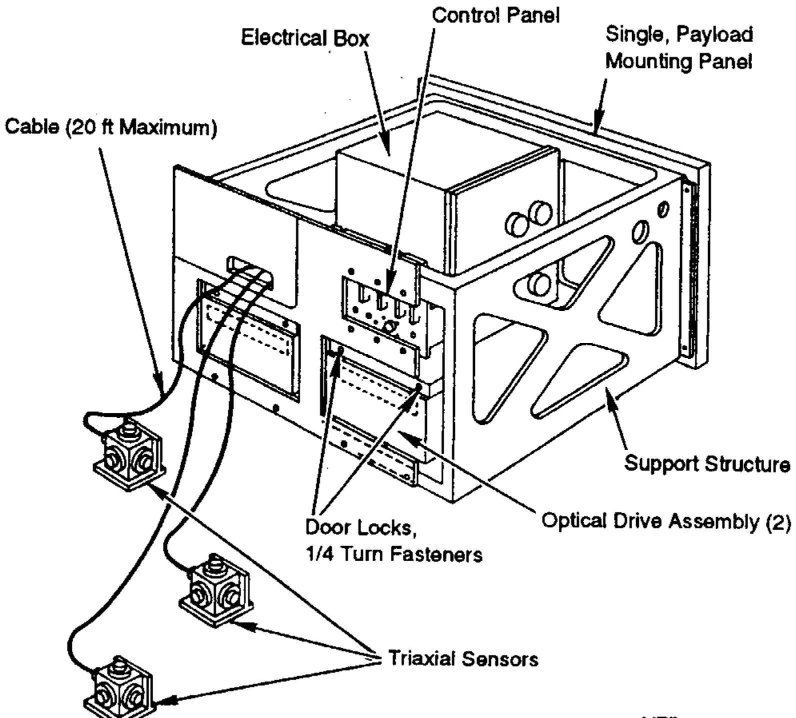
Animal Enclosure Module

surements of disturbances caused by the operation of the experiments, the orbiter's rotational motions, and vehicle drag will be used to calculate the level of SPACEHAB microgravity.

The Consortium for Materials Development in Space, a NASA CCDS based at the University of Alabama in Huntsville, is the sponsor of this payload. Jan Bijvoet of the University of Alabama is the principal investigator.

Space Acceleration Measurement System

SAMS will measure low-level accelerations caused by experiment operation, amplify the sensor signals, convert them to digital data, and store them on optical disks for downlink to a ground control center. There, scientists and principal investigators of SPACEHAB experiments will review the data for events that could affect their experiment results. This information, and data from previous missions, will be used to reduce and isolate experiment disturbances on future missions, including space station research projects.



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SAMS Hardware

SAMS is sponsored by NASA's Lewis Research Center, which also designed and developed the hardware.

SAMPLE RETURN EXPERIMENT

The objectives of the Sample Return Experiment are to collect cometary-like particles, qualify the SRE hardware, and develop techniques for handling the particles. Unlike the other SPACEHAB experiments, SRE is located outside the pressurized envelope of the module and orbiter cabin. It consists of two 80-by-100-cm panels mounted on the roof of the SPACEHAB module. The 80 silica aerogel cells on each panel are designed to capture cosmic dust.

The Jet Propulsion Laboratory is sponsoring this experiment. Dr. Peter Tsou is the principal investigator.

STIRLING ORBITER REFRIGERATOR/FREEZER

The SOR/F is being flown as part of the SPACEHAB payload to obtain information about its operation in microgravity. If the technology works, the SOR/F will replace vapor compression systems, which have had marginal reliability and lower theoretical efficiencies. The Stirling system uses environmentally benign helium as its working fluid and can be chilled quickly. Its capacity is easily varied and its motor is hermetically sealed within the fluid loop, which prevents leaks.

The SOR/F is the size of two standard lockers. The refrigerator/freezer has a volume of 1 cubic foot. The unit's temperature set points range from -22°C to 10°C.

The SOR/F was developed under the auspices of the Life Sciences Project Division at the Johnson Space Center in Houston.

Commercial Generic Bioprocessing Apparatus Investigations

Commercial Opportunity	Principal Investigator's Affiliation	Process/Product Development	Experiment Description
BIOMEDICAL TESTING AND DRUG DEVELOPMENT			
Immune disorders	University of Alabama, Huntsville	Lymphocyte induction process	Examines immune system's ability to respond to infectious materials
	Kansas State University	T-cell induction test model	Examines immune system's ability to respond to infectious materials
		TNF-mediated cytotoxicity test model	Examines immune cells' ability to kill infectious cells
		Bone marrow cell culture test system	Studies bone marrow cultures in microgravity
Bone disorders	Kansas State University	Bone organ culture test model	Studies the effects of microgravity on bone development
Development disorders	Kansas State University	Pancreas and lung development tests	Examines organ development in microgravity
		Brine shrimp test system	Examines brine shrimp development in microgravity
Cancer	Kansas State University	Inhibitor protein test model	Studies inhibition of cell division processes
Cellular disorders	Kansas State University	Gap junction processes	Investigates ability of protein channels to pass materials through cell membranes
	University of Colorado	Cell division processes	Studies stimulation of cell division processes
Toxicological testing	Kansas State University	Brine shrimp test system model	Examines ability of brine shrimp to be used for toxicity tests
	University of Colorado	Miniature wasp test system model	Examines ability of miniature wasps to be used for toxicity tests
ECOLOGICAL TEST SYSTEMS			
Closed agriculture systems	University of Colorado	Seed germination products	Studies seed germination in microgravity
	Kansas State University	Seedling processes	Examines seeding processes in microgravity
	University of Colorado	Miniature wasp test system	Investigates miniature wasp development in microgravity
	Kansas State University	Bacterial nitrogen fixation model	Studies important symbiotic relationships between bacteria and plants
	University of Colorado	Plant tissue culture processes	Studies secondary metabolic production during space flight
	University of Colorado	Plant bacterial infection processes	Studies important symbiotic relationships between bacteria and plants
Waste management	University of Colorado	Bacterial products and processes	Studies bacterial products and processes in microgravity
	Kansas State University	Bacterial products and processes	Studies bacterial products and processes in microgravity
	Kansas State University	Bacterial products and processes	Studies important symbiotic relationships between bacteria and plants
	University of Colorado	Bacterial colony test system	Studies bacterial colony products and processes in microgravity
Microbial controls	Kansas State University	Zirconium perioxide product testing	Examines effectiveness of zirconium peroxide as a decontaminant
BIOMATERIALS PRODUCTS AND PROCESSES			
Drug delivery system	Kansas State University	Virus capsid product	Evaluates assembly of virus shells
Drug development	University of Colorado	Protein crystal morphology products	Growth of large protein crystals
		RNA crystal growth products	Growth of large RNA crystals
Data mass storage	Syracuse University	Bacteriorhodopsin biomatrix products	Formation of more homogeneous bacteriorhodopsin gels for use as mass data storage devices
Synthetic implants	University of Colorado	Fibrin clot materials	Use of fibrin clot materials as a model of potentially implantable materials
		Collagen materials	Use of collagen as a model of potentially implantable materials
Pharmaceutical development	University of Colorado	Taxol culture model	Investigates the production of taxol in microgravity
Drug development	University of Colorado	Bacterial drug resistance	Investigates the effects of microgravity on drug resistance
		Yeast reproduction	Investigates the use of yeast as drug producers

Commercial Biotechnology Experiments Overview

Experiment	Sponsor	Affiliates	Experiment Description	Potential Commercial Applications
ASTROCULTURE	Wisconsin Center for Space Automation and Robotics, Madison, Wis. (CCDS)	Automated Agriculture Assoc., Inc., Biotronics, Technologies, Inc., Quantum Devices, Inc., Orbital Technologies Corp.	Validates technologies for supplying water and nutrients to plants growing in microgravity and providing a controlled environment	Development of an enclosed environmental system with Earth-based and space-based uses, including improved dehumidification/humidification and energy-efficient lighting
Penn State Biomodule	Center for Cell Research (CCR), St. College, Pa. (CCDS)	Novo Nordisk Entotech, Inc.	The biomodule is a computer-controlled, fluid transfer, mixing device. The microbes studied in the biomodule are specifically effective on the Colorado potato beetle	Improvement of environmentally friendly pest-control agents
Bioserve Pilot Laboratory (BPL)	Bioserve Space Technologies, Boulder, Colo. (CCDS)	Abbot Labs, Alza, Aquatic Products, Chiron, Martin Marietta, Spaceport Florida Authority, Synchrocell	Determines the response of cells to various hormones and stimulating agents in microgravity	Development of next-generation drugs and space-grown polymers
Commercial generic Bioprocessing Apparatus (CGBA)	Bioserve Space Technologies, Boulder, Colo. (CCDS)	Abbot Labs, Aquatic Products, Chiron, Martin Marietta, Omni-Data, Spaceport Florida Authority, Synchrocell, Water Technologies	Processes biological fluids by mixing components in a microgravity environment	Improvement of bioimplantable products, immune disease research and waste management systems
IMMUNE	Bioserve Space Technologies, Boulder, Colo. (CCDS)	Chiron Corp.	The IMMUNE-01 experiment is a study of 12 rats. The drug PEG-IL-2 will be used in an attempt to alleviate the immunosuppression induced by the environment	The experiment may provide a new therapy to treat the effects of space flight on the human immune system as well as on physiological systems affected by the immune system
Organic Separation (ORSEP)	Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)	Interfacial Dynamics Corp., Space Hardware Optimization Technology, Inc.	Explores the use of phase separation techniques in microgravity conditions to separate cells, cell fragments, and heavy molecules	Improvement of techniques for processing pharamaceutical and biotechnology products
Commercial Protein Crystal Growth (CPCG)	Center for Macromolecular Crystallography, Birmingham, Ala. (CCDS)	Medical Foundation of Buffalo	Growth of high-quality protein crystals in microgravity using temperature as the primary controlling factor in crystallization. One of the two systems uses laser light scattering techniques to monitor crystallization for enhanced control	Acceleration or enabling of drug research and development using or requiring crystallography to determine molecular structure

Supporting Hardware Overview

Hardware	Sponsor	Hardware Operation	Potential Applications
3-Dimensional Microgravity Accelerometer (3-DMA)	Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)	Measure accelerations in three axes within SPACEHAB to record the microgravity levels experienced during the flight	Characterization of low-gravity environment of the SPACEHAB space research laboratory and the acquisition of acceleration data to support experiment data analysis. Two different systems are being flown to satisfy different program objectives and to correlate the data obtained by the two systems. This also allows the comparison of the data with data gathered on other flights where only one or the other system has been flown
Space Acceleration Measurement System (SAMS)	NASA Lewis Research Center, Cleveland, Ohio		

SPACEHAB 2 Technology Development Overview

Hardware	Sponsor	Hardware Operation	Potential Applications
Stirling Orbiter Refrigerator Freezer (SOR/F)	NASA Johnson Space Center, Houston, Texas	Flight test and characterization of advanced refrigerator/freezer technology in microgravity	Enhanced refrigerator/freezer capability to support biotechnology, life sciences, and other investigations on orbit

SPACEHAB 2 Commercial Materials Processing Experiments

Experiment	Sponsor	Affiliates	Experiment Description	Potential Commercial Applications
Equipment for Controlled Liquid-Phase Sintering Experiment (ECLiPSE)	Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)	Wyle Laboratories, Kennametal, Inc.	Uses a rack-mounted, enclosed furnace assembly to investigate controlled liquid-phase sintering of metallic systems in microgravity	Development of stronger, lighter, more durable bearings, cutting tools, electrical contact points, and irregularly shaped parts for high-stress environments
Space Experiment Furnace (SEF)	Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)	Boeing Commercial Space Development Company, McDonnell Douglas Aerospace	The SEF can accommodate three furnaces in one unit. This flight will carry one transparent furnace and one opaque core furnace	The opaque furnace will be used for a sintered and alloyed materials project. The transparent furnace will be used by the Clarkson CCDS for cadmium-telluride crystal growth

GETAWAY SPECIAL PROGRAM

With this mission, NASA is celebrating a milestone in its Getaway Special program—the flight of the 100th GAS payload. Ninety-seven payloads were flown on the first 19 GAS missions. The 100th GAS payload is a NASA Headquarters and Lewis Research Center project called the Pool Boiling Experiment.

"The program works as planned," said Clarke Prouty, GAS mission manager. The program affords the average person a chance to perform small experiments in space. It enhances education by making opportunities for hands-on space research available and generates new activities unique to space. Customers also are able to inexpensively test ideas that could later grow into major space experiments.

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

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

The GAS program began in 1982 and is managed by the Goddard Space Flight Center, Greenbelt, Md.

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

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

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

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

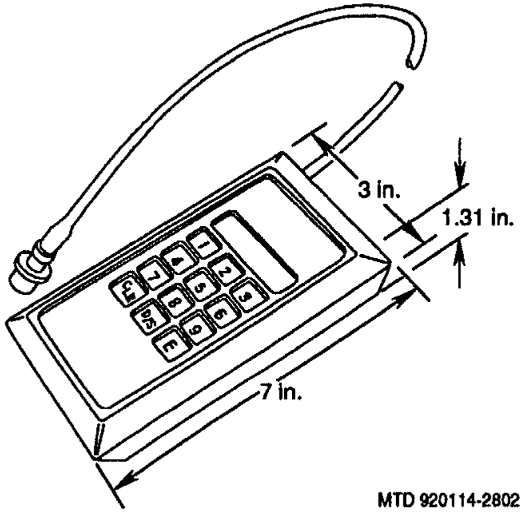
The cost of this unique service depends on the size and weight of the experiment. Getaway specials of 200 pounds and 5 cubic feet cost $10,000; 100 pounds and 2.5 cubic feet, $5,000; and 60 pounds and 2.5 cubic feet, $3,000. The weight of the GAS container, experiment mounting plate and its attachment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

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

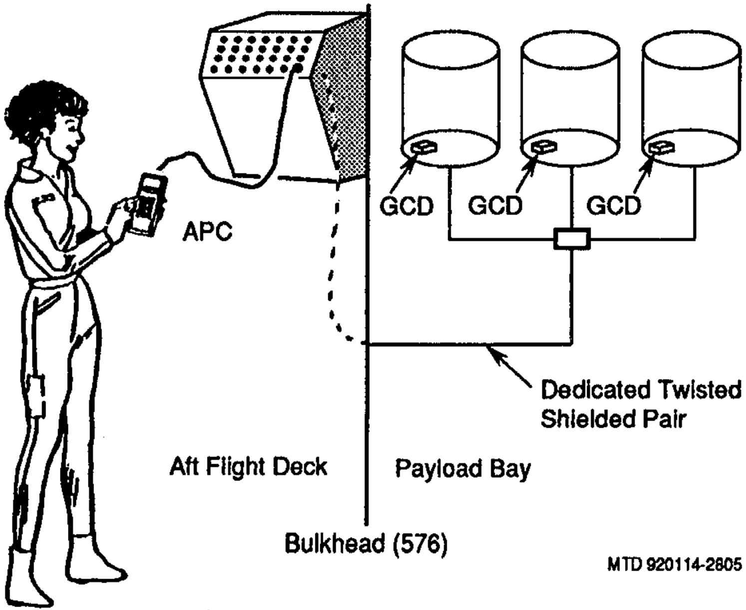
The GAS container is made of aluminum, and the circular end plates are 0.625-inch-thick aluminum. The bottom 3 inches of the container are reserved for NASA interface equipment, such as command decoders and pressure regulating systems. The container is a pressure vessel that can be evacuated before or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

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

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



GAS Autonomous Payload Controller



Getaway Special Control Concept

STS-60 GETAWAY SPECIAL BRIDGE ASSEMBLY EXPERIMENTS

Discovery will be carrying four getaway special payloads when it lifts off from the Kennedy Space Center—the 98th, 99th, 100th, and 101st since the program began in 1982. Along with the four GAS payloads, the GAS bridge assembly will also carry two other payloads.

The GAS payloads are the Pool Boiling Experiment (G-536), the Capillary Pumped Loop Experiment (G-557), the Orbiter Ball Bearing Experiment (G-071), and the Orbiter Stability Experiment (G-514). The other payloads are the Orbital Debris Radar Calibration Spheres and the University of Bremen Satellite.

UNIVERSITY OF BREMEN SATELLITE

BREMSAT is a small deployable satellite that is intended as a low-cost orbiting platform for small experiments. The 140-pound satellite will be deployed from its GAS canister, which is equipped with an ejection system.

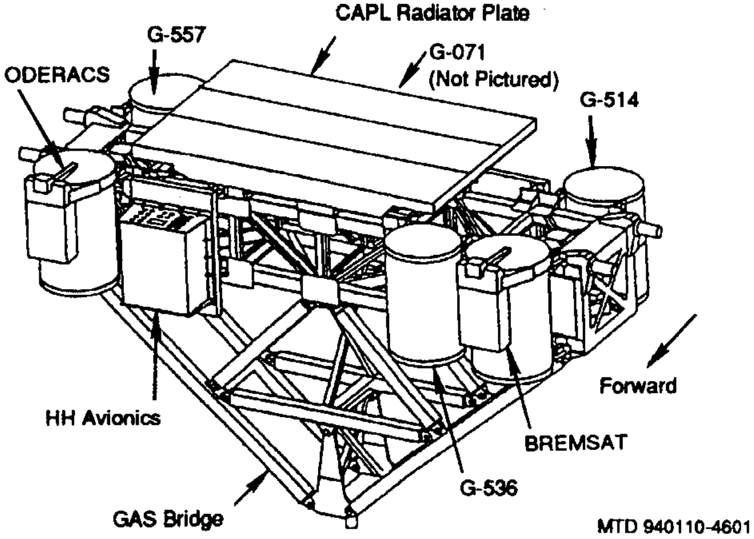
BREMSAT will carry six scientific experiments that will be conducted before and after the satellite is deployed and as the satellite reenters the Earth's atmosphere. Two of the experiments will study the thermal conductivity of solutions and residual acceleration forces to estimate the in-orbit microgravity quality on board the satellite before the satellite is deployed. During the orbital phase, other experiments will investigate the density distribution and dynamics of micrometeorites and dust particles in low Earth orbit, map atomic oxygen, and measure the exchange of momentum and energy between the molecular flow and the rotating satellite. The sixth experiment will measure pressure and temperature and residual accelerations for as long as possible before the satellite burns up when it reenters the atmosphere.

BREMSAT was built by the University of Bremen's Center of Applied Space Technology and Microgravity under the sponsorship of the German space agency, DARA.

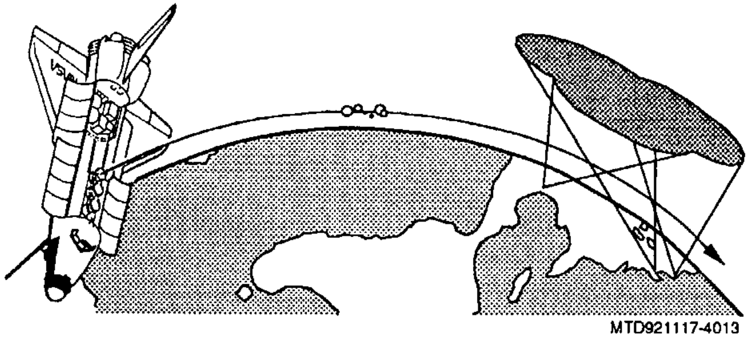
ORBITAL DEBRIS RADAR CALIBRATION SPHERES

The primary purpose of this experiment is to enable scientists to fine-tune Earth-based radar and optical instruments so they can keep better tabs on the thousands of pieces of man-made space junk orbiting the Earth. Of the approximately 6,500 artificial objects in space catalogued by the U.S. Air Force, only 6 percent are functional satellites; the rest are debris, some of it as small as 10 centimeters in diameter.

Since objects smaller than 10 centimeters can damage spacecraft, NASA would like to be able to locate, characterize, and track



Getaway Special Bridge and Payloads

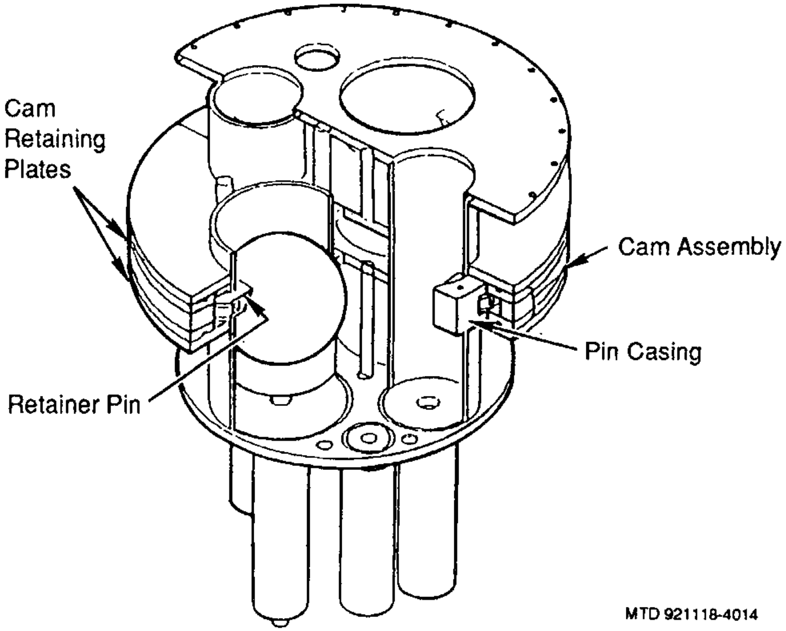


Deployment of ODERACS Calibration Spheres

accurately space debris as small as 1 millimeter so that adequate shielding can be designed for the U.S. space station, which is planned to be assembled in low Earth orbit later in this decade. More accurate information about the size of orbital debris and its distribution would also mean the station would have to make fewer maneuvers to avoid any debris that its shielding cannot protect it against. This experiment is expected to give NASA greater confidence in its ability to characterize the orbital debris environment.

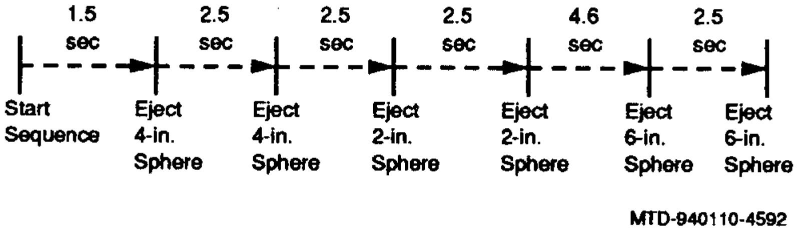
For this experiment, six metal spheres—two 6 inches in diameter, two 4 inches in diameter, and two 2 inches in diameter—will be ejected from the payload bay of the shuttle on its 97th orbit of the Earth. The spheres will pass over several radars and optical telescopes located around the world. These facilities will detect and analyze the spheres, and the data gathered will be used to verify the accuracy of the debris-tracking instruments and their data collection and analysis systems.

The ODERACS ejection system fits inside a 5-cubic-foot getaway special (GAS) canister that is mounted on the GAS bridge assembly. The spheres are held in cylinders by cam-operated retainer pins. Springs eject the spheres from the cylinders when the retainer pins are retracted by rotating the cam.

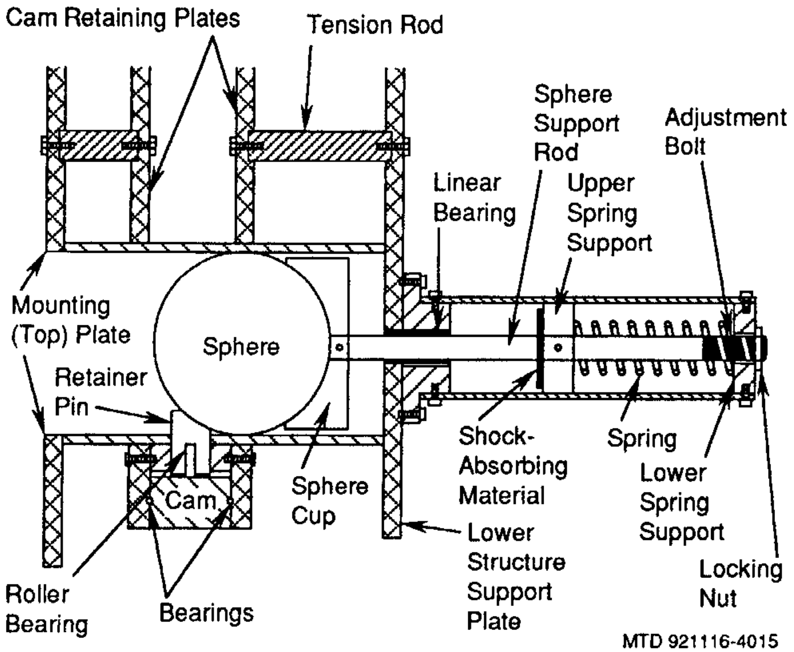


ODERACS Ejection System

From the aft flight deck of the orbiter, a crew member will initiate the deployment of the spheres. The crew member will visually



ODERACS Ejection Sequence



ODERACS Ejection System Mechanism

verify that the GAS canister's door opens, the spheres are released, and the canister door closes.

Scientists will calibrate their instruments by comparing the known dimensions, compositions, reflectivity, and electromagnetic scattering properties of the six spheres to empirical optical and radar debris signatures.

The 2- and 4-inch spheres are made of solid stainless steel and have a polished finish. The smaller sphere weighs 1.17 pounds and the larger one weighs 9.36 pounds. The 6-inch spheres are made of solid aluminum and weigh 11 pounds. The surface of the 6-inch spheres has been sandblasted to a matte finish to allow scientists to make reflectivity and phase function comparisons.

The useful life of the 2- and 6-inch spheres is about 45 days. After about 65 days in orbit, they will reenter the atmosphere and burn up. The 4-inch spheres are expected to have a longer useful life of about 70 days. They will reenter the Earth's atmosphere after about 120 days in space and burn up.

After they are deployed, the calibration targets will pass through the Eglin Air Force Base FPS-85 radar fence and within the Millstone radar coverage on the same orbit. Alternatively, the spheres may make a descending pass through Millstone coverage followed by a pass through the Eglin coverage within one orbit or (least desirable) an ascending pass through the Kwajalein coverage to Millstone coverage on the same orbit.

The ODERACS payload was flown on the STS-53 mission in December 1992, but it could not be deployed because of an equipment malfunction.

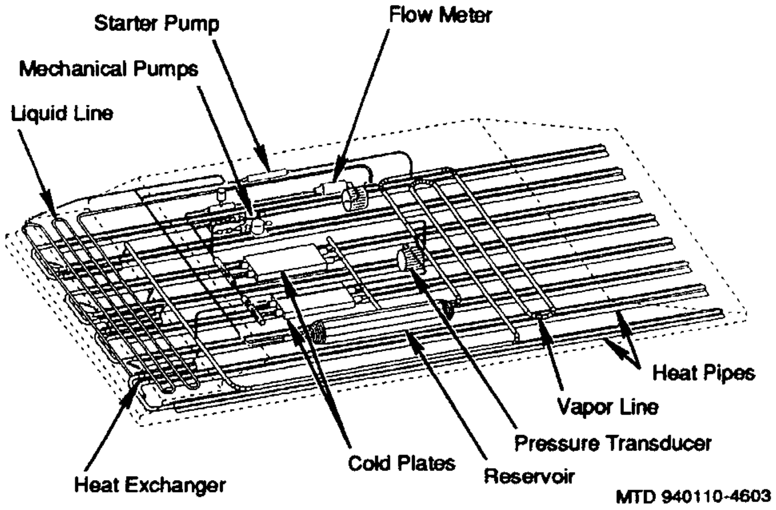
The ODERACS experiment is a project of the Space Sciences Branch of the Solar System Exploration Division at JSC.

CAPILLARY PUMPED LOOP (CAPL)

This experiment will study the behavior of a full-scale capillary pumped loop heat transfer system in space. Researchers will evaluate the CAPL's fluid management reservoirs, cold plates, and heat pipe heat exchangers and will compare data on the behavior of a capillary pumped loop in microgravity with analytical predictions and the performance of Earth-based capillary pumped loops.

The capillary pumped loop is a sealed, pressurized loop that absorbs and carries heat from evaporators to condensers. The CAPL contains no mechanical moving parts; all of the pumping of heat is done by capillary forces. The unit is a prototype of the thermal control system that NASA plans to use on the Earth Observing System.

The CAPL heat transfer unit is mounted on top of the GAS bridge. The 425-pound assembly contains all of the heat rejection



CAPL Experiment Assembly

and fluid systems for the CAPL. Pumping action is produced by high-density polyethylene wick inserts in the capillary pumps inside two identical cold plates. Fifteen 50-watt heaters inside each cold plate simulate the heat loads equipment would generate.

The CAPL transfers heat from the cold plates to the heat pipe heat exchangers. Dual capillary pumps in the cold plates move ammonia (and heat). The heat vaporizes the ammonia, and the vapor travels down an 8-meter-long line to the heat exchangers, which transfer the heat to four sets of heat pipes. The heat is then radiated to space, and the ammonia vapor is cooled by the heat exchangers, causing it to condense. The liquid ammonia then travels back to the cold plates.

ORBITER BALL BEARING

A team of researchers from the Aerospace Group at California State University in Northridge is hoping to produce the world's first seamless hollow ball bearing during this mission by melting a metal pellet and resolidifying it in space. Hollow ball bearings are expected to have an improved service life rating, which would permit higher speeds and higher load applications and may reduce the friction encountered by ball bearings in normal operation.

At a predetermined point in the mission, a crew member will activate the experiment and melt several metal pellets that are encased in wax. As the container cools, the pellets are expected to form perfect spheres, and the melted wax will solidify around the spheres, forming a protective package for the return to Earth.

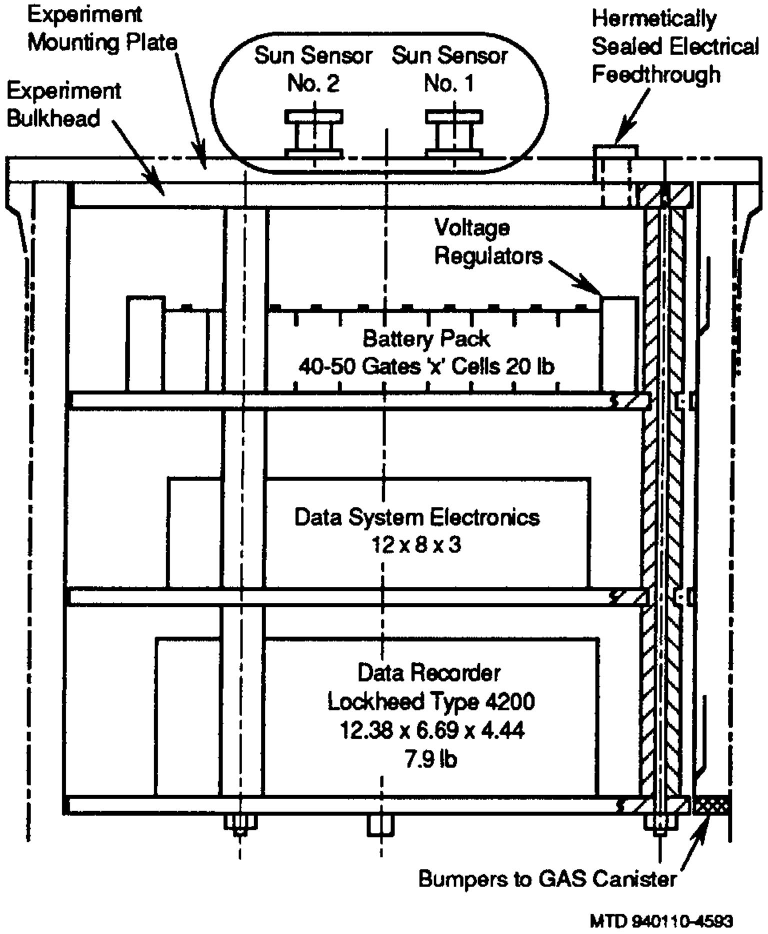
ORBITER STABILITY

This Goddard Space Flight Center experiment will measure any high-frequency vibrations that occur in the orbiter's structure during routine in-flight operations. Vibrations caused by minor orbiter disturbances, such as normal crew activities, could limit the imaging performance of fine-pointed optical instruments that are mounted directly to the orbiter in the cargo bay. The experiment will obtain data on the stability of the orbiter by using solar sensors to detect and record deviations of the orbiter's line of sight from solar inertial pointing.

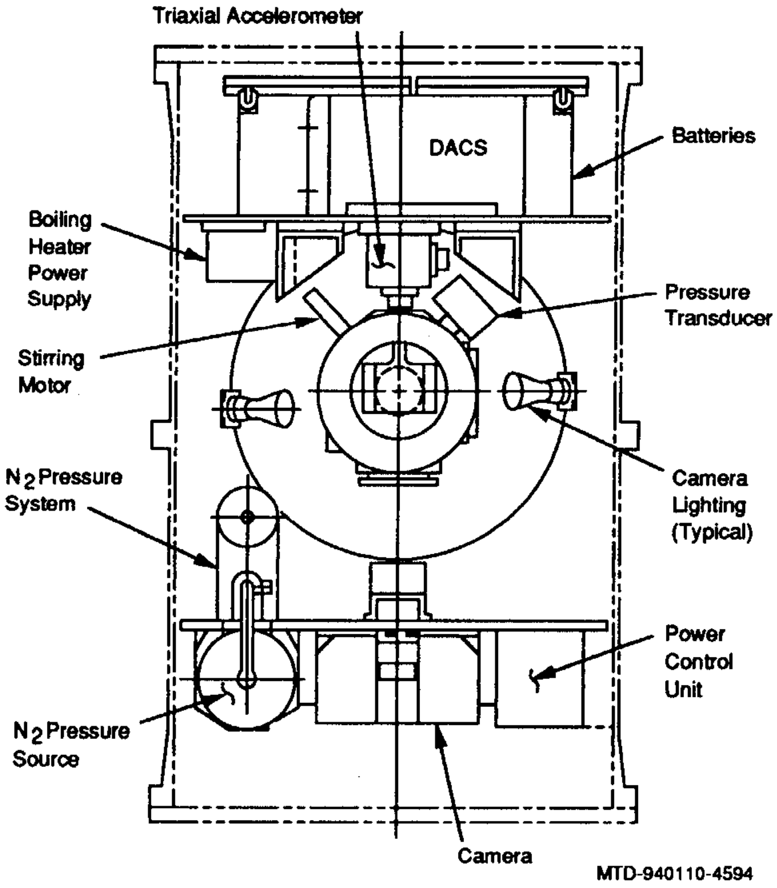
Two student experiments will be flown piggyback with the Goddard experiment. Students from Morgan State University in Baltimore and Howard University will fly over-the-counter medications to evaluate their potency after exposure to microgravity. Native American high school students from South Dakota who are part of NASA's Scientific Knowledge for Indian Learning and Leadership program will be conducting an experiment on the effects of zero gravity on seeds.

POOL BOILING EXPERIMENT

This is the third flight for this Lewis Research Center experiment, which is designed to improve the understanding of the boiling process by bringing a pool of liquid into contact with a surface that heats the liquid. The experiment will collect data on heating and vapor bubble dynamics associated with the growth and collapse of bubbles and the subsequent motion of bubbles. The lack of gravity-driven motion in space makes it easier to study boiling.



G-514 Payload Configuration



G-536 Payload Configuration

AURORAL PHOTOGRAPHY EXPERIMENT B

The Auroral Photography Experiment (APE) B is an Air Force-sponsored payload designed to photograph and record the spectra of airglow aurora, auroral optical effects, irradiation effects, the shuttle glow phenomena, and orbiter OMS exhaust plume emissions and port and starboard yaw thruster firings using the imaging, Fabry-Perot, and spectrometer modes of still photography and on-board CCTV cameras, whose images will be recorded on two video cassettes. The data collected during the experiment will be used to develop target acquisition models for space-based sensor systems. Only aurora and airglow will be studied on STS-60.

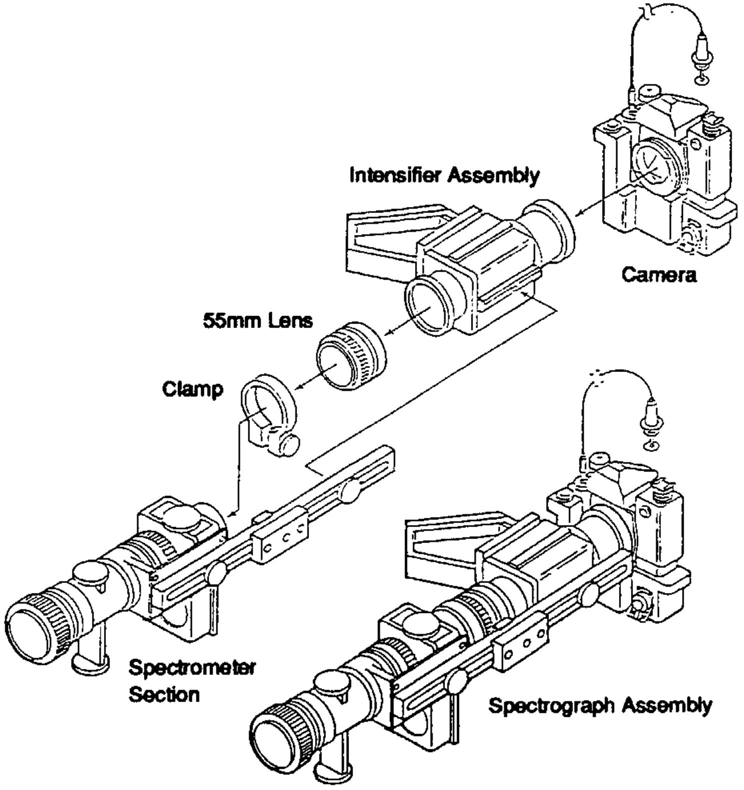
APE-B will also be used during the nighttime Wake Shield Facility CHAWS runs to investigate the shuttle glow phenomenon on the WSF Langmuir probe.

APE hardware can be assembled in three basic experiment configurations to support various objectives. This experiment will be conducted in the imaging mode of photography (hardware configuration 1) as well as in the Fabry-Perot (hardware configuration 2) and spectrometer (hardware configuration 3) modes.

APE-B hardware consists of a Nikon 35mm camera, 55mm lens, shroud adapter, Noctron V image intensifier, Fabry-Perot filter/lens, spectrometer, filter carrier, filters, spare AA batteries, and film. The hardware will be mounted on the aft flight deck using the APE window mount. A "witch's hat" shroud and shroud adapter will be used to block light from the crew compartment.

The experiment will be operated by the flight crew at predetermined times throughout the mission.

APE-B photography will occur with Discovery in darkness and with minimal moonlight, with the payload bay lights off, and with the crew cabin darkened or the windows covered. No water dumps or fuel cell purges should be scheduled during any data collections, and it is desirable that the orbiter flash evaporator system (FES) not be operated during photographic sessions. Shuttle glow and window effects data are collected for a number of different orientations of the window and orbiter surfaces relative to the orbiter ram and wake directions.



MTD-940110-4598

APE-B

SHUTTLE AMATEUR RADIO EXPERIMENT II

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

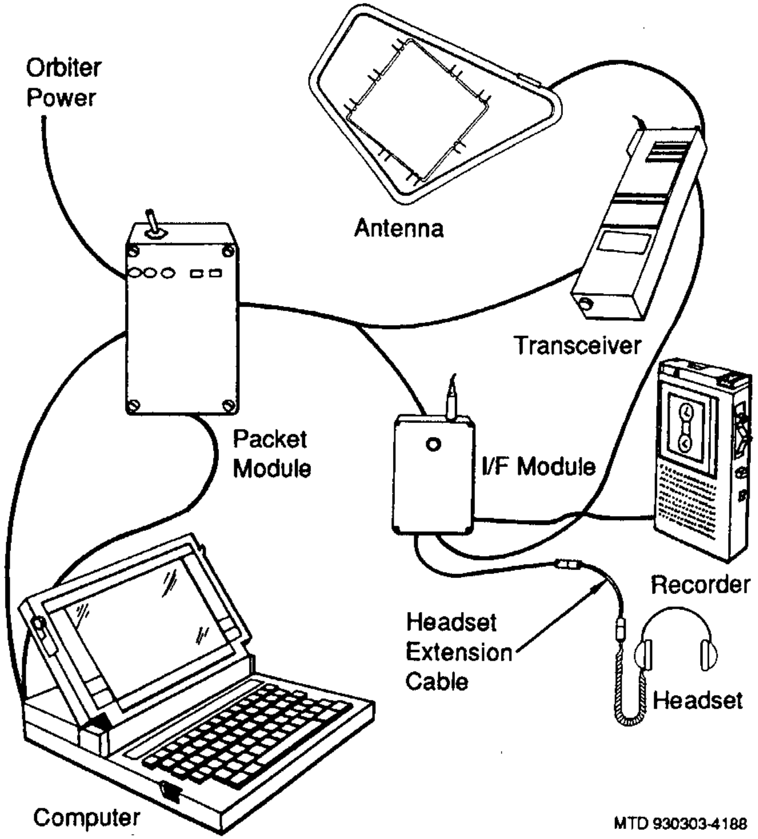
SAREX has been flown on missions STS-9, -51F, -35, -37, -45, -50, -47, -56, -55, -57, and -58 in different configurations. Configuration C will be flown on STS-60. The equipment complement is stowed in one and one-half middeck lockers.

SAREX communicates with amateur stations within Discovery'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 crew members who are licensed amateur radio operators. Shuttle commander Charles Bolden (license pending) and mission specialists Ronald Sega (license pending) and Sergei K. Krikalev (call sign U5MIR) will talk with students in five schools in the U.S. and Russia on ham radio.

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

- Boise Senior High School, Boise, Idaho (WA7QKD)
- Chariton High School, Chariton, Iowa (KB0IWE)
- James Bean School, Sidney, Maine (N1IFP)
- Mars Area Middle School, Mars, Pa. (N3HKN)



SAREX Optional Configuration

- House of Science and Technology for Youth, Central Moscow, Russia (UA3CR)

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

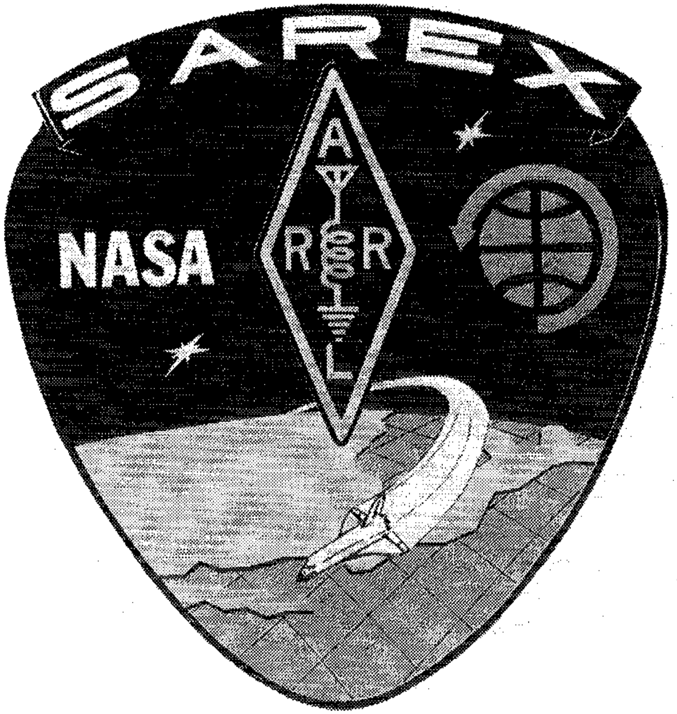
Ham operators may communicate with the shuttle by using 2-meter digital packet (automated computer-to-computer) and VHF FM voice transmissions, a mode that makes contact widely available without the purchase of more expensive equipment.

The primary frequencies intended for use during the mission are 145.55 MHz for downlink from Discovery and 144.91, 144.93, 144.95, 144.97, and 144.99 MHz for uplink (except Europe). The voice uplink frequencies for Europe only are 144.70, 144.75, and 144.80. The astronauts will not favor any one of these frequencies. Therefore, to talk to an astronaut, ham operators will have to select one of the frequencies chosen by the astronaut. A spacing of 600 kHz was deliberately chosen for this primary pair to accommodate those whose split-frequency capability is limited to the customary repeater offset. Digital packet will operate on 145.55 MHz for downlink transmission and 144.49 MHz for uplink transmission.

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

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

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



SAREX Insignia

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

RADIOBIOLOGICAL EFFECTS (DSO 200)

Dosimetry measurements are necessary in order to quantify the exposure of crew members to ionizing radiation and the risk from such exposure. Measurements taken throughout the crew compartment will provide the data necessary to estimate exposure in the event crew dosimeters are lost or damaged and to validate and/or improve models used to calculate crew exposures. The purpose of this DSO is to compare the space flight dosimeter calibration techniques of the NASA Space Radiation Analysis Group (SRAG) and Russian Institute for Biomedical Problems to identify systematic errors between the two; correlate the independent, simultaneous space radiation exposure measurements and calculations made by the two space programs; and assess the radiobiological effects of high-charge, high-energy particles on actively metabolizing biological samples.

Passive dosimeters will be mounted in the crew compartment and worn by crew members throughout the mission. The tissue equivalent proportional counter (TEPC) will be deployed on flight day 1 and stowed before the return. Seed containers and an active autonomous dosimeter will be affixed to the TEPC for the duration of the mission.

SENSORY-MOTOR INVESTIGATIONS (DSO 201)

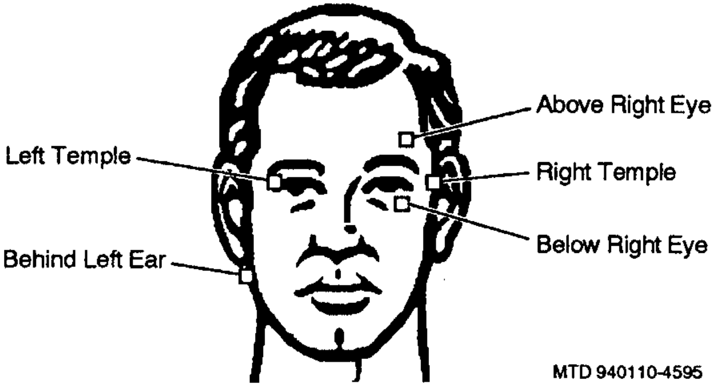
DSO 201 is intended to enhance the understanding of adaptation to space flight and readaptation after flight on various aspects of human spatial orientation, neurosensory, sensory-motor, physiological, and perceptual functions and on autonomic gastric functions associated with space motion sickness. The DSO will correlate the postflight recovery of postural equilibrium control, head and gaze stability, and readaptation changes in vestibular function and will examine the relationship between voluntary oculomotor performance and passive vestibulo-ocular responses following space flight.

On-orbit investigation protocols are voluntary head movements (VHMs), optokinetic nystagmus (OKN), and electrogastrography (EGG) monitoring of autonomic and gastric function.

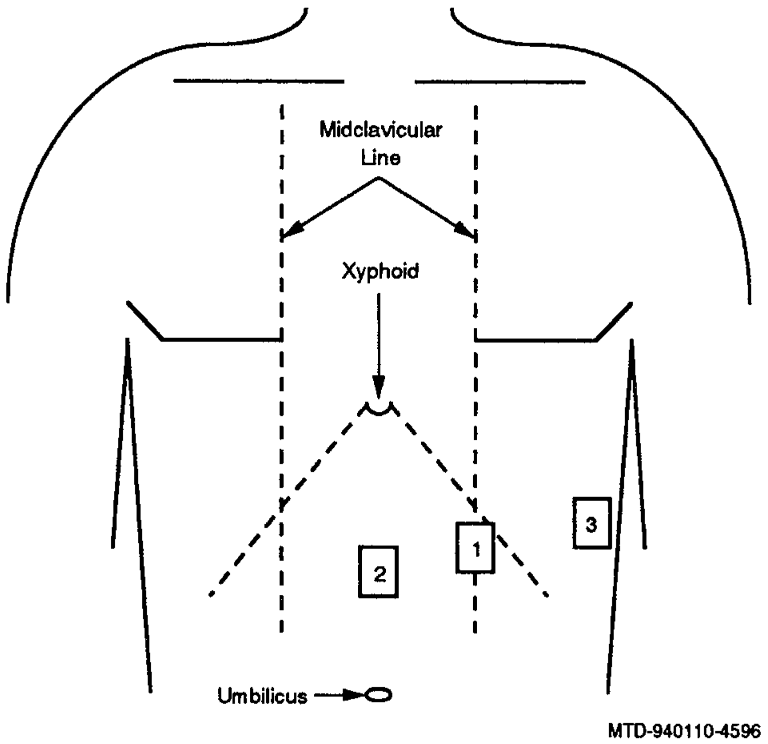
Since VHM and OKN data are both recorded on the "superpocket" data recorder, all VHM and OKN sessions must be performed serially.

METABOLIC (DSO 202)

Exposure to microgravity is known to have profound effects on fluid homeostasis within the human body. The headward shift of fluids observed in microgravity results in an increased excretion of fluids and electrolytes; space motion sickness causes further depletion. Fluid and electrolyte balance in the body is regulated by several systems, any or all of which are potentially responsible for the microgravity-induced changes in total body water, extracellular



Electrode Placement (Mirror Image)



EGG Electrode Locations

fluid volume, and plasma volume; fluid/electrolyte regulatory hormones; and energy expenditure. This DSO will investigate the effect of microgravity on total body water, extracellular fluid volume, and plasma volume; body fluid distribution; sodium/potassium balance; fluid/electrolyte regulatory hormones; and energy expenditure.

Metabolic activities include ingesting bromide and/or doubly labeled water, taking blood samples, measuring peripheral venous pressure using a catheter, and collecting urine and saliva samples. Metabolic samples will be stored in passive gaseous nitrogen freezers.

VISUAL OBSERVATIONS FROM SPACE (DSO 204)

The Russian cosmonauts who have flown on board the Mir space station have extensive experience in visual observations of the Earth from space. The purpose of this DSO is to observe Earth features with remote imaging and recording. A modified set of optical equipment is being manifested for these observations, as well as for studies of the solar terminator and the stars. This investigation can also be accomplished in concert with ongoing Earth observation objectives for the U.S. portion of this investigation.

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

Ascent compartment venting evaluation (DTO 305D). This DTO will collect data under operational conditions to validate and upgrade the ascent venting math model and verify the capability of the vent system to maintain compartment pressures within design limits.

Entry compartment venting evaluation (DTO 306D). This DTO will collect data under operational conditions to validate and upgrade the descent venting math model and verify the capability of the vent system to maintain compartment pressures within design limits.

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

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

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

APU shutdown test, sequence B (shutdown 2, then 3, then 1) (DTO 414). This DTO will explore the hypothesis that delays between shutting down individual auxiliary power units on ascent can lead to "backdriving" the nonoperational hydraulic system's speed brake hydraulic motor. Reviews of mission data have shown that when an individual APU is shut down prematurely on ascent while the remaining APUs continue to operate, there is the possibility of extended hydraulic supply pressure (i.e., the hydraulic pressure of the shutdown system remains at an elevated level for a significant period of time). The explanation for this behavior is that the operational hydraulic systems are backdriving the speed brake hydraulic motor of the system that has been shut down. Performing this DTO during flight will produce the most representative data for this behavior. This DTO will be flown on missions in order to create a representative data base. On STS-60, the APUs will be shut down in the following order: 2, 3, 1. The pilot will wait at least five seconds before shutting down the next APU.

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

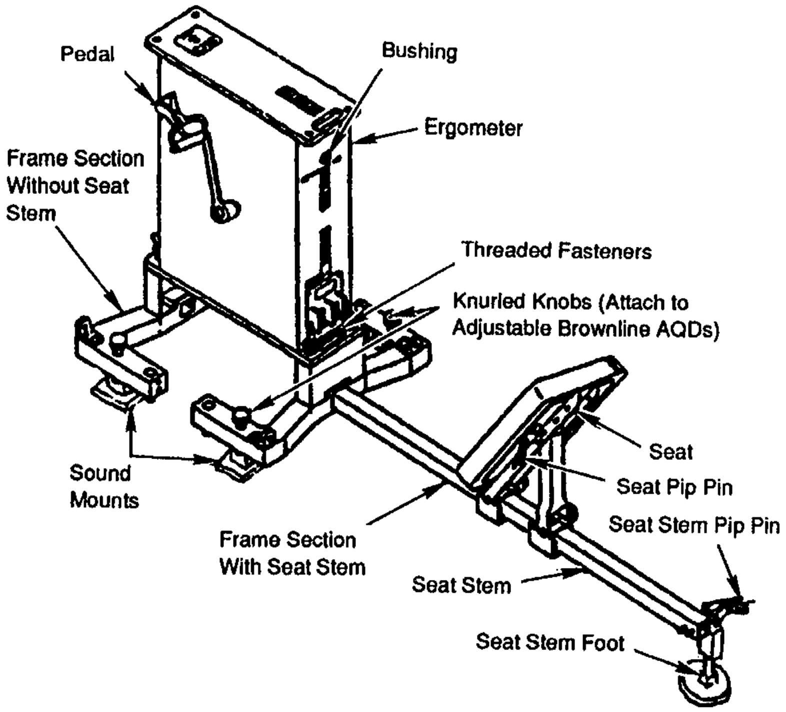
PGSC single-event upset monitoring (DTO 656). This DTO will evaluate the payload and general-support computer's random-access susceptibility to single-event upset caused by cosmic radiation. This information could lead to improved procedures, hardware, or software to reduce radiation effects. This DTO will run continuously once initiated on the PGSC and will be interrupted only if the crew needs to use the PGSC for PADM operations.

Cabin temperature survey (DTO 664). The purpose of this DTO is to compile a temperature profile of the crew cabin in a variety of orbiter attitudes and configurations and to correlate the cabin temperature sensor reading with the cabin temperature profile during on-orbit operations.

Evaluation of passive cycle isolation system (DTO 670). The purpose of this DTO is to compare the magnitude and frequency of the vibrations of the ergometer when the PCIS vibration isolation system is used to those that occur when the hard mount is used and to evaluate the ease of set up and stowage of the PCIS and its impact on the performance of exercise activities and crew habitation in the middeck. The Space Acceleration Measurement System (SAMS) hardware will be used to measure the levels of vibration. The PCIS is intended to preserve the microgravity environment by attenuating cycling forces before they are transmitted to the shuttle and to shuttle payloads.

Laser range and range rate device (DTO 700-2). This DTO will demonstrate the capability to provide the orbiter flight crew with range and range rate data for rendezvous, proximity, and deployment operations. The major objective is to show that a hand-held laser can provide accurate and reliable range and range rate information even if the target does not have a laser reflector. The DTO will assess the best means of displaying the data, addressing location as well as frequency of update. The hardware consists of two hand-held, in-cabin laser range and range rate devices.

Orbiter data for real-time navigation evaluation (DTO 700-7). This DTO will permit the other DTOs or payloads requiring orbiter data to be supported. If flown with DTOs 700-5 and 700-6, it will permit a more accurate assessment of the payload bay laser as a rendezvous and proximity navigation aid and real-time evaluation of relative GPS. Objectives include the following: (1) increase the accuracy of payload bay laser navigation by providing orbiter attitude information to the laser software in real time and (2) collect orbiter and payload GPS state vector information in real time to assist in evaluating relative GPS. Orbiter attitude information and the payload GPS state vector will be extracted from the 128-kilobit-per-second data stream and processed, and the data will be shipped to the PGSC running payload bay-mounted laser software or the GPS software.



MTD 921013-3966

Ergometer

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

DETAILED SUPPLEMENTARY OBJECTIVES

Joint U.S.-Russian investigation: radiobiological effects (DSO 200). See STS-60 Joint U.S.-Russian Investigations section.

Joint U.S.-Russian investigation: sensory-motor investigations (DSO 201). See STS-60 Joint U.S.-Russian Investigations section.

Joint U.S.-Russian investigation: metabolic (DSO 202). See STS-60 Joint U.S.-Russian Investigations section.

Joint U.S.-Russian investigation: visual observations from space (DSO 204). See STS-60 Joint U.S.-Russian Investigations section.

Dried blood method for in-flight storage (protocol 1) (DSO 325). This DSO will test the techniques used to take dried blood samples and assess the paper filters and the effects of microgravity on the collection process. Protocol 1 uses an already-manifested centrifuge and requires drawing blood and preparing several dried blood samples as well as some frozen control samples for analysis on the ground. Protocol 2 involves 32 prefilled syringes and does not require blood collection. Both protocols require either a gaseous nitrogen canister or space in a freezer.

Window impact observations (target of opportunity) (DSO 326). This DSO will visually document window abrasions made by orbital debris. This DSO is designed to link window damages found during orbiter turnaround processing to mission time, attitude, and altitude. This data will aid significantly in the effort to identify the sources of this damage. Crew members will check the windows every morning and evening for new abrasions and will record their findings in a log. This DSO is a target of opportunity. It is called out as an EZ activity on flight days 1 and 11. The crew will make other observations if time is available.

Immunological assessment of crew members (DSO 487). This DSO will examine the mechanisms of space flight-induced alterations in human immune function. As shuttle mission duration increases, the potential for crew members to develop infectious illness during flight also increases. This investigation will assess the immune system function using the immune cells from the standard flight medicine blood draw. There are no on-orbit crew activities associated with this DSO.

Documentary television (DSO 901). The purpose of DSO 901 is to provide live television transmission or VTR dumps of crew activities and spacecraft functions such as payload bay views, STS and payload crew activities, in-flight crew press conference, orbiter operations, payload deployment and retrieval and operations, Earth views, rendezvous and proximity operations, and unscheduled activities. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. The broadcast is accomplished using operational air-to-ground and/or operational intercom audio. VTR recording may be used when live television is not possible.

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

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

PRELAUNCH COUNTDOWN TIME LINE

T - (MINUS) HR:MIN:SEC	EVENT
06:00:00	Verification of the launch commit criteria is complete at this time. The liquid oxygen and liquid hydrogen systems chill-down commences in order to condition the ground line and valves as well as the external tank (ET) for cryo loading. Orbiter fuel cell power plant activation is performed.
05:50:00	The space shuttle main engine (SSME) liquid hydrogen chill-down sequence is initiated by the launch processing system (LPS). The liquid hydrogen recirculation valves are opened and start the liquid hydrogen recirculation pumps. As part of the chill-down sequence, the liquid hydrogen prevalves are closed and remain closed until T minus 9.5 seconds.
05:30:00	Liquid oxygen chill-down is complete. The liquid oxygen loading begins. The liquid oxygen loading starts with a "slow fill" in order to acclimate the ET. Slow fill continues until the tank is 2-percent full.
05:15:00	The liquid oxygen and liquid hydrogen slow fill is complete and the fast fill begins. The liquid oxygen and liquid hydrogen fast fill will continue until that tank is 98-percent full.
05:00:00	The calibration of the inertial measurement units (IMUs) starts. The three IMUs are used by the orbiter navigation systems to determine the position of the orbiter in flight.
04:30:00	The orbiter fuel cell power plant activation is complete.
04:00:00	The Merritt Island (MILA) antenna, which transmits and receives communications, telemetry and ranging information, alignment verification begins.
03:45:00	The liquid hydrogen fast fill to 98 percent is complete, and a slow topping-off process is begun and stabilized to 100 percent.
03:30:00	The liquid oxygen fast fill is complete to 98 percent.
03:20:00	The main propulsion system (MPS) helium tanks begin filling from 2,000 psi to their full pressure of 4,500 psi.
03:15:00	Liquid hydrogen stable replenishment begins and continues until just minutes prior to T minus zero.
03:10:00	Liquid oxygen stable replenishment begins and continues until just minutes prior to T minus zero.
03:00:00	The MILA antenna alignment is completed.

T - (MINUS) HR:MIN:SEC	EVENT
03:00:00	The orbiter closeout crew goes to the launch pad and prepares the orbiter crew compartment for flight crew ingress.
03:00:00 Holding	Begin 2-hour planned hold. An inspection team examines the ET for ice or frost formation on the launch pad during this hold.
03:00:00 Counting	Two-hour planned hold ends.
02:55:00	Flight crew departs Operations and Checkout (O&C) Building for launch pad.
02:25:00	Flight crew orbiter and seat ingress occurs.
02:10:00	Postingress software reconfiguration occurs.
02:00:00	Checking of the launch commit criteria starts at this time.
02:00:00	The ground launch sequencer (GLS) software is initialized.
01:50:00	The solid rocket boosters' (SRBs') hydraulic pumping units' gas generator heaters are turned on and the SRBs' aft skirt gaseous nitrogen purge starts.
01:50:00	The SRB rate gyro assemblies (RGAs) are turned on. The RGAs are used by the orbiter's navigation system to determine rates of motion of the SRBs during first-stage flight.
01:35:00	The orbiter accelerometer assemblies (AAs) are powered up.
01:35:00	The orbiter reaction control system (RCS) control drivers are powered up.
01:35:00	The flight crew starts the communications checks.
01:25:00	The SRB RGA torque test begins.
01:20:00	Orbiter side hatch is closed.
01:10:00	Orbiter side hatch seal and cabin leak checks are performed.
01:01:00	IMU preflight align begins. Flight crew functions from this point on will be initiated by a call from the orbiter test conductor (OTC) to proceed. The flight crew will report back to the OTC after completion.
01:00:00	The orbiter RGAs and AAs are tested.
00:50:00	The flight crew starts the orbiter hydraulic auxiliary power units' (APUs') water boilers preactivation.
00:45:00	Cabin vent redundancy check is performed.
00:45:00	The GLS mainline activation is performed.
00:40:00	The eastern test range (ETR) shuttle range safety system (SRSS) terminal count closed-loop test is accomplished.

T - (MINUS) HR:MIN:SEC	EVENT
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.
00:30:00	The gaseous nitrogen system for the orbital maneuvering system (OMS) engines is pressurized for launch. Crew compartment vent valves are opened.
00:26:00	The ground pyro initiator controllers (PICs) are powered up. They are used to fire the SRB hold-down posts, liquid oxygen and liquid hydrogen tail service mast (TSM), and ET vent arm system pyros at lift-off and the SSME hydrogen gas burn system prior to SSME ignition.
00:25:00	Simultaneous air-to-ground voice communications are checked. Weather aircraft are launched.
00:22:00	The primary avionics software system (PASS) is transferred to the BFS computer in order for both systems to have the same data. In case of a PASS computer system failure, the BFS computer will take over control of the shuttle vehicle during flight.
00:21:00	The crew compartment cabin vent valves are closed.
00:20:00	A 10-minute planned hold starts.
<u>Hold 10 Minutes</u>	All computer programs in the firing room are verified to ensure that the proper programs are available for the final countdown. The test team is briefed on the recycle options in case of an unplanned hold.
	The landing convoy status is again verified and the landing sites are verified ready for launch.
	The IMU preflight alignment is verified complete.
	Preparations are made to transition the orbiter on-board computers to Major Mode (MM)-101 upon coming out of the hold. This configures the computer memory to a terminal countdown configuration.
00:20:00	The 10-minute hold ends.
<u>Counting</u>	Transition to MM-101. The PASS on-board computers are dumped and compared to verify the proper on-board computer configuration for launch.
00:19:00	The flight crew configures the backup computer to MM-101 and the test team verifies the BFS computer is tracking the PASS computer systems. The flight crew members configure their instruments for launch.
00:18:00	The Mission Control Center-Houston (MCC-H) now loads the on-board computers with the proper guidance parameters based on the prestated lift-off time.
00:16:00	The MPS helium system is reconfigured by the flight crew for launch.
00:15:00	The OMS/RCS crossfeed valves are configured for launch.

T - (MINUS) HR:MIN:SEC	EVENT
	All test support team members verify they are "go for launch."
00:12:00	Emergency aircraft and personnel are verified on station.
00:10:00	All orbiter aerosurfaces and actuators are verified to be in the proper configuration for hydraulic pressure application. The NASA test director gets a "go for launch" verification from the launch team.
00:09:00	A planned 10-minute hold starts.
Hold 10 Minutes	NASA and contractor project managers will be formally polled by the deputy director of NASA, Space Shuttle Operations, on the Space Shuttle Program Office communications loop during the T-minus-9-minute hold. A positive "go for launch" statement will be required from each NASA and contractor project element prior to resuming the launch countdown. The loop will be recorded and maintained in the launch decision records.
	All test support team members verify that they are "go for launch."
	Final GLS configuration is complete.
00:09:00 Counting	The GLS auto sequence starts and the terminal countdown begins.

T - (MINUS) HR:MIN:SEC	EVENT
	From this point, the GLSs in the integration and backup consoles are the primary control until T-0 in conjunction with the on-board orbiter PASS redundant-set computers.
00:09:00	Operations recorders are on. MCC-H, Johnson Space Center, sends a command to turn these recorders on. They record shuttle system performance during ascent and are dumped to the ground once orbit is achieved.
00:08:00	Payload and stored prelaunch commands proceed.
00:07:30	The orbiter access arm (OAA) connecting the access tower and the orbiter side hatch is retracted. If an emergency arises requiring flight crew activation, the arm can be extended either manually or by GLS computer control in approximately 30 seconds or less.
00:06:00	APU prestart occurs.
00:05:00	Orbiter APUs start. The orbiter APUs provide pressure to the three orbiter hydraulic systems. These systems are used to move the SSME engine nozzles and aerosurfaces.
00:05:00	ET/SRB range safety system (RSS) is armed. At this point, the firing circuit for SRB ignition and destruct devices is mechanically enabled by a

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

T - (MINUS) HR:MIN:SEC	EVENT
00:02:50	The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted.
00:02:35	Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the on-board tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.
00:02:30	The caution/warning memory is cleared.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.

T - (MINUS) HR:MIN:SEC	EVENT
00:00:47	The liquid oxygen and liquid hydrogen outboard fill and drain valves are closed.
00:00:40	The external tank bipod heaters are turned off.
00:00:38	The on-board computers position the orbiter vent doors to allow payload bay venting upon lift-off and ascent in the payload bay at SSME ignition.
	The SRB forward MDM is locked out.
00:00:37	The gaseous oxygen ET arm retract is confirmed.
00:00:31	The GLS sends "go for redundant set launch sequence start." At this point, the four PASS computers take over main control of the terminal count. Only one further command is needed from the ground, "go for main engine start," at approximately T minus 9.7 seconds. The GLS in the integration console in the launch control center still continues to monitor several hundred launch commit criteria and can issue a cutoff if a discrepancy is observed. The GLS also sequences ground equipment and sends selected vehicle commands in the last 31 seconds.
00:00:28	Two hydraulic power units in each SRB are started by the GLS. These provide hydraulic power for SRB nozzle gimbaling for ascent first-stage flight control.
	The orbiter vent door sequence starts.
00:00:21	The SRB gimbal profile is complete. As soon as SRB hydraulic power is applied, the SRB engine nozzles are commanded through a preprogrammed pattern to assure that they will be ready for ascent flight control during first stage.
00:00:21	The liquid hydrogen high-point bleed valve is closed.
	The SRB gimbal test begins.
00:00:18	The on-board computers arm the explosive devices, the pyrotechnic initiator controllers, that will separate the T-0 umbilicals, the SRB hold-down posts, and SRB ignition, which is the final electrical connection between the ground and the shuttle vehicle.
00:00:16	The sound suppression system water is activated.
00:00:15	If the SRB pyro initiator controller (PIC) voltage in the redundant-set launch sequencer (RSLS) is not within limits in 3 seconds, SSME start commands are not issued and the on-board computers proceed to a countdown hold.
00:00:13	The aft SRB MDM units are locked out. This is to protect against electrical interference during flight. The electronic lock requires an unlock command before it will accept any other command.
	SRB SRSS inhibits are removed. The SRB destruct system is now live.

T - (MINUS) HR:MIN:SEC	EVENT
00:00:12	The MPS helium fill is terminated. The MPS helium system flows to the pneumatic control system at each SSME inlet to control various essential functions.
00:00:10	LPS issues a "go" for SSME start. This is the last required ground command. The ground computers inform the orbiter on-board computers that they have a "go" for SSME start. The GLS retains hold capability until just prior to SRB ignition.
00:00:09.7	Liquid hydrogen recirculation pumps are turned off. The recirculation pumps provide for flow of fuel through the SSMEs during the terminal count. These are supplied by ground power and are powered in preparation for SSME start.
00:00:09.7	In preparation for SSME ignition, flares are ignited under the SSMEs. This burns away any free gaseous hydrogen that may have collected under the SSMEs during prestart operations. The orbiter goes on internal cooling at this time; the ground coolant units remain powered on until lift-off as a contingency for an aborted launch. The orbiter will redistribute heat within the orbiter until approximately 125 seconds after lift-off, when the orbiter flash evaporators will be turned on.
00:00:09.5	The SSME engine chill-down sequence is complete and the on-board computers command the three MPS liquid hydrogen prevalves to open. (The MPS's three liquid oxygen prevalves were opened during ET tank loading to permit engine chill-down.) These valves allow liquid hydrogen and oxygen flow to the SSME turbopumps.
00:00:09.5	Command decoders are powered off. The command decoders are units that allow ground control of some on-board components. These units are not needed during flight.
00:00:06.6	The main fuel and oxidizer valves in each engine are commanded open by the on-board computers, permitting fuel and oxidizer flow into each SSME for SSME start. All three SSMEs are started at 120-millisecond intervals (SSME 3, 2, then 1) and throttle up to 100-percent thrust levels in 3 seconds under control of the SSME controller on each SSME.
00:00:04.6	All three SSMEs are verified to be at 100-percent thrust and the SSMEs are gimbaled to the lift-off position. If one or more of the three SSMEs does not reach 100-percent thrust at this time, all SSMEs are shut down, the SRBs are not ignited, and an RSLS pad abort occurs. The GLS RSLS will perform shuttle and ground systems safing. Vehicle bending loads caused by SSME thrust buildup are allowed to initialize before SRB ignition. The vehicle moves towards ET including ET approximately 25.5 inches.

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

STS-60 MISSION HIGHLIGHTS TIME LINE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
	DAY ZERO
0/00:00:07	Tower is cleared (SRBs above lightning rod tower).
0/00:00:10	180-degree positive roll maneuver (right-clockwise) is started. Pitch profile is heads down, wings level.
0/00:00:19	Roll maneuver ends.
0/00:00:26	All three SSMEs throttle down from 100 to 70 percent for maximum aerodynamic load (max q).
0/00:00:52	Max q occurs.
0/00:00:57	All three SSMEs throttle to 104 percent.
0/00:02:05	SRBs separate. When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration. At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:04:08	Negative return. The vehicle is no longer capable of return-to-launch-site abort at Kennedy Space Center runway.
0/00:07:00	Single-engine press to main engine cutoff (MECO).
0/00:08:27	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:32	MECO occurs at approximate velocity of 25,921 feet per second, 40 by 187 nautical miles (46 by 215 statute miles).

Editor's Note: This time line lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-60 Flight Plan, Ascent Checklist, Postinsertion Checklist, Rendezvous Checklist, Deorbit Prep Checklist, and Entry Checklist.

On every shuttle mission, some day-to-day replanning takes place to adjust crew and event time lines according to unforeseen developments or simply to optimize the use of time in orbit. Each day's replanning effort will produce an execute plan defining the approach for the next day's activities in space and on the ground.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:08:40	Zero thrust.
0/00:08:51	ET separation is automatic with flight crew manual backup switch to the automatic function (does not bypass automatic circuitry).
	The orbiter forward and aft RCSs, which provide attitude hold and negative Z translation of 11 fps to the orbiter for ET separation, are first used.
	Orbiter/ET liquid oxygen/liquid hydrogen umbilicals are retracted.
	Negative Z translation is complete.
	In conjunction with this thrusting period, approximately 1,700 pounds of liquid hydrogen and 3,700 pounds of liquid oxygen are trapped in the MPS ducts and SSMEs, which results in an approximate 7-inch center-of-gravity shift in the orbiter. The trapped propellants would sporadically vent in orbit, affecting guidance and creating contaminants for the payloads. During entry, liquid hydrogen could combine with atmospheric oxygen to form a potentially explosive mixture. As a result, the liquid oxygen is dumped out through the SSME combustion chamber nozzles, and the liquid hydrogen is dumped out through the right-hand T-minus-zero umbilical overboard fill and drain valves.
	MPS dump terminates.
	APUs shut down.
	MPS vacuum inerting occurs. — Remaining residual propellants are vented to space vacuum, inerting the MPS. — Orbiter/ET umbilical doors close (one door for liquid hydrogen and one door for liquid oxygen) at bottom of aft fuselage, sealing the aft fuselage for entry heat loads. — MPS vacuum inerting terminates.
0/00:42	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 46 seconds in duration, at 269 fps, 191 by 191 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS), payload specialist (PS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.
0/00:59	MS configures aft flight station.
0/01:02	MS unstows, sets up, and activates PGSC.
0/01:05	MS configures for payload bay door operations.
0/01:06	Pilot activates payload bus (panel R1).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
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 X velocity vector attitude.
0/01:17	Commander activates radiators.
0/01:28	MS opens payload bay doors.
0/01:36	Mission Control Center (MCC), Houston (H), informs crew to "go for orbit operations."
0/01:37	Commander and pilot seat egress.
0/01:38	Commander and pilot clothing configuration.
0/01:39	MS/PS clothing configuration.
0/01:51	MS activates teleprinter (if flown).
0/01:53	Commander begins post-payload bay door operations and radiator configuration.
0/01:54	MS/PS remove and stow seats.
0/01:55	Commander starts ST self-test and opens door.
0/01:56	MS configures and activates WCS.
0/01:57	MS activates switch configuration/galley.
0/01:58	MS stows escape pole.
0/02:00	MS configures water loop.
0/02:01	Pilot activates auxiliary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:06	Commander configures vernier controls.
0/02:09	Commander, pilot configure controls for on orbit.
0/02:17	MS performs on-orbit initialization.
0/02:19	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	DSO 202—metabolic.
0/02:30	WSF panel checks.
0/02:35	DSO 326—window impact observations.
0/02:35	Ku-band antenna deployment.
0/02:35	Galley water sample collection—DSO 202.
0/02:40	WSF carrier power activation.
0/02:45	Ku-band antenna activation.
0/02:50	WSF PGSC setup.
0/02:55	CAPL activation.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:00	SPACEHAB activation.
0/03:00	EGG monitoring preparation—DSO 201.
0/03:10	WSF PGSC boot-up.
0/03:15	TEPC deployment—DSO 200.
0/03:15	PSB activation (SPACEHAB).
0/03:20	In-bay communications checkout.
0/03:30	Ground-commanded WSF carrier command check.
0/03:40	Neuro setup—DSO 201.
0/03:50	Priority Group B power-down.
0/05:00	Catheter placement/baseline blood collection—DSO 202.
0/05:00	IMMUNE operations (SPACEHAB).
0/05:05	EOG preparation—DSO 201.
0/05:15	SPACEHAB fan clamp removal.
0/05:20	VHM operations—DSO 201.
0/05:30	Saliva sample—DSO 202.
0/05:35	SOR/F setup (SPACEHAB).
0/05:45	SPACEHAB module setup.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/05:50	EOG preparation—DSO 201.
0/05:50	ORSEP operations (SPACEHAB).
0/06:00	CPCG setup (SPACEHAB).
0/06:00	Blood sample processing—DSO 202.
0/06:35	PVP operations—DSO 202.
0/06:40	CPCG warmup (SPACEHAB).
0/07:10	EOG preparation—DSO 201.
0/07:15	GAPC unstow.
0/07:20	CPCG activation (SPACEHAB).
0/07:25	SAMS activation (SPACEHAB).
0/07:25	Group A GAS experiments.
0/07:30	Urine/saliva samples—DSO 202.
0/07:40	3-DMA on-orbit mode (SPACEHAB).
0/07:55	DTO 623—cabin air monitoring.
0/07:55	PSB monitoring (SPACEHAB).
0/08:00	Gaseous nitrogen freezer/sample cooler—DSO 202.
0/08:00	Crew begins presleep activities.
0/08:00	Neuro stow—DSO 201.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/10:40	Catheter flush—DSO 202.
0/11:00	Crew begins sleep period.
0/19:00	Crew begins postsleep activities.
0/19:00	Urine/saliva collection—DSO 202.
0/19:00	Catheter flush—DSO 202.
0/19:15	Gaseous nitrogen freezer/sample cooler—DSO 202.
0/19:20	Urine/saliva collection—DSO 202.
0/19:50	Catheter placement/baseline blood collection operations—DSO 202.
0/20:10	DLW/bromide ingestion—DSO 202.
0/20:30	PVP operations—DSO 202.
0/20:45	Blood sample processing—DSO 202.
0/20:50	PVP operations—DSO 202.
0/22:00	PSB monitoring (SPACEHAB).
0/22:05	SAMS disk changeout (SPACEHAB).
0/22:15	IMMUNE operations (SPACEHAB).
0/22:15	Ergometer setup—DTO 670.
0/22:35	CPCG check (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/22:40	DTO 670.
0/22:45	Saliva collection—DSO 202.
0/22:50	Post-bromide ingestion blood sample collection—DSO 202.
0/23:00	DTO 670 setup—evaluate passive cycle isolation system.
0/23:05	DTO 700-2 setup—laser range and rate device.
0/23:10	RMS power-up.
0/23:20	DTO 700-2 laser checkout.
0/23:25	RMS checkout.
0/23:35	DTO 700-2 laser stow.
0/23:50	Blood sample processing—DSO 202.

MET DAY ONE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:00	3-DMA check (SPACEHAB).
1/00:05	CPCG check (SPACEHAB).
1/00:10	RMS payload bay survey.
1/00:20	DSO 326—window impact observations.
1/00:20	EGG tape change—DSO 201.
1/00:30	Autonomic and gastric function debrief—DSO 201.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/00:40	Urine/saliva collection—DSO 202.
1/00:50	CPCG check (SPACEHAB).
1/00:50	Neuro setup—DSO 201.
1/00:55	CPCG No. 1 crystal growth.
1/00:55	EOG preparation—DSO 201.
1/01:00	RMS power-down.
1/01:05	SAREX setup.
1/01:10	VHM operations—DSO 201.
1/01:15	Begin CGBA monitoring.
1/01:20	CPCG check (SPACEHAB).
1/01:30	SEF setup/activation (SPACEHAB).
1/01:35	BPL activation (SPACEHAB).
1/01:50	SAREX packet operations.
1/02:05	OKN operations—DSO 201.
1/02:15	SAREX voice operations—Surrey, England (test).
1/02:20	Galley water sample collection—DSO 202.
1/02:45	CPCG check (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/03:35	EOG preparation—DSO 201.
1/03:35	BPL deactivation (SPACEHAB).
1/03:35	SAREX voice operations—Boise, Idaho.
1/03:50	BPL activation (SPACEHAB).
1/03:50	CPCG check (SPACEHAB).
1/03:50	ORSEP activation (SPACEHAB).
1/03:55	SEF crystal growth (SPACEHAB).
1/04:10	CGBA initiation (SPACEHAB).
1/04:35	Begin CGBA monitoring.
1/04:55	CPCG check (SPACEHAB).
1/05:00	Begin CGBA sample processing (SPACEHAB).
1/05:05	EOG preparation—DSO 201.
1/05:15	SEF crystal growth (SPACEHAB).
1/05:15	VHM operations—DSO 201.
1/05:15	PAO event.
1/05:20	BPL activation (SPACEHAB).
1/05:35	CPCG check (SPACEHAB).
1/05:35	CGBA termination (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/05:45	Initiate CGBA sample processing (SPACEHAB).
1/05:50	BPL deactivation (SPACEHAB).
1/06:20	SAMS disk changeout (SPACEHAB).
1/06:35	EOG preparation—DSO 201.
1/06:40	CPCG postnucleation data rate change (SPACEHAB).
1/06:50	DTO 623—cabin air monitoring.
1/07:30	DTO 664—cabin temperature survey.
1/07:30	Group B GAS experiments.
1/07:40	SEF crystal growth (SPACEHAB).
1/08:00	Crew begins presleep activities.
1/08:00	Gaseous nitrogen freezer/sample cooler—DSO 202.
1/08:15	Neuro stow—DSO 201.
1/08:50	SAREX voice operations—personal contact.
1/11:00	Crew begins sleep period.
1/19:00	Crew begins postsleep activities.
1/19:00	Urine/saliva collection—DSO 202.
1/21:55	PSB monitoring (SPACEHAB).
1/22:00	PGSC boot-up.
1/22:00	Galley water sample collection—DSO 202.
1/22:00	RMS power-up.
1/22:10	In-bay communications checkout.
1/22:10	DSO 326—window impact observations.
1/22:10	DTO 664—cabin temperature survey.
1/22:15	WSF grapple.
1/22:25	CPCG check (SPACEHAB).
1/22:25	DTO 700-7 setup.
1/22:25	SAMS disk changeout.
1/22:30	CGBA termination (SPACEHAB).
1/22:30	Monitor PGSC setup.
1/22:35	3-DMA status check (SPACEHAB).
1/22:40	IMMUNE operations check (SPACEHAB).
1/22:40	DTO 700-7 PGSC connections.
1/22:45	Monitor PGSC boot-up.
1/22:50	Begin CGBA monitoring (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/23:00	BPL deactivation (SPACEHAB).
1/23:00	Laser setup—DTO 700-2 laser range and rate device.
1/23:10	SEF crystal growth (SPACEHAB).
1/23:30	WSF post-unberth configuration.
1/23:30	WSF unberth.
1/23:40	CGBA termination (SPACEHAB).

MET DAY TWO

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/00:00	CGBA termination (SPACEHAB).
2/00:00	Position RMS for ram cleaning.
2/00:05	Ram cleaning.
2/00:05	Passive accelerometer tube alignment experiment operations.
2/00:15	EGG tape change—DSO 201.
2/00:20	SAREX robot mode deactivation.
2/00:25	Autonomic and gastric function debrief—DSO 201.
2/00:35	WSF RHEED operations.
2/02:00	TIPS communications setup.
2/02:05	CGBA termination (SPACEHAB).
2/02:05	SEF crystal growth (SPACEHAB).
2/02:15	WSF deployment period begins.
2/02:25	Position RMS for MBE checkout.
2/02:30	Priority Group B power-up.
2/02:30	WSF ADACS checkout.
2/03:00	Pre-WSF release operations.
2/03:50	RMS to release position—WSF release.
2/04:45	RMS power-down.
2/05:25	Open vent valves—ORSEP (SPACEHAB).
2/05:30	SEF crystal growth (SPACEHAB).
2/05:30	WSF monitor.
2/05:40	ASC-3 activation (SPACEHAB).
2/05:40	Laser stow—DTO 700-7.
2/06:30	SEF crystal growth (SPACEHAB).
2/07:40	SEF crystal growth (SPACEHAB).
2/07:45	DTO 664—cabin temperature survey.
2/08:05	Begin CGBA monitoring (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/08:15	SAMS disk changeout (SPACEHAB).
2/08:25	CPCG check (SPACEHAB).
2/08:27	NC1 multiaxis RCS burn.
2/08:30	Crew begins presleep activities.
2/08:35	Priority Group B power-down.
2/08:40	DTO 623—cabin air monitoring.
2/08:55	Disable rendezvous navigation.
2/09:30	Initiate MBE run 1 (WSF).
2/11:30	Crew begins sleep period.
2/19:30	Crew begins postsleep activities.
2/19:30	Urine/saliva collection—DSO 202.
2/21:25	PI and MCC tag-up.
2/21:40	WSF communications safing.
2/22:25	ORSEP check (SPACEHAB).
2/22:25	ASC-3 download data (SPACEHAB).
2/22:30	PSB monitoring (SPACEHAB).
2/22:30	CPCG check (SPACEHAB).
2/22:30	SAREX voice—Moscow school.
2/22:35	Neuro setup—DSO 201.
2/22:40	EOG preparation—DSO 201.
2/22:45	IMMUNE check (SPACEHAB).
2/22:55	VHM operations—DSO 201.
2/23:00	SAMS disk changeout (SPACEHAB).
2/23:00	ASC-3 chamber test (SPACEHAB).
2/23:10	3-DMA status check (SPACEHAB).
2/23:15	BPL deactivation (SPACEHAB).
2/23:30	DTO 664—cabin temperature survey.
2/23:35	SEF crystal growth (SPACEHAB).
2/23:35	Galley water sample collection—DSO 202.
2/23:45	OKN operations—DSO 201.
	MET DAY THREE
3/00:00	PAO event.
3/00:10	EGG tape change—DSO 201.
3/00:10	CERL activation (WSF).
3/00:20	CGBA termination (SPACEHAB).
3/00:20	EGG autonomic and gastric function debrief (DSO 201).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/00:25	SAREX robot mode deactivation.
3/00:30	DSO 326—window impact observations.
3/00:35	EOG preparation—DSO 201.
3/00:45	VHM operations—DSO 201.
3/01:00	Terminate MBE run 2 (WSF).
3/01:00	SEF crystal growth (SPACEHAB).
3/01:10	ASC-3 chamber test (SPACEHAB).
3/01:14	NC2 multiaxis RCS burn.
3/01:30	Begin MBE run 3 (WSF).
3/01:40	OKN operations—DSO 201.
3/02:50	SEF crystal growth (SPACEHAB).
3/04:00	EOG preparation—DSO 201.
3/04:00	SEF crystal growth (SPACEHAB).
3/04:10	VHM operations—DSO 201.
3/05:00	OKN operations—DSO 201.
3/05:00	Terminate MBE run 3 (WSF).
3/05:30	Begin MBE run 4 (WSF).
3/05:30	SAREX voice—Australia bridge (Mars, Penn).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/05:50	SEF crystal growth (SPACEHAB).
3/06:05	EOG preparation—DSO 201.
3/07:00	NPC multiaxis RCS burn.
3/07:05	Rendezvous preparation.
3/07:20	ASC-3 chamber test (SPACEHAB).
3/07:35	NC3 multiaxis RCS burn.
3/07:40	ASC-3 download data (SPACEHAB).
3/07:40	SAMS disk changeout (SPACEHAB).
3/07:45	Neuro stow—DSO 201.
3/07:55	DTO 623—cabin air monitoring.
3/08:00	Terminate MBE run 4 (WSF).
3/08:00	CPCG check (SPACEHAB).
3/08:00	NC3 burn.
3/08:10	SEF crystal growth (SPACEHAB).
3/08:10	ORSEP check (SPACEHAB).
3/08:15	DTO 664—cabin temperature survey.
3/08:20	EGG stow—DSO 201.
3/08:25	Group C GAS experiments.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/08:30	Begin MBE run 5 (WSF).
3/08:30	Crew begins presleep activities.
3/10:00	WSF communications safing.
3/11:30	Crew begins sleep period.
3/19:30	Crew begins postsleep activities.
3/19:30	Urine/saliva collection—DSO 202.
3/20:30	WSF communications safing.
3/21:00	Fuel cell purge.
3/21:55	Priority Group B power-up.
3/22:05	PSB monitor (SPACEHAB).
3/22:10	WSF rendezvous time line begins.
3/22:15	TIPS activation (S-band configuration).
3/22:20	IMMUNE check (SPACEHAB).
3/22:30	SEF completion/deactivation/stow (SPACEHAB).
3/22:30	CPCG check (SPACEHAB).
3/22:35	SAMS disk changeout (SPACEHAB).
3/22:35	Galley water sample collection—DSO 202.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/22:45	3-DMA status check (SPACEHAB).
3/22:45	ORSEP check (SPACEHAB).
3/22:50	BPL deactivation (SPACEHAB).
3/22:50	CGBA termination (SPACEHAB).
3/23:06	NC4 burn.
3/23:10	Begin CGBA monitoring (SPACEHAB).
3/23:30	CGBA termination (SPACEHAB).
3/23:52	NH1 burn.

MET DAY FOUR

4/01:12	NCC burn.
4/01:40	-Rbar crossing (WSF rendezvous).
4/02:00	RMS power-up.
4/02:09	TI burn.
4/02:31	MC1 burn.
4/02:58	MC2 burn.
4/03:08	MC3 burn.
4/03:15	ASC-3 deactivation (SPACEHAB).
4/03:18	MC4 burn.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/03:40	Establish +Vbar (WSF rendezvous).
4/03:50	WSF plume impingement.
4/04:50	Approach to 200 ft (WSF).
4/05:05	Establish 200-ft. station keeping (WSF).
4/06:10	Transition to -Vbar station keeping (WSF).
4/07:25	100-ft plume test (WSF).
4/07:30	RMS proximity operations (WSF).
7/07:50	Pitch flyaround (WSF).
4/08:00	WSF grapple.
4/08:05	Maneuver RMS to overnight park position.
4/08:45	SAMS disk changeout (SPACEHAB).
4/08:45	Priority Group B power-down.
4/08:45	CPCG check (SPACEHAB).
4/08:50	ORSEP check (SPACEHAB).
4/08:55	DTO 623—cabin air monitoring.
4/09:00	Crew begins presleep activities.
4/12:00	Crew begins sleep period.
4/20:00	Urine/saliva collection—DSO 202.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/20:00	Crew begins postsleep activities.
4/22:15	Close MATLAB cover (WSF).
4/23:00	CPCG check (SPACEHAB).
4/23:00	Neuro setup—DSO 201.
4/23:00	CERL-2 activation (WSF).
4/23:00	SAMS disk changeout (SPACEHAB).
4/23:05	EOG preparation—DSO 201.
4/23:10	IMMUNE check (SPACEHAB).
4/23:10	Galley water sample collection—DSO 202.
4/23:15	ORSEP check (SPACEHAB).
4/23:20	OKN operations—DSO 201.
4/23:20	DSO 326—window impact observations.
4/23:25	BPL deactivation (SPACEHAB).
4/23:35	DTO 670—PCIS stow.
4/23:40	DTO 664—cabin temperature survey.
4/23:45	EOG preparation—DSO 201.
4/23:55	PSB monitor (SPACEHAB).
	MET DAY FIVE
5/00:00	OKN operations—DSO 201.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/00:05	PAO event.
5/00:40	CHAWS PGSC setup (WSF).
5/00:40	ASC-3 activation (SPACEHAB).
5/01:15	Position RMS for CHAWS (WSF).
5/01:30	CGBA termination (SPACEHAB).
5/01:35	Begin CHAWS operations (WSF).
5/01:40	CHAWS I night operations (WSF).
5/02:10	CHAWS day operations (WSF).
5/03:10	CHAWS pitchover test (WSF).
5/03:30	3-DMA status check (SPACEHAB).
5/03:35	Close SPACEHAB viewport.
5/04:45	CHAWS II night operations (WSF).
5/05:15	CHAWS DAY operations (WSF).
5/06:15	RMS berth preparation.
5/06:15	CHAWS power-down (WSF).
5/06:25	WSF berth preparations.
5/06:25	WSF berth.
5/06:30	RMS power-down.
5/06:30	Open SPACEHAB viewport.
5/06:40	ORSEP close (SPACEHAB).
5/06:45	WSF closeout.
5/06:45	RMS power-down.
5/07:10	CERL deactivation (WSF).
5/07:15	CHAWS PGSC stow (WSF).
5/07:20	EOG preparation—DSO 201.
5/07:20	OMS burn.
5/07:30	OKN operations—DSO 201.
5/07:45	On-orbit OMS burn, if required.
5/07:55	DTO 664—cabin temperature survey.
5/08:00	EOG preparation—DSO 201.
5/08:10	DTO 623—cabin air monitoring.
5/08:10	OKN operations—DSO 201.
5/08:15	ECLiPSE activation (SPACEHAB).
5/08:35	SAMS disk changeout (SPACEHAB).
5/08:45	ECLiPSE setup for overnight (SPACEHAB).
5/08:45	DTO 656 setup—PGSC SEUM.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/08:50	Neuro stow—DSO 201.
5/08:50	CPCG check (SPACEHAB).
5/08:55	ORSEP check (SPACEHAB).
5/09:00	Crew begins presleep activities.
5/12:00	Crew begins sleep period.
5/20:00	Crew begins postsleep activities.
5/20:00	Urine/saliva collection—DSO 202.
5/20:20	Gaseous nitrogen freezer/sample cooler—DSO 201.
5/20:30	Catheter placement/baseline blood sample operations—DSO 202.
5/20:50	Bromide ingestion—DSO 202.
5/21:00	Manual fuel cell purge.
5/21:35	Blood sample processing—DSO 202.
5/21:45	PVP operations—DSO 202.
5/22:05	PVP operations—DSO 202.
5/23:00	ASC-3 download data (SPACEHAB).
5/23:30	SAREX voice operations—Chariton, Iowa.
5/23:35	DTO 656 power-down—PGSC SEUM.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/23:40	CPCG status check (SPACEHAB).
5/23:45	SAMS disk changeout (SPACEHAB).
5/23:55	3-DMA status check (SPACEHAB).
	MET DAY SIX
6/00:00	Neuro setup—DSO 201.
6/00:00	Post-bromide ingestion blood collection—DSO 202.
6/00:00	IMMUNE check (SPACEHAB).
6/00:05	EOG preparation—DSO 201.
6/00:20	VHM operations—DSO 201.
6/01:00	PSB monitor (SPACEHAB).
6/01:10	OKN operations—DSO 201.
6/01:10	Blood sample processing—DSO 201.
6/01:30	ECLiPSE deactivation (SPACEHAB).
6/01:40	Galley water sample collection—DSO 202.
6/01:50	EOG preparation—DSO 201.
6/01:50	Priority Group B power-up.
6/01:50	ODERACS deploy attitude.
6/02:00	ORSEP operations (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/02:10	ODERACS deploy setup.
6/02:20	ODERACS door open.
6/02:25	DSO 325 card drying.
6/02:46	ODERACS deployment.
6/02:50	DSO 326—window impact observations.
6/02:50	ODERACS closeout.
6/03:20	SAREX voice operations—personal contact.
6/04:30	Crew press conference.
6/05:00	BPL deactivation (SPACEHAB).
6/05:05	Deactivate dry box—DSO 325—dried blood.
6/05:10	ORSEP close vacuum isolation valve (SPACEHAB).
6/05:15	SEF opaque growth setup and activation (SPACEHAB).
6/05:15	CGBA termination (SPACEHAB).
6/05:15	EOG preparation—DSO 201.
6/05:25	VHM operations—DSO 201.
6/05:25	SAREX robot mode deactivation.
6/05:35	CGBA transfer polycorder data (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/06:00	Millstone acquisition of signal (ODERACS).
6/06:15	OKN operations—DSO 201.
6/06:15	CGBA termination (SPACEHAB).
6/06:35	CGBA transfer polycorder data (SPACEHAB).
6/06:40	EOG preparation—DSO 201.
6/06:55	BREMSAT predeploy health check.
6/07:10	Maneuver to BREMSAT deployment attitude.
6/07:15	CGBA termination (SPACEHAB).
6/07:30	SEF monitor (SPACEHAB).
6/07:36	Elgin acquisition of signal (ODERACS).
6/07:39	BREMSAT deployment.
6/07:40	ASC-3 download data (SPACEHAB).
6/07:40	BREMSAT closeout.
6/08:15	SEF monitor (SPACEHAB).
6/08:15	Priority Group B power-down.
6/08:25	Neuro stow—DSO 201.
6/08:30	DTO 664—cabin temperature survey.
6/08:50	CPCG check (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/08:50	Gaseous nitrogen freezer/sample cooler—DSO 202.
6/08:55	SAMS disk changeout (SPACEHAB).
6/08:55	DTO 623—cabin air monitoring.
6/08:55	ORSEP status check (SPACEHAB).
6/09:00	Crew begins presleep activities.
6/12:00	Crew begins sleep period.
6/20:00	Crew begins postsleep activities.
6/20:00	Urine/saliva collection—DSO 201.
6/20:15	DLW ingestion—DSO 202.
6/22:50	DSO 326—window impact observations.
6/22:55	CPCG status check (SPACEHAB).
6/22:55	PSB monitor (SPACEHAB).
6/22:55	Saliva collection—DSO 202.
6/23:00	Terminate SEF sample processing (SPACEHAB).
6/23:00	Neuro setup—DSO 201.
6/23:00	SAMS disk changeout (SPACEHAB).
6/23:00	CPCG deactivation (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/23:05	EOG preparation—DSO 201.
6/23:05	Galley water sample collection—DSO 202.
6/23:10	DTO 664—cabin temperature survey.
6/23:20	VHM operations—DSO 201.
6/23:25	ASC-3 download data (SPACEHAB).
6/23:25	RCS hot fire test.
6/23:40	FCS checkout.

MET DAY SEVEN

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/00:00	VHM operations—DSO 201.
7/00:20	OKN operations—DSO 201.
7/00:45	Urine/saliva collection—DSO 202.
7/00:45	EOG preparation—DSO 201.
7/00:50	ORSEP status check (SPACEHAB).
7/00:55	SEF monitor (SPACEHAB).
7/01:05	EGG autonomic and gastric function debriefing—DSO 201.
7/01:40	3-DMA status check (SPACEHAB).
7/01:40	SAREX robot mode deactivation.
7/01:45	IMMUNE check (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/01:55	CGBA termination (SPACEHAB).
7/02:15	EOG preparation—DSO 201.
7/02:30	PAO event.
7/02:35	SEF monitor (SPACEHAB).
7/02:45	Close SPACEHAB viewport.
7/02:55	Group D GAS experiments.
7/03:05	ASC-3 deactivation (SPACEHAB).
7/03:15	ORSEP data off-load (SPACEHAB).
7/03:45	Group E GAS experiments.
7/03:50	Open SPACEHAB viewport.
7/04:00	SAREX voice operations—personal.
7/04:45	SAREX voice operations—Sidney, Maine.
7/05:00	Group F GAS experiments.
7/05:00	EOG preparation—DSO 201.
7/05:05	APC stow.
7/05:15	CPCG deactivation (SPACEHAB).
7/05:30	SEF deactivation (SPACEHAB).
7/05:30	SAREX power-down.
7/05:35	SAREX stow.
7/05:45	Ergometer stow.
7/06:00	SPACEHAB module teardown.
7/06:00	DTO 623—cabin air monitoring.
7/06:15	ORSEP deactivation (SPACEHAB).
7/06:30	SAMS disk changeout (SPACEHAB).
7/06:30	Cabin stow.
7/06:45	Neuro stow—DSO 201.
7/06:45	PSB deactivation (SPACEHAB).
7/09:25	Ku-band antenna stow.
7/09:30	Crew begins presleep activities.
7/12:30	Crew begins sleep period.
7/20:30	Crew begins postsleep activities.
7/20:30	Urine/saliva collection—DSO 202.
7/23:30	DSO 326—window impact observations.
7/23:30	Priority Group B power-up.
7/23:30	CPCG status check (SPACEHAB).
7/23:30	PSB monitor (SPACEHAB).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/23:30	Configure 3-DMA for reentry mode (SPACEHAB).
7/23:30	IMMUNE check (SPACEHAB).
7/23:35	SAMS deactivation (SPACEHAB).
7/23:40	Galley water sample collection—DSO 202.
7/23:45	SOR/F stow (SPACEHAB).
7/23:45	CAPL deactivation.
7/23:50	SPACEHAB fan clamp replacement.
7/23:55	SPACEHAB final deactivation.

MET DAY EIGHT

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/00:00	DTO 664—cabin temperature survey.
8/00:15	EGG deorbit preparation.
8/00:28	Crew begins deorbit preparation.
8/00:30	CRT timer setup.
8/00:33	Commander initiates cold soak.
8/00:42	Stow radiators, if required.
8/01:00	Commander configures DPS for deorbit preparation.
8/01:03	Mission Control Center updates IMU star pad, if required.
8/01:12	MS configures for payload bay door closure.
8/01:20	WSF nitrogen purge.
8/01:23	MCC-H gives "go/no-go" command for payload bay door closure.
8/01:33	Maneuver vehicle to IMU alignment attitude.
8/01:45	IMU alignment/payload bay door operations.
8/02:08	MCC gives the crew the go for OPS 3.
8/02:15	Pilot starts repressurization of SSME systems.
8/02:19	Commander and pilot perform DPS entry configuration.
8/02:28	MS deactivates ST and closes ST doors.
8/02:30	All crew members verify entry payload switch list.
8/02:45	All crew members perform entry review.
8/02:47	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
8/03:00	Commander and pilot configure clothing.
8/03:15	MS/PS configure clothing.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/03:26	Commander and pilot seat ingress.
8/03:28	Commander and pilot set up heads-up display (HUD).
8/03:30	Commander and pilot adjust seat, exercise brake pedals.
8/03:38	Final entry deorbit update/uplink.
8/03:44	OMS thrust vector control gimbal check is performed.
8/03:45	APU prestart.
8/04:00	Close vent doors.
8/04:04	MCC-H gives "go" for deorbit burn period.
8/04:13	Maneuver vehicle to deorbit burn attitude.
8/04:16	MS/PS ingress seats.
8/04:23	First APU is activated.
8/04:28	Deorbit burn.
8/04:31	Initiate post-deorbit burn period attitude.
8/04:35	Terminate post-deorbit burn attitude.
8/04:43	Dump forward RCS, if required.
8/04:51	Activate remaining APUs.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/04:56	Entry interface, 400,000 feet altitude.
8/05:01	Automatically deactivate RCS roll thrusters.
8/05:08	Automatically deactivate RCS pitch thrusters.
8/05:11	Initiate first roll reversal.
8/05:16	Initiate second roll reversal.
8/05:17	TACAN acquisition.
8/05:19	Initiate air data system (ADS) probe deploy.
8/05:20	Initiate third roll reversal.
8/05:22	Begin entry/terminal area energy management (TAEM).
8/05:22	Initiate payload bay venting.
8/05:23	Automatically deactivate RCS yaw thrusters.
8/05:27	Begin TAEM/approach/landing (A/L) interface.
8/05:31	Initiate landing gear deployment.
8/05:32	Vehicle has weight on main landing gear.
8/05:32	Vehicle has weight on nose landing gear.
8/05:32	Initiate main landing gear braking.
8/05:33	Wheel stop.

GLOSSARY

A/G	air-to-ground
AA	accelerometer assembly
ACS	active cooling system
ADACS	attitude determination and control system
ADS	air data system
AFB	Air Force base
AFD	aft flight deck
AG	airglow
A/L	approach and landing
AOS	acquisition of signal
APC	autonomous payload controller
APCS	autonomous payload control system
APE-B	Auroral Photography Experiment B
APU	auxiliary power unit
ASC-3	Astroculture-3 (SPACEHAB)
ASE	airborne support equipment
BFS	backup flight control system
BHPS	boiling heater power supply
BPL	Bioserve Pilot Laboratory (SPACEHAB)
BREMSAT	University of Bremen Satellite
CAPL	capillary pumped loop
CCD	charge-coupled device
CCTV	closed-circuit television
CDMS	command and data management subsystem
CERL	U.S. Army Construction Engineering Research Laboratory
CGBA	Commercial Generic Bioprocessing Apparatus
CHAWS	Charge Analysis and Wake Studies
CMAM	commercial middeck augmentation module (SPACEHAB)
COAS	crewman optical alignment sight
CONCOP	containerless coating process
CP	condenser profile
CPCG	commercial protein crystal growth
CRIM	commercial refrigerator/incubator module
CRT	cathode ray tube
C/W	caution/warning
DACA	data acquisition and control assembly
DA	detector assembly
DACS	data acquisition and control system
DAP	digital autopilot
DC	detector controller
DLW	doubly labeled water (DSO 202)
DOD	Department of Defense
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECLiPSE	Equipment for Controlled Liquid-Phase Sintering Experiment
ECLSS	environmental control and life support system
EDO	extended-duration orbiter
EDOMP	extended-duration orbiter medical project
EGG	electrogastrography (DSO 201)
EHF	extremely high frequency
ELV	expendable launch vehicle
EMP	enhanced multiplexer/demultiplexer pallet
EMU	extravehicular mobility unit
EOM	end of mission
EPS	electrical power system
EPS	electrical power subsystem
ESA	European Space Agency

ESC	electronic still camera
ESS	equipment support section
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FCP	fuel cell power plant
FCS	flight control system
FDF	flight data file
FES	flash evaporator system
FF	flight forward
FPA	fluid processing apparatus
fps	feet per second
FRCS	forward reaction control system
FSTV	fast-scan TV
GAS	getaway special
GBA	getaway special bridge assembly
GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GSFC	Goddard Space Flight Center
HAINS	high-accuracy inertial navigation system
HRM	high-rate multiplexer
HUD	heads-up display
IFM	in-flight maintenance
IMMUNE	immune experiment (SPACEHAB)
IMU	inertial measurement unit
I/O	input/output
IR	infrared

IV	intravehicular
JSC	Johnson Space Center
KEAS	knots equivalent air speed
KSC	Kennedy Space Center
LBNP	lower body negative pressure
LCD	liquid crystal display
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
MATLAB	materials laboratory (WSF)
MBE	molecular beam epitaxy
MCC-H	Mission Control Center—Houston
MCP	microchannel plate
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merritt Island
MLP	mobile launcher platform
MM	major mode
MOD	Mission Operations Directorate
MPM	manipulator positioning mechanism
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCC	corrective combination maneuver
NH	differential height adjustment that adjusts the altitude of orbiter's orbit
nm	nanometer
nmi	nautical miles
NOR	Northrup Strip

NSR	coelliptic maneuver that circularizes orbiter's orbit
O&C	operations and checkout
OAA	orbiter access arm
OCP	Office of Commercial Programs
ODERACS	orbital debris radar calibration spheres
OG	orbiter glow
OKN	optokinetic nystagmus (DSO 201)
OMS	orbital maneuvering system
OPF	Orbiter Processing Facility
ORSEP	organic separation
OSE	Orbiter Stability Experiment (G-514)
OTC	orbiter test conductor
PAO	public affairs officer
PASS	primary avionics software system
PC	proportional counter
PCIS	passive cycle isolation system
PCMMU	pulse code modulation master unit
PCS	pressure control system
PCU	power control unit
PDI	payload data interleaver
PDU	playback/downlink unit
PGSC	payload and general-support computer
PI	payload interrogator
PIC	pyro initiator controller
PLBD	payload bay door
PMCU	payload measurement and control unit
POCC	Payload Operations Control Center
PRCS	primary reaction control system
PRD	payload retention device
PRLA	payload retention latch assembly
PRSD	power reactant storage and distribution
PS	payload specialist
PSB	Penn State Biomodule (SPACEHAB)
PTI	preprogrammed test input
P/TV	photo/TV
RAAN	right ascension of the ascending node
RAM	random-access memory
RCRS	regenerable carbon dioxide removal system
RCS	reaction control system
RF	radio frequency
RGA	rate gyro assembly
RHEED	reflection high-energy electron diffraction
RMS	remote manipulator system
ROEU	remotely operated electrical umbilical
RPM	revolutions per minute
RSA	Russian Space Agency
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SA	solar array
SAAMD	stand-alone acceleration measurement device (WSF)
SAF	Secretary of the Air Force
SAMS	Space Acceleration Measurement System
SAREX	Shuttle Amateur Radio Experiment
SDA	sealed door assembly
SEF	Space Experiment Facility (SPACEHAB)
SHF	superhigh frequency
SM	statute miles
SOR/F	Stirling orbiter refrigerator/freezer
SPASP	small payload accommodations switch panel
SPOC	shuttle payload of opportunity carrier
SRAG	Space Radiation Analysis Group
SRB	solid rocket booster
SRE	Sample Return Experiment
SRM	solid rocket motor
SRSS	shuttle range safety system
SSME	space shuttle main engine

SSP	standard switch panel
SSP	sensory perception performance (DSO 201)
SSPP	Shuttle Small Payload Project
SSPP	solar/stellar pointing platform
SSTV	slow-scan TV
ST	star tracker
STA	structural test article
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite system
TEPC	tissue equivalent proportional counter
TFL	telemetry format load
3-DMA	three-dimensional microgravity accelerometer
TI	thermal phase initiation burn
TIG	time of ignition
TIPS	thermal impulse printer system
TPS	thermal protection system
TSM	tail service mast
TT&C	telemetry, tracking, and communications
TV	television
TVC	thrust vector control
UHF	ultrahigh frequency
Vbar	along the velocity vector
VHM	voluntary head movements (DSO 201)
VRCS	vernier reaction control system
VQS	vapor quality sensor (CAPL)
VTR	videotape recorder
WCCS	wireless crew communication system
WCS	waste collection system
WSF	Wake Shield Facility