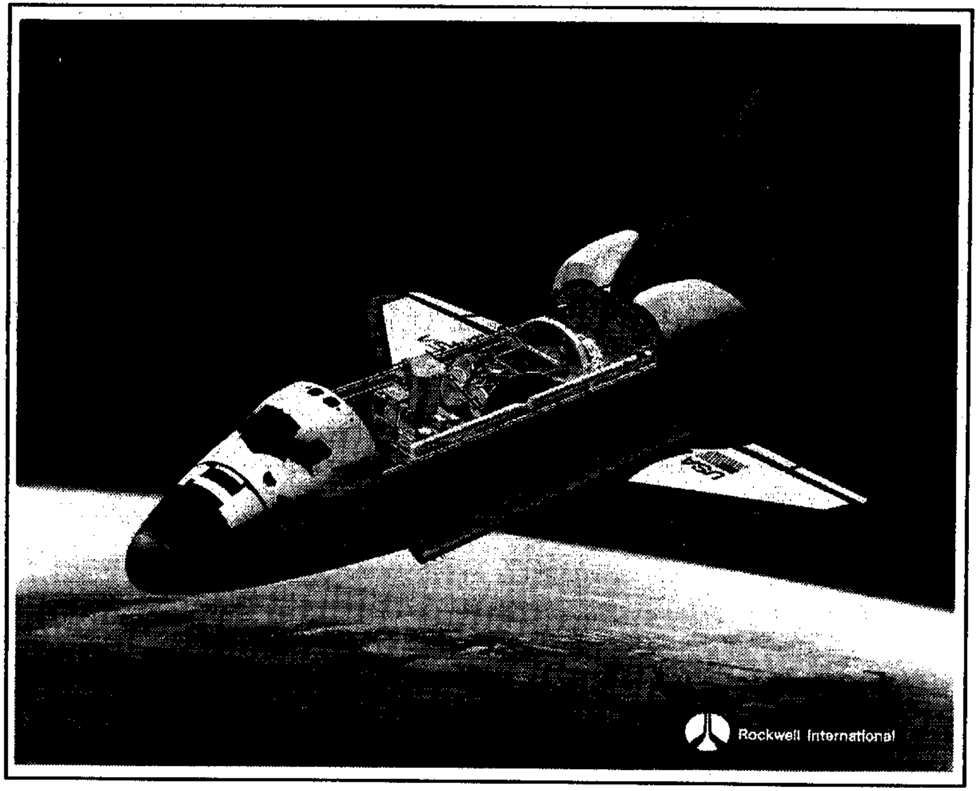

STS-51

PRESS INFORMATION AND MISSION TIME LINE

July 1993

Rockwell International
Space Systems Division

Office of External Communications &
Media Relations

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CONTENTS

MISSION OVERVIEW

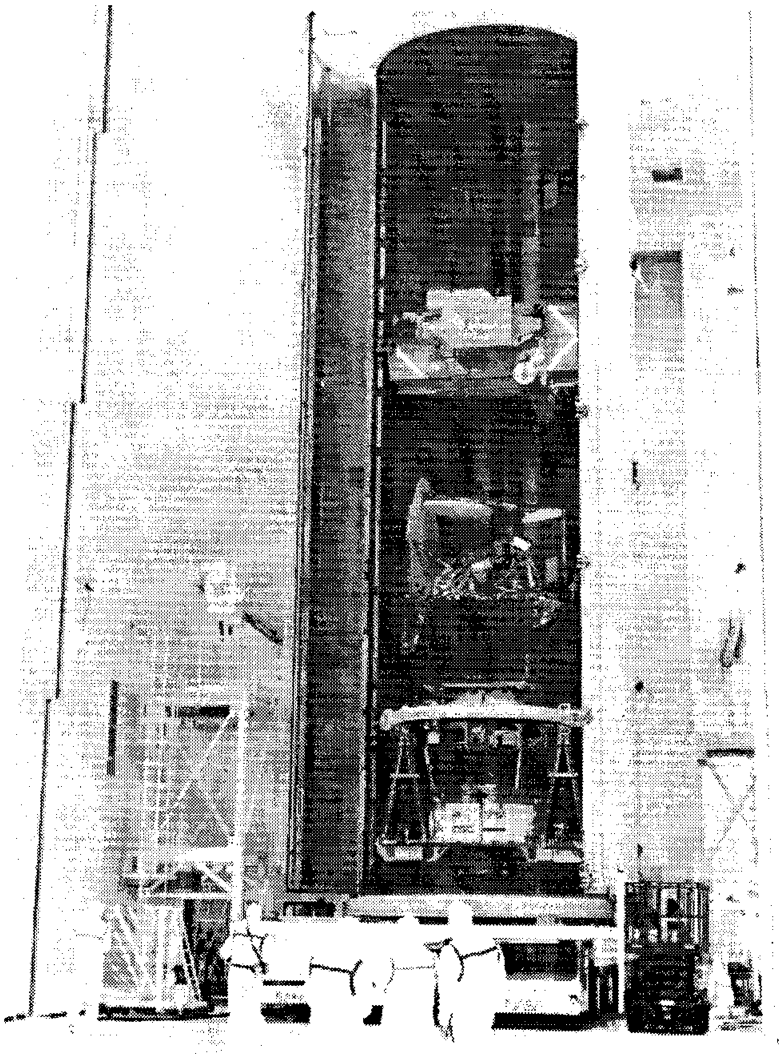
This is the 17th flight of Discovery and the 57th for the space shuttle.

The flight crew for the STS-51 mission is commander Frank L. Culbertson, Jr.; pilot William (Bill) F. Readdy; and mission specialists Daniel (Dan) W. Bursch, James (Jim) H. Newman, and Carl E. Walz.

STS-51 has two primary mission objectives: to deploy the Advanced Communications Technology Satellite (ACTS)/Transfer Orbit Stage (TOS) payload and to deploy and retrieve the German-built Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite (ORFEUS-SPAS).

ACTS/TOS consists of two major elements and their respective airborne support equipment (ASE). ACTS is a communications satellite designed to provide flight verification of advanced high-risk communications satellite concepts and technology to support future communication systems in the Ka-band frequencies. The ACTS payload will be propelled into a geosynchronous transfer orbit on Flight Day 1 by the TOS propulsive stage after they are deployed from the orbiter payload bay.

ORFEUS-SPAS is a free-flying payload that is deployed and retrieved by the orbiter's remote manipulator system. The payload will carry the ORFEUS and Interstellar Medium Absorption Profile Spectrograph (IMAPS) telescopes as well as a remote IMAX camera system (RICS) camera, passive Surface Effects Sample Monitor (SESAM), and a video camera/transmitter (EMU-TV). ORFEUS is a telescope system that will provide information on how stars are born and how they die and will also study gaseous interstellar clouds. ORFEUS will study molecular hydrogen, and IMAPS will observe contrasts in the chemical and physical properties of the interstellar medium. ORFEUS is housed in Discovery's payload bay. Its carrier, the SPAS, will be deployed from the orbiter for 40



ORFEUS-SPAS (top) and ACTS/TOS (bottom), ready to be taken to launch pad in payload transporter canister. They will be placed in cargo bay of Discovery on the pad.

to 60 hours on Flight Day 2 to allow observations during the flight before being retrieved and returned to Earth on Flight Day 8.

STS-51 secondary objectives include Limited-Duration Space Environment Candidate Materials Exposure (LDCE), Commercial Protein Crystal Growth (CPCG) Block II, Chromosome and Plant Cell Division in Space (CHROMEX), High-Resolution Shuttle Glow Spectroscopy (HRSGS) A, Auroral Photography Experiment (APE) B, Investigations Into Polymer Membrane Processing (IPMP), Radiation Monitoring Equipment (RME) III, Air Force Maui Optical Site Calibration Test (AMOS), and the IMAX In-Cabin Camera.

LDCE's primary objective is to introduce developmental composite materials to a flux of atomic oxygen atoms in low Earth orbit. The candidate materials—polymeric, coated polymeric, and light metallic composite—will have undergone extensive ground-based material performance testing before they are attached to reusable test fixtures designed for multimission space shuttle use. LDCE is contained in a getaway special canister mounted in the payload bay. Beam configuration C is being flown on STS-51.

CPCG will supply information on the scientific methods and commercial potential for growing large, high-quality protein crystals in microgravity. The configuration on this flight, Block II, consists of a commercial refrigerator/incubator module and a protein crystallization facility.

CHROMEX is designed to determine whether plant roots can be started and grown in microgravity in a plant growth unit at a level equivalent to that on Earth. Postflight data will be compared to that of similar plants grown at 1 g on Earth. Activities consist of crew verification and logging of nominal operations each flight day during the experiment's day cycle.

HRSGS-A is designed to obtain high-resolution spectra in the visible and near-visible wavelength range of the shuttle surface glow seen on the vertical tail of the orbiter in low Earth orbit. The glow is observed only on shuttle surfaces that face the velocity vector, and it is hoped that the spectral resolution of 2 angstroms will help identify the cause of shuttle glow.

APE-B will photograph and record the spectra of the following aurora phenomena: shuttle glow, thruster emissions, aurora effects on the orbiter, aurora, and airglow layer. APE-B equipment consists of a 35mm SLR camera, a 55mm lens, a 135mm lens, an image intensifier, spectrometer bar, filter holder, and various filters. Only shuttle glow images are scheduled in the STS-51 flight plan.

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

RME III consists of a hand-held instrument with replaceable memory modules that takes measurements of the radiation environment at a specified sample rate.

AMOS uses the orbiter during cooperative overflights of Maui, Hawaii, and Arecibo to obtain imagery and/or signature data to support the calibration of ground-based sensors and to observe plume phenomenology. No unique on-board hardware is associated with the AMOS test; however, crew and orbiter participation may be required to establish controlled conditions for cooperative overflights.

The IMAX payload is a 70mm motion picture camera system. The camera and supporting equipment are stowed in the middeck and are for in-cabin use. On STS-51, IMAX will be used to photograph ACTS/TOS and ORFEUS-SPAS activities.

A six-hour extravehicular activity, or spacewalk (DTO 1210), is also scheduled to be performed on STS-51. Its primary objective is to isolate and demonstrate specific differences between training facility simulations and operations in the actual EVA environment. Additional objectives are to broaden the EVA team experience base and to demonstrate improved proficiency and capability to support future EVAs, including Hubble Space Telescope and space station assembly and maintenance.

Nineteen development test objectives and 14 detailed supplementary objectives are scheduled to be flown on STS-51.

Crew Insignia

MISSION STATISTICS

Vehicle: Discovery (OV-103), 17th flight

Launch Date/Time:

7/17/93	9:22 a.m., EDT
	8:22 a.m., CDT
	6:22 a.m., PDT

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

Launch Window: 1 hour, 2 minutes (based on end-of-mission lighting and ACTS/TOS deploy constraints)

Mission Duration: 8 days, 21 hours, 59 minutes. A highly desirable additional day cannot be guaranteed due to consumables, but could be possible. Planning will accommodate the longer duration wherever appropriate. The capability exists for two additional days to allow for contingency operations and to avoid bad weather.

Landing: Nominal end-of-mission landing on orbit 143

7/26/93	7:21 a.m., EDT
	6:21 a.m., CDT
	4:21 a.m., PDT

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

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

Return to Launch Site: KSC

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

Inclination: 28.45 degrees

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

The OMS-1 thrusting maneuver after main engine cutoff plus approximately 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: 160 nautical miles (184 statute miles) circular orbit

Space Shuttle Main Engine Thrust Level During Ascent: 104 percent

Space Shuttle Main Engine Locations:

No. 1 position: Engine 2030
No. 2 position: Engine 2033
No. 3 position: Engine 2032

External Tank: ET-59

Solid Rocket Boosters: BI-060

Mobile Launcher Platform: 3

Editor's Note: The following weight data are current as of July 12, 1993.

Total Lift-off Weight: Approximately 4,525,869 pounds

Orbiter Weight, Including Cargo, at Lift-off: Approximately 261,597 pounds

Orbiter (Discovery) Empty and 3 SSMEs: Approximately 173,542 pounds

Payload Weight Up: Approximately 42,687 pounds

Payload Weight Down: Approximately 15,931 pounds

Orbiter Weight at Landing: Approximately 206,329 pounds

Payloads—Payload Bay (* denotes primary payload): Advanced Communications Technology Satellite (ACTS)/Transfer Orbit Stage (TOS),* Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite (ORFEUS-SPAS),* Limited-Duration Space Environment Candidate Materials Exposure (LDCE)

Payloads—Middeck: Commercial Protein Crystal Growth (CPCG) Block II, Chromosome and Plant Cell Division in Space (CHROMEX), High-Resolution Shuttle Glow Spectroscopy (HRSGS) A, Auroral Photography Experiment (APE) B, Investigations Into Polymer Membrane Processing (IPMP), Radiation Monitoring Equipment (RME) III, Air Force Maui Optical Site (AMOS) Calibration Test, IMAX In-Cabin Camera

Flight Crew Members:

Commander: Frank L. Culbertson, Jr., second space shuttle flight
Pilot: William (Bill) F. Readdy, second space shuttle flight
Mission Specialist 1: James (Jim) H. Newman, first space shuttle flight
Mission Specialist 2: Daniel (Dan) W. Bursch, first space shuttle flight
Mission Specialist 3: Carl E. Walz, first space shuttle flight

Ascent and Entry Seating:

Ascent:

Flight deck, front left seat, commander Frank L. Culbertson
Flight deck, front right seat, pilot William F. Readdy
Flight deck, aft center seat, mission specialist Daniel W. Bursch
Flight deck, aft right seat, mission specialist James H. Newman
Middeck, mission specialist Carl E. Walz

Entry:

Flight deck, front left seat, commander Frank L. Culbertson
Flight deck, front right seat, pilot William F. Readdy
Flight deck, aft center seat, mission specialist Daniel W. Bursch
Flight deck, aft right seat, mission specialist Carl E. Walz
Middeck, mission specialist James H. Newman

Extravehicular Activity Crew Members, if Required:

Extravehicular (EV) astronaut 1: mission specialist Carl E. Walz
EV-2: mission specialist James H. Newman

Intravehicular Astronaut: William F. Readdy

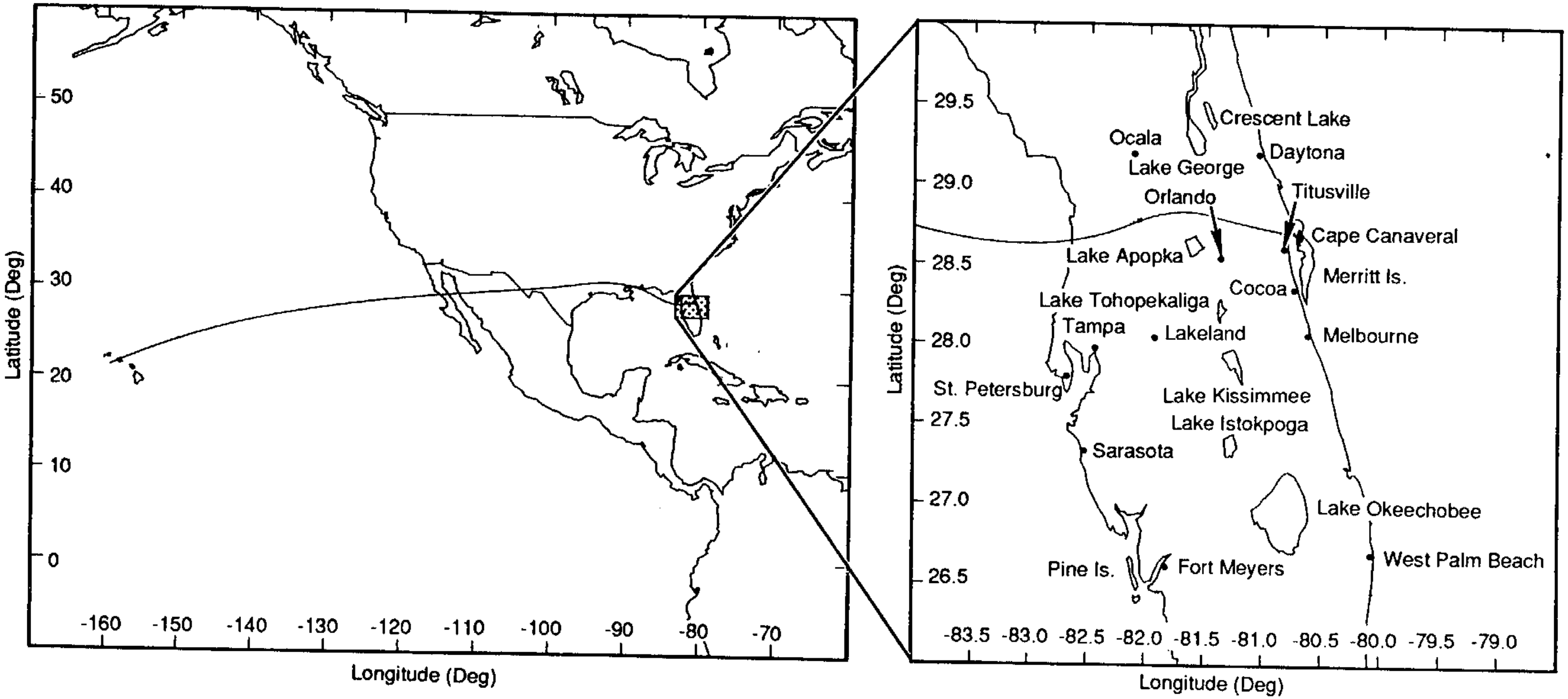
STS-51 Flight Directors:

Ascent/Entry Team: Rich Jackson
Orbit 1 Team Lead: Bob Castle
Orbit 2 Team: Rob Kelso
Planning Team: Wayne Hale

Entry: Automatic mode until subsonic, then control stick steering

Notes:

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



MTD 930713-4373

STS-51 Descent Trajectory to KSC Runway 15

MISSION OBJECTIVES

- Primary objectives
  - Advanced Communications Technology Satellite (ACTS)/Transfer Orbit Stage (TOS) deployment
  - Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite (ORFEUS-SPAS) deployment and retrieval
- Secondary objectives
  - Payload bay
    - Limited-Duration Space Environment Candidate Materials Exposure (LDCE)
  - Middeck
- Commercial Protein Crystal Growth (CPCG) Block II
- Chromosome and Plant Cell Division in Space (CHROMEX)
- High-Resolution Shuttle Glow Spectroscopy (HRSGS) A
- Auroral Photography Experiment (APE) B
- Investigations Into Polymer Membrane Processing (IPMP)
- Radiation Monitoring Equipment (RME) III
- Air Force Maui Optical Site (AMOS) Calibration Test
- IMAX In-Cabin Camera
- 19 development test objectives/14 detailed supplementary objectives

FLIGHT ACTIVITIES OVERVIEW

Flight Day 1

Launch
OMS-2 burn
Payload bay doors open
Unstow cabin
ACTS/TOS activation and checkout
RMS powerup
RMS checkout
RMS powerdown
CHROMEX check
CPCG activation
RME activation
Maneuver to deploy attitude
Raise ACTS/TOS to deploy position
ACTS/TOS deploy
RCS, OMS separation burns
TOS SRM ignition

Flight Day 2

RMS powerup
HITE TIG
SPAS grapple
ORFEUS-SPAS checkout
Circularization burn ignition
ORFEUS-SPAS release
RMS powerdown
RCS separation burns
CHROMEX check
Cabin depressurization to 10.2 psi

Flight Day 3

Stationkeeping burns
IPMP activation
CHROMEX check

Flight Day 4

EMU checkout
ECLSS redundant component checkout
Stationkeeping burns
RME check

Flight Day 5

EVA preparations
Airlock depressurization
EVA (six hours)
Airlock repressurization
Stationkeeping burns
CHROMEX check

Flight Day 6

Stationkeeping burns
APE setup
HRSGS setup
CHROMEX check
LDCE operations

Flight Day 7

Stationkeeping burns
LDCE operations

APE operations
HRSGS operations
HRSGS stow
CHROMEX check
RME check

Flight Day 8

Stationkeeping burns
RMS powerup
ORFEUS-SPAS rendezvous
ORFEUS-SPAS berth
RMS powerdown
CHROMEX check
DTO 412—fuel cell shutdown

Flight Day 9

RMS powerup
Cabin repressurization to 14.7 psi
RMS powerdown
FCS checkout
RCS hot fire
AMOS
CHROMEX check
Cabin stow
DTO 412—fuel cell restart
Ku-band antenna stow

Flight Day 10

Deorbit preparations
Deorbit burn
Entry
Landing

Notes:

- If mission is extended one day, ORFEUS-SPAS science collection will be extended an extra day so that retrieval would occur on Flight Day 9. Activities nominally scheduled for Flight Day 6 and beyond would occur as planned but one day later. This ensures that the orbiter is not exposed to additional risks from orbital debris.
- Each flight day includes a number of scheduled housekeeping activities. These include inertial measurement unit alignment, supply water dumps (as required), waste water dumps (as required), fuel cell purge, Ku-band antenna cable repositioning, and a daily private medical conference.

CREW ASSIGNMENTS

Commander: Frank L. Culbertson, Jr.

Overall mission decisions
Payload—CPCG*
DTOs/DSOs—ALBRT, exercise, ENH stand, fuel cell,* skeletal/muscle*
Other—photography/TV, Earth observations

Pilot: William F. Readdy

Payload—IMAX, AMOS, CHROMEX*
DTOs/DSOs—fuel cell, laser range (hand), VRCS, posture, skeletal/muscle, blood IV, laser range (cargo bay),* exercise*
Other—photography/TV, Earth observations, medic, IV, in-flight maintenance

Mission Specialist 1: James (Jim) H. Newman

Payload—ORFEUS-SPAS, CHROMEX, IPMP, HRSGS, APE*
DTOs/DSOs—PGSC, thermal print (TIPS), PCMMU, entry ortho tolerance, visual vestibular, EV-2, ET photo,* GPS,* VRCS,* exercise,* skeletal/muscle,* gastro function,* ENH stand*

Mission Specialist 2: Daniel (Dan) W. Bursch

Payload—CPCG, ACTS/TOS,* IPMP,* AMOS
DTOs/DSOs—laser range (cargo bay), gastro function, ALBRT,* laser range (hand),* exercise,* skeletal/muscle,* blood IV*
Other—medic

Mission Specialist 3: Carl E. Walz

Payload—ACTS/TOS, APE, RME, IMAX,* HRSGS*
DTOs/DSOs—EV-1, ET photo, GPS, PGSC,* thermal print (TIPS),* PCMMU,* exercise,* entry ortho tolerance,* posture,* skeletal/muscle,* EHN stand*
Other—photography/TV

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*Denotes backup responsibility.

STS-51 CREW—The five astronauts assigned to this mission are (from left) mission commander Frank L. Culbertson, Jr.; mission specialists Daniel W. Bursch and Carl E. Walz; pilot William F. Readdy; and mission specialist James H. Newman.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DTOs

- Ascent structural capability evaluation (DTO 301D)
- Ascent compartment venting evaluation (DTO 305D)
- Descent compartment venting evaluation (DTO 306D)
- Payload bay acoustic evaluation (DTO 308D)
- ET TPS performance (method 3) (DTO 312)
- Orbiter/payload acceleration and acoustics environment data (DTO 319D)
- On-orbit fuel cell shutdown/restart (fuel cell 1) (DTO 412)
- Orbiter drag chute system (DTO 521)
- PGSC single-event upset monitoring (DTO 656)
- Thermal impulse printer system demonstration (DTO 660)
- Advanced lower body restraint test (DTO 668)
- EVA hardware for future scheduled EVA missions (DTO 671)
- Laser range and range rate device (DTO 700-2)
- Payload bay-mounted rendezvous laser (DTO 700-5)
- Global Positioning System on-orbit demonstration (DTO 700-6)
- Orbiter data for real-time navigation evaluation (DTO 700-7)
- STS orbiter attitude control translational thrusting (DTO 779)
- Crosswind landing performance (DTO 805)
- EVA operations procedures/training (DTO 1210)

DSOs

- In-flight aerobic exercise (cycle ergometer) (DSO 476)
- Inter-Mars tissue equivalent proportional counter (ITEPC) (DSO 485)
- Immunological assessment of crew members (DSO 487)
- Orthostatic function during entry, landing, and egress (DSO 603B*)
- Visual-vestibular integration as a function of adaption (DSO 604 OI-1 and OI-3*)
- Postural equilibrium control during landing/egress (DSO 605*)

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*EDO buildup medical evaluation

- Evaluation of functional skeletal muscle performance following space flight (DSO 617*)
- In-flight use of Florinef to improve orthostatic intolerance after flight (DSO 621*)
- Gastrointestinal function during extended-duration space flight (DSO 622*)
- Measurement of blood volumes before and after flight (DSO 625*)
- Cardiovascular and cerebrovascular responses to standing before and after space flight (DSO 626*)
- Documentary television (DSO 901)
- Documentary motion picture photography (DSO 902)
- Documentary still photography (DSO 903)

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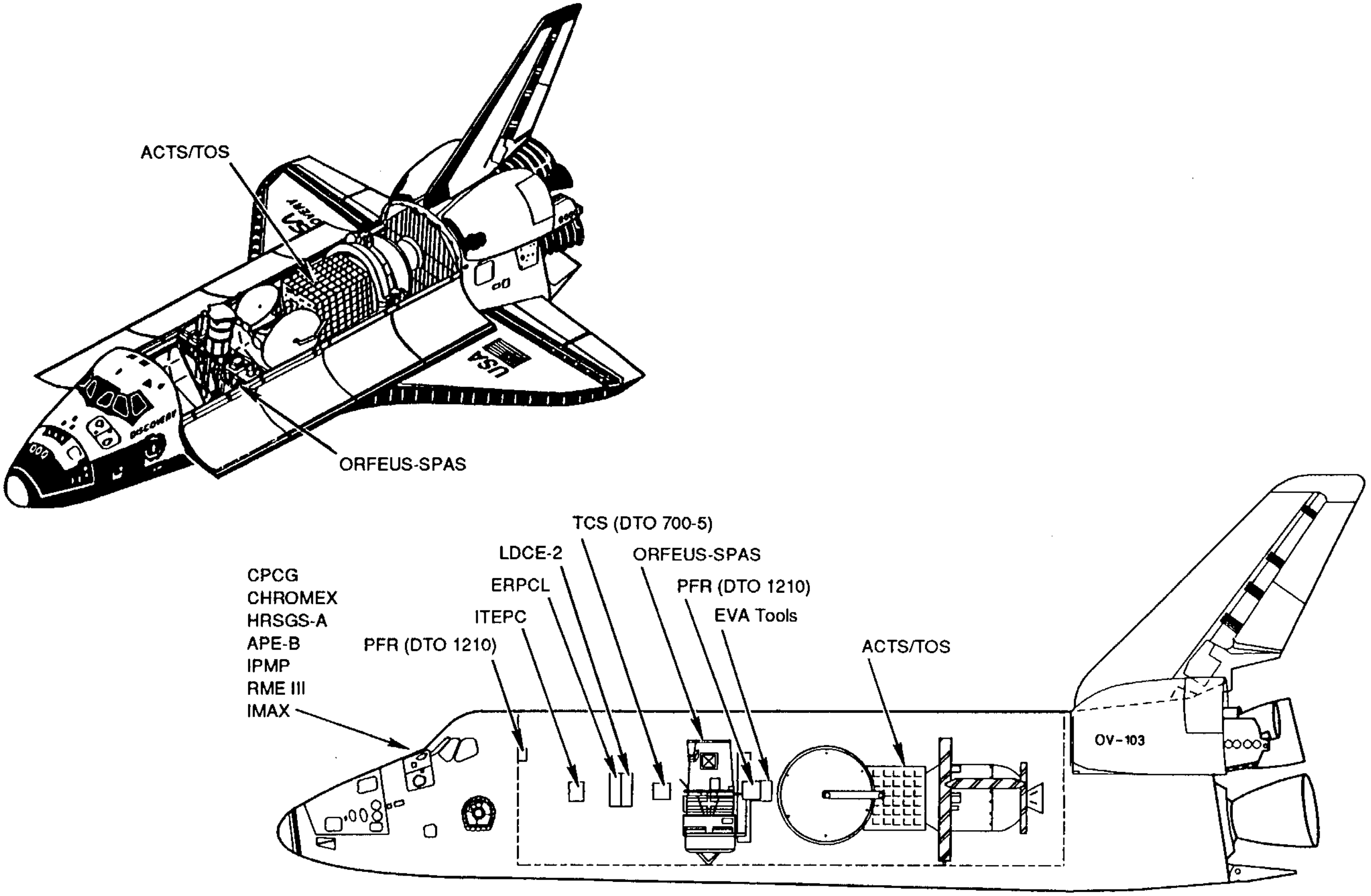
*EDO buildup medical evaluation

STS-51 PAYLOAD CONFIGURATION



MTD 930708-4346

ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

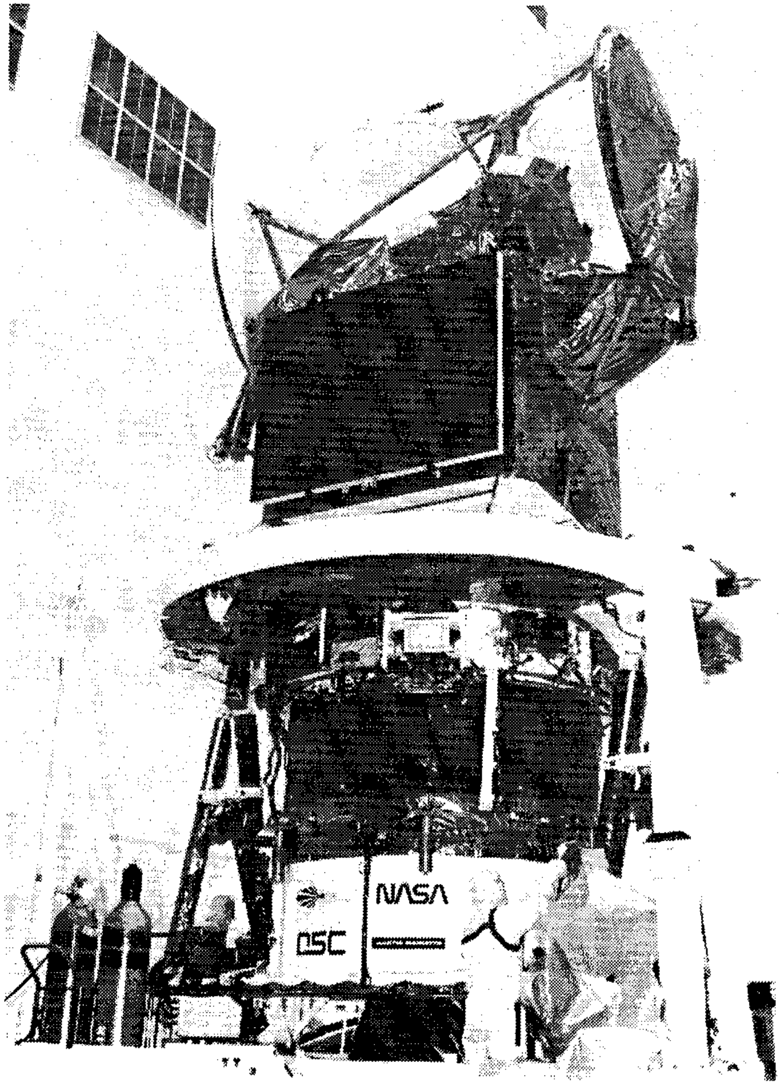
The Advanced Communications Technology Satellite (ACTS) that will be launched from the space shuttle Discovery's cargo bay during the STS-51 mission represents a joint NASA-U.S. industry effort to maintain America's preeminence in the field of satellite communications, which the United States pioneered, in the face of intense international competition by Europeans and the Japanese.

Hailed as the prototype of future telecommunication satellites, ACTS will be used as a space-based test bed for high-risk technologies that may dramatically enhance the capabilities of the satellite communications industry and reduce the cost of using the system. The advanced technologies that NASA and its industry, government, and academic partners hope to demonstrate through a series of 71 experiments over the next two years are expected to create newer roles for communications satellites, improve service and reliability, provide more cost-effective delivery of existing services, and increase the flexibility of telecommunications.

NEW TECHNOLOGIES

Although it weighs the same as current telecommunications satellites, the experimental ACTS has three times the communications capacity and 20 times the data rate for communications between users of the satellite. It also offers on-demand digital services not offered by existing communications systems and greater flexibility in networking.

These improvements are made possible by the introduction of the commercial use of the Ka-band, which operates at 30 gigahertz for transmissions from the ground to the satellite and 20 gigahertz in the opposite direction. This band has 2.5 gigahertz of spectrum available, five times that provided by lower-frequency bands.



Workers prepare to hoist ACTS/TOS into test cell at KSC.

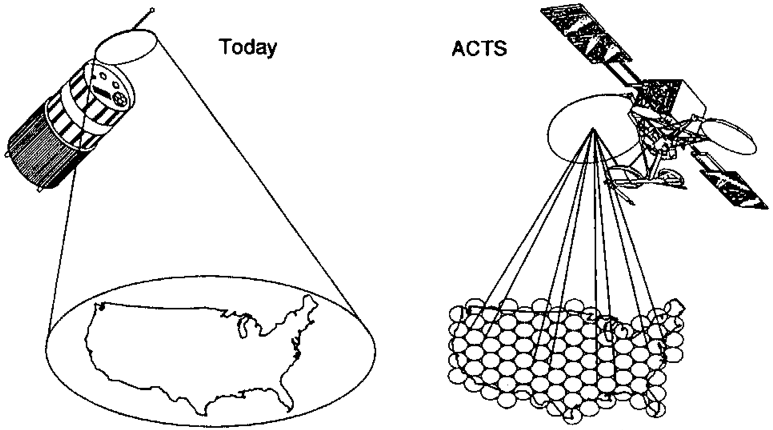
Other new technologies that ACTS will demonstrate are very high gain hopping beam antennas, on-board baseband switching, a steerable antenna, and a microwave switch matrix.

- The hopping spot beams that ACTS will generate are narrower and higher powered than the beams generated by the present generation of communications satellites. Because they deliver a great deal of information very quickly, these beams can link widely separated geographic areas and make it possible to use smaller, less costly Earth stations.
- On-board baseband switching turns the satellite into an orbiting computer that electronically sorts and routes signals, a function that now requires ground stations.
- The microwave switch matrix will enable gigabit-per-second transmissions between users. (A gigabit equals 1 billion bits of information.)
- The steerable antenna will allow ACTS users to communicate with any place in the Western Hemisphere.

Services that the new technologies could make feasible include medical image diagnostics at remote sites, global personal communications, and the interconnection of supercomputers. Motorola is already adapting ACTS' Ka-band and on-board switching to its Iridium satellite system for global voice and data communications.

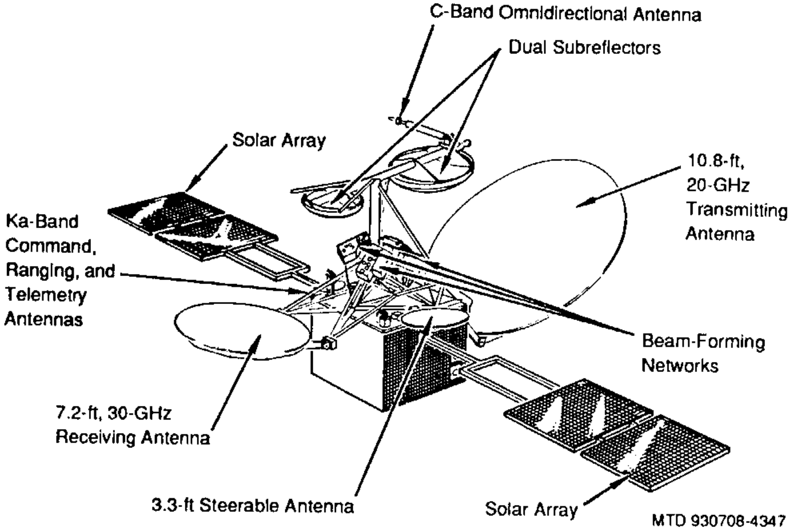
THE SATELLITE

ACTS consists of a spacecraft bus that contains basic housekeeping functions and the multibeam communications package. The 3,250-pound satellite measures 47.1 feet (from tip to tip of the solar arrays) by 29.9 feet (across the main receiving and transmitting antennas).



MTD 930712-4363

Satellite Systems Comparison



MTD 930708-4347

Advanced Communications Technology Satellite Fully Deployed

DEPLOYMENT SCENARIO

About two hours after the shuttle lifts off from the Kennedy Space Center, the crew will begin the sequence of events that will prepare the satellite and its transfer orbit stage (TOS) for deployment from Discovery's cargo bay. When the sequence is complete about six hours later, the crew will fire a pyrotechnic mechanism that will unlatch the TOS-satellite, and springs will gently nudge the mated pair out of the cargo bay about 160 nautical miles above the Earth. Forty-five minutes later, a timer on board the TOS will fire the booster's solid rocket motor, and the 110-second burn will place the satellite in a geosynchronous transfer trajectory.

ACTS will separate from the TOS about 15 minutes after the solid rocket motor burn ends. A solid rocket motor on the satellite will then position ACTS in a drift orbit, where it will remain drifting for seven days while the satellite's thrusters bring it to its final geosynchronous equatorial orbit at 100 degrees west longitude, 21,519 nautical miles above the Earth at its maximum altitude.

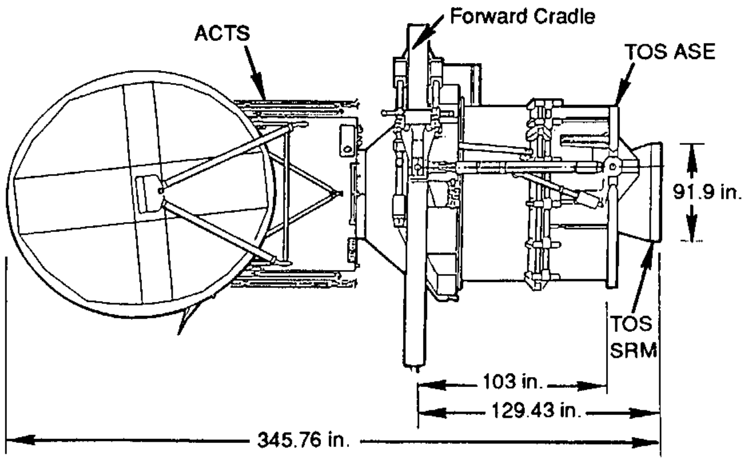
After it has reached its final orbit location, the satellite will deploy its solar arrays, lock on to the Earth and sun, and deploy its communications antennas. Experiments will begin 12 weeks later, after the satellite has been checked out.

ACTS' geosynchronous orbit makes the satellite appear to be motionless over one spot on the Earth. It has this appearance because the satellite takes 24 hours to make a complete revolution, the same as the Earth.

Although the mission is planned to last two years, ACTS is carrying enough fuel to remain on station for more than four years.

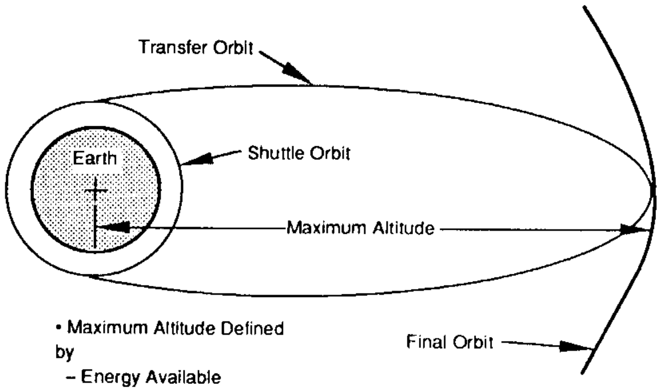
GROUND SEGMENT

The master ground station for ACTS at NASA's Lewis Research Center in Cleveland, Ohio, includes the NASA ground station, which converts signals to 30 gigahertz for transmission to the satellite and amplifies and converts 20-gigahertz signals from ACTS. The ground station also modulates and demodulates baseband communications signals.



MTD 930713-4374

ACTS/TOS in ASE Cradle



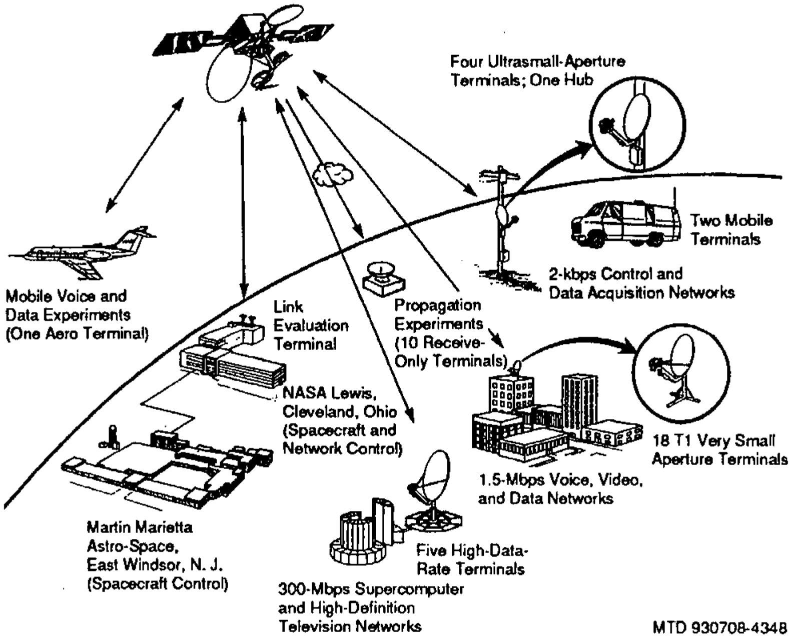
- Maximum Altitude Defined by
  - Energy Available
  - Weight of Spacecraft

MTD 930709-4361

TOS provides energy to increase orbit altitude of a payload.

Also at the master ground station is the master control station, which is part of the on-orbit testing of the satellite's baseband processor and its multibeam antenna. The master control station also enables the collection of satellite telemetry data and the execution of experiments.

A microwave switch matrix-link evaluation terminal at the master ground station enables researchers to test the satellite's microwave switch matrix and multibeam antenna and conduct wide-band communications experiments.



ACTS Ground Segment

At the satellite operations center in East Windsor, New Jersey, researchers will generate flight system commands and analyze, process, and display flight telemetry data transmitted over land lines to the center from the master ground station in Ohio. The center also plans and executes orbital maneuvers and performs the satellite's primary housekeeping functions.

More than 40 Ka-band terminals have been set up for use by the industry, government, and university organizations that will participate in the experiment program.

EXPERIMENT PROGRAM

During the two-year experiment program, 86 government, industry, and academic organizations will conduct 71 experiments that will use most of the satellites time. These investigations will demonstrate the commercial viability and market acceptability of new voice, data, and video networks and services; verify the performance of the satellite's advanced technologies; demonstrate and evaluate the networking aspects of the switching and processing technologies; and characterize the Ka-band medium.

In one experiment, American Express will test the high-speed transmittal and reception of data through ACTS' small ground stations for possible use in the future in an operational system. The Mayo Foundation will demonstrate medical support of remote communities and the transfer of high-definition imagery. The National Science Foundation's Palmer Station in Antarctica will transmit data and imagery.

Lewis Research Center, in Cleveland, Ohio, is the NASA center that is responsible for the ACTS project.

TRANSFER ORBIT STAGE

After it is deployed from the cargo bay of the space shuttle Discovery, the Advanced Communications Technology Satellite (ACTS) will receive a boost to its final orbital station from the transfer orbit stage (TOS), which is being used for the first time on a shuttle mission. The single-stage, solid-propellant motor rocket will propel ACTS from low Earth orbit to a geosynchronous transfer orbit with a maximum altitude of 21,519 nautical miles.

This is the second mission for the TOS, which is qualified for use on both the shuttle and Titan rockets. It was first used in September, 1992, to propel NASA's Mars Observer Mission spacecraft on a trajectory to the Red Planet after it was launched on a rocket.

The development of the TOS began as a commercial venture of Orbital Sciences Corp., of Dulles, Va. It was built by Martin Marietta Astronautics Group in Denver, Colo. The government purchased the first TOS in 1987, making it the latest addition to NASA's fleet of upper stages used to boost satellites on the second leg of their journey to high-altitude orbit or spacecraft toward their interplanetary objectives.

The TOS is constructed primarily of a high-strength aluminum alloy and, with its fuel, weighs 20,780 pounds. It is about 11 feet long and 7.5 feet in diameter. Gold foil insulation protects the TOS from the heat of the sun.

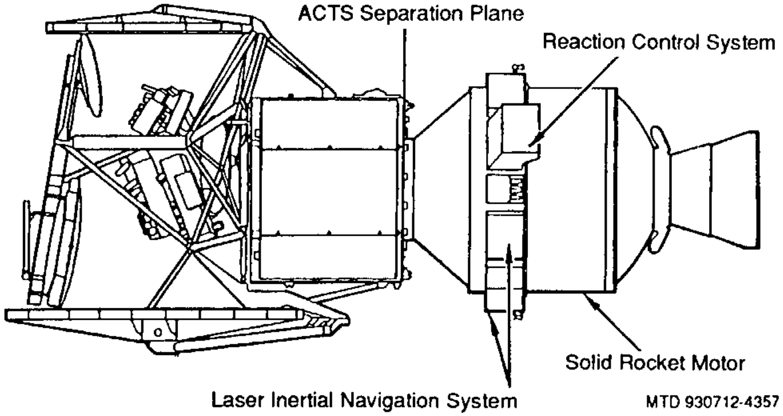
TOS ELEMENTS

The major elements of the TOS are the solid rocket main propulsion system, a navigation and guidance system, a reaction control system (RCS), and an airborne support equipment (ASE) cradle.

TOS' main propulsion system supplies the primary thrust for powered flight, which lasts just 110 seconds. The motor burns 18,013 pounds of the solid propellant HTPB (hydroxyl terminated polybutadiene) to provide the 59,000 pounds of thrust needed to put the satellite or spacecraft in its transfer orbit. Two thrust vector control actuators gimbal the solid rocket motor during the burn to maneuver the satellite-upper stage combination.

A laser inertial navigation system acts as the brains of the TOS by sensing its location and maintaining the proper trajectory. Laser gyroscopes that have no moving parts reduce the chances of guidance system malfunctions in space. All TOS operations are performed autonomously, and performance data from TOS electronics are recorded and sent to ground controllers at the Kennedy Space Center in Florida.

Using information from the navigation system, the RCS thruster assembly maneuvers the upper stage and its payload throughout the mission. The assembly comprises 12 small rockets that are used to place the TOS and its payload in the correct orientation before the TOS' solid rocket motor ignites. The RCS rockets also turn the



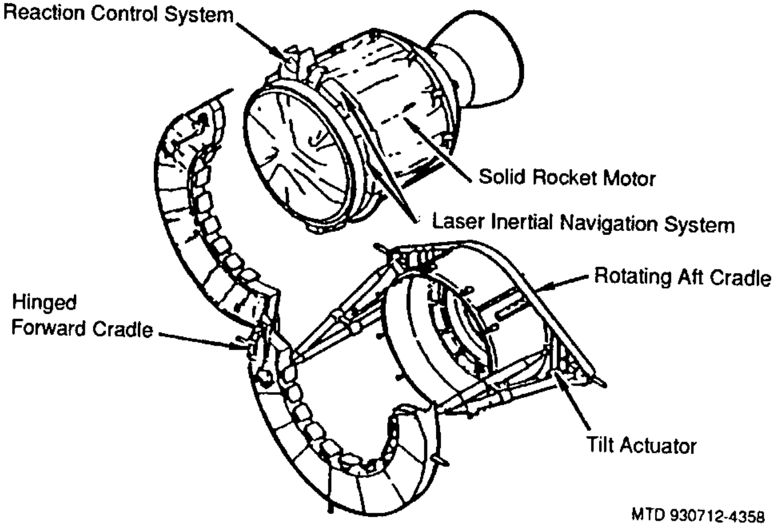
ACTS/TOS Configuration

upper stage and payload slowly to help prevent overheating from the sun. The rockets are used again just before the TOS separates from its payload to make final adjustments in their attitude.

The ASE adapts the TOS-satellite to the space shuttle. In the shuttle's payload bay, the TOS rests in an aft cradle and is attached firmly to the cargo bay by a forward cradle.

If the ASE develops a mechanical problem before or after the TOS-satellite deployment, two astronauts could take a spacewalk to fix it with tools specially designed for the purpose. It is not expected that the ASE will need to be repaired, however, because its systems have built-in backups.

The ORBUS-21 solid rocket motor is manufactured by United Technologies Chemical Systems Division in San Jose, Calif. The laser inertial navigation system is built by Honeywell, Inc. in Clearwater, Fla. UTC/Hamilton Standards Division, Windsor Locks, Conn., builds the RCS thruster assembly, and Martin Marietta makes the ASE.



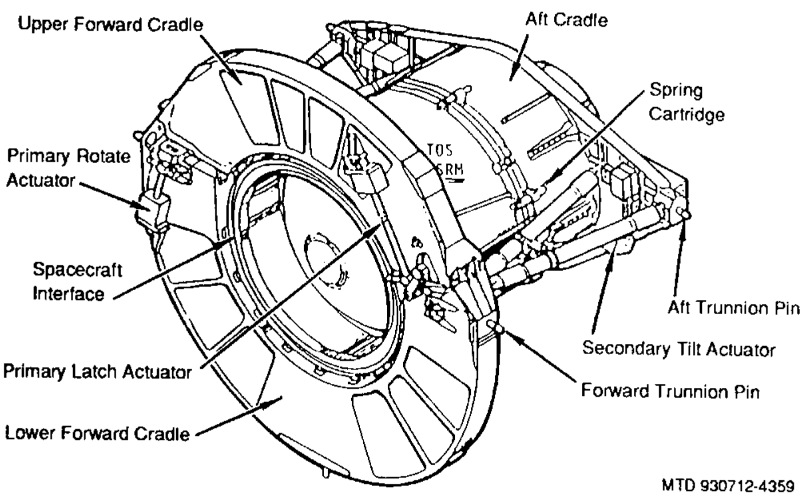
TOS and Airborne Support Equipment

DEPLOYMENT SCENARIO

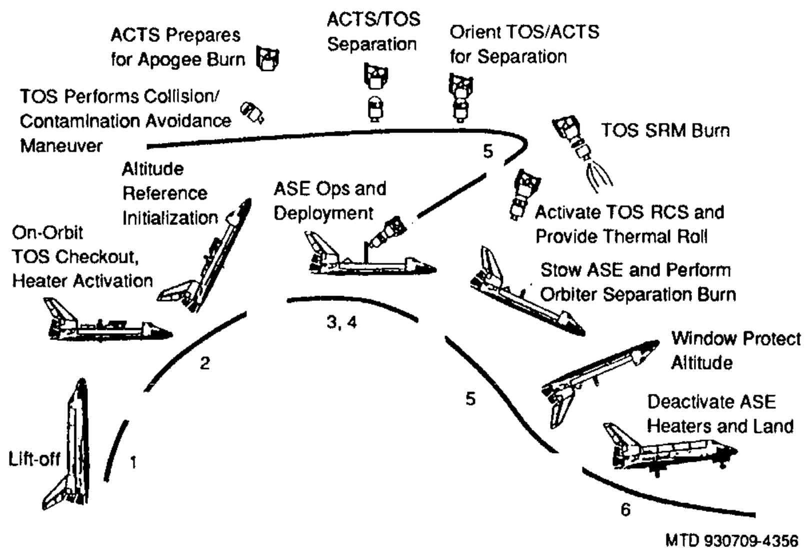
Discovery crew members will check out all critical TOS systems before it is deployed to ensure that the systems are healthy and ready for deployment. After the upper forward cradle is unlatched and rotated open, the booster and satellite will be elevated 45 degrees so that they point out of the payload bay.

The booster and ACTS, which will be continuously monitored for problems, can be lowered back into the payload bay, latched, and returned to Earth at this point in the deployment if any trouble is detected. If no problems are found, a pyrotechnic mechanism will release the booster-satellite, and springs will gently push the mated pair from the payload bay.

After the deployment, the Discovery crew will maneuver the orbiter about 12 miles away from the TOS-satellite to avoid a collision or damage from the TOS' rocket exhaust. When the booster's RCS rockets have placed the ACTS in the proper attitude, the booster's solid rocket motor will ignite and continue firing for 110 seconds to reach the 22,800-mph velocity required to place ACTS in its geostationary transfer orbit. As the satellite races toward its maxi-



TOS ASE Components



TOS Mission Profile

mum altitude above the Earth, the TOS will make final adjustments in attitude.

Soon after the upper stage's motor burns out, the TOS and satellite will separate, and the TOS will maneuver out of the path of the satellite. The satellite's own thrusters and solid rocket motor will place it in its final geostationary orbit. Ground controllers will determine the timing of the burns.

The TOS program is managed by the Space Systems Projects Office at the Marshall Space Flight Center in Huntsville, Ala.

ORBITING AND RETRIEVABLE FAR AND EXTREME ULTRAVIOLET SPECTROGRAPH (ORFEUS)-SHUTTLE PALLET SATELLITE (SPAS)

ORFEUS-SPAS is a German-developed mission to measure the ultraviolet radiation from stars and the interstellar medium. Through the use of ultraviolet spectroscopy, astronomers will try to increase our knowledge of how stars are born and die and the properties of the gas swirling among the stars.

The ORFEUS payload of spectrographic instruments is mounted on the reusable, free-flying spacecraft ASTRO-SPAS, which was designed specifically to carry instruments that require precision pointing. Shuttle crew members will use the orbiter's remote manipulator arm to remove ORFEUS-SPAS from the cargo bay and place it in orbit on the second day of the mission. During six or seven days of observations, the satellite will orbit the Earth about 40 miles behind the shuttle. The crew will recapture the satellite and return it to Earth for reuse.

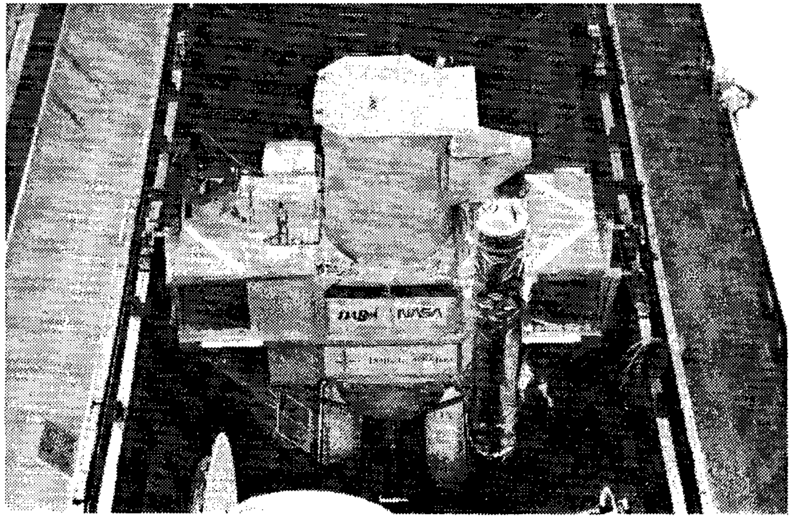
This is the first of four planned missions for the German-built ASTRO-SPAS. Each mission will have different scientific objectives and a different complement of instruments provided by Germany and NASA. A second flight of ORFEUS-SPAS is planned in about two years.

ASTRO-SPAS is a successor to SPAS-1, which was used on shuttle missions in 1983 and 1984. It can be tailored to accommodate varying scientific payloads and provides precise pointing for the instruments it carries. During the satellite's four- to eight-day missions it is controlled from its own operations center at the Kennedy Space Center. The shuttle orbiter acts as the communication link between ASTRO-SPAS and the ground for command and telemetry data, but scientific data are recorded on board the satellite.

The primary ORFEUS-SPAS instruments are the German ORFEUS and NASA's Interstellar Medium Absorption Profile Spectrograph (IMAPS).

ORFEUS and IMAPS will conduct observations in the far ultraviolet (90 to 125 nanometers) and extreme ultraviolet (40 to 90 nanometers) ranges of the electromagnetic spectrum. (A nanometer is one billionth of a meter.) The observations are being conducted 160 nautical miles above the Earth's surface because the Earth's atmosphere absorbs most of the ultraviolet radiation that enters it, protecting us from the harmful rays but making life difficult for Earth-bound astronomers.

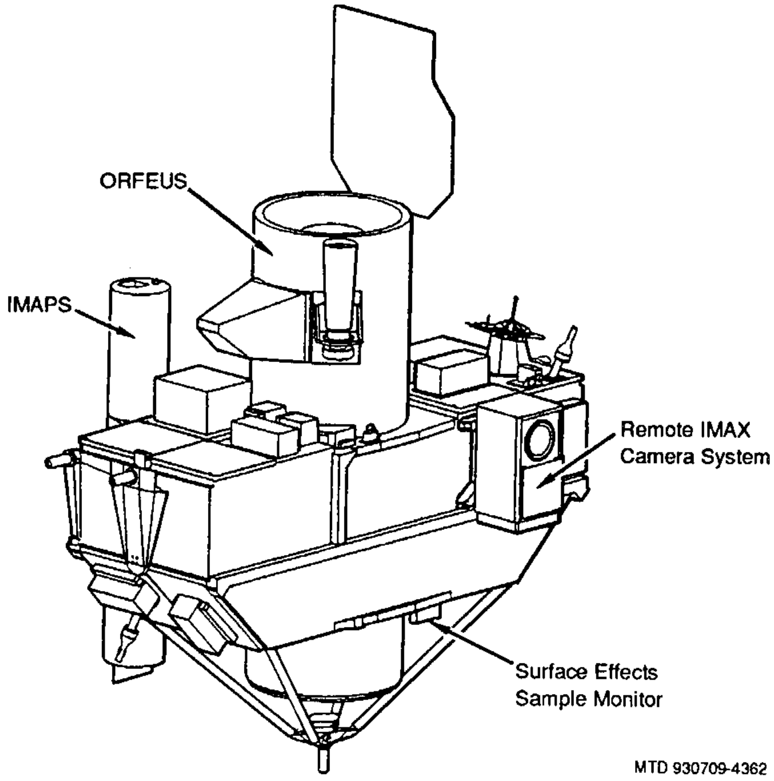
Hot celestial objects, like our sun, emit large amounts of ultraviolet light. Since every chemical element produces a unique pattern of ultraviolet spectral lines under certain conditions, such as temper-



ORFEUS-SPAS payload sits in payload transporter at KSC. Top of Advanced Communications Technology Satellite is visible at bottom.

ature, astronomers are able to determine the chemical composition, temperature, structure, and motion of stars and other celestial objects by studying their spectral lines.

The primary scientific goal of the ORFEUS and IMAPS investigations is to study the physical conditions in cold interstellar clouds that may be breeding new stars; the atmospheres of stars that are three times hotter than Earth's sun; emissions from close binary systems (stars that revolve around each other) in which one star shows activity; the extent and composition, and thus the origin, of hot gas in the fringes of our galaxy; and emissions and absorption from stars and diffuse matter in distant galaxies. In addition to investigating cold interstellar gas, the instruments will study the 1-billion-degree interstellar gas which forms a bubble around our sun that extends out about 600 light years to determine whether the bubble is unique to the sun or a common feature throughout the universe.

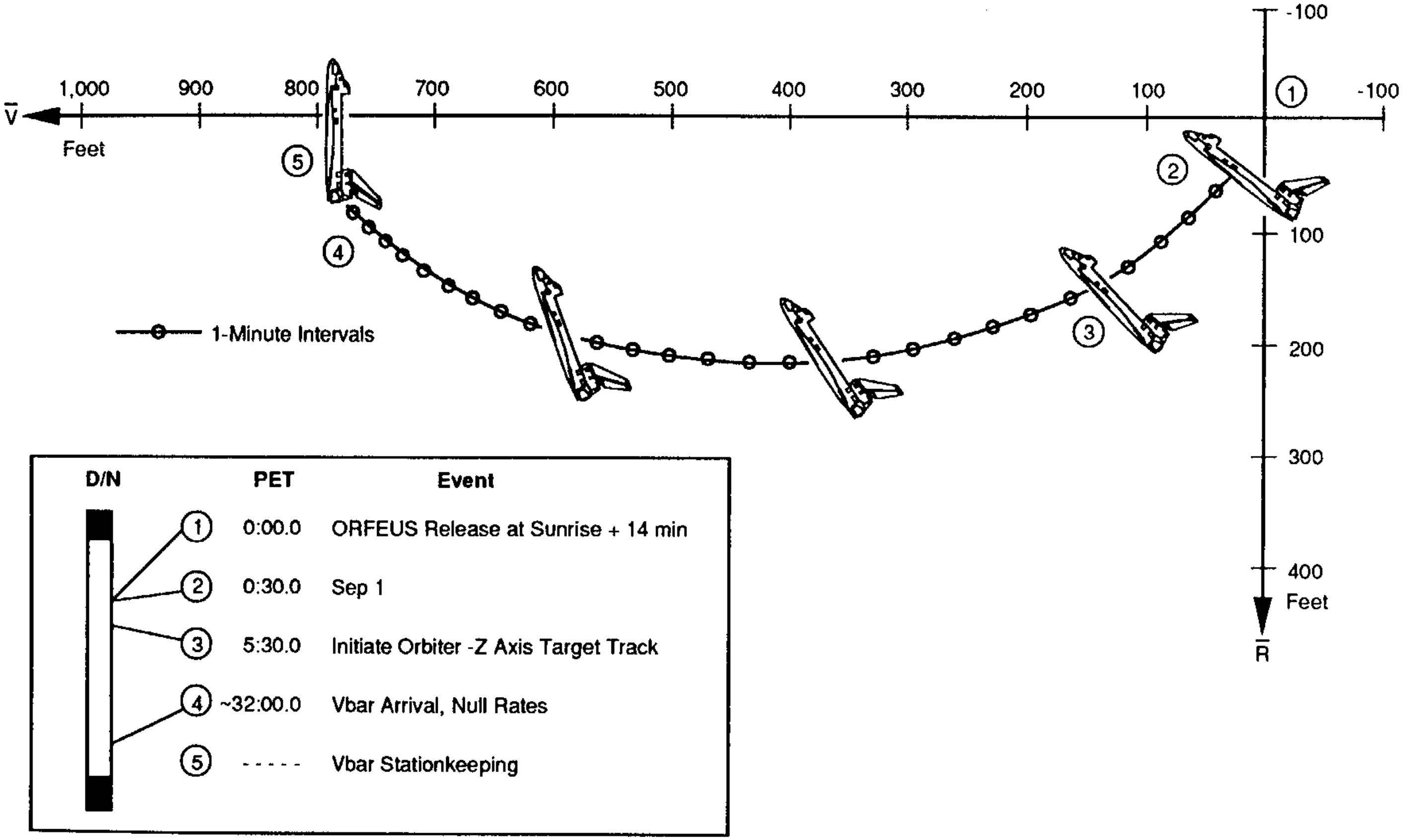


ORFEUS-SPAS Spacecraft

ORFEUS consists of a telescope with a 39-inch mirror and two spectrographs. The mirror, which is coated with iridium to enhance its ability to gather ultraviolet light, deflects the light from distant stars onto either the far ultraviolet or the extreme ultraviolet spectrograph. The FUV spectrograph has unparalleled sensitivity and resolution, and the EUV spectrograph's resolution is 10 times greater than that of any previous instrument. IMAPS, which has the highest spectral resolution of any instrument ever flown in space, will focus on the interstellar gas around bright, nearby stars.

The ORFEUS-SPAS payload also includes the Surface Effects Sample Monitor (SESAM). The German-built experiment will expose samples of state-of-the-art optical surfaces with potential applications in detectors to space to evaluate the amount of degradation they experience.

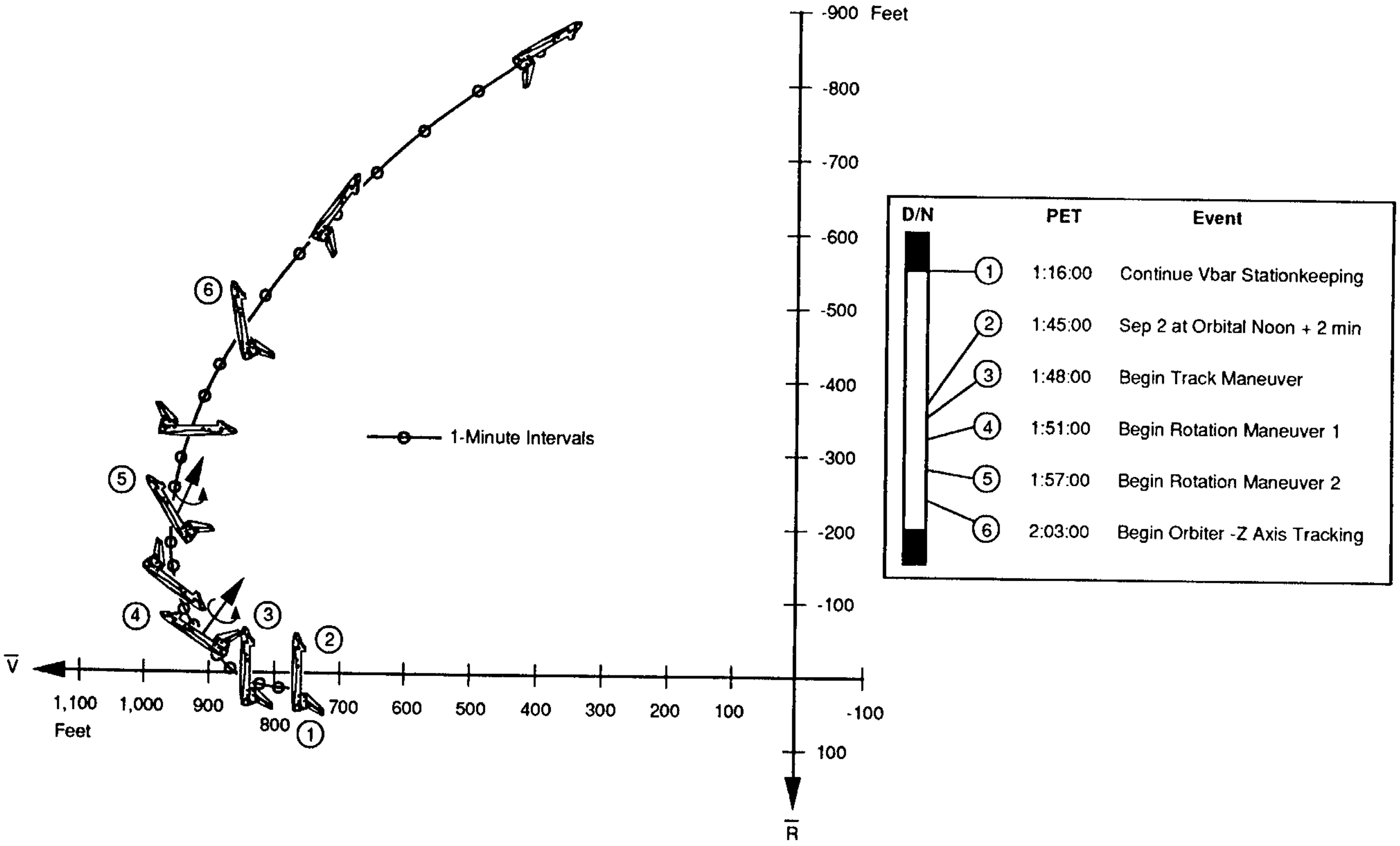
An IMAX camera on board ORFEUS-SPAS will record the deployment and retrieval of the satellite by the shuttle robotic arm. A camera on the shuttle will also record these activities. The scenes filmed will be made available to IMAX theaters throughout the world.



	PET	Event
①	0:00.0	ORFEUS Release at Sunrise + 14 min
②	0:30.0	Sep 1
③	5:30.0	Initiate Orbiter -Z Axis Target Track
④	~32:00.0	Vbar Arrival, Null Rates
⑤	- - - - -	Vbar Stationkeeping

MTD 930713-4376

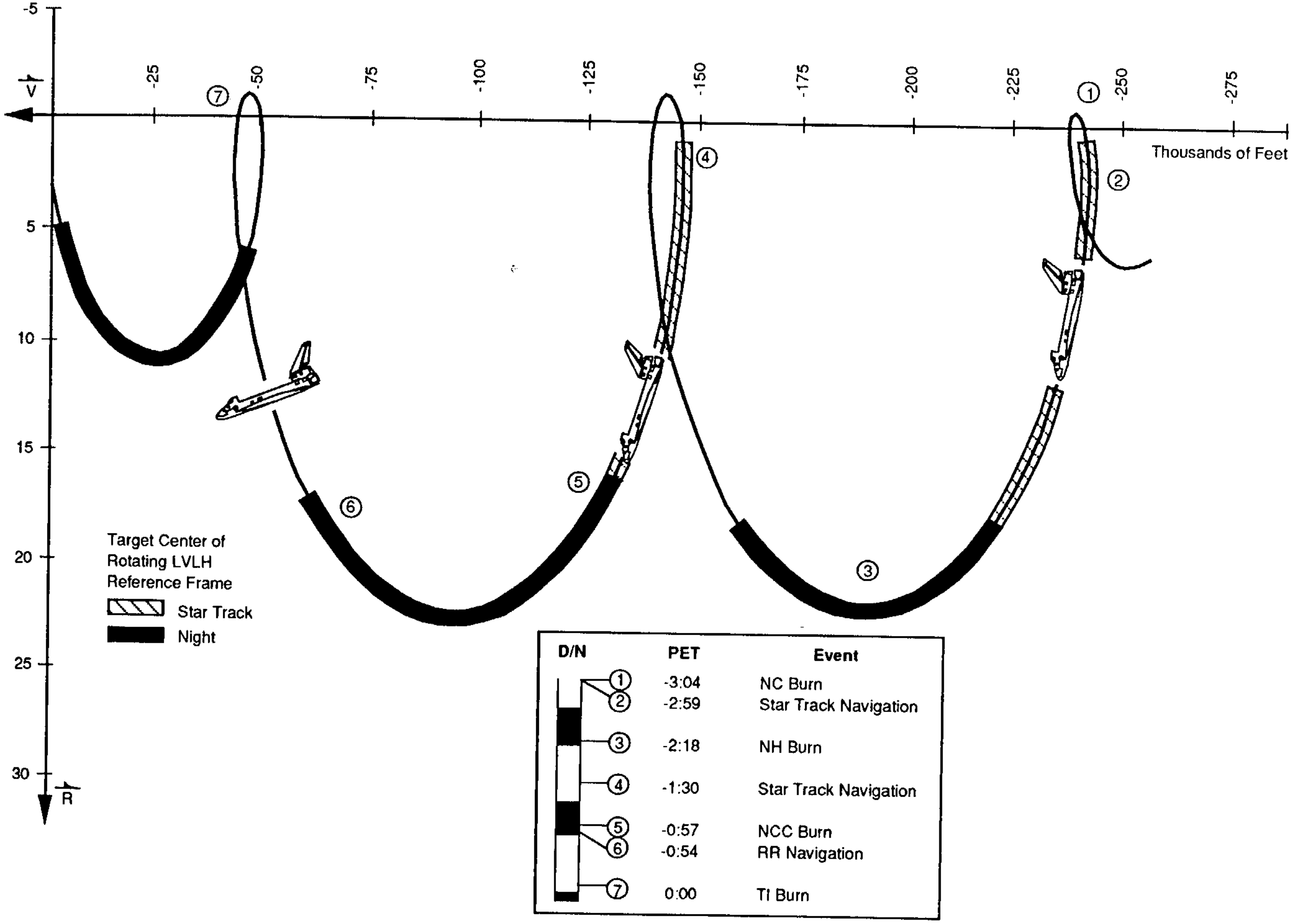
ORFEUS-SPAS Separation 1 Profile



D/N	PET	Event
①	1:16:00	Continue Vbar Stationkeeping
②	1:45:00	Sep 2 at Orbital Noon + 2 min
③	1:48:00	Begin Track Maneuver
④	1:51:00	Begin Rotation Maneuver 1
⑤	1:57:00	Begin Rotation Maneuver 2
⑥	2:03:00	Begin Orbiter -Z Axis Tracking

MTD 930713-4377

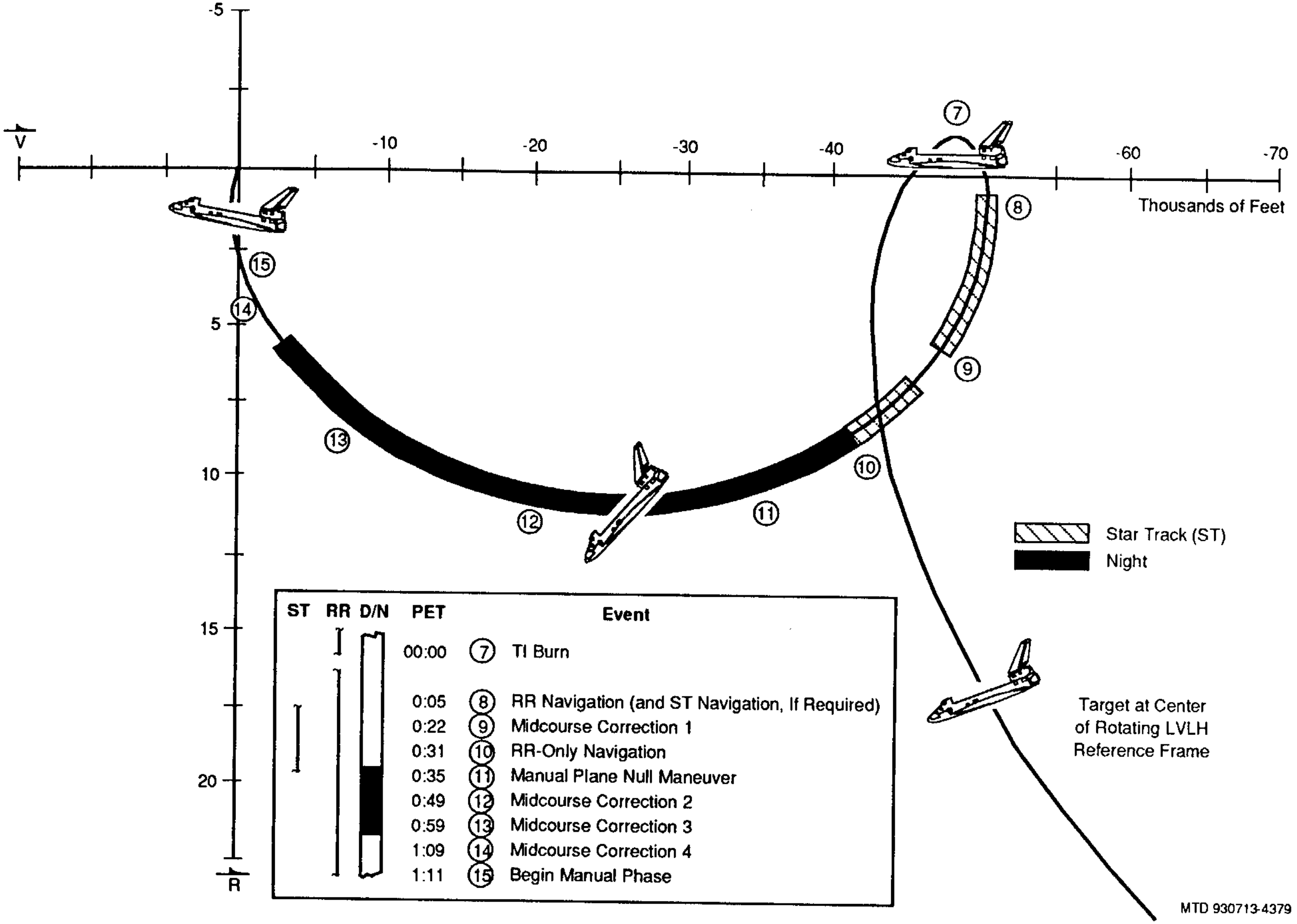
ORFEUS-SPAS Separation Profile



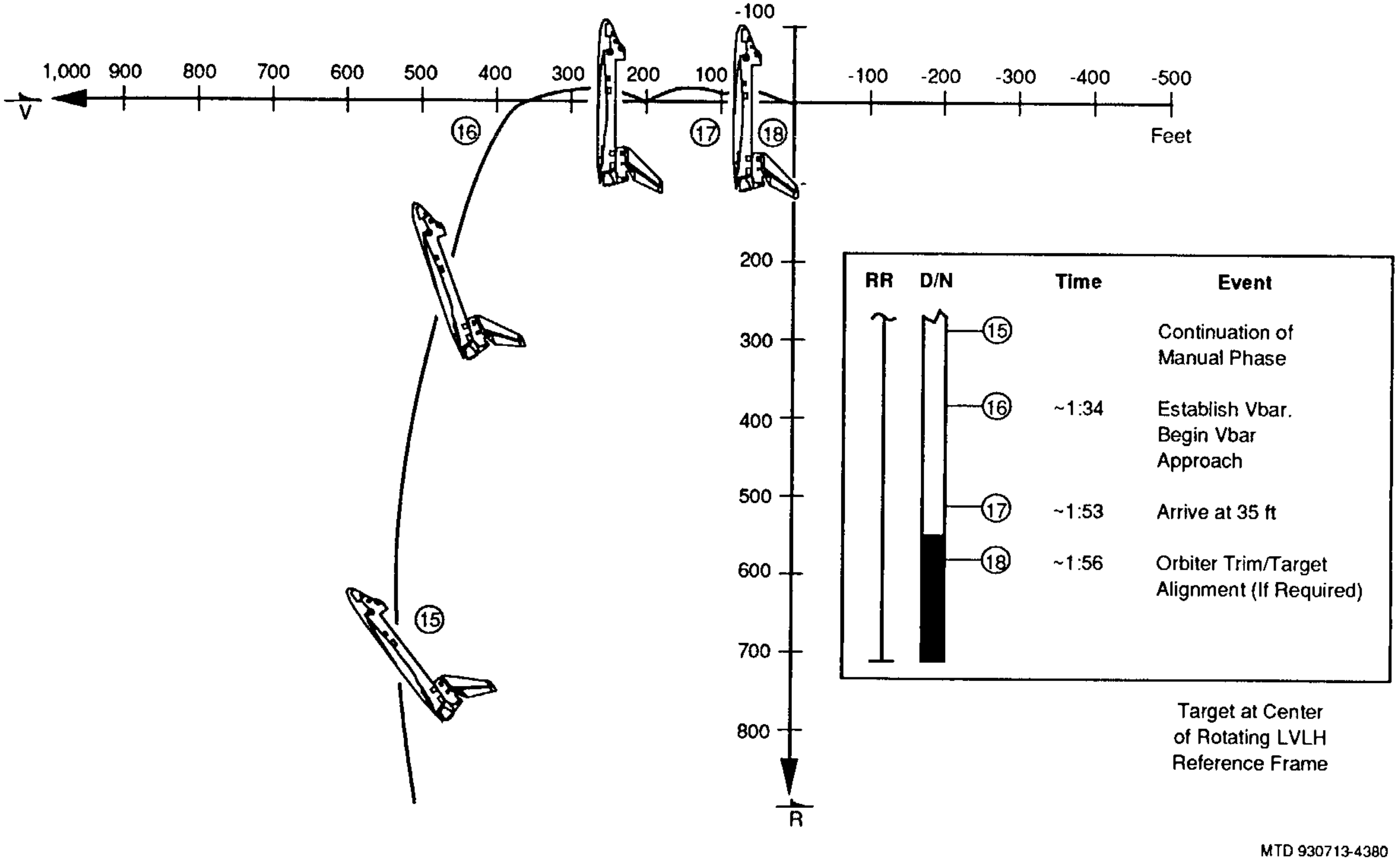
D/N	PET	Event
①	-3:04	NC Burn
②	-2:59	Star Track Navigation
③	-2:18	NH Burn
④	-1:30	Star Track Navigation
⑤	-0:57	NCC Burn
⑥	-0:54	RR Navigation
⑦	0:00	TI Burn

ORFEUS-SPAS Rendezvous Profile

MTD 930713-4378



ORFEUS-SPAS Rendezvous Profile



Time	Event
⑮	Continuation of Manual Phase
⑯ ~1:34	Establish Vbar. Begin Vbar Approach
⑰ ~1:53	Arrive at 35 ft
⑱ ~1:56	Orbiter Trim/Target Alignment (If Required)

Target at Center
of Rotating LVLH
Reference Frame

ORFEUS-SPAS Rendezvous Profile

LIMITED-DURATION SPACE ENVIRONMENT CANDIDATE MATERIALS EXPOSURE

The limited-duration space environment candidate materials exposure manifested on STS-51 is a nonstandard secondary payload in NASA's complex autonomous payload program. It uses the small self-contained payload standard carrier system hardware (getaway special hardware) and is sponsored by NASA's Goddard Space Flight Center Shuttle Small Payload Project (SSPP).

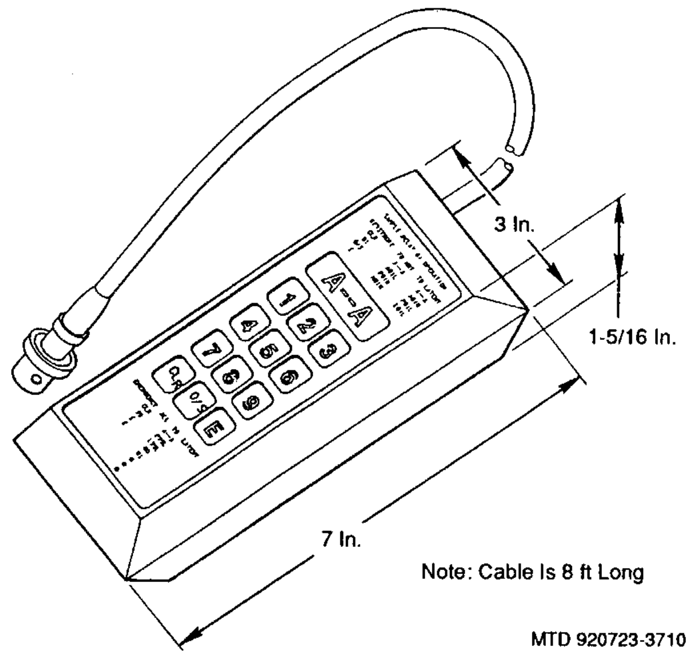
The payload is controlled through the autonomous payload control system (APCS), which includes the command encoder, known as the autonomous payload controller (APC); the auxiliary input/output (I/O) data line; GAS control decoders (GCDs); and payload power contactors (PPCs).

Configuration C of LDCE, consisting of LDCE 1 and LDCE 2, will be flown on this mission.

The CAP is integrated into two standard 5-cubic-foot GAS cylindrical canisters. They are mounted on 125-pound Johnson Space Center-supplied adapter beams in the payload bay, with connecting cables to provide communication to the experiment via the APC. LDCE 1 is located in the forward portion of the port side of bay 13 with a GAS canister fitted with a sealed door assembly. LDCE 2 is located in the aft portion with a GAS canister fitted with an MDA.

LDCE

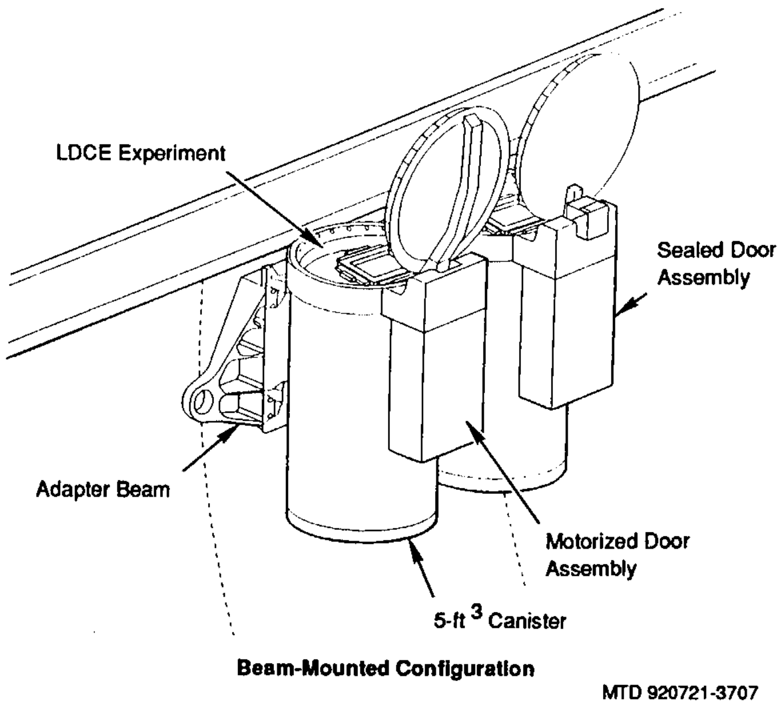
The second of the LDCE payload series is sponsored by NASA's Office of Commercial Programs. The LDCE project on STS-51 represents an opportunity to evaluate candidate space structure materials in low Earth orbit. The payload first flew on STS-46.



Autonomous Payload Controller

The objective of the project is to provide engineering and scientific information to those involved in materials selection and development for space systems and structures. By exposing such materials to representative space environments, an analytical model of the performance of these materials in a space environment can be obtained.

Each experiment has a 19.65-inch-diameter support disc with a 15.34-inch-diameter section that contains the candidate materials. The disc facilitates the mounting of five different candidate space materials holders (low, moderate, and high density; thin film; and single-sample holders). The support disc for LDCE 1 and 2 will be exposed only when the GAS canisters' doors are opened by a crew



LDCE Configuration C

member. While the payload bay is facing the velocity vector (-ZVV), the LDCE door assemblies are commanded open to expose the candidate materials to the ambient oxygen atom flux. Other than opening and closing the doors, LDCE payload operations are completely passive. The doors will be opened once the shuttle achieves orbit and will be closed periodically during shuttle operations, such as water dumps, jet firings, and attitude changes.

The primary objective of these passive experiments is to introduce developmental composite materials to a flux of atomic oxygen atoms in low Earth orbit. The candidate materials—polymeric, coated polymeric, and light metallic composites—will have undergone extensive ground-based material performance testing prior to being attached to reusable test fixtures designed for multimission space shuttle use.

Two primary commercial goals of the flight project are to identify environmentally stable structural materials to support continued humanization and commercialization of the space frontier and to establish a technology base to service growing interest in space materials environmental stability.

The LDCE payload is managed and developed by the Center for Materials on Space Structures, a NASA Center for the Commercial Development of Space at Case Western Reserve University in Cleveland. Dr. John F. Wallace, director of Space Flight Programs at Case Western, is lead investigator. Dawn Davis, also of Case Western, is program manager.

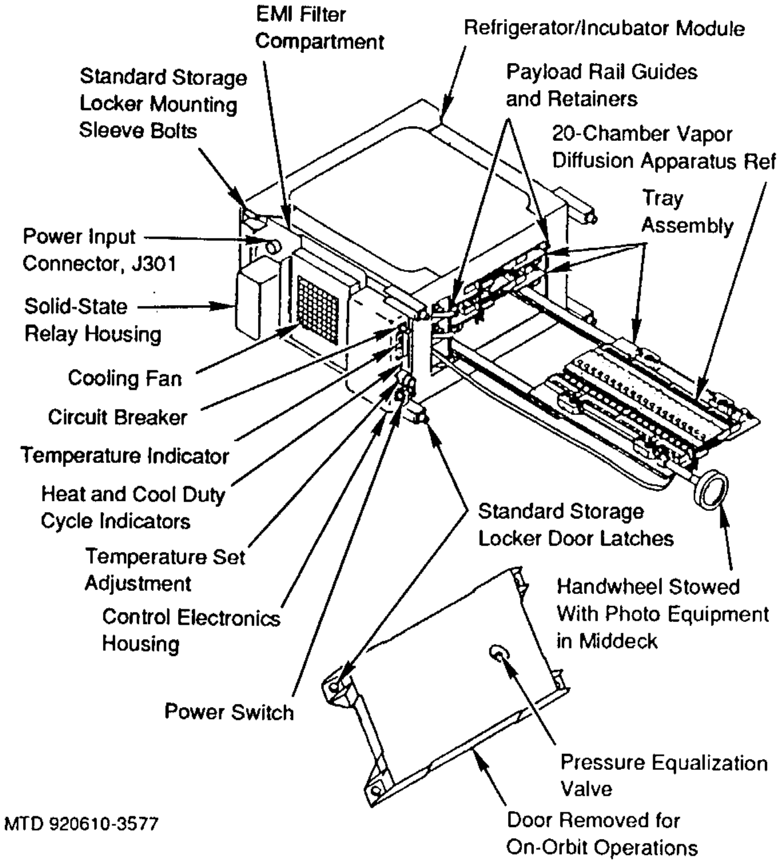
COMMERCIAL PROTEIN CRYSTAL GROWTH EXPERIMENT

Metabolic processes involving proteins play an essential role in our lives, from providing nourishment to fighting disease. In the past decade, rapid growth in protein pharmaceutical use has resulted in the successful application of proteins to insulin, interferons, human growth hormone, and tissue plasminogen activator. The pharmaceutical industry seeks these pure protein crystals because their purity will simplify Federal Drug Administration approval of new protein-based drugs. Pure, well-ordered protein crystals of uniform size are in demand as special formulations for use in drug delivery.

Such research has attracted firms in the pharmaceutical, biotechnological, and chemical industries. In response, the Center for Macromolecular Crystallography (CMC), a NASA Center for the Commercial Development of Space at the University of Alabama in Birmingham, has formed affiliations with a variety of companies that are investing substantial amounts of time, research, and money developing protein samples for use in evaluating the benefits of microgravity. Structural information gained from CPCG activities can provide a better understanding of the body's immune system and aid in the design of safe and effective treatments for disease and infections.

Protein crystal growth investigations are conducted in space because space-grown crystals tend to be larger, purer, and more highly structured than Earth-grown crystals. Such crystals greatly facilitate the study of protein structures. Scientists want to learn about a protein's three-dimensional structure to understand how it works, how to reproduce it, or how to change it. X-ray crystallography is widely used to determine a protein's three-dimensional structure. This technique requires large, well-ordered crystals for analysis.

During the past five years, several hardware configurations have been used to conduct protein crystal growth middeck experiments on nine space shuttle flights. The objective of these experiments is to supply information on the scientific methods and commercial potential for growing large, high-quality protein crystals in microgravity. On STS-51, the protein crystallization facility



PCG Flight Hardware

(PCF), developed by CMC, will grow crystals in batches, using temperature as a means to initiate and control crystallization, thereby virtually eliminating temperature-induced convection currents that can interfere with crystal growth.

The CPCG Block II PCF includes four plastic cylinders of the same diameter but different volumes (500, 200, 100, and 50 milliliters). These cylinders allow a relatively minimal temperature gradient and require less protein solution to produce quality crystals.

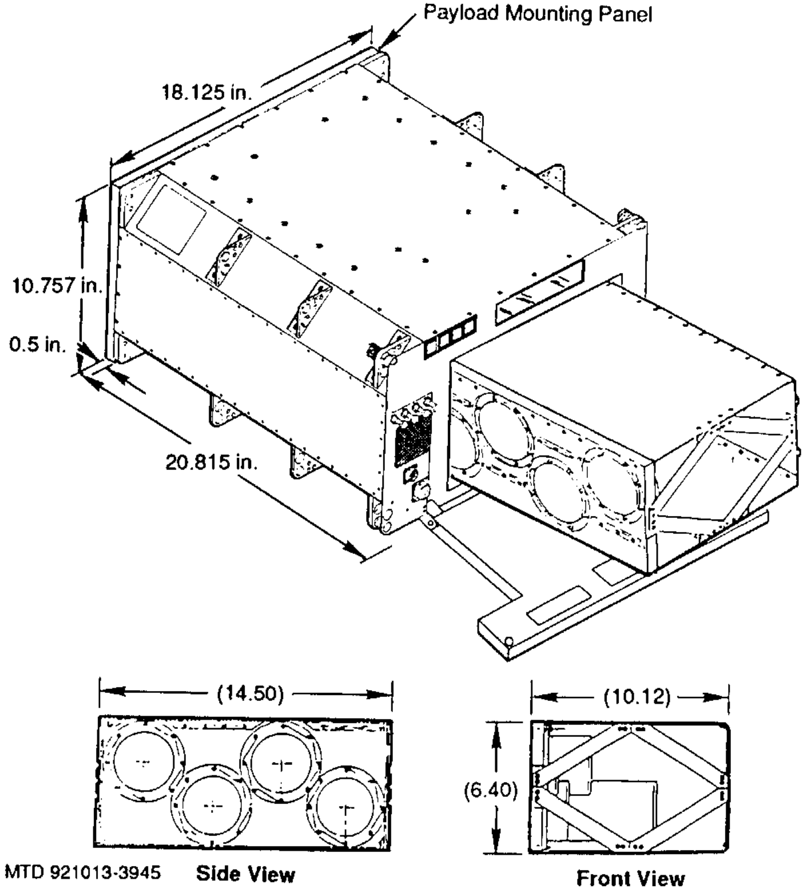
Also flying on STS-51 as part of the CPCG payload complement is a state-of-the-art commercial refrigerator/incubator module (CRIM) that permits CRIM temperatures to be programmed before launch. The temperatures are monitored during flight by a feedback loop. Developed by Space Industries, Inc., of Webster, Texas, for CMC, the CRIM also has an improved thermal capability and a microprocessor that uses "fuzzy logic" (a branch of artificial intelligence) to control and monitor the CRIM's thermal environment. A thermoelectric device is used to electrically "pump" heat in or out of the CRIM.

The CPCG payload is installed in a middeck locker and requires nearly continuous 28-Vdc power.

The PCF serves as the growth chamber for significant quantities of protein crystals. Each of the PCF cylinders on STS-51 is encapsulated in individual aluminum tubes and supported by an aluminum structure. Prior to launch, the cylinders will be filled with the protein to be flown and then will be mounted in the CRIM. Each cylinder lid will pass through the left wall of the aluminum structure and come in direct contact with a metal plate in the CRIM that is temperature-controlled by the thermoelectric device.

Shortly after reaching orbit, the crew will activate the PCF experiment by initiating the preprogrammed temperature profile. Depending on the protein used, the temperature is either lowered or raised in as many as five steps over Flight Days 1 and 2. The change in CRIM temperature will be transferred from the cold plate through the cylinder's lids to the protein.

Once activated, the payload will not require any further crew interaction (except for periodic monitoring) or any modifications for landing.



Commercial Protein Crystal Growth CRIM Block II Configuration

In general, purified proteins have a very short lifetime in solution; therefore, the CPCG payload and CRIM will be loaded on the shuttle no earlier than 24 hours prior to launch. Due to the instability of the resulting protein crystals, the CRIM will be retrieved from the shuttle within three hours of landing. The CRIM will be battery-powered continuously from the time the samples are placed in the CRIM and loaded on the shuttle until it is recovered and delivered to the investigating team. For launch delays of more than 24 hours, the payload will need to be replenished with fresh samples.

When the samples are returned to Earth, they will be analyzed by morphometry to determine size distribution and absolute/relative crystal size. They also will be analyzed with X-ray crystallography and biochemical assays of purity to determine internal molecular order and protein homogeneity, respectively.

The Commercial Protein Crystal Growth payload is sponsored by NASA's Office of Commercial Programs and is developed and managed by the Center for Macromolecular Crystallography. This is the center's 18th protein crystal growth experiment aboard the shuttle. Dr. Charles E. Bugg, director of CMC, is lead investigator of the CPCG experiment. Dr. Marianna Long, CMC associate director for commercial development, is also a CPCG investigator, as is CMC deputy director Dr. Lawrence DeLucas.

CHROMOSOME AND PLANT CELL DIVISION IN SPACE EXPERIMENT 4

The Chromosome and Plant Cell Division in Space Experiment (CHROMEX) 4 is the fourth in a series of life science middeck experiments designed to gain an understanding of the reproductive abnormalities that apparently occur to plants exposed to microgravity, and to determine if these physiological changes may result from spaceflight conditions such as microgravity. This experiment also will help understanding how gravity influences fertilization and development on Earth.

To date, only a few studies have been conducted on developing seeds in space, and they all showed very poor seed production. NASA would like to use plants as a source of food and atmospheric cleansing for astronauts staying in space for extended periods of time. Seed production is vital if crops like wheat and rice are to be utilized for food.

The CHROMEX-4 payload consists of three scientific experiments: plant reproduction studies that are a reflight of the CHROMEX-3 experiment, plant cell developmental studies that carry the studies of CHROMEX-1 and CHROMEX-2 to another plant species, and cell wall formation and gene expression studies. The CHROMEX-4 payload also will provide an opportunity to evaluate a new nutrient support system developed at Washington State University.

The anticipated science benefits may lead to new strategies to manipulate and exploit the effect of gravity in plant growth, development, biochemistry, and biotechnology. Such understandings will directly benefit the agriculture, horticulture, and forestry industries, which depend on plant growth for their products.

The plants being studied on CHROMEX-4 are mouse-ear cress (*Arabidopsis thaliana*) and a strain of wheat (*Triticum aestivum*).

Arabidopsis is a small, fast-growing plant widely studied by plant scientists. It is found in the wild and cultivated for research. This plant will self-pollinate during the nine-day mission and begin producing seeds. The effects of the microgravity environment on seed production and seed-forming structures of the plants will be studied.

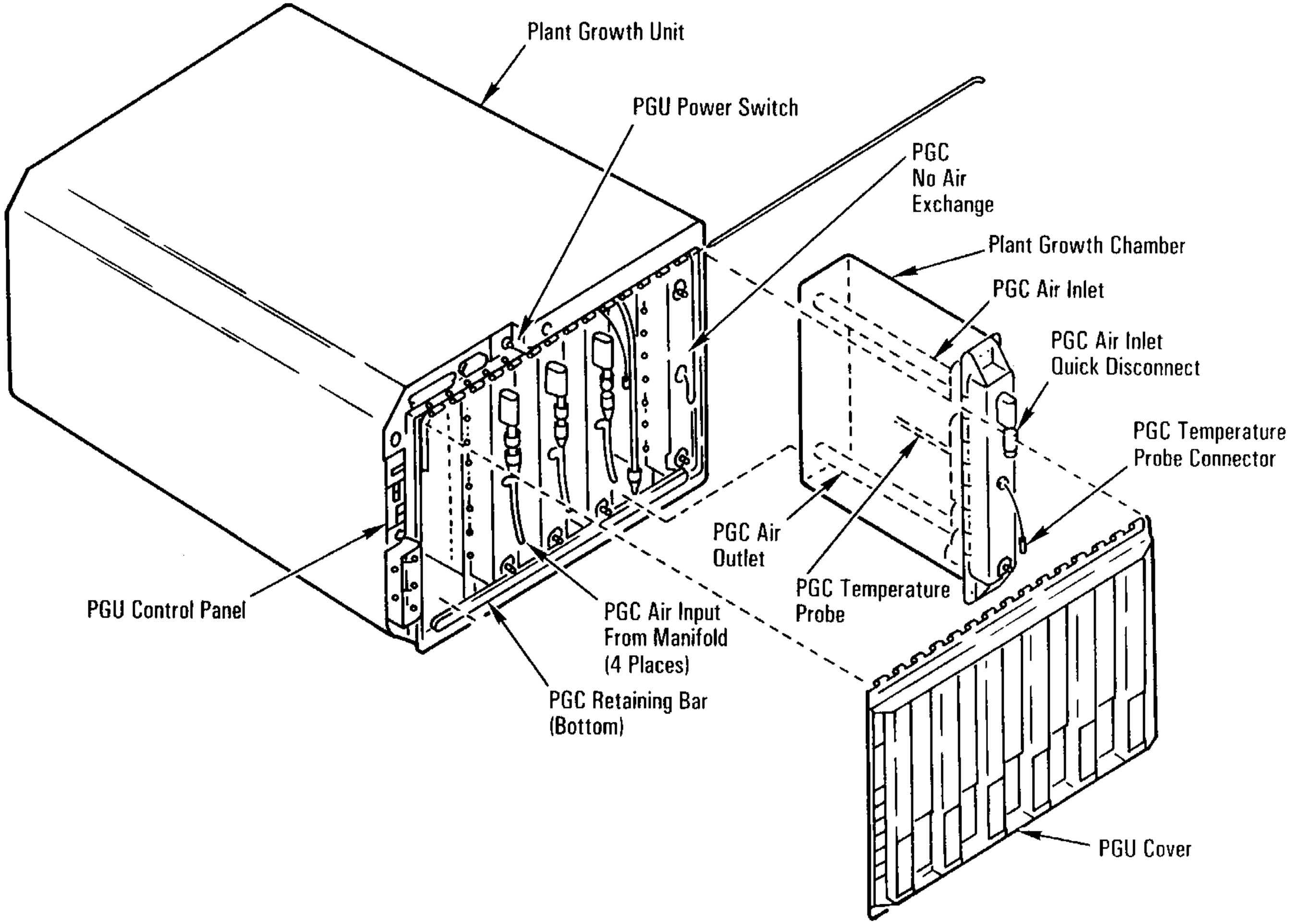
Triticum is a superdwarf variety of wheat that has been widely studied by plant researchers. Root and shoot development, cell wall formation, and gene expression studies are being conducted on these specimens.

These plants will be flown inside the plant growth unit (PGU), a closed system that provides day/night lighting located in the orbiter middeck. The plant specimens and their nutrient support systems will be integrated with the plant growth chambers (PGCs) approximately one day before launch. The PGU will hold six PGCs, each of which will contain six plants. The PGCs provide structural and nutritional support to the plants while on orbit.

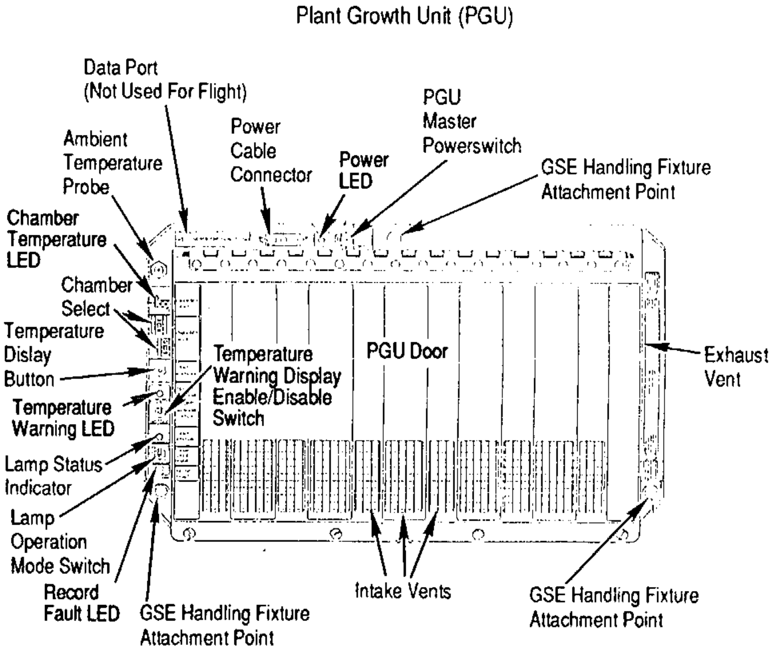
The PGU replaces one standard middeck locker and requires 28 volts of power from the orbiter. This hardware provides lighting, limited temperature control, and data acquisition for postflight analysis. The PGU has previously flown on STS-3, -51F, -29, -41, and -54.

CHROMEX will test if the normal rate, frequency, and patterning of cell division in the plant root tips can be sustained upon exposure to microgravity. This study will also determine whether the fidelity of the partitioning of the chromosomes is maintained during and after exposure to microgravity.

As soon as the plants are returned to Earth, the reproductive structures will be subjected to gross morphological and histological

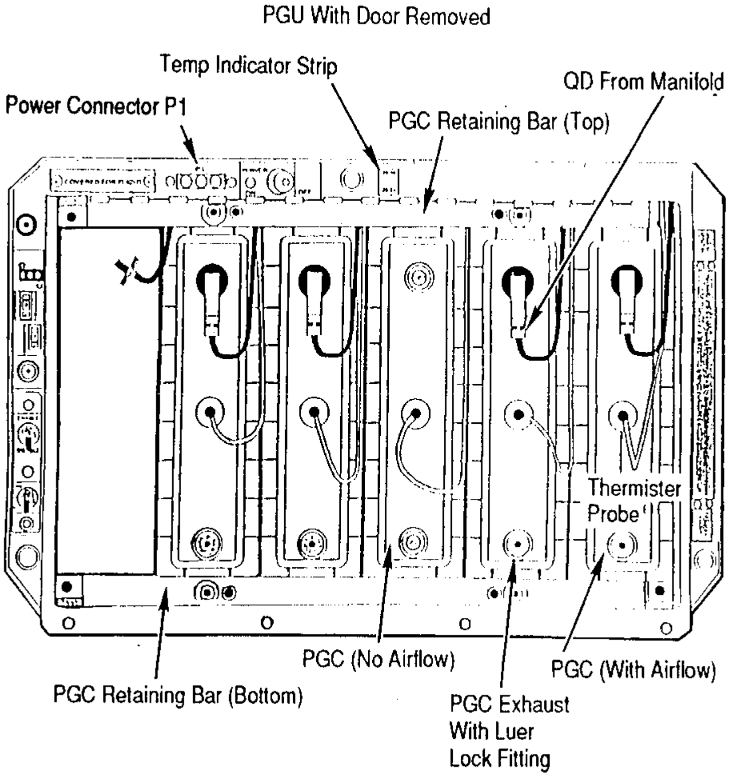


Plant Growth Unit With Atmosphere Exchange System



CHROMEX Plant Growth Unit

analyses to determine the location and life cycle stage of any reproductive abnormality that occurred. The remaining plant tissues will be analyzed for soluble carbohydrates, starches, and chlorophyll. Sections of the roots and leaves will be examined to determine other physiological processes that might be affected as a result of exposure to microgravity. All data will be compared to similar data gathered from ground control tests that will be conducted at normal gravity at a later date using identical hardware.

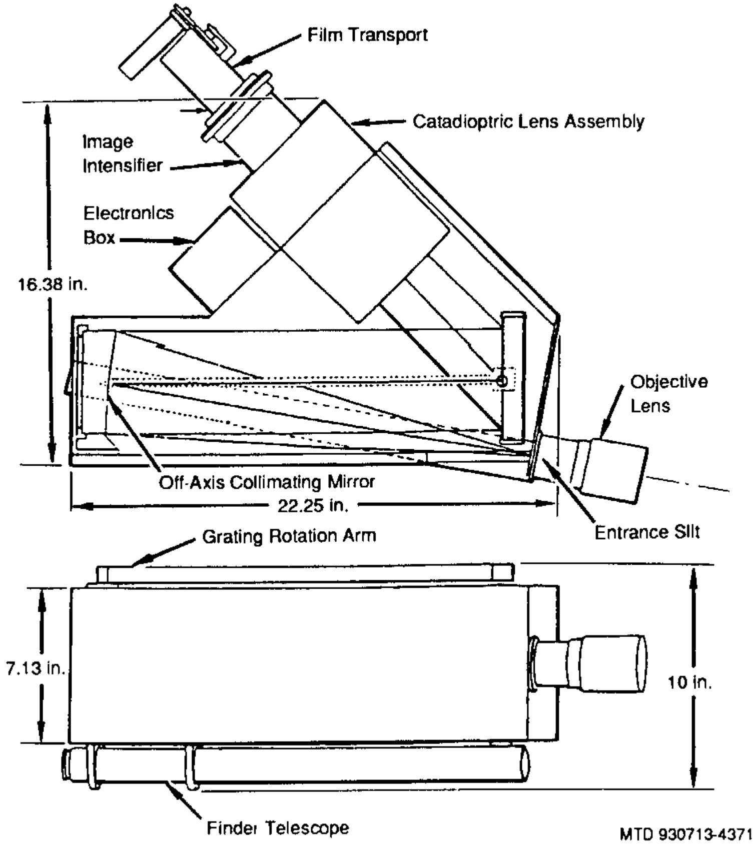


PGU Configuration

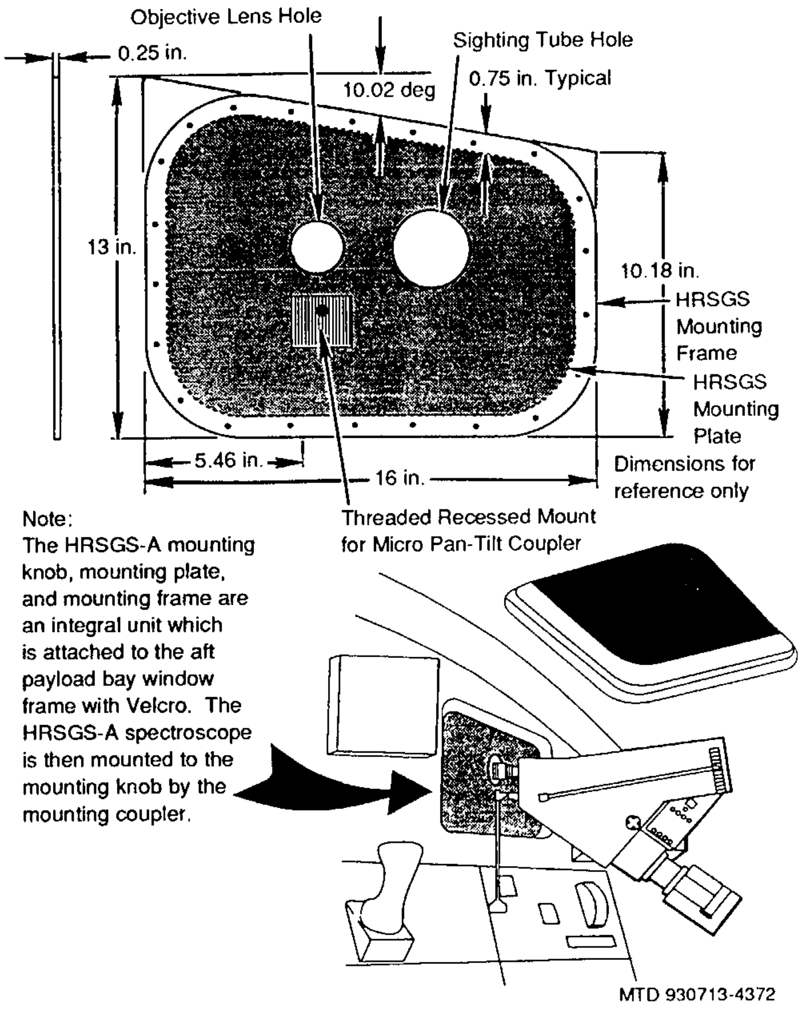
Dr. Mary Musgrave of Louisiana State University, Dr. Abraham Krikorian of the State University of New York at Stony Brook, and Dr. Norman Lewis of Washington State University are the principal investigators. The experiment is sponsored by NASA's Office of Life and Microgravity Sciences and Applications. The experiment is managed by the Kennedy Space Center.

HIGH-RESOLUTION SHUTTLE GLOW SPECTROSCOPY (HRSGS) A

The HRSGS-A payload is designed to obtain high-resolution spectra in the visible and near-visible wavelength range (4,000 to 8,000 angstroms) of the shuttle surface glow seen on the vertical tail of the orbiter in low Earth orbit. The glow is observed only on shuttle surfaces that face the velocity vector, and it is hoped that the spectral resolution of 2 angstroms will help identify the cause of shuttle glow. Spectral data will be recorded only during orbital night in complete darkness. HRSGS-A will look at the vertical tail, orbital maneuvering system pod, or a suitable alternative.



HRSGS-A Payload



Note:
The HRSGS-A mounting knob, mounting plate, and mounting frame are an integral unit which is attached to the aft payload bay window frame with Velcro. The HRSGS-A spectroscope is then mounted to the mounting knob by the mounting coupler.

HRSGS-A Installed

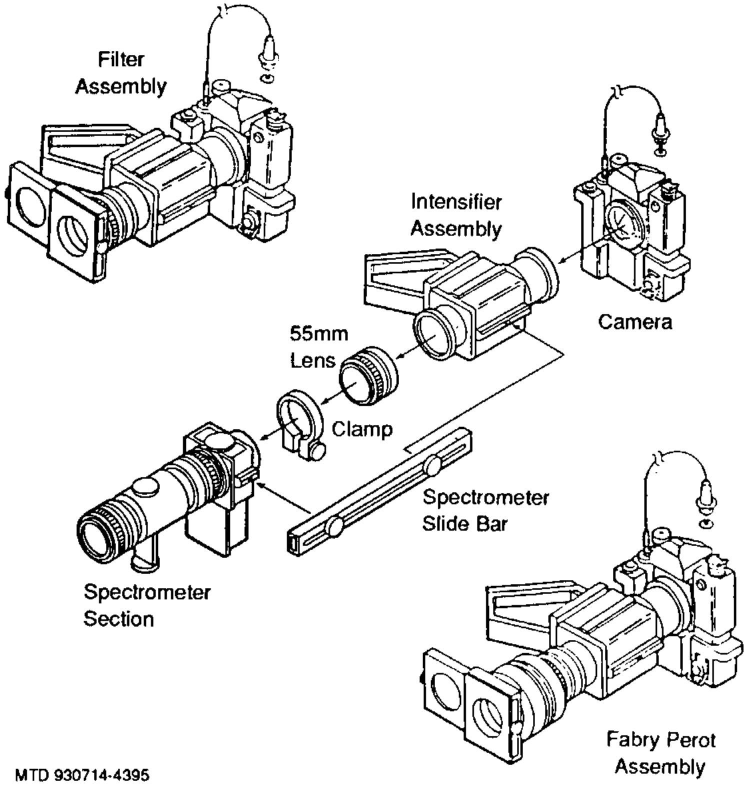
AURORAL PHOTOGRAPHY EXPERIMENT B

The Auroral Photography Experiment (APE) B is an Air Force-sponsored payload designed to study airglow aurora, auroral optical effects, irradiation effects, the shuttle glow phenomena, and orbiter OMS exhaust plume emissions and port and starboard yaw thruster firings in the imaging, Fabry-Perot, and spectrometer modes of photography. The data collected during the experiment will be used to develop target acquisition models for space-based sensor systems. Only shuttle glow images are scheduled in the STS-51 flight plan.

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, 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.

APE-B photography will occur with Discovery in darkness and with minimal moonlight, payload bay lights off, and the crew cabin darkened or 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.



APE-B

INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING

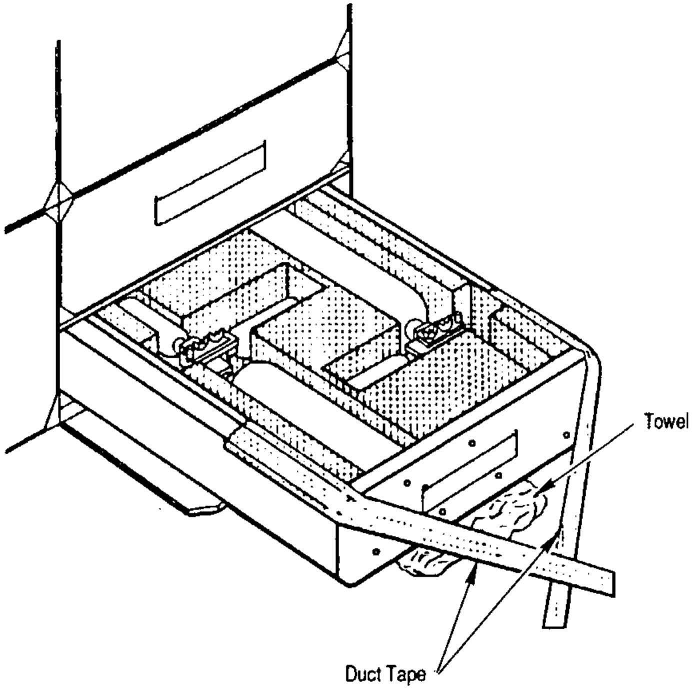
Investigations Into Polymer Membrane Processing will make its ninth space shuttle flight for the Office of Commercial Programs-sponsored Battelle Advanced Materials Center for the Commercial Development of Space in Columbus, Ohio. IPMP flew previously on STS-31, -41, -43, -48, -42, -45, -50, and -57. The objective of the IPMP is to investigate the physical and chemical processes that occur during the formation of polymer membranes in microgravity so that the improved knowledge base can be applied to commercial membrane-processing techniques.

Polymer membranes, which are porous films, have been used in the separation industry for many years for such applications as desalination of water, filtration during the processing of food products, atmospheric purification, purification of medicines, and dialysis of kidneys and blood. The greatest contribution of improved membranes may be in environmental monitoring by significantly reducing dangerous gas emissions.

Polymer membranes frequently are made in a two-step process. A sample mixture of polymer and solvents is applied to a casting surface. The first step involves the evaporation of solvents from the mixture. In the second step, the remaining sample is immersed in a fluid bath (typically water) to precipitate the membrane, form the solution and complete the process. Previous flights of IPMP have involved the complete process (STS-41, -43, -48, -42, and -50), the evaporation step alone (STS-31), and the precipitation step alone (STS-45). On the STS-51 mission, the complete process will be performed.

The IPMP payload on STS-51 consists of two experimental units containing different solvent solutions that occupy a single small stowage tray (half of a middeck locker). Each unit consists of two 304L stainless steel sample cylinders measuring 4 inches and 2 inches in diameter. The cylinders are connected to each other by a stainless steel packless valve with an aluminum cap. The IPMP payload weighs approximately 17 pounds and does not require power or data interfaces.

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



IPMP Configuration

sealed with threaded stainless steel plugs using a Teflon tape threading compound.

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

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

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

RADIATION MONITORING EQUIPMENT III

The Radiation Monitoring Equipment (RME) III microdosimeter will display and record the dose rate and total accumulated dosage of the STS-51 crew's exposure to ionizing radiation at different locations in Discovery's crew compartment. RME-III measures gamma ray, electron, neutron, and proton radiation and uses a tissue-equivalent proportional counter spatial ionization chamber radiation detector, which effectively simulates a target size of a few microns of tissue (the dimensions of a typical human cell) and calculates, in real time, exposure in RADS-tissue equivalent.

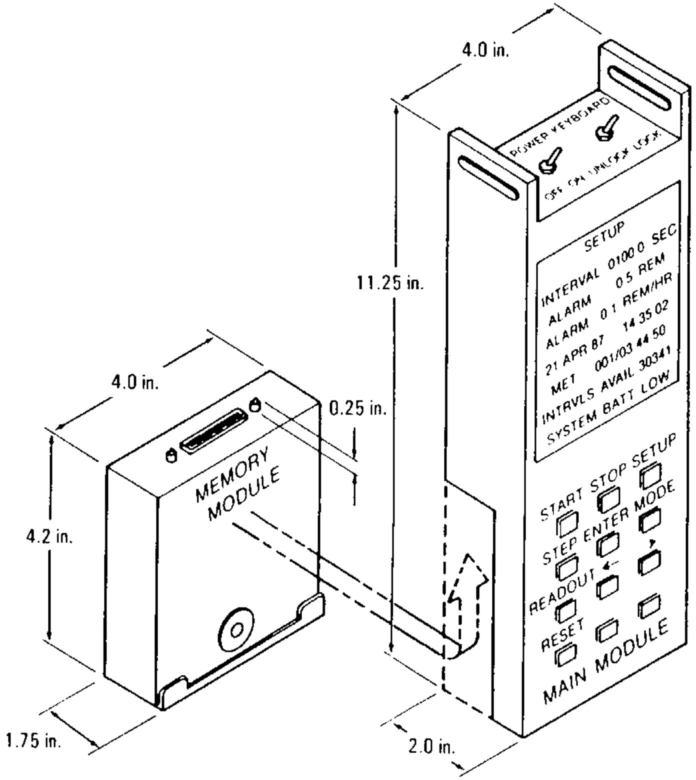
RME-III data is being archived and used to update and refine models of the space radiation environment in low Earth orbit. This will help space mission planners to more accurately assess risk and safety factors for future long-term space missions, such as the space station. Next-generation instruments will be flown on the space station and on future manned and unmanned missions to the moon, Mars, and beyond. RME-III is also being used to measure radiation exposure in high-altitude aircraft, such as the Concorde.

RME-III consists of a hand-held instrument with replaceable memory modules. The equipment contains a liquid crystal display for real-time data presentation and a keyboard for controlling its functions. The self-contained experiment has four zinc-air and five AA batteries in each memory module and four zinc-air batteries in the main module. RME weighs approximately 23 pounds.

RME-III will be stored in a middeck locker during flight except when it is activated and when memory modules are being replaced. It will be activated as soon as possible following orbit insertion and programmed to operate throughout the entire mission. A crew member will be required only to enter the correct mission elapsed time upon activation and to change the memory module every two days. The equipment takes measurements of the radiation environment at a specified sample rate. All data stored in the memory modules will be analyzed upon return.

RME-III has been flown on 14 shuttle missions since STS-26. It replaces two earlier configurations. It has been flown in conjunction with other radiation experiments, such as the CREAM and Shuttle Activation Monitor. RME will be flown on several future shuttle missions.

RME-III is under the direction of the Department of Defense's Space Test Program. It is sponsored by the DOD in cooperation with the Human Systems Division of NASA's Space Radiation Advisory Group.



RME Configuration

AIR FORCE MAUI OPTICAL SITE (AMOS) CALIBRATION TEST

The AMOS tests allow ground-based electro-optical sensors located on Mt. Haleakala in Maui, Hawaii, to collect imagery and/or signature data of the space shuttle orbiters during cooperative overflights. Cooperative overflights are defined as those planned times when AMOS test conditions can be met and the STS mission timeline and propellant budget permit the requested orbiter activities to be performed.

This experiment is a continuation of tests made during the STS-29, -30, -34, -32, -31, -41, -35, -37, -43, -48, -44, -49, -56, and -57 missions. The scientific observations of the orbiters during those missions consisted of reaction control system thruster firings and water dumps or activation of payload bay lights. They were used to support the calibration of the AMOS ground-based infrared and optical sensors, using the shuttle as a well-characterized calibration target, and to validate spacecraft contamination models through observations of contamination/exhaust plume phenomenology under a variety of orbiter attitude and lighting conditions.

No unique on-board hardware is associated with the AMOS test. Crew and orbiter participation may be required to establish the controlled conditions for the Maui overflights. AMOS is being flown as a payload of opportunity and will be conducted if crew time permits.

The AMOS facility was developed by the Air Force Systems Command through its Rome Air Development Center at Griffiss Air Force Base, N.Y. It is administered and operated by the AVCO Everett Research Laboratory on Maui. The principal investigators for the AMOS tests on the space shuttle are from AFSC's Air Force Geophysical Laboratory at Hanscom Air Force Base, Mass., and AVCO.

Flight planning and mission support activities for the AMOS test opportunities are performed by a detachment from AFSC's Space Systems Division at the Johnson Space Center in Houston. Flight operations are conducted at the JSC Mission Control Center in coordination with the AMOS facilities in Hawaii.

IMAX CAMERA

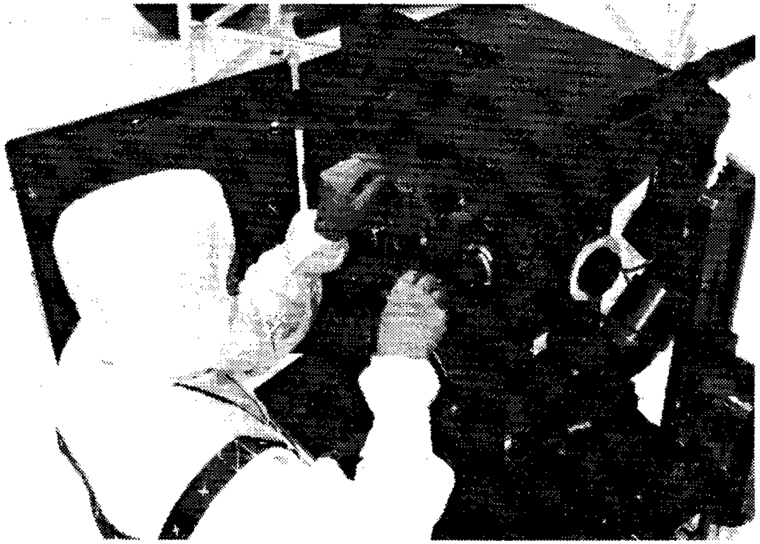
The IMAX project is a collaboration between NASA, the Smithsonian Institution's National Air and Space Museum, IMAX Systems Corp., and the Lockheed Corp. to document significant space activities and promote NASA's educational goals using the IMAX film medium. This system, developed by IMAX Systems Corp. of Toronto, Canada, uses specially designed 70mm cameras and projectors to record and display very high definition color motion pictures which, accompanied by six-channel high-fidelity sound, are displayed on screens that are up to ten times larger than a conventional screen, producing a feeling of "being there."

IMAX cameras have been flown on space shuttle missions STS 41-C, 41-D, 41-G, -29, -34, -32, -31, -42, and -46 to document crew operations in the payload bay and the orbiter's middeck and flight deck as well as to film spectacular views of space and Earth. Film from those missions was used as the basis for the IMAX productions "The Dream Is Alive" and "The Blue Planet."

On the last IMAX mission, the cameras were used to film activities associated with the deployment and retrieval of the tethered satellite system and the deployment of EURECA and various Earth views. On STS-51, ACTS/TOS and ORFEUS-SPAS activities will be photographed with the remote IMAX camera system mounted on the OREFUS-SPAS payload and an IMAX in-cabin camera. IMAX's secondary objectives are to film Earth views. Scene opportunities are provided to the crew both before the flight and in real time. The footage will be used in a new film dealing with our use of space to gain new knowledge of the universe and the future of mankind in space.

The system consists of a camera, lenses, rolls of film, two magazines with film, an emergency speed control, a Sony recorder and associated equipment, two photographic lights, mounting brackets to accommodate the mode of use, two cables, and various supplemental equipment.

The IMAX uses two interchangeable film magazines which can be reloaded with film. Each magazine runs for approximately three minutes. Lenses are interchanged based on scene requirements. The IMAX will be installed in the orbiter middeck approximately seven days before the launch.



Cameraman loads 70mm film in one of the IMAX cameras used to film processing of ORFEUS payload at KSC.

EXTRAVEHICULAR ACTIVITY

STS-51 crew members Carl Walz and Jim Newman will perform a six-hour extravehicular activity (EVA), or spacewalk, on the fifth day of the mission. This EVA is part of a series of test spacewalks NASA is conducting to gain experience with spacewalks and refine training methods.

Walz is designated extravehicular crew member 1 (EV-1) and Newman is EV-2. Pilot Bill Readdy will serve as the intravehicular (IV) crew member inside Discovery, supervising the coordination of spacewalk activities in the shuttle's cargo bay.

In addition to performing tasks that investigate a spacewalker's mobility in general, Walz and Newman will evaluate several tools that may be used during the servicing of the Hubble Space Telescope (HST) later this year on STS-61. The tools include a power socket wrench, a torque wrench, foot restraint, safety tethers, and a tool holder.

Walz and Newman will spend part of their time outside Discovery testing various types of rigid and semirigid tethers as well as moving up and down the bay carrying each other to evaluate how well spacewalking astronauts can maneuver in weightlessness while holding a large object.

Other tests include an evaluation of how well an astronaut must be restrained in weightlessness to apply a large amount of tightening to a bolt with the tools provided. In addition, the spacewalkers will try out a large tool on board Discovery for use in case of a problem with the ACTS/TOS satellite's deployment to evaluate methods of using bulky tools.

The STS-51 EVA will be one of the lowest priorities of the flight, subject to cancellation if there is a problem with one of the primary payloads.

The planned spacewalk will be the third this year. Spacewalk tests were conducted on STS-54 in January and STS-57 in June. NASA plans to continue adding spacewalks to shuttle flights when they can be performed without interferring with the primary activities. The STS-51 spacewalk is the final test EVA planned for 1993. The spacewalks planned for STS-61 in December will be performed to service the HST and not for test purposes.

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.

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

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

Payload bay acoustic evaluation (DTO 308D). This DTO will obtain vibration and acoustic data during ascent to define the operational vibroacoustic input environment for payloads and the PDRS.

ET TPS performance, method 3 (DTO 312). This DTO will obtain photographs of the external tank after separation in order to determine TPS charring patterns, identify regions of TPS material spallation, and to evaluate overall TPS performance.

Orbiter/payload acceleration and acoustics environment data (DTO 319D). This DTO will obtain low-frequency (0 to 50 Hz) payload/orbiter interface data to develop computer prediction techniques to validate math models and forcing functions.

On-orbit fuel cell shutdown/restart (fuel cell 1) (DTO 412). Current flight rules assume the capability to restart a fuel cell once it has been shut down; the capability has never been verified. DTO 412 will demonstrate the capability of shutting down and restarting a fuel cell on orbit. It will determine the magnitude of voltage degradation due to shutdown. It will also determine how fast the fuel cell will cool down and what temperature it will reach. The data will be used to support space station (assembly and man-tended operations) long-duration flights requiring fuel cell shutdown for extended periods. The selected fuel cell will be shut down for a 24-hour period (attitude/temperature permitting). Shutdown will occur approximately EOM minus two days. Fuel cell restart occurs at EOM minus one, to allow for troubleshooting prior to EOM, if the fuel cell cannot be restarted. Fuel cell purge will not be performed on the shutdown fuel cell. This DTO will be performed over a series of three flights (a different fuel cell position will be shut down each flight). This is the third flight of DTO 412.

Orbiter drag chute system (DTO 521). This DTO will evaluate the orbiter drag chute system performance through a series of landings with increasing deployment speeds. The DTO will be performed on vehicles equipped to measure drag forces imposed by the drag chute system. This DTO has two phases. Phase I consisted of two flights, with the first-flight drag chute deployment at nose gear touchdown (STS-49) and the second-flight initiation at initiation of derotation. Now that Phase I testing is complete, the drag chute is cleared for deployment under the same conditions for subsequent missions. Phase II consists of seven additional flights with gradually increasing landing speeds from initiation at derotation of 185 knots equivalent air speed (KEAS) to initiation at 205 KEAS and will use concrete runways whenever possible. For STS-51, the drag chute will be deployed after derotation (nose in the air) with five ribbons removed from the chute.

PGSC single-event upset monitoring (DTO 656). This DTO will determine PGSC random-access memory susceptibility to single-event upset (SEU) caused by cosmic radiation. The knowledge of PGSC susceptibility to SEU could lead to procedure and/or hardware and software changes to reduce the effects of cosmic radiation on PGSC operations.

Thermal impulse printer system demonstration (DTO 660). The purpose of this DTO is to evaluate the operational capability of the TIPS to uplink text and graphics via the orbiter S-band and Ku-band communication links. The printer will be evaluated as an alternative to the on-board text and graphics system hard copier and teleprinter. The evaluation consists of uplinking various test patterns and messages to the TIPS printer in the S-band and Ku-band modes.

Advanced lower body restraint test (DTO 668). This DTO is to provide on-orbit evaluation of an advanced lower body restraint which provides variability in positioning, adjustable lower body flexibility/rigidity, and upper body movement/reach envelope. The restraint will be used on the aft flight deck during remote manipulator system operations. Flight crew evaluations and photo/TV documentation will be used as design data to support restraint development.

EVA hardware for future scheduled EVA missions (DTO 671). This DTO provides part of the hardware used to support the activities/procedures scheduled for DTO 1210. The hardware manifested for this DTO will be used for the high-torque evaluations and tether management evaluations tests. Prior flight experience has revealed limitations in the ability to fully assess hardware operability during ground simulations and subsequently predict on-orbit EVA performance with new and infrequently used hardware and/or associated techniques. The information collected will be used to modify hardware design and/or associated EVA techniques to increase the probability of success for future scheduled EVA missions. Tests 3, 4, 6, and 7 will be performed.

Laser range and range rate device (DTO 700-2). The laser range and range rate DTO will demonstrate the capability to provide the orbiter flight crew with range and range rate data for rendezvous, proximity operations, 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 update frequency.

Payload bay-mounted rendezvous laser (DTO 700-5). Like DTO 700-2, this DTO will demonstrate the capability to provide the orbiter crew with rendezvous data required for precise on-orbit rendezvous, proximity operations, and payload berthing or deployment operations, while minimizing direct crew involvement for acquiring this data. The DTO should demonstrate design capabilities planned for the space station cargo bay laser. The DTO will interface with the payload and general-support computer (PGSC) and will evaluate the feasibility of using the PGSC for displaying data directly to the pilot.

Global Positioning System on-orbit demonstration (DTO 700-6). This DTO will evaluate the performance of a GPS receiver in orbit by comparing its orbiter GPS state vector to that determined by ground tracking and orbiter inertial measurement units. The DTO will evaluate the number and location of GPS antennas required to provide best satellite coverage for flight deck experiment applications. The quality of GPS data received during on-orbit operations will be determined by collecting GPS health data, such as figure of merit and channel tracking status. In addition, if SPAS GPS data is available real time, the accuracy of relative GPS will be evaluated using orbiter radar and laser range finders as reference data. Data will be collected on the PGSC.

GPS and payload bay rendezvous laser data comparison (DTO 700-7). This DTO will permit the capability to support DTO 700-5 and/or 700-6. It will permit a more accurate assessment of the payload bay laser as a rendezvous and proximity navigation aid as well as real-time evaluation of relative GPS. The specific objectives are (1) to increase the accuracy of the payload bay laser navigation by providing orbiter attitude information to the laser software real time and (2) to collect orbiter and payload GPS state vector information in real time to assist in evaluating relative GPS. Specifically, the relative GPS as a rendezvous aid with respect to ground tracking, the star tracker, and the Ku-band will be evaluated by comparing their guidance solutions in real time.

STS orbiter attitude control translational thrusting (DTO 779). This test will provide the data necessary to complete the data base of vehicle thrusting that is necessary to maintain attitude during various unbiased attitude holds. These data can then be used in the flight design process to refine the predicted trajectory. The data will also be used real-time to improve trajectory prediction in the mission operations computer.

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

EVA operations procedures/training (14.7-psi protocol) (DTO 1210) This DTO will isolate and demonstrate specific differences between training facility simulations and operations in the actual extravehicular activity environment. This will also broaden EVA procedures and training experience bases and proficiency in preparation for future EVAs, such as Hubble Space Telescope and space station.

In-flight aerobic exercise (cycle ergometer) (DSO 476). The objectives of this DSO are to document the effects of daily aerobic exercise on (a) protection of left ventricular dimensions, (b) postflight orthostatic function, and (c) the rate at which these factors return to their preflight baseline values during the postflight period. Also, the effects of regular aerobic exercise on the maintenance of aerobic power and economy will be determined.

Inter-Mars tissue equivalent proportional counter (ITEPC) (DSO 485). The purpose of this DSO is to demonstrate the ability of hardware to withstand the radiation environment of space flight in preparation for the Mars '94 mission and to demonstrate the expanded capability of experiment software over the previously flown middeck TEPC. In addition, the experiment will gather key data on the radiation environment for future extravehicular activity (EVA) and single-event upset data that affect the orbiter's hardware. This experiment will be flown on an adaptive payload carrier (APC) and is sidewall mounted on the starboard side of bay 2. It consists of a spectrometer, radiation detector, and support electronics. The equipment is activated by a barometric pressure switch and requires no crew involvement.

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 the development of infectious illnesses in crew members during flight also increases. This investigation will assess the immune system function using the immune cells from the standard flight medicine blood draw.

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

Visual-vestibular integration as a function of adaptation (DSO 604*). The objective of this DSO is to investigate visual-vestibular and perceptual adaptive responses as a function of mission duration. The operational impact of these responses on the crew members' ability to conduct entry, landing, and egress procedures will also be investigated. These data will be used to develop training and/or countermeasures to assure the safety and success of extended missions by promoting optimal neurosensory function needed for entry, landing, and possible emergency egress. The crew will perform investigations OI-1 and OI-3.

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

Evaluation of functional skeletal muscle performance following space flight (DSO 617*). The objectives of this investiga-

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*Indicates EDO buildup—medical evaluation DSO.

tion are to determine the physiological effect of long-duration space flight on skeletal muscle strength, endurance, and power. Specific objectives are (1) to evaluate the concentric and eccentric functional changes before and after flight for the trunk and upper and lower limbs and (2) to determine the etiology of neuromuscular dysfunction as measured by EMG. The rationale for the DSO is that altered motor function and control resulting from the muscular deconditioning associated with adaptation to weightlessness could have negative implications for effective completion of many operational tasks, including landing and egress. Isokinetic testing and different velocities are used to assess skeletal muscle integrity at different rates of tension and functional speeds. Velocity spectrum testing can be a valuable means of identifying functional deficits in the musculoskeletal system. Additionally, it will provide knowledge necessary to support the development of future countermeasure prescriptions essential for nominal performance.

In-flight use of Florinef to improve orthostatic intolerance after flight (DSO 621*). The purpose of this DSO is to evaluate the efficacy of Florinef on postflight orthostatic tolerance using heart rate, blood pressure, stroke volume, and other cardiovascular responses to orthostatic stress. A cardiovascular profile will be determined before and after flight for crew members participating in this investigation.

Gastrointestinal function during extended-duration space flight (DSO 622*). This DSO will (1) measure changes in gastric emptying rate by estimating absorption and half-life of acteaminophen after oral administration before, during, and after space flights of seven days or longer; (2) estimate changes in gastrointestinal motility by measuring time to reach peak breath-hydrogen levels after lactulose administration before, during, and after space flights of six days or longer; (3) calculate intestinal transit time and estimate percent changes for gastric emptying rate and gastrointestinal transit time; and (4) estimate percent changes in the absorption and metabolism of acetaminophen that collectively alter its bioavailability using urinary excretion of acetaminophen and its metabolites.

Measurement of blood volumes before and after space flight (DSO 625*). This DSO will measure the effects of space flight on blood volume.

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

Documentary television (DSO 901). This purpose of DSO 901 is to provide live television transmission or VTR dumps of crew activities and spacecraft functions, which include payload bay views, STS and payload crew activities, VTR downlink of crew activities, in-flight crew press conference, orbiter operations, payload deployment/retrieval and operations, Earth views, rendezvous and proximity operations, and unscheduled activities. Telecasts are planned for communication periods with seven or more minutes of uninterrupted viewing time. 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, and middeck activities and any unscheduled motion picture photography. These films provide a historical record of the flight as well as material for release to the news media, independent publishers, and film producers.

Documentary still photography (DSO 903). This DSO requires still photography of crew activities in the orbiter, spacecraft

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*Indicates EDO buildup—medical evaluation DSO.

functions, and mission-related scenes of general public and historical interest. Exterior and interior photographs will be taken.

STS-51 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.
03:00:00	The orbiter closeout crew goes to the launch pad and prepares the orbiter crew compartment for flight crew ingress.

T - (MINUS) HR:MIN:SEC	EVENT
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.
00:40:00	Cabin leak check is completed.
00:32:00	The backup flight control system (BFS) computer is configured.

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

T - (MINUS) HR:MIN:SEC	EVENT
00:15:00	The OMS/RCS crossfeed valves are configured for launch.
	All test support team members verify they are "go for launch."
00:12:00	Emergency aircraft and personnel are verified on station.
00:10:00	All orbiter aerosurfaces and actuators are verified to be in the proper configuration for hydraulic pressure application. The NASA test director gets a "go for launch" verification from the launch team.
00:09:00	A planned 10-minute hold starts.
<u>Hold 10 Minutes</u>	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 <u>Counting</u>	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 motor-driven switch called a safe and arm device (S&A).

T - (MINUS) HR:MIN:SEC	EVENT
00:04:30	As a preparation for engine start, the SSME main fuel valve heaters are turned off.
00:04:00	The final helium purge sequence, purge sequence 4, on the SSMEs is started in preparation for engine start.
00:03:55	At this point, all of the elevons, body flap, speed brake, and rudder are moved through a preprogrammed pattern. This is to ensure that they will be ready for use in flight.
00:03:30	Transfer to internal power is done. Up to this point, power to the space vehicle has been shared between ground power supplies and the on-board fuel cells. The ground power is disconnected and the vehicle goes on internal power at this time. It will remain on internal power through the rest of the mission.
00:03:25	The SSMEs' nozzles are moved (gimbaled) through a preprogrammed pattern to ensure that they will be ready for ascent flight control. At completion of the gimbal profile, the SSMEs' nozzles are in the start position.
00:02:55	ET liquid oxygen prepressurization is started. At this point, the liquid oxygen tank vent valve is closed and the ET liquid oxygen tank is pressurized to its flight pressure of 21 psi.
00:02:50	The gaseous oxygen arm is retracted. The cap that fits over the ET nose cone to prevent ice buildup on the oxygen vents is raised off the nose cone and retracted.
00:02:35	Up until this time, the fuel cell oxygen and hydrogen supplies have been adding to the on-board tanks so that a full load at lift-off is assured. This filling operation is terminated at this time.
00:02:30	The caution/warning memory is cleared.
00:01:57	Since the ET liquid hydrogen tank was filled, some of the liquid hydrogen has turned into gas. In order to keep pressure in the ET liquid hydrogen tank low, this gas was vented off and piped out to a flare stack and burned. In order to maintain flight level, liquid hydrogen was continuously added to the tank to replace the vented hydrogen. This operation terminates, the liquid hydrogen tank vent valve is closed, and the tank is brought up to a flight pressure of 44 psia at this time.
00:01:15	The sound suppression system will dump water onto the mobile launcher platform (MLP) at ignition in order to dampen vibration and noise in the space shuttle. The firing system for this dump, the sound suppression water power bus, is armed at this time.
00:01:00	The SRB joint heaters are deactivated.
00:00:55	The SRB MDM critical commands are verified.

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

T - (MINUS) HR:MIN:SEC	EVENT
	SRB SRSS inhibits are removed. The SRB destruct system is now live.
00:00:12	The MPS helium fill is terminated. The MPS helium system flows to the pneumatic control system at each SSME inlet to control various essential functions.
00:00:10	LPS issues a "go" for SSME start. This is the last required ground command. The ground computers inform the orbiter 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-51 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.
0/00:00:28	All three SSMEs throttle down from 100 to 67 percent for maximum aerodynamic load (max q).
0/00:00:54	All three SSMEs throttle to 104 percent.
0/00:01:05	Max q occurs.
0/00:02:04	SRBs separate.
	When chamber pressure (Pc) of the SRBs is less than 50 psi, automatic separation occurs with manual flight crew backup switch to the automatic function (does not bypass automatic circuitry). SRBs descend to approximately 15,400 feet, when the nose cap is jettisoned and drogue chute is deployed for initial deceleration.
	At approximately 6,600 feet, drogue chute is released and three main parachutes on each SRB provide final deceleration prior to splashdown in Atlantic Ocean, where the SRBs are recovered for reuse on another mission. Flight control system switches from SRB to orbiter RGAs.
0/00:03:57	Negative return. The vehicle is no longer capable of return-to-launch site abort at Kennedy Space Center runway.
0/00:06:58	Single engine press to main engine cutoff (MECO).
0/00:07:31	All three SSMEs throttle down to 67 percent for MECO.
0/00:08:28	MECO occurs at approximate velocity 25,875 feet per second, 35 by 158 nautical miles (40 by 182 statute miles).
0/00:08:36	Zero thrust.

Editor's Note: This time line lists selected highlights only. For full detail, please refer to the NASA Mission Operations Directorate STS-51 Flight Plan, Ascent Checklist, Post Insertion Checklist, Deploy Checklist, Rendezvous Checklist, Deorbit Prep Checklist, and Entry Checklist. The schedule assumes a nine-day mission.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/00:08:48	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.
0/00:40	OMS-2 thrusting maneuver is performed, approximately 2 minutes, 26 seconds in duration, at 222 fps, 162 by 160 nautical miles.
0/00:51	Commander closes all current breakers, panel L4.
0/00:53	Mission specialist (MS) seat egress.
0/00:54	Commander and pilot configure GPCs for OPS-2.
0/00:57	MS configures preliminary middeck.
0/00:59	MS configures aft flight station.
0/01:02	MS unstows, sets up, and activates PGSC.
0/01:05	MS configures for payload bay door operations.
0/01:06	Pilot activates payload bus (panel R1).
0/01:08	Commander and pilot don and configure communications.
0/01:12	Pilot maneuvers vehicle to payload bay door opening attitude, biased negative Z local vertical, positive Y velocity vector attitude.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/01:17	Commander activates radiators.
0/01:28	MS opens payload bay doors.
0/01:30	Commander loads payload data interleaver DFL.
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).
0/01:52	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.
0/01:58	Pilot closes main B supply water dump isolation circuit breaker, panel ML86B, opens supply water dump isolation valve, panel R12L.
0/02:01	Pilot activates auxiliary power unit steam vent heater, panel R2, boiler controller/heater, 3 to A, power, 3 to ON.
0/02:05	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	Ku-band antenna deployment.
0/02:30	ERPCL heater activation.
0/02:30	TOS ASE heater activation.
0/02:35	ERPCL temperature check.
0/02:40	Ku-band antenna activation.
0/02:40	ACTS/TOS activation and checkout.
0/02:50	TOS power on.
0/03:00	Engage ACTS.
0/03:10	ACTS predeployment checkout.
0/03:20	TOS predeployment checkout.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/03:25	CHROMEX check.
0/03:35	RMS powerup.
0/03:50	RMS checkout.
0/03:55	CPCG activation.
0/03:55	DSO 604.
0/04:15	RME activation and checkout.
0/04:30	RMS payload bay survey.
0/05:05	RMS powerdown.
0/05:30	Accuracy improvement maneuver.
0/06:10	Burn initialization maneuver (TOS).
0/06:20	TIPS activation (DTO 660).
0/06:25	Maneuver to deploy attitude.
0/06:35	Raise ACTS/TOS to deploy position.
0/07:00	TOS payload interrogator setup.
0/07:25	ACTS transfer orbit configuration.
0/07:40	Begin ACTS/TOS deploy countdown.
0/07:58	ACTS/TOS deploy.
0/08:05	TOS ASE heater activation.
0/08:05	Separation maneuver.
0/08:15	OMS burn.
0/08:30	Close and latch ASE.
0/08:43	TOS SRM ignition.
0/08:55	ERPCL temperature check.
0/09:00	Crew begins presleep activities.
0/09:30	DTO 656.
0/11:00	Crew begins sleep period.
0/19:00	Crew begins postsleep activities.
0/19:00	DSO 476.
0/20:00	DTO 656.
0/20:05	PADM setup.
0/21:15	RMS powerup.
0/21:53	OMS HITE TIG.
0/21:55	ERPCL temperature check.
0/22:00	SPAS grapple.
0/22:00	TCS setup (DTO 700-5).
0/22:15	SPAS activation/checkout.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
0/22:30	DTO 668 setup.
0/22:41	RCS circularization burn ignition.
0/23:00	SPAS activation and checkout II.
0/23:35	Data tape recorder reset.
	MET DAY ONE
1/00:10	Gyro maneuvers.
1/00:40	SPAS unberth.
1/01:00	RMS maneuver to deploy position.
1/01:15	Maneuver to release attitude.
1/01:30	SPAS door test.
1/01:40	Special-purpose end effector deadface.
1/01:45	SPAS release.
1/01:50	Tracking maneuver.
1/02:35	RMS powerdown.
1/03:30	RCS separation 2 burn TIG.
1/03:40	RICS maneuver.
1/03:45	DSO 476.
1/03:55	Tracking maneuver.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/04:00	DTO 700-6 setup.
1/04:30	CHROMEX check.
1/05:00	RCS separation 3 burn TIG.
1/05:05	10.2-psi preparation.
1/05:15	DSO 604.
1/05:20	Cabin depress to 10.2 psi.
1/05:50	10.2-psi configuration.
1/05:50	DSO 476.
1/06:00	DTO 700-7 setup.
1/06:15	Public Affairs Office event.
1/06:40	ERPCL temperature check.
1/06:50	TCS shutdown (DTO 700-5).
1/07:00	Crew begins presleep activities.
1/08:00	DTO 656.
1/08:02	RCS NC1 burn TIG.
1/08:30	10.2-psi maintenance.
1/10:00	Crew begins sleep period.
1/18:00	Crew begins postsleep activities.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
1/18:00	DSO 476.
1/19:00	DTO 656.
1/19:05	PADM setup.
1/20:30	10.2-psi maintenance.
1/21:00	RME memory module checkout.
1/21:10	ERPCL temperature check.
1/21:36	RCS NC2 burn TIG.
1/22:00	IPMP activation.

MET DAY TWO

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
2/00:00	GPS operations (DTO 700-6).
2/02:30	CHROMEX check.
2/03:35	RCS NC 3 burn TIG.
2/03:50	Public Affairs Office event.
2/04:15	DSO 476.
2/04:50	DSO 476.
2/05:50	ERPCL temperature check.
2/06:00	Crew begins presleep activities.
2/06:30	10.2-psi maintenance.
2/07:00	DTO 656.
2/07:24	RCS NC 4 burn TIG.
2/09:00	Crew begins sleep period.
2/17:00	Crew begins postsleep activities.
2/17:00	DSO 476.
2/18:00	DTO 656.
2/18:05	PADM setup.
2/19:15	10.2-psi maintenance.
2/20:00	ERPCL temperature check.
2/20:30	EVA equipment preparation.
2/20:57	RCS NC 5 burn TIG.
2/21:00	EMU checkout 10.2 psi.
2/22:30	DTO 700-6.
2/23:05	Public Affairs Office event.
2/23:30	CHROMEX check.

MET DAY THREE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/01:00	Middeck preparation.
3/01:40	ECLSS redundant component checkout.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
3/02:59	RCS NC 6 burn TIG.
3/03:00	Prepare for donning.
3/03:15	DSO 476.
3/03:45	DSO 476.
3/04:45	ERPCL temperature check.
3/04:55	RME memory module checkout.
3/05:00	Crew begins presleep activities.
3/05:45	10.2-psi maintenance.
3/06:00	DTO 656.
3/06:45	RCS NC 7 burn TIG.
3/08:00	Crew begins sleep period.
3/16:00	Crew begins postsleep activities.
3/16:00	DSO 476.
3/17:00	DTO 656.
3/17:05	PADM setup.
3/18:30	10.2-psi maintenance.
3/18:45	EVA preparation begins.
3/19:10	ERPCL temperature check.
3/20:19	RCS NC 8 burn TIG.
3/21:00	Airlock depressurization.
3/21:15	EVA (DTOs 1210 and 671).
	MET DAY FOUR
4/00:50	RCS NC 9 burn TIG.
4/02:30	CHROMEX check.
4/03:15	Airlock repressurization.
4/03:30	Post-EVA.
4/03:35	ERPCL temperature check.
4/04:00	EMU suit dry seal lube.
4/04:00	Crew begins presleep activities.
4/04:36	RCS NC 10 burn TIG.
4/05:00	DTO 656.
4/05:15	10.2-psi maintenance.
4/07:00	Crew begins sleep period.
4/15:00	Crew begins postsleep activities.
4/15:00	DSO 476.
4/15:00	DSO 622.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
4/15:45	DSO 622.
4/16:00	DTO 656.
4/16:05	PADM setup.
4/17:30	10.2-psi maintenance.
4/18:00	ERPCL temperature check.
4/18:00	EVA survey.
4/19:41	RCS NC 11 burn TIG.
4/21:10	DSO 476.
4/21:30	DTO 700-6.
4/22:00	RME memory module checkout.
4/22:41	RCS NC 12 burn TIG.
4/23:00	LDCE activation.

MET DAY FIVE

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/00:35	HRSGS setup.
5/01:05	HRSGS PTG.
5/01:15	HRSGS operations.
5/01:15	APE operations—orbiter surfaces.
5/01:25	Public Affairs Office event.
5/01:45	DSO 476.
5/01:55	HRSGS temporary stow.
5/02:26	RCS NC 13 burn TIG.
5/02:30	CHROMEX check.
5/03:30	ERPCL temperature check.
5/03:40	Crew begins presleep activities.
5/04:30	10.2-psi maintenance.
5/04:40	DTO 656.
5/05:28	RCS NC 14 burn TIG.
5/06:40	Crew begins sleep period.
5/14:40	Crew begins postsleep activities.
5/14:40	DSO 476.
5/15:40	DTO 656.
5/15:45	PADM setup.
5/16:45	10.2-psi maintenance.
5/17:40	ERPCL temperature check.
5/17:50	APE operations—orbiter surfaces.
5/18:17	RCS NC 15 burn TIG.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
5/18:55	TIPS paper checkout (DTO 660).
5/19:10	HRSGS PTG.
5/19:20	HRSGS operations.
5/19:20	APE operations—orbiter surfaces.
5/20:00	HRSGS temporary stow.
5/20:40	HRSGS PTG.
5/20:50	HRSGS operations.
5/20:50	APE operations—orbiter surfaces.
5/21:20	LDCE deactivation.
5/21:30	HRSGS stow.
5/23:25	LDCE activation.
5/23:50	APE operations—orbiter surfaces.

MET DAY SIX

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/00:00	APE operations—orbiter surfaces.
6/00:17	RCS NC 16 burn TIG.
6/00:30	Public Affairs Office event.
6/00:50	DTO 668.
6/01:20	APE operations—airglow.
6/01:30	DSO 476.
6/02:10	DSO 476.
6/02:30	CHROMEX check.
6/03:00	ERPCL temperature check.
6/03:15	RME memory module checkout.
6/03:20	Crew begins presleep activities.
6/04:00	10.2-psi maintenance.
6/04:20	DTO 656.
6/04:50	RCS NC 17 burn TIG.
6/06:20	Crew begins sleep period.
6/14:20	DSO 476.
6/14:20	Crew begins postsleep activities.
6/15:20	DTO 656.
6/15:25	PADM setup.
6/16:30	10.2-psi maintenance.
6/16:35	LDCE deactivation.
6/16:40	Priority Group B powerup.
6/17:20	Thermal control system setup (DTO 700-5).

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
6/17:26	RCS NC 18 burn TIG.
6/17:30	ERPCL temperature check.
6/17:30	DTO 668.
6/18:56	RCS NC 19 burn TIG.
6/19:25	RMS powerup.
6/19:35	DTO 668.
6/20:20	RMS maneuver to precradle position.
6/21:01	RCS NCC burn TIG.
6/21:57	RCS Ti burn TIG.
6/22:05	RMS maneuver to capture position.
6/22:18	MC 1 burn TIG.
6/22:44	MC 2 burn TIG.
6/22:54	MC 3 burn TIG.
6/23:04	MC 4 burn TIG.
6/23:30	Vbar arrival.
6/23:55	Grapple SPAS.

MET DAY SEVEN

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/00:10	RICS photo sequence.
7/00:10	Thermal control system shutdown (DTO 700-5).
7/00:45	Public Affairs Office event.
7/01:50	SPAS deactivation.
7/02:05	SPAS berth.
7/02:30	CHROMEX check.
7/02:35	RMS powerdown.
7/02:45	Fuel cell 1 shutdown (DTO 412).
7/02:50	ERPCL temperature check.
7/03:00	Crew begins presleep activities.
7/03:00	10.2-psi maintenance.
7/04:00	DTO 656.
7/06:00	Crew begins sleep period.
7/14:00	Crew beings postsleep activities.
7/14:00	DSO 476.
7/15:00	DTO 656.
7/15:05	PADM setup.
7/16:00	RMS heater activation.
7/17:00	RMS powerup.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/17:05	ERPCL temperature check.
7/17:15	DTO 668.
7/17:15	Cabin repressurization to 14.7 psi.
7/17:45	RMS powerdown.
7/18:00	Post-EVA entry preparation.
7/18:05	FCS checkout.
7/18:35	DSO 604.
7/19:15	RCS hot fire.
7/19:20	PADM powerdown.
7/19:35	DTO 700-6 stow.
7/20:05	DTO 700-7 stow.
7/20:30	RME memory module checkout.
7/20:40	DSO 604.
7/21:15	APE operations—thruster emissions.
7/21:25	AMOS RCS TIG.
7/22:35	Crew press conference.
7/22:50	APE stow.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
7/23:30	CHROMEX check.
	MET DAY EIGHT
8/00:00	Cabin stow.
8/02:25	Fuel cell 1 powerup (DTO 412).
8/02:50	ERPCL temperature check.
8/02:55	Ku-band antenna stow.
8/03:00	Crew begins presleep activities.
8/06:00	Crew begins sleep period.
8/14:00	Crew begins postsleep activities.
8/14:00	DSO 476.
8/15:45	DSO 604.
8/16:15	DSO 603B.
8/16:59	Begin deorbit preparation.
8/17:02	CRT timer setup.
8/17:05	Commander initiates cold soak.
8/17:14	Stow radiators, if required.
8/17:22	Ku-band antenna stow.
8/17:32	Commander configures DPS for deorbit preparation.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/17:35	Mission Control Center updates IMU star pad, if required.
8/17:44	MS configures for payload bay door closure.
8/17:55	MCC-H gives "go/no-go" command for payload bay door closure.
8/18:00	Maneuver vehicle to IMU alignment attitude.
8/18:15	IMU alignment/payload bay door operations.
8/18:38	MCC gives the crew the go for OPS 3.
8/18:44	Pilot starts repressurization of SSME systems.
8/18:48	Commander and pilot perform DPS entry configuration.
8/18:57	MS deactivates ST and closes ST doors.
8/18:59	All crew members verify entry payload switch list.
8/19:14	All crew members perform entry review.
8/19:16	Crew begins fluid loading, 32 fluid ounces of water with salt over next 1.5 hours (2 salt tablets per 8 ounces).
8/19:29	Commander and pilot configure clothing.
8/19:44	MS/PS configure clothing.
8/19:55	Commander and pilot seat ingress.
8/19:57	Commander and pilot set up heads-up display (HUD).
8/19:59	Commander and pilot adjust seat, exercise brake pedals.
8/20:07	Final entry deorbit update/uplink.
8/20:13	OMS thrust vector control gimbal check is performed.
8/20:14	APU prestart.
8/20:29	Close vent doors.
8/20:33	MCC-H gives "go" for deorbit burn period.
8/20:42	Maneuver vehicle to deorbit burn attitude.
8/20:45	MS/PS ingress seats.
8/20:52	First APU is activated.
8/20:59	Deorbit burn.
8/21:02	Initiate post-deorbit burn period attitude.
8/21:06	Terminate post-deorbit burn attitude.
8/21:14	Dump forward RCS, if required.
8/21:22	Activate remaining APUs.
8/21:28	Entry interface, 400,000 feet altitude.
8/21:33	Automatically deactivate RCS roll thrusters.

T + (PLUS) DAY/ HR:MIN:SEC	EVENT
8/21:39	Automatically deactivate RCS pitch thrusters.
8/21:43	Initiate first roll reversal.
8/21:47	Initiate second roll reversal.
8/21:48	TACAN acquisition.
8/21:50	Initiate air data system (ADS) probe deploy.
8/21:52	Begin entry/terminal area energy management (TAEM).
8/21:52	Initiate third roll reversal.
8/21:52	Initiate payload bay venting.
8/21:54	Automatically deactivate RCS yaw thrusters.
8/21:56	Begin TAEM/approach/landing (A/L) interface.
8/21:58	Initiate landing gear deployment.
8/21:59	Vehicle has weight on main landing gear.
8/21:59	Vehicle has weight on nose landing gear.
8/21:59	Initiate main landing gear braking.
8/22:00	Wheel stop.

GLOSSARY

A/G	air-to-ground
AG	airglow
AA	accelerometer assembly
ACS	active cooling system
ACTS	Advanced Communications Technology Satellite
ADS	air data system
AFB	Air Force base
A/L	approach and landing
AMOS	Air Force Maui Optical Site calibration test
AOS	acquisition of signal
APC	autonomous payload controller
APCS	autonomous payload control system
APE-B	Auroral Photography Experiment B
APU	auxiliary power unit
ASE	airborne support equipment
BFS	backup flight control system
CCD	charge-coupled device
CCDS	Center for the Commercial Development of Space
CDMS	command and data management subsystem
CHROMEX	Chromosome and Plant Cell Division in Space
COAS	crewman optical alignment sight
CPCG	Commercial Protein Crystal Growth
CRT	cathode ray tube
C/W	caution/warning
DACA	data acquisition and control assembly
DA	detector assembly
DC	detector controller
DAP	digital autopilot
DOD	Department of Defense
DPS	data processing system
DSO	detailed supplementary objective
DTO	development test objective
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
EDO	extended-duration orbiter
EDOMP	extended-duration orbiter medical project
EHF	extremely high frequency
ELV	expendable launch vehicle
EMP	enhanced multiplexer/demultiplexer pallet
EMU	extravehicular mobility unit
EOM	end of mission
EPS	electrical power system
ERCPL	extended-range payload communication link
ESC	electronic still camera
ESA	European Space Agency
ESS	equipment support section
ET	external tank
ETR	Eastern Test Range
EV	extravehicular
EVA	extravehicular activity
FC	fuel cell
FCP	fuel cell power plant
FCS	flight control system
FDF	flight data file
FES	flash evaporator system
FPA	fluid processing apparatus
fps	feet per second
FRCS	forward reaction control system
GAP	group activation pack
GAS	getaway special

GLS	ground launch sequencer
GN&C	guidance, navigation, and control
GPC	general-purpose computer
GSFC	Goddard Space Flight Center
HAINS	high-accuracy inertial navigation system
HRM	high-rate multiplexer
HRSGS-A	High-Resolution Shuttle Glow Spectroscopy A
HUD	heads-up display
IFM	in-flight maintenance
IMU	inertial measurement unit
I/O	input/output
IPMP	Investigations Into Polymer Membrane Processing
IR	infrared
IUS	inertial upper stage
IV	intravehicular
JSC	Johnson Space Center
KEAS	knots equivalent air speed
KSC	Kennedy Space Center
LBNP	lower body negative pressure
LCD	liquid crystal display
LDCE	Limited-Duration Space Environment Candidate Materials Exposure
LES	launch escape system
LPS	launch processing system
LRU	line replaceable unit
MCC-H	Mission Control Center--Houston
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merritt Island
MLP	mobile launcher platform
MM	major mode
MPM	manipulator positioning mechanism
MPS	main propulsion system
MS	mission specialist
MSFC	Marshall Space Flight Center
NCC	corrective combination maneuver
NH	differential height adjustment that adjuists the altitude of orbiter's orbit
nmi	nautical mile
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
OG	orbiter glow
OMS	orbital maneuvering system
OPF	orbiter processing facility
ORFEUS	Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph
OTC	orbiter test conductor
PAO	public affairs officer
PASS	primary avionics software system
PC	proportional counter
PCMMU	pulse code modulation master unit
PCS	pressure control system
PDU	playback/downlink unit
PGSC	payload and general-support computer
PI	payload interrogator
PIC	pyro initiator controller
POCC	Payload Operations Control Center
PRCS	primary reaction control system
PRD	payload retention device

PRLA	payload retention latch assembly
PRSD	power reactant storage and distribution
PS	payload specialist
PTI	preprogrammed test input
P/TV	photo/TV
RAAN	right ascension of the ascending node
RCRS	regenerable carbon dioxide removal system
RCS	reaction control system
RF	radio frequency
RGA	rate gyro assembly
RICS	remote IMAX camera system
RMS	remote manipulator system
ROEU	remotely operated electrical umbilical
RME-III	Radiation Monitoring Equipment III
rpm	revolutions per minute
RSLS	redundant-set launch sequencer
RSS	range safety system
RTLS	return to launch site
S&A	safe and arm
SA	solar array
SAF	secretary of the Air Force
SHF	superhigh frequency
SM	statute miles
SPAS	shuttle pallet satellite
SPASP	small payload accommodations switch panel
SPOC	shuttle payload of opportunity carrier
SRB	solid rocket booster
SRM	solid rocket motor
SRSS	shuttle range safety system
SSCE	solid surface combustion experiment
SSME	space shuttle main engine
SSP	standard switch panel
SSPP	Shuttle Small Payload Project
SSPP	solar/stellar pointing platform
ST	star tracker
STA	structural test article
STS	Space Transportation System
SURS	standard umbilical retraction/retention system
TAEM	terminal area energy management
TAGS	text and graphics system
TAL	transatlantic landing
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TFL	telemetry format load
TI	thermal phase initiation burn
TIG	time of ignition
TIPS	thermal impulse printer system
TOS	transfer orbit stage
TPS	thermal protection system
TSM	tail service mast
TT&C	telemetry, tracking, and communications
TV	television
TVC	thrust vector control
UHF	ultrahigh frequency
VRCS	vernier reaction control system
VTR	videotape recorder
WCCS	wireless crew communication system
WCS	waste collection system