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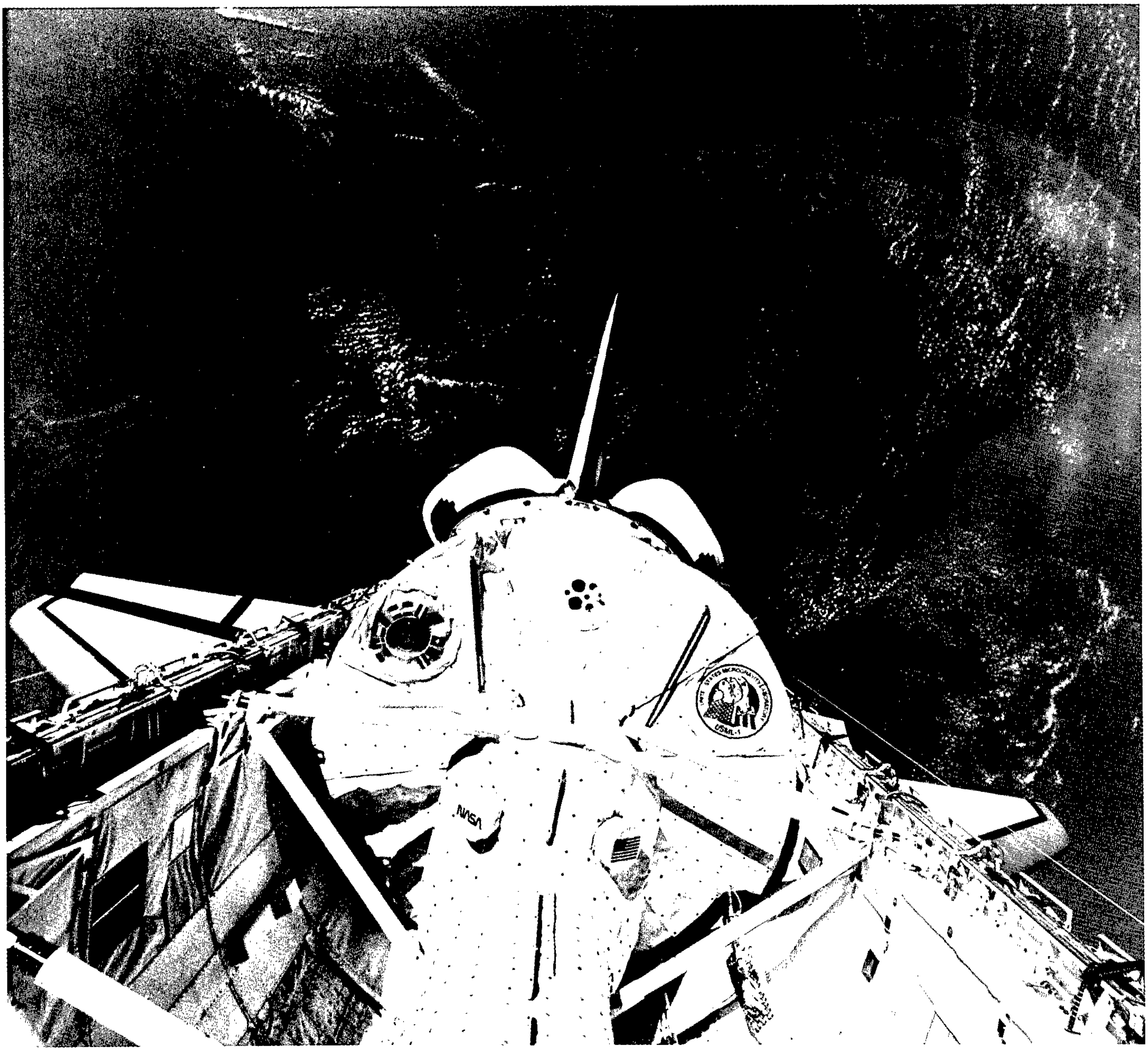
National Aeronautics and
Space Administration

Information Summaries

PMS-021 (MSFC)
September 1994

Spacelab



The Spacelab module rests inside the Shuttle Discovery's cargo bay for the first United States Microgravity Laboratory (USML-1) mission in 1992.

Space — the very word conjures up images of adventure and discovery.

When Spacelab transforms NASA's Space Shuttle into an orbiting laboratory, the adventure is performing research impossible on Earth, and the discoveries help unravel the secrets of science.

Spacelab is a versatile laboratory carried in the Shuttle's cargo bay for special research flights. Its various elements can be combined to accommodate the many types of scientific research which can be performed best in space. In the enclosed pressurized laboratory module, scientists in orbit work much as they do in labs on Earth. Open U-shaped pallets expose some experiments directly to space. When pallet experiments fly without the module, crew members operate them remotely from the orbiter or members of the science team operate them from the ground.

Spacelab missions are cooperative efforts between scientists and engineers from around the world. Teams from NASA centers, universities, private industry, government agencies and international space organizations design the experiments. Some of these scientists even get the opportunity to fly aboard the Shuttle with their experiments as part of the science crew.

During missions, scientists on the ground work together with their colleagues in space — monitoring results through computer displays and TV from orbit, commanding the instruments, and talking with the crew. This close interaction lets them follow their experiments in progress and adjust them if necessary to get the best possible results.

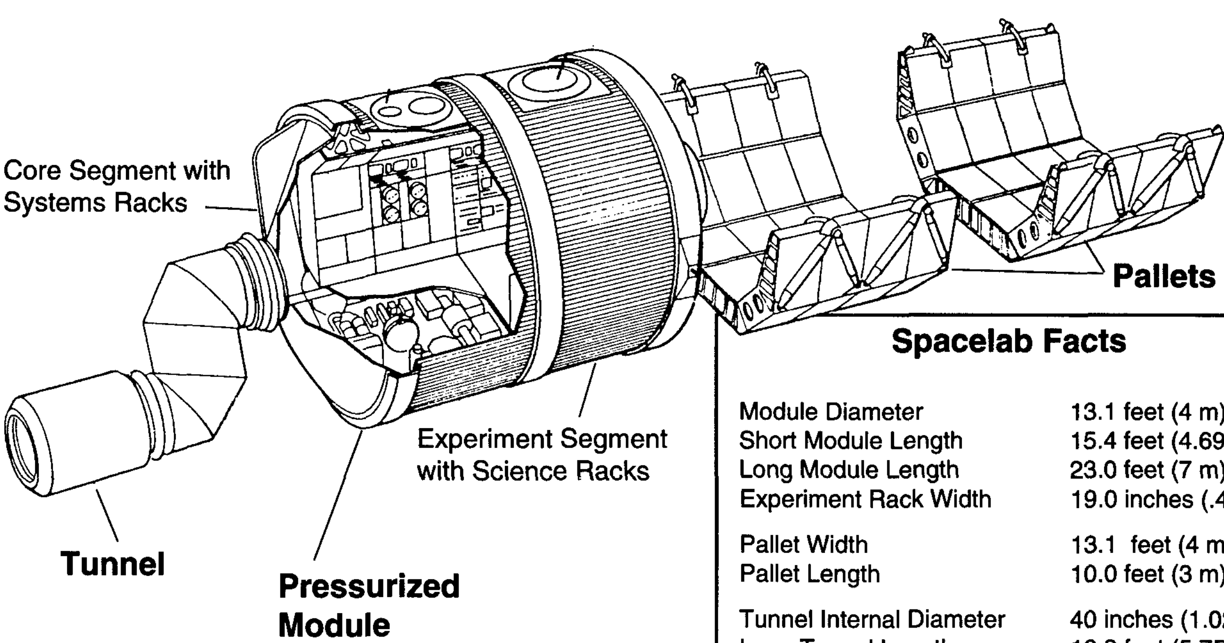
The reusable Spacelab allows scientists to bring experiment samples back to Earth for post-flight analysis. Their equipment is returned, reworked and improved for future flights.

A Decade of Spacelabs

The European Space Agency (ESA) developed Spacelab in the late 1970s and early 1980s as its contribution to America's Space Shuttle program. The Marshall Space Flight Center in Huntsville, Ala., NASA's lead center for Spacelab, worked closely with ESA and managed the program for NASA.

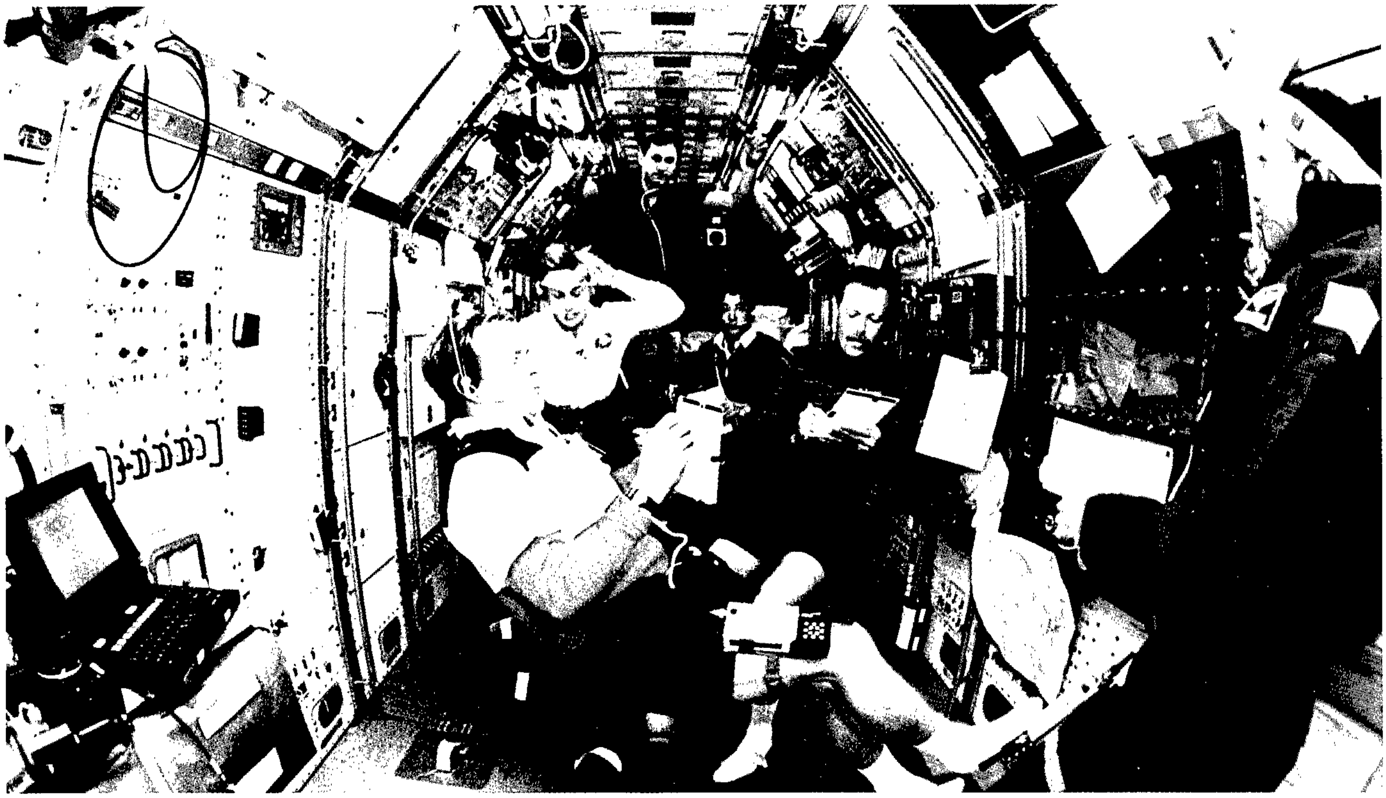
Spacelab 1, which flew aboard STS-9 in 1983, was both a test flight of the Spacelab module and an ambitious research mission, with 73 experiments in seven science disciplines. The laboratory module flew again on the STS 51-B **Spacelab 3** mission, which emphasized low-gravity materials processing and fluids experiments. **Spacelab 2** on STS 51-F, a test flight for Spacelab pallets used without the module, concentrated on solar science and on measuring the space environment around the Shuttle. **Spacelab D-1** aboard STS 61-A underscored the international character of the Spacelab program. The German space agency, which managed the mission, controlled science activities from its space operations center near Munich, Germany.

Spacelab flights have become more specialized in the 1990s. **Astro** missions are dedicated to ultraviolet



Spacelab Facts

Module Diameter	13.1 feet (4 m)
Short Module Length	15.4 feet (4.69 m)
Long Module Length	23.0 feet (7 m)
Experiment Rack Width	19.0 inches (.48 m)
Pallet Width	13.1 feet (4 m)
Pallet Length	10.0 feet (3 m)
Tunnel Internal Diameter	40 inches (1.02 m)
Long Tunnel Length	18.8 feet (5.75 m)
Short Tunnel Length	8.7 feet (2.66 m)



The Spacelab J crew prepares for a shift handover inside the pressurized Spacelab module.

and X-ray astronomy. The **Atmospheric Laboratory for Applications and Science (ATLAS)** series maps Earth's atmosphere to compare global ozone levels and any factors which may influence them. **Spacelab Life Sciences (SLS)** flights study how people, plants and animals respond to weightlessness. The **United States Microgravity Laboratory (USML)** module missions advance American expertise in low-gravity research. Some low-gravity experiments requiring direct exposure to space are controlled remotely by ground-based scientists during **United States Microgravity Payload (USMP)** missions.

Scientists around the world make the most of Spacelab resources by scheduling both crew-intensive life-science research and power-consuming materials experiments during **International Microgravity Laboratory (IML)** flights. **Spacelab J** in 1992 featured Japanese materials processing and life science experiments. **Spacelab D-2**, a 1993 German Spacelab mission, built on experience gained from the first German flight.

Space as a Laboratory

Space is an unequaled research laboratory. There, characteristics of life and materials are revealed which are masked by gravity on Earth. "Weightlessness" can be achieved for a few seconds in drop towers on the ground and on special airplane flights, or for several minutes aboard sounding rockets. But only in orbit is it possible to conduct experiments in very low gravity for days, weeks or even longer.

Actually, the force of gravity in low-Earth orbit is almost as strong as on the ground. But the outward force on the Shuttle as it circles the Earth counterbalances gravity's downward pull. The result of this free-fall state creates an environment called "microgravity," about one-millionth the gravity on Earth. Because they fall together, all unsecured objects within the spacecraft — including people — float, appearing to be weightless.

Microgravity Science

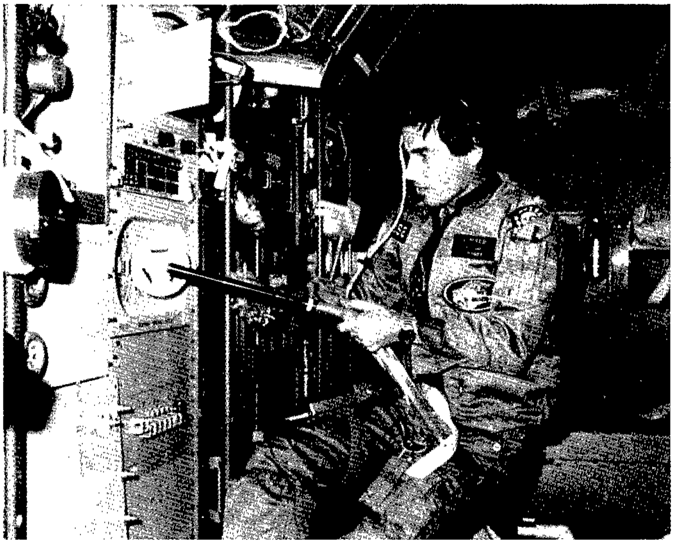
Scientists in labs on Earth arrive at conclusions about materials and physical processes by varying one factor at a time in their experiments: changing the temperature, adjusting the mixture, lengthening or shortening the duration. But on Earth, there is one factor they cannot remove: gravity.

Because of gravity, some materials will not mix uniformly to form desired alloys; metallic and electronics crystals have defects that reduce their strength or electrical properties; protein crystals clump together instead of forming distinctly enough for detailed analysis; fluids are deformed by containers.

When scientists conduct experiments in space, they can essentially "turn off" the gravity and greatly reduce the limitations it creates.

Metals and Alloys. Metal casting is one of the oldest technologies, but until recently most casting advances have been achieved by trial and error. To create sophisticated materials for tomorrow's technologies, designers must thoroughly understand how molten metals solidify and how different metals combine to form alloys.

Removing gravity-induced fluid flows simplifies the process. For instance, space may be the only place where accurate measurements can be made of how atoms in liquefied metals move, or flow, past one another. As early as 1983, such measurements made aboard Spacelab 1 were 300 times more precise than



Payload Specialist Ulf Merbold, the first European astronaut, places a sample for a crystal growth experiment into the Spacelab 1 gradient heating furnace.

ground-based tests. Experiments in the 1990s are building on this experience, testing more combinations of materials for alloys and composites, designing furnaces with wider temperature ranges, and adding improved diagnostic tools that allow scientists on the ground to monitor their samples as they melt and solidify.

Protein Crystals. Proteins are essential to all life, playing roles from providing nourishment to fighting disease. One group of space experiments is helping scientists determine the structure of certain proteins. As with casting, most pharmaceuticals are formulated by trial and error. But if scientists can identify the precise structure of a disease-related protein, they can design a drug to fit it like a key fits a lock. Researchers use a method called X-ray crystallography to determine the three-dimensional structure of proteins, but this requires relatively large, single protein crystals, about the size of a grain of salt. Earth-grown crystals large enough to study often have numerous flaws, probably caused by gravity. Crystals grown in space tend to have more uniform internal structures, allowing much better X-ray studies.

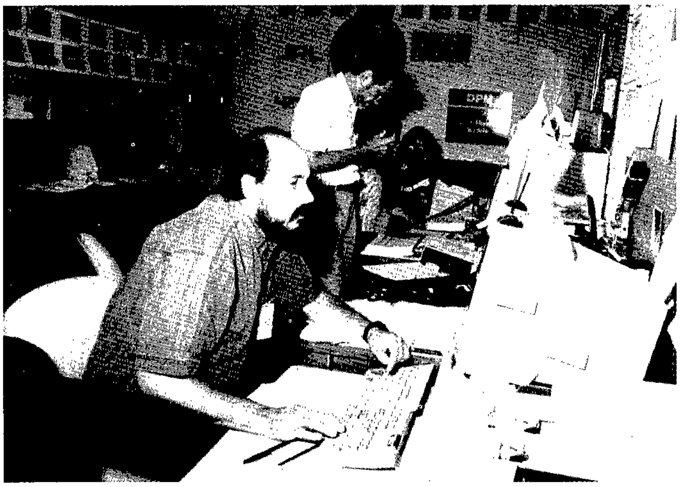
Protein crystal growth experiments have flown on the Shuttle since 1985, producing some of the best crystals yet of a number of different proteins. Drug companies are using structures determined or enhanced by some of these space-grown crystals to develop medicines. Protein crystallographer Dr. Larry DeLucas joined the USML-1 Spacelab crew as a payload specialist. He was able to substantially improve the quality of the crystals by monitoring growth in progress and adjusting the experiments based on his observations.

Electronics. One important technique for processing a mixture of elements, directional solidification, is used to prepare semiconductors — valuable crystals which have controllable electronic properties. Flows caused by gravity complicate this process, making it difficult to measure and predict, and even harder to control. Spacelab crystal growth furnaces, such as those flown on USML and the USMP missions, are effective tools in semiconductor research. By removing gravity-induced fluid flows, USML-1 scientists learned some important aspects of crystal growth which will significantly improve Earth-based processing.

Mercury iodide crystals, prized as nuclear radiation detectors because they operate at room temperature, also have been grown in space. The fragile crystals can be deformed by their own weight when grown on Earth. On Spacelab 3, crew members and ground-based scientists monitored a mercury iodide crystal as it grew in microgravity for 100 hours. Its large size was comparable to the best Earth-grown crystals, and its internal quality was better. The experiment was repeated on IML-1. With 132 hours of growth, the IML-1 mercury iodide crystal grew to more than twice the size of the Spacelab 3 specimen.

Fluids Physics. Aboard Spacelab, scientists can study subtle movements and behavior in fluids, both liquids and gases, which are masked by gravity-driven flows on Earth. Fluid physics research is letting scientists see how these factors influence ground-based crystal growth or glass processing and is allowing them to test some fundamental physics theories.

Several recent Spacelab experiments have examined convection, or temperature-driven fluid flows. In gravity, flows are created as warmer fluids rise to the top. Scientists know that temperature variations along the free surfaces of liquids generate other fluid motions. Away from the stronger force of gravity-induced flows, a USML-1 experiment measured this surface-tension-



USML-1 scientists monitor drop behavior in microgravity from the science operations area of NASA's Spacelab Mission Operations Control facility in Huntsville, Ala.

driven convection in unprecedented detail, confirming the theory. As scientists analyze results from such fluids experiments, they can improve designs for fluid handling processes on Earth.

Other Spacelab fluids experiments have manipulated liquid drops with sound waves to study how fluids behave without the interference of containers. Spacelab scientists also are testing Nobel-prize-winning theories about the critical transition points of fluids, where a precise combination of temperature and pressure can capture a fluid at the point where it is in the process of changing between a liquid and a gas, with subsequent changes in properties.

SLS-2 Astronaut Rhea Seddon spins Payload Specialist Marty Fettman in a rotating chair to test his sense of orientation and balance in weightlessness.

Life Sciences

The near-weightlessness of space provides a unique opportunity for life scientists. All living organisms, from single cells to human beings, developed under the influence of gravity. In space, away from that influence, significant changes take place. The versatile Spacelab enables scientists to study in unprecedented detail the effects of both weightlessness and space radiation on life.

Researchers are especially interested in how people adjust to living in space. Blood and other fluids accumulate in the upper body in space since gravity is no longer pulling them downward. Muscles and bones which do not strain against gravity lose strength. About two-thirds of all space travelers show symptoms similar to motion sickness during the first few days of flight, as their bodies adjust to being without the familiar feeling of up and down provided by gravity.

The causes and results of these changes must be thoroughly understood to ensure astronauts' safety and comfort during longer space station stays and on eventual exploration voyages. New insights into how life adapts to a microgravity environment will teach medical researchers more about basic life processes on Earth as well.

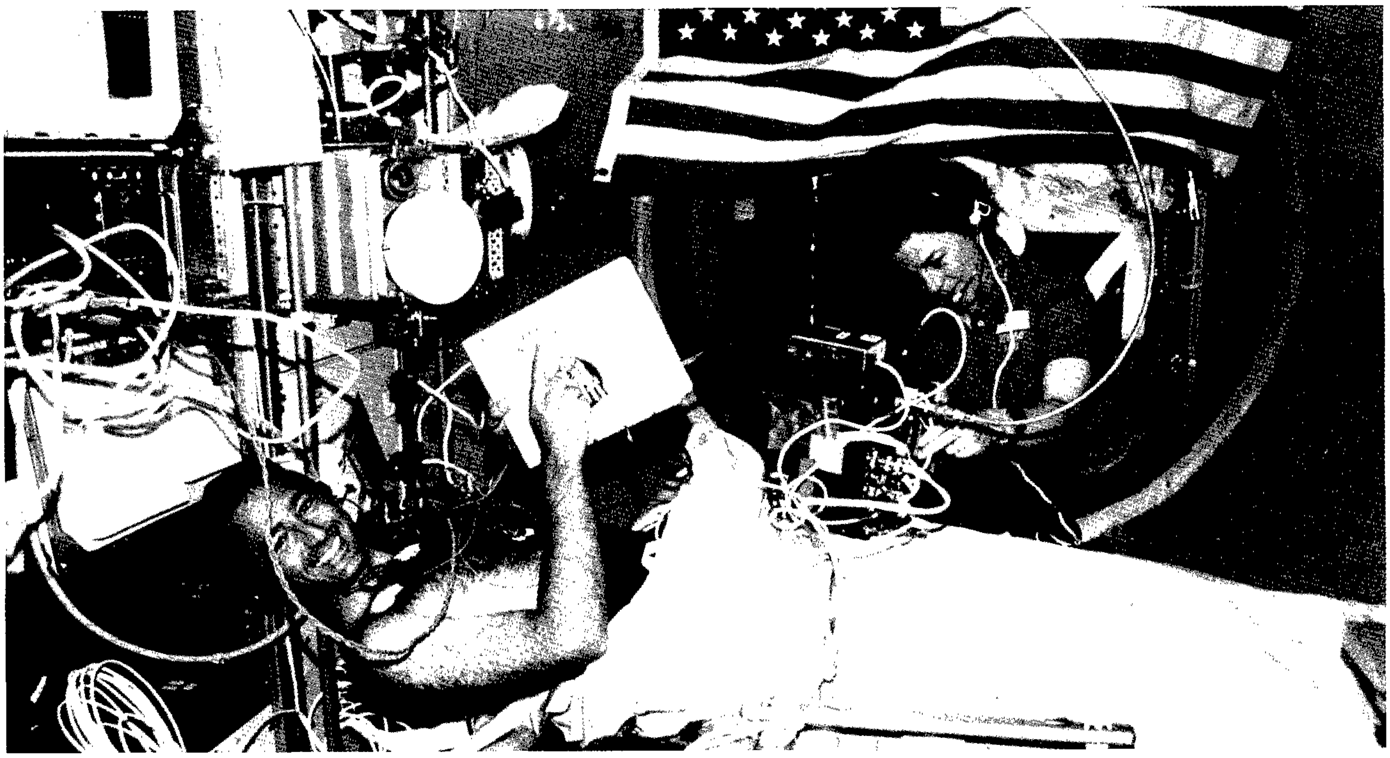
Experiments in the 1990s, particularly those on Spacelab Life Sciences missions, are building on earlier research to help scientists understand how space flight affects life. Crew members both operate and are subjects of experiments. These tests typically are repeated before launch; during the space flight near the beginning, middle and end of the mission; and then again after landing. Comparisons tell scientists when physical changes take place, how soon space adaptation begins and how long it takes to readapt to gravity. When possible, human and animal studies parallel each other to confirm that changes occurring in animals are similar to those observed in humans. Scientific theories can only be substantiated when supported by statistical results from experiments repeated more than once with an adequate number of subjects — whether humans or animals.

Some early results of 1990s flights seemed to confirm previous theories, while outcomes of other tests surprised researchers. In one experiment, for instance, astronauts' heart size increased in spite of a drop in blood pressure. Scientists also have been surprised to learn that distribution of air and blood in the lungs does not change as much in space as they expected, indicating there may be other factors besides gravity governing that distribution. Flight after flight, researchers have observed changes in astronauts' blood during weightlessness. The number of red blood cells decreases, perhaps due to changes in the cell-producing function of the bone marrow. The amount of total blood fluid also decreases. Disease-fighting white blood cells lose some of their ability to respond to infection. Tests on rats show a difference in weight gain and growth between animals onboard Spacelab and others in identical tests on the ground.

Extensive tests to determine why some astronauts experience space motion sickness are shedding new light on the function of the motion-sensing organs of the inner ear. Onboard diagnostic equipment, such as a small device placed on the skin during Spacelab D-2 to measure the heart's pumping power, could improve diagnostic methods on Earth.

Some Spacelab experiments test methods for counteracting the influence of weightlessness. One experiment studies astronauts before flight in "biofeedback" techniques, teaching them to maintain conscious awareness of involuntary bodily processes to control space motion sickness. In another experiment, crew members drink salt water while they spend hours at a time with their lower bodies encased in a bag filled with air at slightly lower pressure than cabin air. This "negative pressure" helps the body readapt for landing by increasing the amount of fluid in the blood vessels and by pulling fluids from the head and chest back into the legs. Without this treatment, astronauts may become dizzy and faint when they return to Earth.

A question asked many times is, "Can animals



Protein crystallographer Larry DeLucas reads up on instructions for his protein crystal growth experiments while the lower body negative pressure bag pulls fluids back into his lower body during USML-1.

develop normally in space?" To begin answering that question, frogs were flown aboard Spacelab J. For the first time, eggs were shed, fertilized and developed into tadpoles in microgravity, then returned to Earth. A large group of "space frogs" at NASA's Ames Research Center in California appear to have developed normally. However, they are still being studied to detect changes in body form or behavior.

Some Spacelab experiments concentrate on much smaller forms of life — bacteria, fungi, single cells and tiny animals. Both radiation and microgravity can affect these life forms. For instance, bacteria reproduce more rapidly in space and show an increased resistance to antibiotics. Experiments which expose cells, developing eggs, spores and seeds to radiation in open space show that single high-energy particles can dramatically change individual cells, causing genetic damage or death.

The space environment affects the way plants grow as well. Without the directing force of gravity, plant roots grow out of the "soil" and into the air. Microgravity alters both the chromosomes and metabolism of plants. Samples in an IML-1 test sprouted much sooner in space and grew about 30 percent more rapidly than their ground-based counterparts.

Learning to Work in Space

Some Spacelab experiments help engineers, scientists and astronauts learn the best ways to work in the unfamiliar environment of weightlessness.

Things people hardly notice on Earth can be big problems in space. A broken test tube, a spilled liquid or a dropped tool can float through the cabin instead of falling harmlessly to the floor, creating a potential hazard for space travelers. During USML-1, the crew proved the value of a new glovebox work station. Tightly fitting cuffs and special gloves allowed them to work on a variety of experiments confined within the clear plastic enclosure. Special fans and filters disposed of debris, and glovebox video cameras gave scientists on Earth close-up views of their experiments.

Commander Ronald Grabe finds the most comfortable position for working at a computer station in an IML-1 experiment.

Floating astronauts can't sit at a desk to operate a computer. An IML-1 experiment used a lap-top computer and an adjustable work station to help determine the most comfortable positions and computer controls for "paperwork" in microgravity.

Some experiments help define the space environment. Acceleration instruments track Shuttle movements to determine how they affect the other experiments. The motion can be as dramatic as an orbiter maneuver or as subtle as a crew member shifting position in the Spacelab. Post-flight comparison of acceleration and vibration records to data from crystal growth or fluids physics experiments helps define how much disturbance a sensitive microgravity experiment can tolerate. During USMP-1, the acceleration measurement system sent down readings for the first time while the mission was in progress. Science teams for the other instruments onboard used that data to adjust their experiments.

A Unique Vantage Point

Space is a unique vantage point for astronomy, solar science, space physics and Earth observations. Telescopes in orbit can view radiation wavelengths which are absorbed by the atmosphere and never reach the ground. Onboard sensors can probe the properties of the space plasma through which a spacecraft travels. Downward-pointing instruments can get a sweeping, bird's-eye view of the forces which shape Earth's environment.

Astrophysics

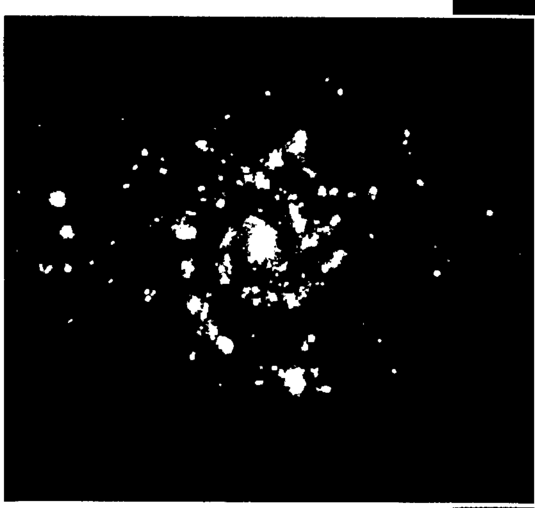
Studying stars, galaxies and other celestial objects from the ground is like reading only a few pages of a book — the reader learns something but does not get the whole story. Visible light (the seven colors of the rainbow perceived with the human eye) is only a small portion of the radiation from celestial objects. Gamma rays, X-rays and ultraviolet light are screened out by our protective atmosphere and cannot be studied from Earth. Even when ground-based astronomical observatories view objects in visible light, atmospheric turbulence distorts the images. NASA places telescopes above the atmosphere to overcome those limitations.

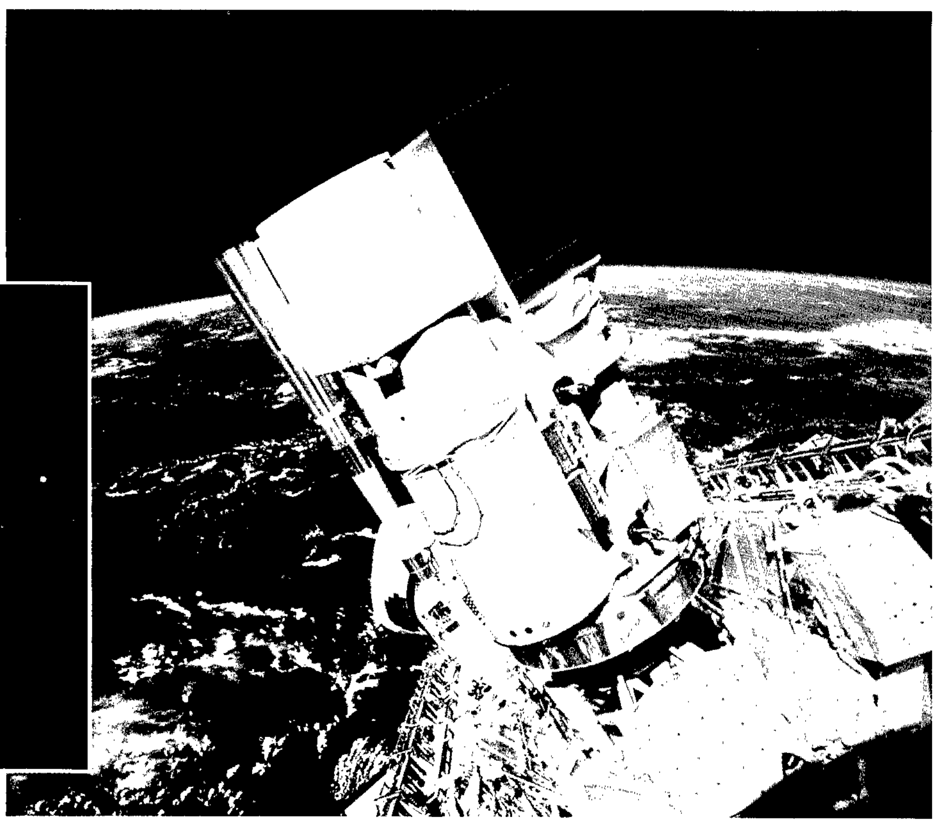
Spacelab astronomy missions complement observations from free-flying, remotely controlled observatories like the Hubble Space Telescope. Astronomers onboard the Shuttle operate Spacelab telescopes much as they would telescopes on the ground, and then return film and instruments for post-flight analysis. Spacelab observations, along with those of free-flying telescopes and ground-based observatories, provide valuable pieces to the puzzle of how stars are born and die.

Telescopes aboard the first three Spacelabs, which studied high-energy radiation invisible from Earth, provided valuable lessons on doing sophisticated astronomical research in space. One Spacelab 2 instrument discovered a remarkably high-energy X-ray source near the center of our galaxy.

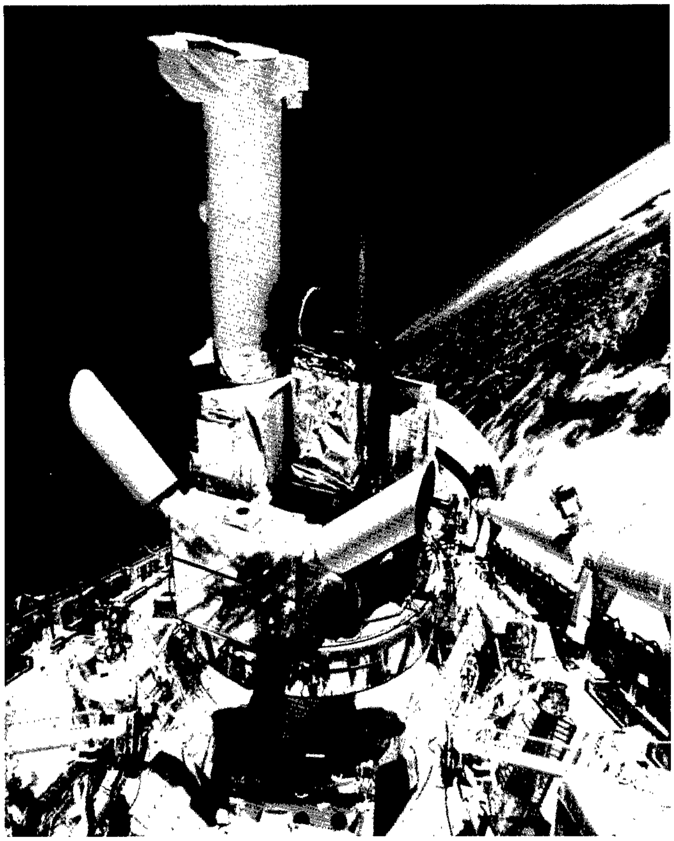
The 1990 Astro 1 astronomy mission concentrated on X-rays and little-explored regions of the ultraviolet spectrum, radiation produced by hotter, more violent cosmic events than those which emit primarily visible light. For many of the stars and galaxies viewed by the Astro 1 telescopes, it was the first time they had been observed in the ultraviolet range.

Astro 1 multiplied astronomers' knowledge of the invisible universe, with observations such as this one of a spiral galaxy seen in ultraviolet light.





Astro 1 provided some intriguing pieces for the astronomical puzzle. For instance, unexpectedly high levels of ultraviolet radiation in elliptical galaxies, which are made up mostly of old stars, are probably produced by low mass stars in late stages of their evolution. Astronomers had thought it came from either the young, hot stars or old, dense stars which emit most of the universe's ultraviolet light. The Astro mission's studies of the smoke-like "dust" between stars in our galaxy indicate properties of the dust vary widely by region and are not uniform as astronomers had believed.



Spacelab 2 instruments gave solar physicists an undistorted view of the sun.

Observations of galaxies emitting huge amounts of ultraviolet radiation, thought to come from massive black holes, revealed several clues about the nature of that little-understood radiation.

Solar Science

The sun is the nearest star to Earth and therefore the one that can be viewed in greatest detail. Its energy sustains life on Earth and drives the Earth's environment. Spacelab solar observations are helping scientists understand the sun as a star, as well as how variations in its intensity or events like sunspots affect our atmosphere and weather.

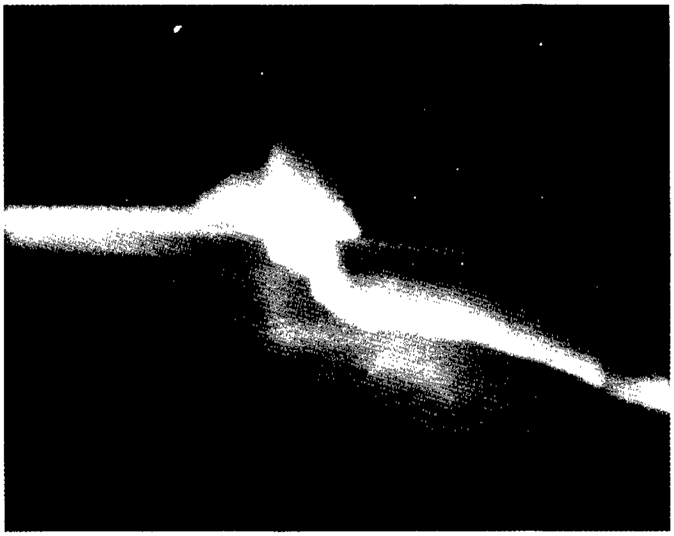
Dazzling images from Spacelab 2 confirmed that solar instruments in low Earth orbit have a uniquely clear view of the sun. They also proved the value of having scientists onboard to analyze results and focus instruments on interesting solar events. The Spacelab Instrument Pointing System provided precise pointing and stability for the telescopes, independent of spacecraft motion. Scientists watched areas as small as 200 miles (350 kilometers) for as long as an hour without distortion. Slight changes in brightness and small scale motions in the sun gave scientists critical clues to the origin of larger, more turbulent solar changes — changes which affect Earth's atmosphere. Astronomers recorded hours of motion pictures of sunspot activities and took 500 still photographs.

Radiation from the sun, particularly in ultraviolet wavelengths, is a primary factor in the chemistry of Earth's atmosphere. Scientists believe that less than a one-percent variation in the sun's total output could create climatic events like the Little Ice Age, which lasted from about 1450 A.D. to 1850. Therefore, instruments which precisely measure the sun's radiation are important parts of the ATLAS atmospheric research flights. These readings will be used for comparisons as the sun goes through an 11-year solar cycle, from maximum to minimum activity and back again.

Space Plasma Physics

Most of the universe is filled with partially ionized or electrified gas called plasma. Like other stars, our sun is a huge plasma ball heated by nuclear fusion. What little matter there is between the Earth and the sun is mainly in the form of plasma. Nature rarely produces plasma on our planet's surface, and it is impossible to duplicate all the plasma processes in stars, comets or even our own atmosphere in Earth-based labs. The best place to learn how matter behaves in a plasma state is the region above the Earth where molecules are ionized by X-rays and ultraviolet radiation from the sun.

One Spacelab 2 experiment put the Shuttle through intricate maneuvers to diagnose its effect on the surrounding plasma. Surprisingly, the ions in the plasma often appeared to change energies, demonstrating that a large, gas-emitting space vehicle like the Shuttle has a significant local impact on the



Spacelab 3 cameras captured this dramatic photograph of an aurora from above.

charged portion of the atmosphere called the ionosphere.

Auroras, the spectacular light shows in Earth's polar skies, are visual indications of plasma. These so-called northern and southern lights are created when charged particles travel along magnetic field lines and strike molecules in the upper atmosphere. By studying changes in the form and motion of auroras, scientists can infer changes in the patterns of Earth's magnetic field. This is of interest because the same processes responsible for auroras cause power blackouts and telecommunications disturbances. Scientists are using the many dramatic aurora images recorded by the Spacelab 3 crew to determine how aurora vary by location.

Two Spacelab 1 auroral experiments flew again on ATLAS 1. Not only did the ATLAS crew photograph natural auroras with low-light television cameras, they also fired electron beams from the Shuttle to create 60 artificial auroras — a scientific first. The crew anticipated the location of the artificial auroras and followed them with the television cameras. Their successes showed that scientists understood auroral processes well enough to create them and predict where they would occur.

Atmospheric Science

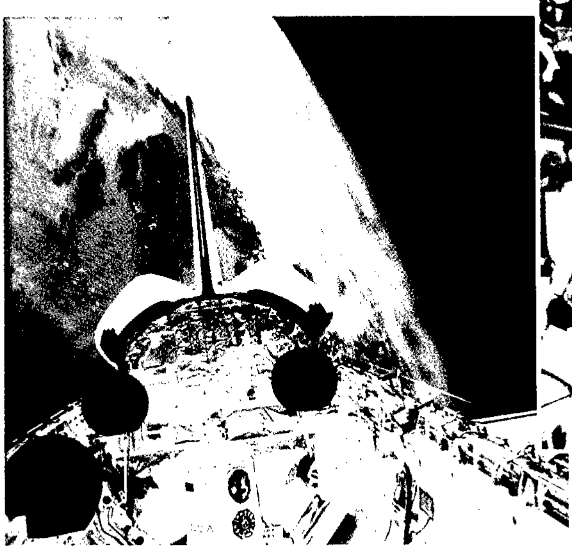
The ATLAS Spacelab series has two objectives: learning how Earth's atmosphere works and pinpointing factors which lead to the loss of life-protecting ozone. This series brings together atmospheric instruments from the first three Spacelab missions, providing a comprehensive information base on the atmosphere against which to measure global change.

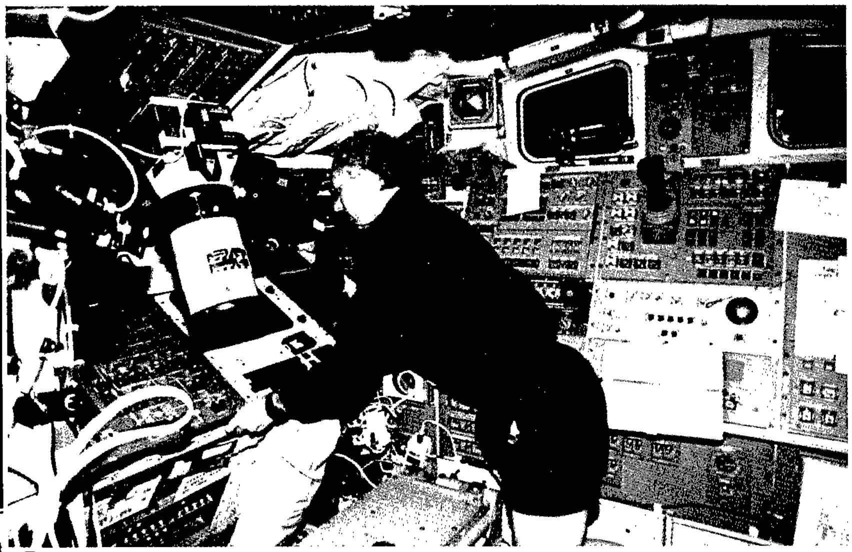
Ozone is both created and destroyed by complex reactions between ultraviolet light and a variety of gases in the middle atmosphere. Some of these changes occur naturally. However, destructive chemicals in the atmosphere are increasing, apparently due to human activity such as releases of chlorofluorocarbons from refrigerants and aerosol products. Comparisons of detailed atmospheric readings taken over a period of time are essential to understanding how much human actions are contributing to ozone destruction.

ATLAS 1 instruments measured the key gases affecting atmospheric chemistry with more detail than ever before. Comparisons of results from early Spacelab flights with ATLAS 1 readings show a 40-percent increase since 1985 of hydrogen chloride and hydrogen fluoride, by-products of chlorofluorocarbons, in the middle atmosphere. Observations painted for the first time a three-dimensional picture of the mesosphere, the coldest region of the atmosphere and one that is still relatively unaffected by human activity. They measured more different gases than ever before in the stratosphere, the atmospheric region where ozone is created and destroyed. The ATLAS 2 mission focused on the stratosphere during a year when record-low ozone levels were being recorded in the Northern Hemisphere.

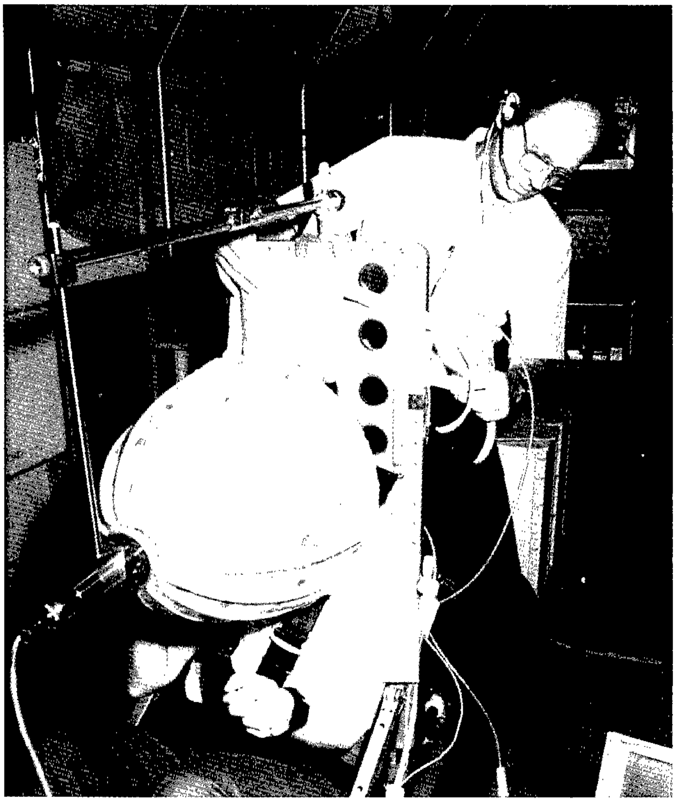
Scientists compare these observations and those of the ATLAS solar instruments to atmospheric models — mathematical predictions of how wind currents, the sun and gases in the atmosphere interact, and how they are affected by humans. The comparisons either confirm the accuracy of the models or allow scientists to adjust models to reflect what is actually there.

ATLAS instruments take a "snapshot" of the atmosphere for a week or two at a time. Instruments aboard free-flying satellites are making continuous atmospheric and solar measurements. However, extended exposure to the harsh environment of space, especially ultraviolet radiation, can degrade the accuracy of those instruments. By comparing data from ATLAS instruments to their sister experiments aboard free-flyers, scientists can adjust for any changes in the satellite instruments and be confident their measurements are accurate.





Payload Specialist Dirk Frimout, from Belgium, operates an atmospheric instrument from the Shuttle aft flight deck during ATLAS-1.



Canadian Payload Specialist Roberta Bondar and Astronaut Norm Thagard practice a space adaptation experiment in the Marshall Space Flight Center's Payload Crew Training Complex.

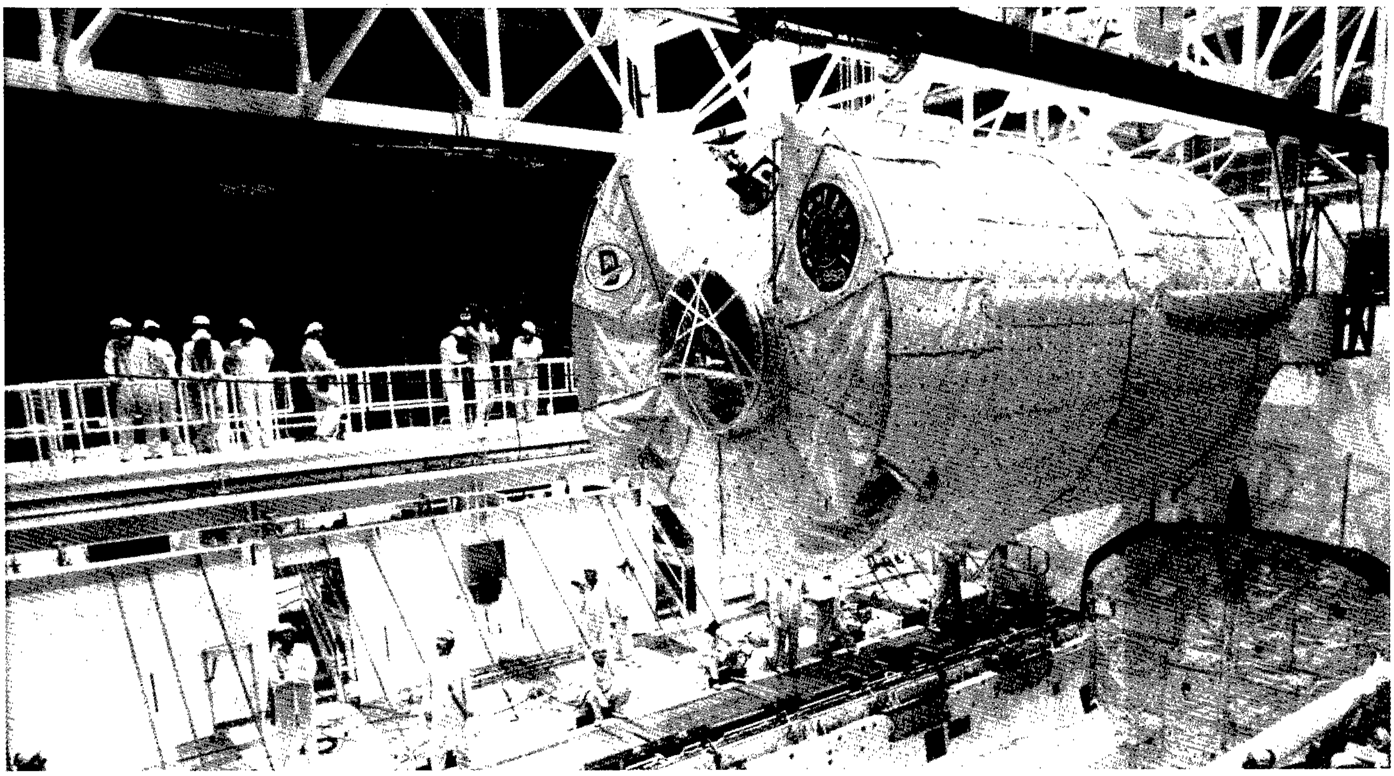
Preparing for a Spacelab Mission

A Spacelab mission starts several years before the flight, when NASA Headquarters selects compatible experiments for a mission payload. A mission manager from a NASA field center leads the planning. Experiment designers, called principal investigators, form an investigators working group under the direction of a NASA mission scientist. Together, the group develops a complex timeline of science operations, squeezing the maximum experiment time into the Spacelab flight. Missions generally last between seven and 14 days.

Two categories of astronauts serve as crew members for Spacelab missions. A commander, pilot and a mission specialist who serves as a flight engineer make up the flight crew. They maneuver the Shuttle into positions required for the experiments and make sure all systems are operating properly. The astronauts who make up the science crew are mission specialists with expertise in various fields of science or engineering. They operate the Spacelab hardware and help perform the experiments.

For many Spacelab missions, scientists designate three or four of their number as payload specialist candidates. The candidates and science mission specialists participate in crew training, lasting from 18 months to two years. In addition to undergoing astronaut training at Johnson Space Center in Houston, Texas, the payload crew practices experiment operations in specially outfitted Spacelab mock-ups at either the Marshall Center's Payload Crew Training Complex or at Johnson. They also travel to principal investigators' labs around the world for detailed instructions on their experiments.

NASA selects one or two of the payload specialist candidates as additional crew members. The payload specialist and other members of the science crew actually perform many of the experiments in space.



After several months of careful preparation at Kennedy Space Center, the Spacelab D-1 module is lowered into the Shuttle cargo bay.

Spacelab science activities are guided from the payload control room at Marshall's Spacelab Mission Operations Control facility in Huntsville.

The remaining candidates, called alternate payload specialists, work in the ground control center during the mission. They serve as a key link between the researchers there and their colleagues in orbit.

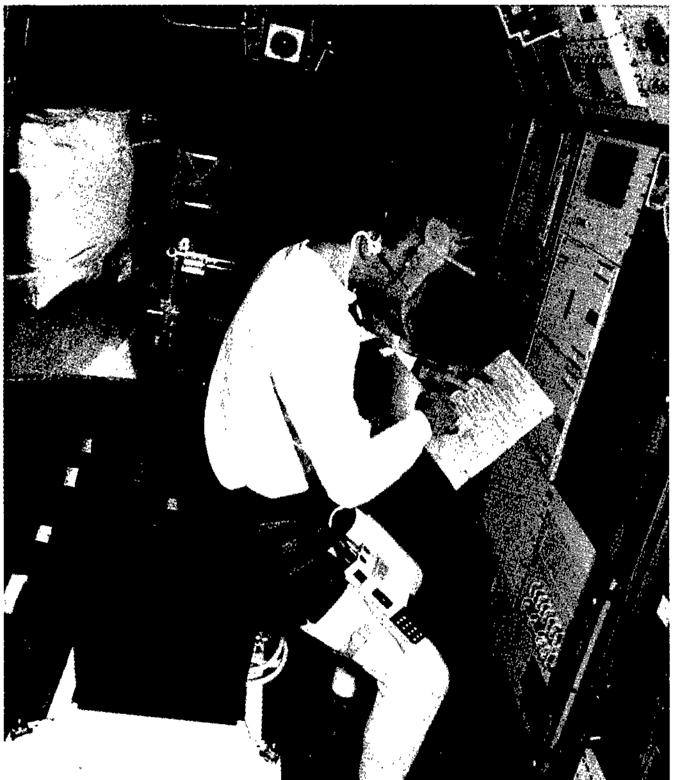
Technicians at the Kennedy Space Center in Florida work for several months prior to launch to prepare the Spacelab for flight — assembling experiment racks and inserting them into the lab, loading experiment samples, and making sure everything works properly for the mission.

During the Flight

As with all Shuttle missions, the orbiter crew gets instructions during flight from Mission Control at Johnson Space Center. For Spacelab missions, "Huntsville" joins "Houston" as a call sign from orbit, as the Spacelab payload crew communicates with ground controllers and experiment scientists stationed in NASA's Spacelab Mission Operations Control facility at the Marshall Space Flight Center in Alabama.

A few hours after launch, the Spacelab crew begins to activate the laboratory and check out equipment. Then the science begins in earnest. Payload specialists and mission specialists work through their minute-by-minute schedule of experiment activities, often staffing the Spacelab around the clock with two 12-hour shifts.

Control team members at Marshall make sure activities are on schedule and everything is operating


Mission Specialist David Hilmers follows the step-by-step experiment timeline during the IML-1 mission.

properly, and determine the impact of mission events on the science timeline. The crew interface coordinator, a member of the control team, and the alternate payload specialist relay instructions from the science teams and control teams to the science crew in space.

The principal investigators and their teams monitor experiments from the control center's science operations area. When useful, a principal investigator may talk personally to his colleague in orbit, allowing them to determine together the best methods for conducting the experiment. Some science teams can remotely control their instruments, sending commands directly from the control center to their equipment aboard the Spacelab.

The mission scientist and principal investigators meet once or twice every day during the mission to review progress and make schedule adjustments for the upcoming day.

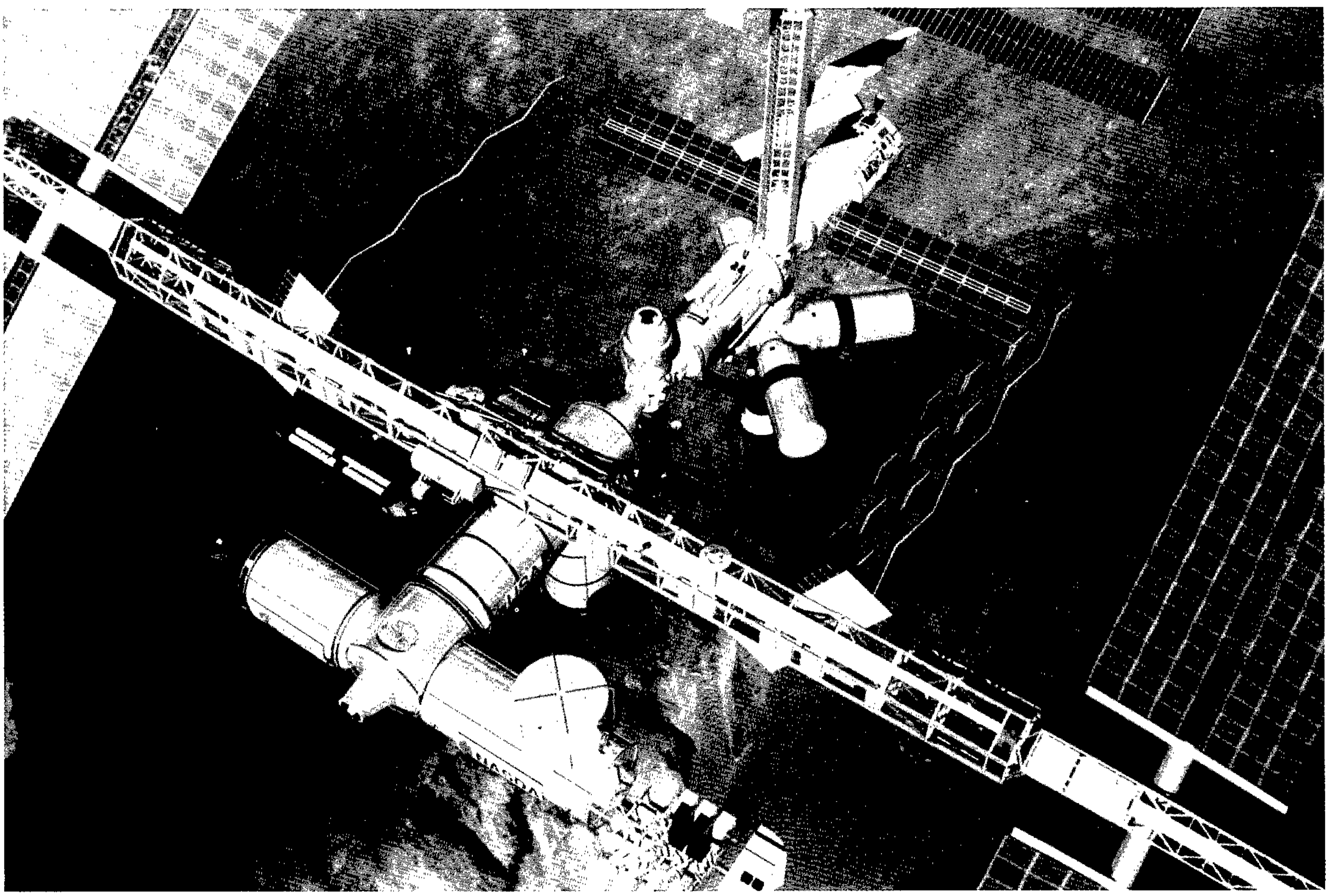
Reaping the Results

Although the Spacelab astronaut crew shuts down experiments a few hours before landing, the science teams' work is just beginning. During a mission, miles of videotape, dozens of samples, hundreds of photographs, and many millions of bits of data are collected. For months after the flight, scientists analyze the mass of information to glean new understanding from their experiments. With expectancy, painstaking study, occasional disappointment and eventual revelation, scientists are proving space to be a unique and valuable observatory and laboratory for science.

Paving the Way for Space Station

Spacelab missions are short-term space stations. The ultimate promise of space research will be realized only as similar experiments can be performed for months onboard a permanent space station, instead of just days or weeks at a time on the Shuttle.

The lessons learned over more than a decade of Spacelab flights form a firm foundation for NASA and its international partners as they design laboratory equipment and make plans for science research onboard their full-time laboratory in orbit — the International Space Station.



The Space Station will be a laboratory where we can study the long-term effects of space travel on the human body. International crews will conduct science research while learning how to build, operate and maintain large systems in space. These are all essential steps that must be taken before the human race can begin the exploration of the solar system.