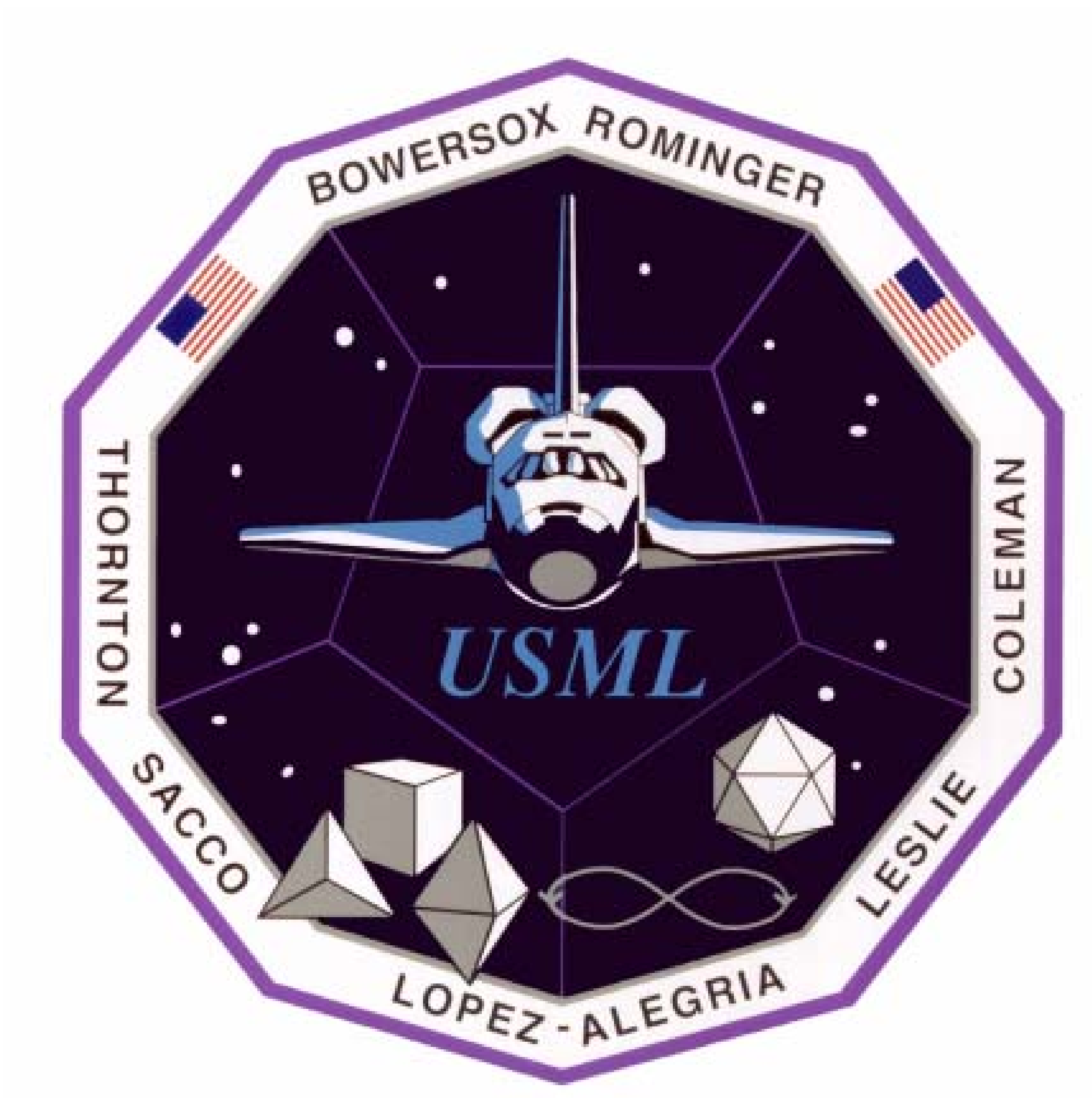
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE SHUTTLE MISSION
STS-73

PRESS KIT
SEPTEMBER 1995



UNITED STATES MICROGRAVITY LABORATORY-2 (USML-2)

STS-73 INSIGNIA

STS073-S-001 -- The insignia for STS-73, the second flight of the United States Microgravity Laboratory (USML-2), depicts the space shuttle Columbia in the vastness of space. In the foreground are the classic regular polyhedrons that were investigated by Plato and later Euclid. The Pythagoreans were also fascinated by the symmetrical three-dimensional objects whose sides are the same regular polygon. The tetrahedron, the cube, the octahedron, and the icosahedron were each associated with the "Natural Elements" of that time: fire (on this mission represented as combustion science); Earth (crystallography), air and water (fluid physics). An additional icon shown as the infinity symbol was added to further convey the discipline of fluid mechanics. The shape of the insignia represents a fifth polyhedron, a dodecahedron, which the Pythagoreans thought corresponded to a fifth element that represented the cosmos.

The NASA insignia design for space shuttle flights is reserved for use by the astronauts and for other official use as the NASA Administrator may authorize. Public availability has been approved only in the form of illustrations by the various news media. When and if there is any change in this policy, which we do not anticipate, it will be publicly announced.

PHOTO CREDIT: NASA or National Aeronautics and Space Administration.

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RELEASE: 95-152

SECOND FLIGHT OF UNITED STATES MICROGRAVITY LABORATORY HIGHLIGHTS SIXTH SHUTTLE MISSION OF 1995

The second United States Microgravity Laboratory (USML- 2) Spacelab mission will be the centerpiece of the STS-73 Space Shuttle flight in late September 1995. The Orbiter Columbia's planned 16-day flight will continue a cooperative effort of the U.S. government, universities and industry to push back the frontiers of science and technology in "microgravity," the near-weightless environment of space.

Combining the strengths of these different communities allows for more extensive ground-based research in preparation for flight, improved methods for microgravity experimentation, and a wider distribution of the knowledge gained in the process. The involvement of U.S. industry also means that the results of both ground-based experiments and Shuttle operations can be "brought down to Earth" in a timely and practical manner.

Leading the five-person STS-73 crew will be Mission Commander Kenneth D. Bowersox who will be making his third space flight. Pilot for the mission is Kent Rominger making his first flight. The three mission specialists for STS-73 are Kathryn Thornton, Payload Commander and Mission Specialist 3 (MS3), making her fourth flight; Catherine Coleman, Mission Specialist 1 (MS1), making her first flight; and Michael Lopez-Alegria, Mission Specialist 2 (MS2) making his first flight. Also aboard Columbia will be two payload specialists--Fred Leslie, Payload Specialist 1 (PS1), and Albert Sacco, Payload Specialist 2 (PS2), both of whom will be making their first space flight.

Launch of Columbia on the STS-73 mission is currently scheduled for no earlier than September 28, 1995 at 9:35 a.m. EDT. The planned mission duration is 15 days, 21 hours and 54 minutes. An on-time launch on September 28 would produce a landing at 7:30 a.m. EDT on October 14 at Kennedy Space Center's Shuttle Landing Facility.

Some of the experiments being carried on the USML-2 payload were suggested by the results of the first USML mission that flew aboard Columbia in 1992 during Mission STS-50. The USML-1 mission provided new insights into theoretical models of fluid physics, the role of gravity in combustion and flame spreading, and how gravity affects the formation of semiconductor crystals. Data collected from several protein crystals grown on USML-1 have enabled scientists to determine the molecular structures of those proteins.

USML-2 builds on that foundation. Technical knowledge gained has been incorporated into the mission plan to enhance procedures and operations. Where possible, experiment teams have refined their hardware to increase scientific understanding of basic physical processes on Earth and in space, as well as to prepare for more advanced operations aboard the international Space Station and other future space programs.

The experiments being carried as part of the USML-2 payload cover a variety of scientific disciplines including fluid physics, materials science, biotechnology and combustion science.

The fluid physics area is fundamental to many types of science, from the ways molten metals solidify and fuels burn, to the way planetary atmospheres operate. In space, subtle and complex phenomena normally hidden by the stronger force of gravity can be revealed for detailed study.

Materials science will increase insight into the relationships between the structure, processing and properties of materials. Mixtures that separate on Earth because of different component densities can be evenly mixed and processed in microgravity. This allows scientists to study the processing of such materials and to create advanced materials for study and comparison. Without the pull of gravity and the associated convective flows, more perfect crystals can be produced, an advance many believe vital for creation of advanced computer chips and semiconductors.

Biotechnology experiments will grow protein crystals in three different experiment facilities, attempting to produce crystals of sufficient size and perfection that scientists can determine their structure and how they form. This approach is being pursued because of the promise it holds for the development of improved drugs. Two other biotechnology experiments address the development of food crops with higher protein content and increased disease resistance.

Combustion science will aid in understanding the way a fire starts and spreads. Understanding the combustion process without the interference of gravity could lead to more efficient fuels and improved fire safety, both in space and on Earth.

Also during the STS-73 mission, students at four sites will interact with Columbia's astronauts to discuss and compare onboard microgravity experiments with similar ground-based experiments. The goal is to involve students as participants in Shuttle investigations in an effort to generate excitement in physical science and chemistry.

STS-73 will be the 18th flight of Space Shuttle Columbia and the 72nd flight of the Space Shuttle system.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS.)

MEDIA SERVICES INFORMATION

NASA Television Transmission

NASA Television is available through the Spacenet-2 satellite system, transponder 5, channel 9, at 69 degrees West longitude, frequency 3880.0 MHz, audio 6.8 Megahertz.

The schedule for television transmissions from the Orbiter and for mission briefings will be available during the mission at Kennedy Space Center, FL; Marshall Space Flight Center, Huntsville, AL; Dryden Flight Research Center, Edwards, CA; Johnson Space Center, Houston; NASA Headquarters, Washington, DC. The television schedule will be updated to reflect changes dictated by mission operations.

Television schedules also may be obtained by calling COMSTOR 713/483-5817. COMSTOR is a computer data base service requiring the use of a telephone modem. A voice update of the television schedule is updated daily at noon Eastern time.

Status Reports

Status reports on countdown and mission progress, on- orbit activities and landing operations will be produced by the appropriate NASA newscenter.

Briefings

A mission press briefing schedule will be issued prior to launch. During the mission, status briefings by a Flight Director or Mission Operations representative and when appropriate, representatives from the payload team, will occur at least once per day. The updated NASA television schedule will indicate when mission briefings are planned.

Access by Internet

NASA press releases can be obtained automatically by sending an Internet electronic mail message to domo@hq.nasa.gov. In the body of the message (not the subject line) users should type the words "subscribe press- release" (no quotes). The system will reply with a confirmation via E-mail of each subscription. A second automatic message will include additional information on the service.

Informational materials also will be available from a data repository known as an anonymous FTP (File Transfer Protocol) server at ftp.pao.hq.nasa.gov under the directory /pub/pao. Users should log on with the user name "anonymous" (no quotes), then enter their E-mail address as the password. Within the /pub/pao directory there will be a "readme.txt" file explaining the directory structure.

The NASA public affairs home page also is available via the Internet. The page contains images, sound and text (press releases, press kits, fact sheets) to explain NASA activities. It also has links to many other NASA pages. The URL is: **http://www.nasa.gov/hqpao/hqpao_home.html**.

Pre-launch status reports from KSC are found under **ftp.hq.nasa.gov/pub/pao/statrpt/ksc**, and mission status reports can be found under **ftp.hq.nasa.gov/pub/pao/statrpt/jsc**. Daily TV schedules can be found under **ftp.hq.nasa.gov/pub/pao/statrpt/jsc/tvsked**.

Access by fax

An additional service known as fax-on-demand will enable users to access NASA informational materials from their fax machines. Users calling (202) 358-3976 may follow a series of prompts and will automatically be faxed the most recent Headquarters news releases they request.

Access by CompuServe

Users with CompuServe accounts can access NASA press releases by typing "GO NASA" (no quotes) and making a selection from the categories offered.

STS-73 QUICK LOOK

Launch Date/Site:	September 28, 1995/KSC Launch Pad 39-B
Launch Time:	9:35 AM EDT
Launch Window:	2 hours, 30 minutes
Orbiter:	Columbia (OV-102), 18th flight
Orbit Altitude/Inclination:	150 nautical miles/39 degrees
Mission Duration:	15 days, 21 hours, 54 minutes
Landing Date:	October 14, 1995
Landing Time:	7:30 AM EDT
Primary Landing Site:	Kennedy Space Center, FL
Abort Landing Sites:	Return to Launch Site - KSC Transoceanic Abort Sites - Ben Guerir, Morocco Moron, Spain Zaragoza, Spain Abort-Once Around - Edwards Air Force Base, CA
Crew:	Ken Bowersox, Commander (CDR), Red Team Kent Rominger, Pilot (PLT), Red Team Catherine Coleman, Mission Specialist (MS 1), Blue Team Michael Lopez-Alegria, MS 2, Blue Team Kathryn Thornton, MS 3, Red Team Fred Leslie, Payload Specialist 1 (PS 1), Blue Team Albert Sacco, (PS 2), Red Team
EVA Crew Members:	Michael Lopez-Alegria (EV1), Catherine Coleman (EV2)
Cargo Bay Payloads:	United States Microgravity Laboratory 2 OARE

Developmental Test Objectives/Detailed Supplementary Objectives

DTO 301D: Ascent Structural Capability Evaluation
DTO 307D: Entry Structural Capability
DTO 312: ET TPS Performance
DTO 319D: Shuttle/Payload Low Frequency Environment
DTO 414: APU Shutdown Test
DTO 623: Cabin Air Monitoring
DTO 655: Foot Restraint Evaluation
DTO 667: Portable In-Flight Landing Operations Trainer
DTO 679: Ku-Band Communications Adapter Demonstration
DTO 805: Crosswind Landing Performance
DTO 913: Microgravity Measuring Device Evaluation
DTO 1121: Ground-to-Air TV Demonstration

DSO 487: Immunological Assessment of Crew Members
DSO 491: Characterization of Microbial Transfer Among the Crew
DSO 603C: Orthostatic Function During Entry, Landing and Egress
DSO 604: Visual Vestibular Integration as a Function of Adaptation
DSO 605: Postural Equilibrium Control During Landing/Egress
DSO 611: Air Monitoring Instrument Evaluation and Atmosphere Test
DSO 621: In-Flight Use of Florinef to Improve Orthostatic Intolerance
DSO 624: Pre and Postflight of Cardiorespiratory Response to Exercise
DSO 626: Cardiovascular and Cerebrovascular Response Before and After Flight
DSO 802: Educational Activities
DSO 901: Documentary Television
DSO 902: Documentary Motion Picture Photography
DSO 903: Documentary Still Photography
DSO 904: Assessment of Human Factors

SPACE SHUTTLE ABORT MODES

The Space Shuttle launch abort philosophy aims toward safe and intact recovery of the flight crew, orbiter and its payload. Abort modes for STS-73 include:

- Abort-To-Orbit (ATO) -- Partial loss of main engine thrust late enough to permit reaching a minimal 105-nautical mile orbit with the orbital maneuvering system engines.

- Abort-Once-Around (AOA) -- Earlier main engine shutdown with the capability to allow one orbit of the Earth before landing at the Edwards Air Force Base, CA.

- TransAtlantic Abort Landing (TAL) -- Loss of one or more main engines midway through powered flight would force a landing at either Ben Guerir, Morocco; Moron, Spain; or Zaragoza, Spain.

- Return-To-Launch-Site (RTLS) -- Early shutdown of one or more engines, and without enough energy to reach a TAL site, would result in a pitch around and thrust back toward KSC until within gliding distance of the Shuttle Landing Facility.

STS-73 ORBITAL EVENTS SUMMARY
(Based on a Sept. 28, 1995 Launch)

Event	MET	Time of Day (EDT)
Launch	0/00:00	9:35 AM, September 28
OMS-2	0/00:43	10:18 AM, September 28
Spacelab Activation	0/02:10	11:41 AM, September 28
Crew News Conference	13/19:30	5:05 AM, October 12
FCS Checkout	14/19:30	5:05 AM, October 13
Spacelab Deactivation	15/13:45	11:20 PM, October 13
Deorbit Burn	15/20:54	6:30 AM, October 14
KSC Landing	15/21:54	7:30 AM, October 14

MISSION SUMMARY TIMELINE

Flight Day 1
Launch/Ascent
OMS-2 Burn
Spacelab Activation
USML-2 Operations

Flight Days 2-14
USML-2 Operations

Flight Day 12
Educational TV event with students in Bozeman, MT, and Las Cruces, NM

Flight Day 13
Educational TV event with students in Worcester, MA, and Louisville, KY

Flight Day 15
USML-2 Operations
Crew News Conference

Flight Day 16
USML-2 Operations
Flight Control System Checkout
Reaction Control System Hot-Fire
Cabin Stow
Spacelab Deactivation

Flight Day 17
Deorbit Prep
Deorbit Burn
Entry
KSC Landing

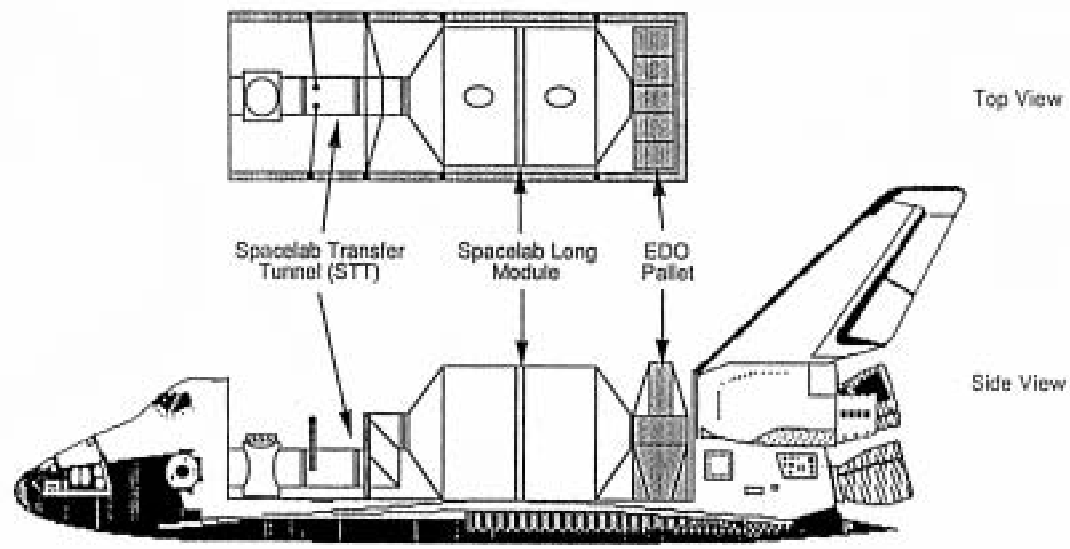
CREW RESPONSIBILITIES

Payloads	Prime	Backup
USML-2	Thornton, Coleman, Sacco, Leslie	
DTO/DSOs		
DTO 312	Coleman, Lopez-Alegria	
DTO 623	Rominger	Bowersox
DTO 655	Thornton, Coleman, Sacco	
DTO 667	Rominger	Bowersox
DTO 679	Bowersox, Lopez-Alegria	Rominger
DTO 682	Rominger, Lopez-Alegria	Bowersox
DTO 913	Rominger, Lopez-Alegria	Bowersox
DSO 603C	Thornton, Leslie, Sacco	
DSO 604	Rominger, Lopez-Alegria	
DSO 605	Bowersox	
DSO 611	Rominger, Lopez-Alegria	
DSO 621	Leslie	
DSO 624	Bowersox, Rominger	
DSO 626	Thornton, Sacco, Leslie	
DSO 802	Coleman, Sacco	
DSO 901	Rominger, Lopez-Alegria	
DSO 902	Rominger, Lopez-Alegria	
DSO 903	Rominger, Lopez-Alegria	
<u>Other Activities</u>		
Earth Observations	Rominger, Lopez-Alegria	Bowersox
EVA (if needed)	Lopez-Alegria (EV1)	Coleman (EV2)
IV Crewmember	Thornton	
Spacelab Activation	Thornton, Sacco	
Spacelab Deactivation	Coleman, Leslie	Lopez-Alegria

VEHICLE AND PAYLOAD WEIGHTS

	Pounds
Orbiter (Columbia) empty and 3 SSMEs	182,070
Spacelab and USML-2 Experiments	22,726
Middeck USML-2 Experiments	897
Orbital Acceleration Research Experiment (OARE)	249
DTOs/DSOs	129
Shuttle System at SRB Ignition	4,521,139
Orbiter Weight at Landing	230,158

USML-2 PAYLOAD CONFIGURATION



UNITED STATES MICROGRAVITY LABORATORY-2 (USML-2)

The second United States Microgravity Laboratory (USML- 2) Spacelab mission builds on the foundation of its predecessor.

The first USML mission, which flew aboard Columbia in 1992 was one of the most successful NASA science missions. It provided new insights into theoretical models of fluid physics, the role of gravity in combustion and flame spreading, and how gravity affects the formation of semiconductor crystals. Data collected from several protein crystals grown on USML-1 have enabled scientists to determine the molecular structures of those proteins.

USML-1 was the first flight for four major experiment facilities -- the Drop Physics Module, the Surface Tension Driven Convection Experiment apparatus, the Crystal Growth Furnace and the Glovebox -- which promise to provide a valuable technology base for future flights. A major objective of the USML program is to develop more capable instruments to support and refine mature space-based experimentation for the future.

Technical knowledge gained has been incorporated into the USML-2 mission plan to enhance procedures and operations. Where possible, experiment teams have refined their hardware to increase scientific understanding of basic physical processes on Earth and in space, as well as to prepare for more advanced operations aboard the international Space Station and other future space programs.

USML-2 Research

Research during the mission is concentrated within the same overall areas as the first USML flight. Reflown experiments will follow-up on results from that mission, probing for answers to the next level of scientific questions.

Fluid physics research with the Drop Physics Module, the Surface Tension Driven Convection Experiment and the Gravitational Fluid Flow Cell will seek to improve understanding of fluid behavior and to apply that understanding to processes of scientific and technical importance. Fluid physics is fundamental to many types of science, from the ways molten metals solidify and fuels burn, to the way planetary atmospheres operate. In space, subtle and complex phenomena normally hidden by the stronger force of gravity can be revealed for detailed study.

Materials science research in the Crystal Growth Furnace and the Zeolite Crystal Growth experiment will increase insight into the relationships between the structure, processing and properties of materials. Mixtures that separate on Earth because of different component densities can be evenly mixed and processed in microgravity. This allows scientists to study the processing of such materials and to create advanced materials for study and comparison. Without the pull of gravity and the associated convective flows, more perfect crystals can be produced, an advance many believe vital for creation of advanced computer chips and semiconductors.

Biotechnology research on USML-2 will grow protein crystals in three different experiment facilities, attempting to produce crystals of sufficient size and perfection that scientists can determine their structure and how they form. This approach is being pursued because of the promise it holds for the development of improved drugs. Two other biotechnology experiments address the development of food crops.

Combustion science, a study of how the basic combustion process is affected by gravity, will be represented by one of seven technology investigations within the versatile Glovebox enclosure. Understanding the way a fire starts and spreads without the interference of gravity could lead to more efficient fuels and improved fire safety, both in space and on Earth.

Three sets of sensors will help scientists evaluate the quality of the microgravity environment, identifying factors which may disturb sensitive experiments.

Several USML-2 experiments will look at how the presence or absence of gravity affects living organisms. This will aid long-term space efforts and also provide a better understanding of life on Earth.

Commercial space processing technologies will again be demonstrated with the Commercial Generic Bioprocessing Apparatus, giving a large number of university and industry researchers access to space for their biological experiments. Techniques for plant cultivation in microgravity will be further advanced in the Astroculture facility.

Several investigators will be able to view live video of their experiments at the same time, thanks to the new six-channel Hi-Pac video downlink system which will be making its first flight on USML-2.

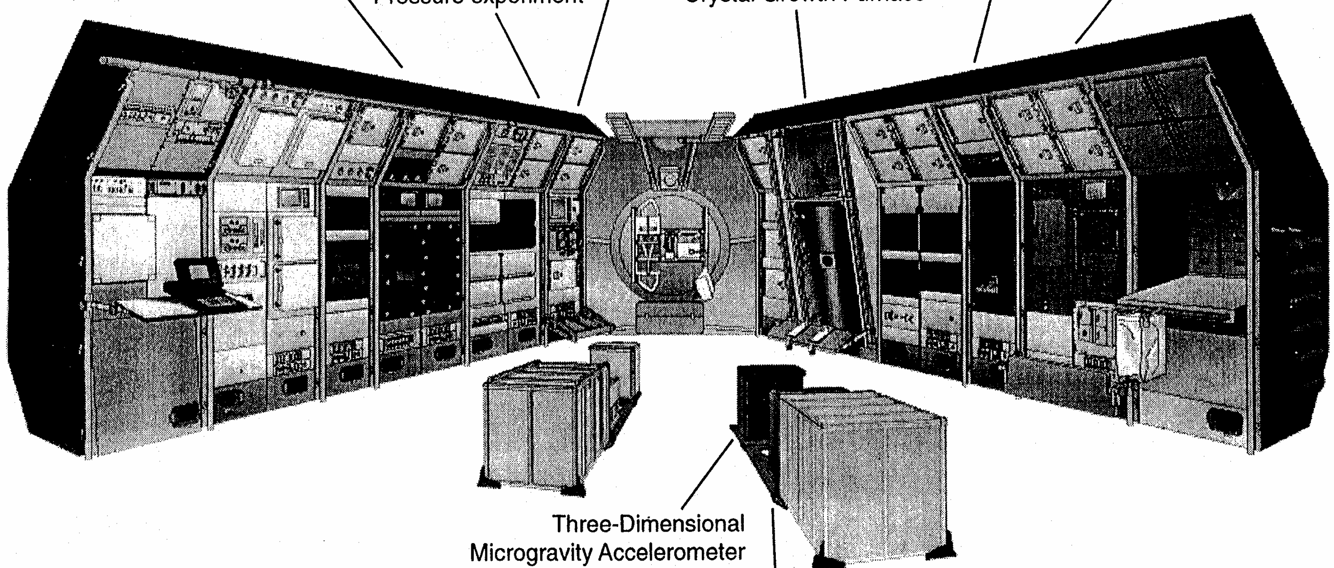
The USML-2 Mission

USML-2 experiment racks will be housed in a 23-foot Spacelab module inside the Shuttle Columbia's cargo bay. The laboratory module is pressurized so researchers can work in their shirtsleeves instead of bulky space suits, and it is furnished with much of the same kind of equipment that they would use in their labs back home.

The seven-member crew will work in two 12-hour shifts, so experiment operations can continue around the clock. The four payload crew members will conduct the majority of USML- 2 science operations. NASA astronaut Dr. Kathryn Thornton is payload commander, and astronaut Dr. Catherine Coleman is a science mission specialist for the flight. Dr. Fred Leslie of the Marshall Space Flight Center, Huntsville, AL, and Dr. Albert Sacco of the Worcester Polytechnic Institute, Worcester, MA, will serve as payload specialists on the USML-2 crew.

USML-2 flight controllers and experiment scientists will direct science activities from NASA's Spacelab Mission Operations Control facility at the Marshall Space Flight Center. In addition, science teams at several NASA centers and universities will monitor and support operations of a number of experiments.

USML-2 Spacelab Rack Assignments



Located in the Shuttle Mid-Deck:

- Mid-deck Protein Crystal Growth Experiments
- Commerical Generic Bioprocessing Apparatus
- Astroculture
- Zeolite Crystal Growth

Surface Tension Driven Convection Experiment

The Surface Tension Driven Convection Experiment apparatus allows investigators to view in great detail the basic fluid mechanics and heat transfer of thermocapillary flows, motions created within fluids by non-uniform heating of their free surfaces. Temperature variations cause irregularities in the fluid's surface tension (the force which makes an unhindered liquid surface tend to form a sphere, like a raindrop), which in turn triggers flows in the fluid. This thermocapillary flow, then, can also be referred to as surface-tension-driven convection.

The facility uses a laser diode to illuminate particles suspended in silicone oil. Particle motions due to fluid flows, created by heating the oil either internally or on its surface, are recorded by a video camera attached to a chamber viewport. An infrared imaging system records oil surface temperature. A third camera, in concert with an optical measurement system, is used to monitor oil surface deformations and motions.

One key factor prompting this research is that unwanted fluid flows during melting and resolidifying can create defects in high-tech crystals, metals, alloys and ceramics.

On Earth, natural convection creates the strongest flows: colder, heavier fluid is pulled down, causing warmer, lighter fluid to rise. Thermocapillary flows occur in many industrial and materials processing methods as well, and they are known to play an important role. However, except in containers with very small dimensions like capillary tubes, thermocapillary flows are overshadowed by gravity-driven convection on Earth and are difficult to measure.

In space, under microgravity conditions, thermocapillary flows become prominent and can be studied in detail. Knowledge of their behavior and effects is important to a thorough understanding of fluid physics. It is also necessary because these flows affect space applications such as bubble and droplet migration, fuel management and storage, and life support systems, as well as material processing methods like crystal growth from liquids, containerless processing, and welding.

Understanding and controlling the effects of thermocapillary flows will become increasingly important as space flights become longer and space station operations begin.

Principal Investigator:
Dr. Simon Ostrach
Case Western Reserve University
Cleveland, OH

This experiment will seek to measure the transition from steady, two-dimensional flows to oscillatory, or three- dimensional, flows within silicone oil. Thermocapillary flows sometimes show these periodic variations in fluid motion speed and temperature during the limited studies possible on Earth.

By comparing conditions for the onset of this oscillation in microgravity and on Earth, scientists will gain insight into what causes it. Both steady thermocapillary flows and oscillatory flows may reduce the purity and uniformity of crystal growth solutions and molten metals.

STDCE scientists will use this experiment to evaluate fluid flow models and theories of how thermocapillary flows transition from steady to oscillatory conditions. They also will attempt to determine how and when oscillatory thermocapillary flows are created: how they are affected by different heat sources and shapes of free fluid surfaces; how flows affect surface shape; and what relationships exist among free surface deformation, surface temperature distribution, and fluid flow velocity.

On USML-1, STDCE experimenters concentrated on steady- state fluid flows, with results confirming many of their theoretical predictions. However, no oscillations were observed. On USML-2, three different sizes of experiment containers and several viscosities of oil will be used to create conditions favorable for oscillations. The STDCE imaging system has been improved to make oscillations easier to observe.

Drop Physics Module

The Drop Physics Module manipulates free-floating liquid drops in microgravity to test and expand current fluid physics models and theories and to measure the properties of liquid surfaces.

People have been observing fluid phenomena for a long time. One of the areas which fluid physicists are studying today is the interface, or boundary, between liquids, and its effects on the fluids on either side of it. In space, where gravity's overwhelming influence is minimized, scientists can unmask and study more subtle forces that drive fluid behavior. This fundamental knowledge can be beneficial for a variety of industries on Earth, from pharmacology to industrial chemistry.

The Drop Physics Module, operating in the microgravity environment of the Shuttle, allows investigators to study large drops in which dynamic phenomena will be slowed down and more easily seen. They can observe how flows inside a drop and the drop's surface interact to provide a variety of dynamic events: symmetric oscillations growing to become wild gyrations; dramatic splitting events where one drop breaks into two parts; and the centering of one drop within a second drop. Equally important, studies of how small amounts of an additive can drastically alter the behavior of a liquid drop will be made.

The module has a rectangular experiment chamber where liquid samples are deployed. The samples are positioned by sound waves emitted by four loudspeaker drivers - one on each side of the chamber's bottom wall. Gentle acoustic forces are all that are required to position the drops in the microgravity environment; this allows the liquid to assume its preferred shape, which is a perfect sphere.

A crew member controls the sound waves in the chamber to make the spherical drops vibrate, rotate, split or recombine, while a camera records the drops' responses. Particles are mixed into the fluid samples before flight to make motion inside the drop visible.

Experiment scientists will monitor drop behavior through real-time video, so they can assess their experiment's progress and can quickly suggest changes for the crew to make to improve the ultimate science return. A film camera inside the module also can be used to make a high-speed record of the drops' behavior for later, more detailed analysis.

Drop Dynamics Experiment
Principal Investigator:
Dr. Taylor Wang
Vanderbilt University
Nashville, TN

This experiment will gather high quality data on the dynamics of liquid drops in low gravity for comparison with theoretical predictions and ground-based studies using very small drops. It will provide scientific and technical inputs for the development of new fields, such as containerless processing of materials and polymer encapsulation of living cells.

On USML-1, Dr. Wang's team used the Drop Physics Module to confirm a theory that was more than 100 years old. Using fluids ranging from water to oils, the module spun single drops until they formed a dog-bone shape. All the drops changed into the same shape at the same point and at exactly the point that had been predicted over a century ago by fluid dynamics pioneer Lord Raleigh.

Having resolved the issues surrounding the point at which the drops change shape, the team will use USML-2 to examine two new aspects of drop phenomena. Again, results will help confirm or refine mathematical theories.

One set of theories to be tested describes the fissioning, or breaking apart, of distorted drops as the viscosity (or thickness) of the fluid is varied. Scientists will observe and analyze conditions at which various sizes and viscosities of drops split.

The second thrust of this effort attempts to lay the ground work for encapsulating living cells which could be used to treat hormonal disorders: a spherical polymer shell would protect the cells from immunological attack and provide timed release. The principal investigator will study the centering of shells (air bubbles within liquid drops) and compound drops (a drop of one liquid encased within a drop of a different liquid). This investigation could demonstrate how to provide uniform encapsulation which would aid scientists in using polymer systems to encapsulate living cells.

In the case of diabetes, an improved treatment would be to inject a pancreatic cell that secretes insulin into the body, rather than injecting insulin itself. But the foreign cell would be immediately attacked by the patient's immune system. If the cell were encapsulated in a spherical shell made of a material strong enough to withstand attack, yet porous enough to allow absorption of nutrients and excretion of insulin, it could enable a marked improvement in treatment for diabetes patients.

Science and Technology of Surface-Controlled Phenomena Principal Investigator: Dr. Robert Apfel Yale University New Haven, CT

This study will use the Drop Physics Module to examine the influence of surfactants on the behavior of drops. Surfactants are substances which alter the surface properties of a liquid, aiding or inhibiting the way it adheres to or mixes with other substances. Processes which rely heavily on surfactants are as varied as dishwashing (soap and water is the classic surfactant-liquid interaction), the manufacture of cosmetics, the dissolution of proteins in synthetic drugs, the recovery of oil and environmental cleanup.

This investigation will have two parts. The first set of experiments will explore single drop oscillation. Drops with varying amounts of surfactants will be squeezed with sound waves; when the distortion is removed, the decay of the resulting oscillations can be analyzed. The second set of experiments will investigate the coalescence or combining of drops with varying concentrations of surfactants. Surfactants should allow the drops to combine more easily, but this is not always the case.

Both experiments will reveal surfactant behavior by creating novel situations that are not possible in Earth's normal gravity environment. Moreover, information gained from the space experiments will enable ground-based scientists to accurately and conveniently measure materials properties during similar tests on Earth.

Results of the surface-controlled phenomena investigation conducted during USML-1 were used to confirm and adjust theoretical models. The USML-2 experiments will help further refine these theories.

Geophysical Fluid Flow Cell Experiment
Principal Investigator:
Dr. John Hart
University of Colorado
Boulder, CO

The purpose of the Geophysical Fluid Flow Cell Experiment is to study how fluids move in microgravity, helping researchers understand the large-scale fluid dynamics of planetary and stellar atmospheres.

The experiment cannot be done in ground-based labs because the downward pull of Earth's gravity there is unlike the acceleration in stars and planets. In microgravity, different forms of acceleration can be simulated without interference.

The experiment uses two hemispheres. One, made of stainless steel and about the size of a baseball, is placed inside a transparent sapphire hemisphere, and a layer of silicone oil fills the space between the two. They are mounted together on a turntable. The transparent sapphire allows a clear view of the oil and conducts heat well so precise temperature control of the sapphire dome can be maintained.

The temperatures of the inner and outer hemispheres are controlled by the experiment computer, as is the speed of rotation. The heating creates a thermally driven motion in the oil, while the rotation mimics that present on rotating planets and stars. A high-voltage electric field is applied across the silicone oil, creating a buoyancy force identical to buoyant forces on Earth and in other atmospheres being modeled. The basic variables for the experiment are hemisphere rotation speed, voltage charge and temperatures. Once the variables are set and the experiment is running, thermally driven fluid flows within the rotating silicone oil are monitored. Dr. Hart and his team will study variations in the fluid's thermal patterns for a wide range of external forces. Different combinations of voltage, speed and temperature will be used during each run, creating unstable and turbulent flows in the rotating sphere shell that will help researchers better understand the dynamics of oceans, planetary atmospheres and stars.

The Gravitational Fluid Flow Cell first flew on the Spacelab 3 mission (STS-51B) in 1985. Several new types of convection were observed in the photographic data from the experiment, which contained images of convection structures, instabilities and turbulence, under varying conditions of different heating and rotation settings. The USML-2 experiment will expand on these results. In addition it will investigate flow instability for atmospheric flows that are more like the layers of Earth's atmosphere. The science team also will investigate patter formations relevant to flows in the Earth's mantle, as well as temperature distributions not studied on Spacelab 3.

Crystal Growth Furnace

The Crystal Growth Furnace is a reusable Spacelab facility for growing crystals of semiconducting material, metals and alloys. The furnace, which had its debut on USML-1, is the first space furnace developed by the United States to process multiple large samples at very high temperatures (above 1,832 degrees Fahrenheit or 1,000 degrees Celsius).

Atoms in many solids line up in orderly rows and columns, forming three-dimensional structures known as crystals. By melting or vaporizing a material and then studying how it changes back from a liquid or gas into a crystalline solid, scientists can learn which conditions affect its physical, chemical and other properties. They also can determine how these properties affect the material's performance. Better understanding of these processes is desirable in designing or enhancing qualities in a specific material.

Crystallization can be more effectively studied in microgravity than on Earth, because the gravity-induced phenomena that obscure or change the process are greatly reduced or eliminated. Gravity-related complications such as convection, sedimentation and buoyancy can result in problems ranging from physical flaws in the internal structure of the crystal to uneven distribution of component materials within it.

By analyzing space-grown crystals with well-defined, orderly atomic structures, investigators can increase their knowledge of many types of materials - both in space and on the ground. In the future, this knowledge could result in improved materials, processing techniques, or products here on Earth.

The four primary USML-2 Crystal Growth Experiments are continuations of investigations from USML-1. Three will be grown with the directional solidification method, where a moving furnace allows the molten material to gradually cool from one end to the other. Since the crystal forms in only one direction, its atomic arrangement is more orderly and defect-free.

The fourth experiment will grow crystals using the vapor crystal growth method. The sample is heated until it begins to sublime, or turn from a solid into a gas. The vaporized material diffuses into a cooler area of the apparatus where it is gradually deposited onto a base material and a single crystal forms.

Near the end of the mission, a fifth sample will be processed in the furnace to determine the effect of different Shuttle attitudes on crystal growth. Solidification of a material whose behavior is well understood on Earth (germanium with a trace of gallium added), will begin with the Shuttle in the particular orientation thought to be best for crystal growth. Midway through the crystal's processing, the Shuttle will maneuver to the standard "gravity gradient," or tail to Earth, attitude normally employed during microgravity missions.

Orbital Processing of High Quality Cadmium Zinc Telluride Compound Semiconductors
Principal Investigator:
Dr. David J. Larson Jr.
Northrop-Grumman Corp. Research and Development Center
Bethpage, NY

This experiment examines the effects of gravity on the growth and quality of alloyed compound semiconductors. This experiment will attempt to produce high quality cadmium zinc telluride crystals with fewer physical defects and more uniform distribution of chemical components than those grown on Earth.

Cadmium zinc telluride is used as a base, or substrate, on which infrared-detecting mercury cadmium telluride crystals are grown. The alloying element, zinc, is added to minimize strain where the two crystals join, thereby reducing defects. The resulting alloy, however, is a relatively soft material which can be deformed during the normal crystal growth process on Earth. These deformations can introduce undesired changes in the arrangement of atoms in the crystal.

By studying space-grown crystals, Dr. Larson can identify the effects of gravity as a factor in causing structural defects in the crystal system. They should be able to predict the distribution of chemical components within a crystal - important information for improving crystal growth technology on Earth.

The cadmium zinc telluride crystal grown during USML-1 was most defect-free where it completely touched the wall of the sample cylinder and where it did not touch the wall at all. Therefore, the primary sample container on USML-2 will be outfitted with a spring-loaded piston, which will move to reduce the volume of the cylinder as the material contracts during cooling. This should eliminate air voids in the crystal and ensure that it maintains even contact with the container wall along its entire surface.

The Study of Dopant Segregation Behavior During the Crystal Growth of Gallium Arsenide (GaAs) in Microgravity
Principal Investigator: Professor D. H. Matthiesen
Case Western Reserve University
Cleveland, OH

This experiment investigates techniques for uniformly distributing a small amount of selenium within a gallium arsenide crystal as it grows in microgravity.

Electronic devices made from gallium arsenide crystals operate at higher speeds and use less power than computer chips and other semiconductor applications made from silicon. Gallium arsenide is used in high-speed digital circuits, optoelectronic integrated circuits, solid-state lasers, and a variety of other products.

Impurities such as selenium, called dopants, are added to these semiconductor compounds to improve or precisely control their electronic characteristics. To produce high quality gallium arsenide crystals, scientists need to understand the process by which these impurities are distributed within the compound during crystal growth.

Growing the crystals in microgravity will greatly reduce the gravitational influences that cause an uneven distribution of dopants in crystals grown on Earth. This will allow Dr. Matthiesen to identify more subtle influences, either confirming or denying the theories and models used to control crystal growth on Earth.

For the USML-2 experiment, the growing crystal will be marked every 100 to 300 seconds by electric pulsing. The pulses will be time-coded to reveal the microscopic growth rate of the crystal and the shape and location of the liquid/solid boundary, or interface, at the various stages of growth.

Crystal Growth of Selected II-VI Semiconducting Alloys by Directional Solidification
Principal Investigator:
Dr. Sandor Lehoczky
NASA Marshall Space Flight Center
Huntsville, AL

This experiment seeks to confirm theories about how gravity influences the introduction and distribution of structural defects in alloy semiconductors during crystal growth. It will grow an approximately three-quarter-inch- long crystal of mercury zinc telluride, which will be analyzed post-flight to determine its chemical and physical properties.

Mercury zinc telluride is referred to as a II-VI alloy since its components appear in the vertical columns IIb and VIa of the periodic table of elements. The crystals have properties that theoretically make them superior infrared detectors for use in defense, space, medicine and commercial industry. The composition being grown on this mission has potential applications in instruments with diverse purposes ranging from locating and managing petroleum on Earth to studying distant stars and galaxies.

By varying proportions of mercury, zinc and tellurium within the alloy, researchers can modify its electronic and optical properties to meet the needs of a range of applications. However, the growth of large, single crystals of mercury zinc telluride containing a predetermined fraction of each chemical component is hampered by the complexity of the chemistry involved and by the effects of gravity during the growing process. Experiments in microgravity should clarify the role that gravity plays in incorporating the different chemical components into the growing crystal.

Vapor Transport Crystal Growth of Mercury Cadmium Telluride in Microgravity
Principal Investigator:
Dr. Herbert Wiedemeier
Rensselaer Polytechnic Institute
Troy, NY

The USML-2 version of this experiment focuses on the initial phase of vapor crystal growth in a complex alloy semiconductor. Dr. Wiedemeier and his team will grow a crystalline layer of mercury cadmium telluride on a cadmium telluride substrate, or base, by the vapor crystal growth method. The vapor transport method will cause layers, or thin films, of mercury cadmium telluride to be grown on the substrate in a process called epitaxial layer growth. The resulting crystal will be analyzed to determine the effects of microgravity on the growth rate, chemical composition, structural characteristics and other properties of the initial crystalline layer that forms on the substrate.

The similar crystal grown on USML-1 showed considerably improved quality over ground-based crystals. During their follow-up analysis, investigators found new information about the effects of microgravity on formation of the initial layer deposited on the substrate. Therefore, the USML-2 experiment zeros in on that stage of growth that determines the atomic arrangement of the entire crystal.

The performance of infrared detectors made from this material will be greatly improved when electronics manufacturers can grow crystals without structural flaws and with more uniform distribution of chemical components. Better understanding of this crystal growth method will enhance ground based production of similar semiconductor materials and lead to further improvements in techniques for producing crystals using this process.

Zeolite Crystal Growth Furnace

Principal Investigator:
Dr. Albert Sacco Jr.
Worcester Polytechnic Institute
Worcester, MA

On USML-2, Dr. Sacco will continue a series of experiments investigating the formation of zeolite crystals, widely used in the chemical process industry as filters, catalysts for reactions, and purifiers. Using the Zeolite Crystal Growth (ZCG) furnace located on the Shuttle's middeck, scientists hope to gain a better understanding of the three-dimensional structure of these crystals, examining techniques for creating large, near-perfect zeolite crystals in microgravity and evaluating new mixtures of zeolite materials which will maximize growth and minimize defects.

Zeolites can act as "molecular sieves" to separate out specific molecules from solutions. They also are active catalysts converting one molecule to another. Zeolites are used in life support systems, petroleum refining, waste management and biomedical fields for purification of fluids. High quality, near-perfect zeolites may one day allow gasoline, oil and other petroleum products to be refined less expensively. Scientists, armed with a better understanding of how zeolites grow and of their crystalline structure, may be able to expand current uses of these crystals.

Thirty-eight zeolite sample containers will be processed during the mission. Each container will be loaded with two solutions - one aluminum-based and one silicon- based. A crew member will mix the solutions on orbit by turning a screw inside each separate sample container. (The proper amount of mixing for different sample containers and mixtures will be dictated by results of Glovebox ZCG mixing tests early in the flight.) The containers then will be placed in the ZCG furnace where they will be heated, allowing crystal growth to begin.

ZCG flew for the first time on USML-1. Results from that flight indicate that crystals whose nucleation and growth was controlled from the onset of the experiment achieved a higher degree of crystal perfection than any crystals produced on Earth.

Glovebox Facility
Project Scientist:
Dr. Donald A. Reiss
NASA Marshall Space Flight Center
Huntsville, AL

The Spacelab Glovebox, provided by the European Space Agency, is a versatile, transparent enclosure where experimenters can test and develop procedures and technologies in microgravity. It enables crew members to handle, transfer, and otherwise manipulate materials in ways that are impractical in the open Spacelab. The facility is equipped with photographic equipment that allows a visual record of experiment operations.
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The Glovebox cabinet provides a clean working space and minimizes contamination risks to both the Spacelab and experiment samples. It provides two types of containment for small quantities of materials: physical isolation and a lower air pressure inside the enclosure than that of the Spacelab module. An air-filtering system also protects the crew from harmful experiment products. When an airtight seal is required, crew members can insert their hands into rugged gloves attached to the glove doors. If an experiment requires more sensitive handling, the crew may don surgical gloves and insert their arms through a set of adjustable sleeves.
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The Glovebox facility first flew on USML-1. Its working area has been increased for this mission, and lighting has been improved. On USML-2, the following seven investigations will use the facility.

Interface Configuration Experiment
Principal Investigator:
Dr. Paul Concus
University of California at Berkeley
Berkeley, CA

This follow-up to a USML-1 investigation studies the shapes that fluid surfaces assume within specific containers in microgravity. It will observe how colored liquid settles to equilibrium within two different shapes of clear plastic containers.

Currently, the behavior in microgravity of free liquid- vapor interfaces, such as the way liquid propellant moves within spacecraft fuel tanks, cannot be predicted satisfactorily. Since many on-orbit operations involve fluids and depend on their behaviors, it is important to test and refine the models used to predict how container shape can affect the location and shape of fluid surfaces.

Oscillatory Thermocapillary Flow Experiment
Principal Investigator:
Dr. Yasuhiro Kamotani
Case Western Reserve University
Cleveland, OH

This investigation, also a USML-1 follow-up, complements the Surface Tension Driven Convection Experiment. It studies the conditions for the onset of oscillations, or periodic variations, in surface-temperature-induced fluid flows. Heat will be applied to silicone oil in four vessels of different volumes and depths to determine how container dimensions affect the onset of oscillations.

On Earth, thermocapillary flows (those generated by temperature variations along a free liquid surface) begin to oscillate under certain conditions. Both the flows themselves and the oscillations may reduce the purity and uniformity of crystal growth solutions and molten metals. By studying the conditions present when oscillations begin in microgravity and by comparing them to onset conditions present on Earth, scientists should be able to determine the cause of the oscillations.

Fiber Supported Droplet Combustion
Principal Investigator:
Dr. Forman A. Williams
University of California at San Diego
San Diego, CA

This new Glovebox investigation tests a technique for studying combustion in microgravity. Droplets of different types of fuel will be suspended on a thin fiber, then ignited. Team members will observe the shape of the flame, how the flame grows and how fast it shrinks as it consumes the fuel.

Droplet combustion studies are very difficult to perform on Earth. Drops burn unevenly because gravity causes high-density drops to sink and buoyancy-induced acceleration forces combustion products to rise. In space, the drop is expected to assume a symmetrical sphere shape and thus burn more evenly, making it easier to validate combustion theories. If successful, this new technique for studying droplet combustion could provide insight into fundamental combustion processes, such as how pollutants are formed.

Protein Crystal Growth - Glovebox
Principal Investigator:
Dr. Larry DeLucas
Center for Macromolecular Crystallography
Birmingham, AL

This repeat of the highly successful USML-1 protein crystal growth Glovebox experiments will help confirm the advantages of crew interaction in the process of growing protein crystals in microgravity.

Protein crystals, important for analyzing the molecular structure of these "building blocks of life," are very difficult to produce. This experiment allows a crew member to modify protein crystal growth conditions such as mixing procedures, crystal seeding, crystal mounting and crystal preservation, based on his observations of previous sets of investigations.

On USML-1, these modifications resulted in several crystals of much higher quality than had ever been grown before. In addition to improving the quality of crystals grown on this mission, USML-2 Glovebox PCG research will be applied to improve protein crystal growth procedures on future Shuttle missions and on the Space Station.

Zeolite Crystal Growth - Glovebox
Principal Investigator:
Dr. Albert Sacco Jr.
Worcester Polytechnic Institute
Worcester, MA

This Glovebox investigation extends the USML-1 evaluation of on-orbit mixing procedures for zeolite crystal growth experiments.

Zeolite crystals are used as catalysts and filters in the chemical processing industry. To produce usable crystals, the growth solutions must be precisely mixed. USML-1 crew members' involvement in the mixing process resulted in more uniform mixing and helped minimize bubble formation. The USML-2 experiment will provide additional mixing information to researchers using the Zeolite Crystal Growth Furnace facility.

Colloidal Disorder-Order Transitions
Principal Investigator:
Dr. Paul Chaikin
Princeton University
Princeton, NJ

This new Glovebox investigation looks at a fundamental question in condensed matter physics: how the density of a substance finely and uniformly dispersed within another substance of a different phase - a mixture called a colloid - affects its transition from a liquid to an ordered solid phase.

For this experiment, several containers will hold different concentrations of fine solid spheres suspended in a liquid. Dr. Chaikin will observe which concentration of spheres is dense enough that they arrange themselves in an ordered state, rather than remaining randomly distributed within the liquid.

A better understanding of what happens at the boundary between solid and liquid states of a colloid should help researchers improve materials processing methods on Earth, as well as in microgravity.

Particle Dispersion Experiment
Principal Investigator:
Dr. John Marshall
NASA Ames Research Center
Moffett Field, CA

This investigation, another follow-up from USML-1, uses the microgravity environment to study how fine natural particles, such as dust, disperse within an atmosphere, then assemble back together (or reaggregate) into larger clusters. A short puff of air will disperse sand particles within a small, transparent container. Dr. Marshall will observe how they cluster in an environment free from the interference of gravity.

In addition to helping scientists understand how planetary atmospheres are cleansed of dust injected by volcanic eruptions, meteorite impacts or dust storms, the experiment tests technologies for future Shuttle and Space Station experiments concerned with the dispersion of aerosols.

The USML-1 investigation successfully demonstrated the effectiveness of methods for dispersing, redispersing and studying the clustering of particles caused by electrical interparticle forces. Electrical fields formed around some of the larger particle clusters. If "giant" electrical fields actually occur in the natural environment, they could have a significant impact on the way dense dust clouds are dispersed.

Protein Crystal Growth Experiments

A record number of protein crystal growth experiment facilities aboard USML-2 will be used to produce large, well-ordered crystals of various proteins under controlled conditions in microgravity. The crystals will be used in ground-based studies to determine the molecular structure of each protein.

Proteins play important roles in daily life, from providing nourishment to fighting disease. Because a protein's structure determines its function, expanding knowledge of the structures of proteins has potential benefits to many areas of biotechnology - the use of advanced techniques to improve the quality of biological products. These benefits include new information on basic biological processes, development of food crops with higher protein content and increased resistance to disease, and basic research toward the development of more effective drugs.

For many crystals, those grown in microgravity show a more uniform and highly ordered structure with fewer defects than are found in crystals of the same proteins produced on Earth.

The protein crystal growth experiments on USML-1 were very successful. Of the more than 30 protein crystals flown, nearly half produced crystals that were large enough for X-ray diffraction analysis.

Canavalin, a plant protein, formed some of the largest crystals of that protein ever grown (more than 2.0 millimeters long). Crystals of Human Proline Isomerase, a protein associated with transplant rejection and a target of drug designers, yielded the highest quality data ever collected on the protein.

Large, well-formed crystals of proteins important to immune disorder studies also were grown. This included HIV Reverse Transcriptase Complex, a protein important in the design of drugs to fight AIDS. The three-dimensional structure of Factor D, a protein that plays a role in complications including inflammation after open-heart surgery, was completed using the high-quality crystals obtained on USML-1.

The variety of protein crystal growth experiment facilities on USML-2 reflects the progress made in this field over almost a decade of space experiments. Growth methods and facility design are continually refined and upgraded, based on results from previous flights.

Single-Locker Protein Crystal Growth - Two Methods
Principal Investigator:
Dr. Daniel Carter
NASA Marshall Space Flight Center
Huntsville, AL

This experiment will process more than 800 protein samples in a facility designed for the production of crystals with enhanced internal order. The Protein Crystallization Apparatus for Microgravity (PCAM) holds more than six times as many samples as are normally accommodated in the same amount of space. The PCAM will grow crystals using the vapor diffusion method, which has been highly effective in previous Shuttle experiments. In vapor diffusion, liquid evaporates from a protein solution and is absorbed by a reservoir solution contained in a wicking material. As the protein concentration rises, the proteins form crystals.

Twelve PCAM cylinders - each holding 63 samples for a total of 756 - will be held in two temperature controlled enclosures, the Single-locker Thermal Enclosure System, each occupying a single Shuttle mid-deck locker. The enclosures will maintain temperatures at 72 degrees Fahrenheit (22 degrees Celsius).

Eight Short PCAMs, containing precipitation ("salt") solutions, will be in an ambient-temperature stowage locker. They will be analyzed to determine the rate at which the vapor diffusion process proceeds in the diffusion-limited environment of microgravity.

To start the PCAM experiments, a crew member will open the front of the enclosure, then rotate a shaft on the end of the cylinder with a ratchet from the Shuttle's tool kit. This will allow diffusion to start and protein crystal growth to begin. Near the end of the mission, a crew member will rotate the shaft in the opposite direction to stop diffusion.

A new experiment chamber called the Diffusion- controlled Crystallization Apparatus for Microgravity (DCAM) also will be tested. It will be housed within a Single Locker Thermal Enclosure System inside the Spacelab module. There will be 81 DCAMs containing protein samples in this enclosure. The experiment will grow model proteins by a combination of the liquid-liquid diffusion and the dialysis methods of protein crystal growth. This is a newly developed method by NASA scientists to passively control the crystallization process over extended periods of time. The space-grown proteins will be compared with those grown by the same method on the ground. The experiment is a precursor for long-duration crystallization experiments aboard the international Space Station and Mir, which would benefit greatly from the ability to control crystal growth times of up to approximately six months in length.

Crystal Growth by Liquid-Liquid Diffusion
Principal Investigator:
Dr. Alexander McPherson Jr.
University of California at Riverside
Riverside, CA

Four Handheld Diffusion Test Cell units containing four test cells each will grow protein crystals by diffusing one liquid into another. In liquid-liquid diffusion, different fluids are brought into contact but not mixed. Over time, the fluids will diffuse into each other through random motion of molecules. The gradual increase in concentration of the precipitant within the protein solution causes the proteins to crystallize. Liquid-liquid diffusion is difficult on Earth because differences in solution densities allow mixing by gravity-driven thermal convection. In addition, the greater density of the crystals allows them to settle into inappropriate parts of the cell.

The end of the test cells, where crystals will grow, and the containment housing are made of clear plastic. Crew members will remove the units from stowage after launch and place them where they can photograph the growing crystals periodically during the mission.

Each test cell has three chambers: protein solution, buffer solution, and precipitant solution. The buffer solution chamber cuts across the width of a shaft between protein and precipitant solutions. Before the experiment, a valve is positioned so each fluid is isolated from the others. A crew member will activate the experiment by rotating the valve 90 degrees, so the buffer contacts the protein and precipitant and the three form a single volume. The rotating valve minimizes liquid movement, limiting alteration of the liquids' shapes and volumes. When the three liquids are in contact, they will slowly diffuse into each other. The crew will close the valves before return to Earth.

Commercial Protein Crystal Growth
Principal Investigator:
Dr. Larry DeLucas
Center for Macromolecular Crystallography
Birmingham, AL

This experiment will grow large quantities of crystals of various proteins using the batch process method.

A Protein Crystallization Facility will be housed in a commercial refrigeration/ incubation module in the Orbiter middeck. The facility contains four cylindrical crystallization chambers which will be kept at 104 degrees Fahrenheit (40 degrees Celsius) until the Shuttle reaches orbit. Then, they will be gradually cooled to 72 degrees Fahrenheit (22 degrees Celsius) over a 100-hour period. The temperature change initiates crystal growth. Crystals form as the chamber cools, and crystal growth continues at 72 degrees for the remainder of the mission.

The experiment also will grow additional crystals in a Vapor Diffusion Apparatus located in a 39-degree-Fahrenheit (4-degree-Celsius) refrigerator/ incubation module.

Advanced Protein Crystallization Facility
Project Scientist:
Dr. Gottfried Wagner University of Giessen
Giessen, Germany

This facility is the first ever designed to use three methods of protein crystal growth: liquid-liquid diffusion, in which a protein solution and a salt solution are separated by a buffer and allowed to mix together slowly once in orbit; dialysis, with protein and salt solutions separated by a membrane; and vapor diffusion, where crystals form inside a drop of protein solution as solvent from the drop diffuses into a reservoir. Developed by the European Space Agency, the facility flew once before on the second International Microgravity Laboratory mission in June 1994.

Video images will be made of crystals as they form. After the mission, the images will allow investigators to study the history of crystal development in microgravity. Scientists are interested particularly in why and how crystals nucleate and begin to form crystals.

<u>Crystallization of Apocrystacyanin C</u>
Principal Investigator:
Dr. Naomi Chayen Imperial College
London, England

This protein is a member of the lipocalin family of proteins, which binds to certain pigments that are widely distributed in plants and animals. Knowledge of the structure of lipocalins will help scientists to alter these proteins to produce carriers that will bind more strongly to the pigment crocetin, which has anti-cancer properties.

<u>Crystal Structure Analysis of the Bacteriophage Lamda Lysozyme</u>
Principal Investigator:
Dr. Jean-Paul Declercq
Catholic University of Louvain Belgium

The bacteriophage Lambda lysozyme is a small protein of 158 amino acids involved in the dissolution of the cell walls of bacteria. Investigators are seeking information about the method of destruction employed by this organism.

<u>Crystallization of RNA Molecules Under Microgravity Conditions</u>
Principal Investigator:
Dr. Volker Erdmann
Free University of Berlin Germany

Ribonucleic acid (RNA) molecules have diverse biological roles, which include carrying genetic information for protein synthesis within living cells. They may also exhibit behavior characteristic of enzymes. Because of the large mass of its molecules, RNA has been extremely difficult to synthesize on Earth.

<u>Crystallization of the Protein Grb2 and Triclinic Lysozyme</u>
Principal Investigator:
Dr. Arnaud Ducruix
Centre National De La Recherche Scientifique Universite de Paris
Sud, France

Grb2 is an adapter protein involved in the transfer of signals from one cell to another. Investigators expect that space-grown crystals will have better resolution than those which have been grown and analyzed in Earth-based labs.

Lysozyme crystals grown in the APCF during the second International Microgravity Lab flight had a much higher level of perfection than those grown on earlier missions. USML-2 investigators want to extend the study to another crystalline structure of lysozyme, expecting to reach even better resolution values.

<u>Microgravity Crystallization of Thermophilic Aspartyl-tRNA Synthetase and Thaumatin</u>
Principal Investigator:
Dr. Richard Giege
Centre National De La Recherche Scientifique
Strasbourg, France

Investigators will continue and expand the IML-2 crystallization studies on thermophilic aspartyl-tRNA synthetase and will crystallize the plant-sweetening protein, thaumatin.

While both proteins are biochemically stable and are purified easily, they also have significant structural and behavioral differences. Therefore, they make interesting subjects for comparative crystallography studies.

In addition, thaumatin tastes extremely sweet when consumed by humans. Since it appears to be non-toxic, non- carcinogenic and low in calories, it may be a good sugar substitute.

<u>Crystallization in Space of Octarellins, de novo Designed (alpha/beta)-Barrell Proteins, and of a Mutated Human TIM Forming a Monomeric (alpha/beta)-Barrell Structure</u>
Principal Investigator:
Dr. Joseph Martial
University of Liege Belgium

The long-term goal of investigators is to design a three-dimensional "scaffold" on which to build amino-acid bonds, eventually producing therapeutic agents for the treatment or prevention of disease. Before this can be accomplished, more knowledge is needed about rules governing protein folding and structure stabilization. Resolution of the three-dimensional structure of crystals of the synthetic protein octarellin may provide this information.

<u>Crystallization in a Microgravity Environment of CcdB, a Protein Involved in the Control of Cell Death</u>
Principal Investigator: Dr. Lode Wyns
Free University of Brussels
Belgium

Clarification of the structure and mode of action of this protein may lead to design of new antibiotics and anti- tumoral drugs. In this experiment, scientists want to improve crystal quality and produce crystals of two specific mutants, which have not produced crystals large enough for data collection on Earth.

<u>A Multivariate Analysis of X-ray Diffraction Data Obtained from Glutathione S Transferase</u>
Principal Investigator:
Dr. Lennart Sjolin
University of Goteborg
Sweden

This experiment will perform extensive comparative analysis of X-ray data from space-grown crystals and ground- based controls to provide a statistical comparison of the two. This will give scientists statistically significant data to either confirm or refute various hypotheses about the value of a convection-free environment for enhanced crystal quality.

Protein Crystal Growth: Light-driven Charge Translocation Through Bacteriorhodopsin
Principal Investigator:
Dr. Gottfried Wagner
University of Geissen
Germany

This protein converts light energy to voltages in the membrane of photoenergetic micro-organisms. High quality bacteriorhodopsin crystals are difficult to grow on Earth because the crystalline clusters show structural disorder and loose bundling. These crystals grown in the APCF during IML-2 had a much higher level of perfection, and for the first time in microgravity showed a precise tendency to form as cubes. Resolution of the three-dimensional structure of bacteriorhodopsin will help scientists understand the mechanisms used to convert light energy to energy for growth.

Crystallization of Ribosomes
Principal Investigator:
Dr. Ada Yonath
Max-Planck Laboratory for Ribosomal Structure
Hamburg, Germany

Ribosomes are responsible for the translation of genetic code to proteins. While they are the only portion of living cells to have been crystallized, most Earth-grown crystals are very thin and crack on handling, making it very difficult to collect and evaluate data.

As APCF growth chambers are almost tailor-made for growing this type of protein, this experiment could result in crystals of improved internal order, shape, size and mechanical properties. The facility also may allow scientists to control specific properties of the crystal's structure and form.

Crystallization of Sulfolobus Solfataricus Alcohol Dehydrogenase
Principal Investigator:
Dr. Adriana Zagari
University of Naples
Italy

Alcohol dehydrogenase (ADH) is an enzyme that occurs in large amounts in the livers of mammals, where it plays an important role in several physiological functions including the breakdown of alcohol. However, mammalian ADH is unstable at high temperatures or in the presence of organic solvents, properties that limit its usefulness for the synthesis of organic compounds. On the other hand, ADH from the bacterium Sulfolobus solfataricus has greater thermal stability and is scarcely affected by the presence of organic solvents. Given these properties, the enzyme is a good candidate for industrial applications.

Crystallization of Turnip Yellow Mosaic Virus, Tomato Aspermy Virus, Satellite Panicum Mosaic Virus, Canavalin, Beef Liver Catalase, Concanavalin B
Principal Investigator:
Dr. Alexander McPherson
University of California Riverside, CA

Canavalin, catalase and concanavalin B are being studied to determine the effects of microgravity on protein crystal growth by evaluating their size, habit, quality, defects and diffraction properties.

Three viruses - very large proteins - are being studied to verify the theory that the effect of altered transport properties in microgravity should be magnified in proportion to the decreased diffusivity of such large molecules.

Crystallization of the Epidermal Growth Factor (EGF) Receptor
Principal Investigator:
Dr. Wolfgang Weber
University of Hamburg
Germany

The receptor for epidermal growth factor is increasing in its importance as a predictor for a series of human malignancies. Knowledge of its three-dimensional structure would open the possibility of tailoring drugs to treat numerous types of tumors. At present, though, the crystal structure of only one hormone receptor (growth hormone) and none of the growth factor receptors has been solved.

Structure of the Membrane-Embedded Protein Complex Photosystem I
Principal Investigator:
Dr. Wolfram Sanger
Free University of Berlin
Germany

This protein complex is one of two responsible for the primary conversion of visible light into chemical energy in water-oxidizing photosynthesis. This experiment aims to identify the complete arrangement of chlorophyll molecules that perform this conversion process in the most efficient way.

Crystallization of Visual Pigment Rhodopsin
Principal Investigator:
Dr. Willem de Grip
University of Nijmegen
The Netherlands

Visual pigments like rhodopsin are the primary photoreceptor proteins for a variety of light-regulated processes, such as vision and photoperiodic reproduction. Analysis of the protein crystals is needed if scientists are to unravel the molecular mechanisms responsible for these processes.

Commercial Generic Bioprocessing Apparatus
Principal Investigator:
Dr. Louis Stodieck
Center for BioServe Space Technologies
University of Colorado
Boulder, CO

The Commercial Generic Bioprocessing Apparatus (CBGA) is a tool which allows a variety of sophisticated bioprocessing experiments to be performed in one piece of hardware.

Many of the experiments which will be processed in the CGBA have applications that could improve life on Earth while providing solutions to issues related to extended stays in space.

Each experiment is housed in a glass tube called a Fluid Processing Apparatus (FPA). Groups of eight FPAs are packaged together so they can be activated simultaneously by turning a crank on the activation pack, and a number of activation packs are being flown on this mission. Each FPA tube holds a neutral storage medium and the sample, an experiment activator that initiates bioprocessing, and a termination fluid that fixes the experiment for post mission analysis. The fluids are separated by rubber stoppers. Once on orbit, a crew member mixes the samples and places them in an incubator for a preprogrammed period. Processing is terminated automatically. Samples will be removed and stored, some in the Spacelab module and others in middeck lockers, for the trip home.

The CGBA flew for the first time on USML-1. On that mission, biomedical experiments included investigations into how the human body fights disease, how infectious organisms like bacteria can be controlled, and how bacteria can be effectively used to treat waste and recover water - information vital for long space flights. There were experiments that investigated how cells and molecules develop and grow in reduced gravity, as well as seed germination experiments and experiments that looked at the microgravity effects on plant and animal development.

Major areas of investigation on USML-2 include:

Biomedical Testing and Drug Development

These experiments will help researchers develop a better understanding of how microgravity affects bone metabolism, the immune system and the neuromuscular system.

Information gleaned from these experiments may help scientists understand the changes caused by exposure to microgravity in order to develop new drugs for the possible treatment of diseases such as cancer, osteoporosis and AIDS.

Ecological Test Systems

This group of investigations will study plant development and the relationships between bacteria and plants in microgravity. Such knowledge is crucial for extended stays in space where plants will be used as both a food source and a means of purifying air.

The experiments will examine how controlled agricultural applications, waste management processes and methods of controlling microbes affect plant seeding, seed germination, plant development and bacterial products and processes of plants.

Biomaterials Products and Processes

These experiments will study the growth of bacteria in microgravity, investigate new pharmaceutical products and delivery systems, and study materials that might be used as replacements for skin, tendons, blood vessels and corneas.

Scientists hope to glean important information on how bacteria grow in the absence of gravity-driven fluid flows, as well as gaining insight on how to grow structures that can deliver drugs directly to cells. These investigations also will provide important information on models for potential implants, such as synthetic skin for burn victims.

Astroculture™ Facility and Experiment
Principal Investigator:
Dr. Raymond J. Bula
Wisconsin Center for Space Automation & Robotics
Madison, WI

The Astroculture™ facility is an apparatus used for growing plants in microgravity. There are two USML-2 objectives for Astroculture. 1) The facility's three main subsystems will be tested to verify the apparatus as an effective on-orbit plant growth system, and 2) the facility will be used to investigate the nature of starch accumulation in microgravity.

Because plants will play an important role in future long-duration space flights, providing crews with oxygen, food, pure water and assisting in removing carbon dioxide from space habitats, it is important to develop an effective plant growth facility. USML-2 will evaluate the facility's plant watering and nutrient-delivery system, humidity control and plant illumination subsystems.

The plant watering system must be able to deliver nutrients to the plants without releasing solutions into crew quarters. The Astroculture facility on USML-2 will test the effectiveness of a delivery system using porous tubes with different pressures to ensure a proper flow to the plants' roots.

Another requirement of the facility is successful humidity control. Air moisture must remain at levels that do not damage experiments and equipment, while maintaining desired humidity levels to plants. The moisture in the air also may be recycled as condensed water for cooking, drinking or as a source of water for plants. On USML-2 the system will humidify and dehumidify the air without needing a gas/liquid separator to recover the condensed water. All current systems in use must supply a separator.

The third requirement for a reliable plant growth system is efficient use of lighting, since electrical power is at a premium on Shuttle flights. The lighting subsystem tested on USML-2 uses light emitting diodes (LEDs) providing high levels of light within the limits of electrical power available on orbit. Its energy conversion capability makes it superior even to fluorescent or sodium lamps. It also provides greater safety than any other light sources currently used by space-based plant growth facilities.

During USML-2, small potatoes will be grown from potato leaf cuttings that can be induced to develop small tubers filled with starch in 10 to 15 days. Starch is an important energy storage compound in plants, and there are indications that starch accumulation in plants is restricted in microgravity. The crew will periodically monitor the status of the environment in the Astroculture plant chamber and the development of the potato plants. Video of the plants will be downlinked periodically during the mission. Post-mission evaluation of data will focus on rates of photosynthesis, movement of photosynthesis products from leaves to tubers, conversion of sugars to starch in storage organs, and enzyme activities for the formation and degradation of starch. Investigators also will study the number, size, shape and distribution of starch grains and the structures that form starch.

The Astroculture equipment has previously flown on the USML-1, and SPACEHAB 1, 2 and 3 missions. During these flights lighting, humidity, acidity-alkalinity balance (pH), nutrient supply and composition, and carbon dioxide and atmospheric contaminant subsystems were successfully evaluated. Technology progress from previous flights has resulted in several commercial products for use on Earth. The lighting subsystem has provided technology to develop a unique lighting system for photosynthesis research and for use in some medical applications. Other commercial products from Astroculture technology include dehumidification/humidification units, water-efficient irrigation systems and energy-efficient lighting systems for large scale commercial nurseries.

After flight qualification on USML-2, the plant growth facility will be available for sale or lease to commercial enterprises. The project is part of a cooperative experiment with the Secondary Payload Programs of NASA's Office of Life and Microgravity Sciences and Applications.

Measuring Microgravity

Whether on Earth or in space, any change in motion produces accelerations, or gravity. An astronaut exercising on the Space Shuttle, for instance, can cause the Orbiter to vibrate in response to the activity taking place inside it, creating gravity. Experiments on the Shuttle need a very stable microgravity environment so their delicate operations will not be disturbed. But with essential activities such as astronauts living and working on the Shuttle, Orbiter maneuvers, and antenna motions, absolute stability is impossible to achieve. Therefore, to interpret results correctly and to develop an understanding of the effects caused by these forces, investigators need to know the precise strength of gravitational influences and vibrations affecting their experiments. USML-2 will include three facilities to measure different types of accelerations, and it will test a device that could be used to isolate sensitive experiments from disturbances.

Space Acceleration Measurement System
Project Manager:
Ron Sicker
NASA Lewis Research Center
Cleveland, OH

The Space Acceleration Measurement System is a facility that measures the acceleration environment of the Spacelab module using three sensor heads to record accelerations over a specific range of frequencies. Sensors located on the Surface Tension Driven Convection Experiment, the Crystal Growth Furnace and the Glovebox will be connected by cables to a control and data storage unit in the Spacelab center aisle.

Data from SAMS will be used to determine what effect crew movements, equipment operations and Shuttle maneuvers can have on the experiments being conducted on USML-2. Scientists will analyze the data post-flight to determine that a disturbance took place at a particular time. They can then make allowances for the disturbance as they analyze their experiment data.

Three Dimensional Microgravity Accelerometer
Principal Investigator:
Jan Bijvoet
University of Alabama, Huntsville
Huntsville, AL

The Three Dimensional Microgravity Accelerometer (3DMA) apparatus will take two kinds of measurements on USML-2: the absolute level of microgravity acceleration, (the differences between zero acceleration and what is experienced during the mission), and microvibrations which could affect the investigations onboard. Using these two measurements, scientists can know the acceleration effects any time during their experiments.

Located in the central housing of the 3DMA hardware are three accelerometers which measure the level of absolute microgravity in three separate axes or directions. Three remote sensors will record the different vibrations and accelerations caused by experiment and Orbiter operations.

The data will be recorded in the central 3DMA unit for post-mission analysis. It will also be sent to the ground in real time. This will allow scientists to call up displays to view measurements of absolute gravity and microvibrations at the same time. The absolute level of microgravity and the data from the three remote sensors will allow quantification of disturbances.

Orbital Acceleration Research Experiment
Project Manager: Jose L. Christian Jr.
NASA Lewis Research Center
Cleveland, OH

The Orbital Acceleration Research Experiment (OARE) is managed by Lewis Research Center as part of NASA's Microgravity Measurements and Analysis Project. Located outside the Spacelab, the OARE acceleration instrument will measure microgravity levels caused by atmospheric drag of the Shuttle, changes in Orbiter velocity and vibrations of onboard machinery, as well as Shuttle and crew operations.

Data from OARE will complement information gathered from the SAMS instrument. While SAMS data on Shuttle accelerations will be analyzed post-mission, high-resolution data from the sensitive OARE instrument will be sent real- time to the ground. This will give scientists an opportunity to make on-the-spot adjustments to their experiments to account for the on-orbit disturbances.

Suppression of Transient Accelerations By Levitation Evaluation
Project Scientist:
Dr. Gerald Nurre
Marshall Space Flight Center
Huntsville, AL

The Suppression of Transient Accelerations By Levitation Evaluation (STABLE) will test a device designed to isolate a small science experiment from high-frequency accelerations, including Shuttle operations and crew activity.

The entire device fits into a single locker space in a Spacelab rack, the bottom of the locker serving as the base of the isolator. The platform is suspended from the base in the center of the locker by three electromagnetic actuators, mechanisms which move and control the platform. Each actuator is composed of a magnet, permanently attached to the platform, and a coil assembly, bolted to the base. Accelerometers are mounted both on the platform and the base, providing feedback of acceleration measurements through a feedback controller, also contained in the locker. This feedback allows position sensors to locate the platform with respect to the base and are used to maintain the platform near its centered position, thus producing a microgravity environment on the platform.

High-Packed Digital Television Technical Demonstration

This is the first flight demonstration of a new digital television system to operate from the Spacelab. It will provide researchers on the ground with up to six channels of video which can be transmitted simultaneously from orbit. Previously, only one video channel at a time could be sent down, or downlinked, limiting the accessibility of video data from experiments and other activities. Experiments requiring live video for analysis by ground teams had to be scheduled at different times.

The new six-channel system will increase science return from the USML-2 mission, since a number of science teams will be able to monitor and modify operation of their experiments simultaneously. The HI-PAC TV technology will serve the remaining Spacelab missions and will extend well into the Space Station era.

Using the Spacelab's high-rate data system, HI-PAC converts standard analog video signals into digital signals, compressing the signal and downlinking it the same way as other digital data. When the signals are received on the ground, the digital data will be converted back into analog signals, then distributed to scientists for viewing on monitors in the science operations area.

STUDENTS PARTICIPATE IN MISSION INVESTIGATIONS

During STS-73, students at four sites will interact with the astronauts to discuss and compare onboard microgravity experiments with similar, ground-based experiments. The goal is to involve students as participants in Shuttle investigations in an effort to generate excitement in physical science and chemistry.

The first live downlink with students is currently scheduled for flight day 12. Middle school students at the following sites will discuss mixing and crystal growth experiments with the Shuttle crew.

1. Museum of the Rockies, Bozeman, MT. Mixing and sedimentation.

2. Sierra Middle School, Las Cruces, NM. Crystallization experiments.

The second live downlink is scheduled for flight day 13. High school students from the following sites will discuss fluids and combustion experiments:

1. South High School, Worcester, MA. Fluid experiments.

2. Louisville Science Center, Louisville, KY. Combustion experiments.

Prior to the mission, NASA's education specialists visited the sites to work with students on their experiments.

A pre-flight education video of the STS-73 crew conducting the ground-based experiments and an accompanying "Microgravity Teacher's Guide with Activities for Physical Science" are available through the NASA Teacher Resource Center network.

Teachers can access copies of the ground-based activities through the "Hot Topics" section in SPACELINK, NASA's electronic network for educators. These experiments use affordable and easily acquired materials. For this and other information, SPACELINK can be accessed via modem line (205) 895-0028; WWW address **http://spacelink.msfc.nasa.gov**; and Telnet, Gopher and Anonymous FTP address **spacelink.msfc.nasa.gov**.

STS-73 CREWMEMBERS

STS073-S-002 -- These five astronauts and two United States Microgravity Laboratory (USML) payload specialists pause from a rigid training schedule for the STS-73 crew portrait. On the front row, left to right, are Albert Sacco Jr., payload specialist; Kent V. Rominger, pilot; Michael E. Lopez-Alegria, mission specialist. On the back row are, left to right, Catherine G. Coleman, mission specialist; Kenneth D. Bowersox, commander; Fred W. Leslie, payload specialist; and Kathryn C. Thornton, payload commander.

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BIOGRAPHICAL DATA

Navy Commander **Kenneth D. Bowersox**, 38, will lead the seven-member STS-73 crew during its 16-day mission in space.

Bowersox was born in Portsmouth, VA, but considers Bedford, IN, to be his hometown. He received a bachelor's degree in aerospace engineering from the United States Naval Academy in 1978, and a master's degree in mechanical engineering from Columbia University in 1979.

Bowersox received his commission in the Navy in 1978 and was designated a Naval Aviator in 1981. He was then assigned to Attack Squadron 22 aboard the USS Enterprise. Following graduation from the United States Air Force Test Pilot School at Edwards Air Force Base, CA, in 1985, he moved to the Naval Weapon Center at China Lake, CA.

Bowersox was selected as an astronaut candidate in June 1987. Since then he has held a variety of technical assignments including flight software testing in the Shuttle Avionics Integration Laboratory; technical assistant to the director of flight crew operations; chief of the Astronaut Office Safety Branch; and spacecraft communicator in the Mission Control Center. A veteran of two space flights, Bowersox has logged more than 591 hours in space.

His first flight, STS-50 in June/July 1992, was the first flight of the U.S. Microgravity Laboratory. Over a two-week period, crew members conducted a variety of experiments in materials processing and fluid dynamics in weightlessness. At that time, STS-50 was the longest Shuttle flight to date. Bowersox's second flight was as pilot of STS-61 in December 1993 which featured the servicing of the Hubble Space Telescope. During the 11-day mission, crew members conducted a record five spacewalks to restore the telescope to its full operating capacity.

Colorado native and Navy Commander **Kent Rominger**, 39, will be making his first Shuttle flight on STS-73.

Born in Del Norte, CO, Rominger received a bachelor's degree in civil engineering from Colorado State University in 1978 and a master's degree in aeronautical engineering from the U.S. Naval Postgraduate School in 1987. Rominger received his commission through the Aviation Reserve Officer Candidate Program in 1979 and was designated a Naval Aviator in September 1980. Following training in the F-14 Tomcat, he was assigned to Fighter Squadron Two and attended the Navy Fighter Weapons School. In 1987, he completed Naval Postgraduate School/Test Pilot School Cooperative Program, and was assigned as the F-14 Project Officer to the Carrier Suitability Branch of the Strike Aircraft Test Directorate at Patuxent River, MD. During his tour of duty, he completed initial carrier suitability sea trials of the F- 14B, logging the first aircraft carrier assessment and catapult launch in the upgraded Tomcat. In 1990, he reported to Fighter Squadron 211 where he served as Operations Officer and completed a Desert Storm Deployment of the Arabian Gulf aboard the USS Nimitz.

Rominger was selected as an astronaut candidate in 1992. He has since completed his candidate training and has been working technical issues for the Astronaut Office Operations Development Branch.

Three-time Shuttle veteran **Kathryn Thornton**, Ph.D., 43, will serve as Payload Commander and Mission Specialist 3 for the USML-2 mission. A native of Montgomery, AL, Thornton received a bachelor's degree in physics from Auburn University in 1974 as well as a master's degree and doctorate in physics from the University of Virginia in 1977 and 1979, respectively.

After receiving her doctorate degree, Thornton was awarded a NATO Postdoctoral Fellowship to continue her research at the Max Planck Institute for Nuclear Physics in Heidelberg, West Germany. She then returned to Charlottesville, VA, where she was employed as a physicist at the US Army Foreign Science and Technology Center.

Thornton completed her initial training as a NASA astronaut in 1985, and since then has logged more than 593 hours in space, including more than 21 hours of extravehicular activity.

Her first flight, in November 1989, was a five-day mission sponsored by the Department of Defense. Her second flight in May 1992 was aboard the maiden voyage of the Space Shuttle Endeavour on a mission to retrieve, repair and redeploy the International Telecommunications Satellite (INTELSAT), and to demonstrate and evaluate numerous EVA tasks to be used for the assembly of a space station. During that mission, Thornton and fellow crew member Tom Akers conducted a seven hour, 45 minute spacewalk.

On her third flight, Thornton was part of the team that conducted five spacewalks to service and repair the Hubble Space Telescope. During the December 1993 mission, which lasted 11 days, Thornton performed two of the spacewalks, spending more than 13 EVA hours.

Air Force Captain **Catherine Coleman**, Ph.D., 34, will be making her first space flight as Mission Specialist 1 during STS-73.

Born in Charleston, SC, Coleman received a bachelor's degree in chemistry from the Massachusetts Institute of Technology in 1983, and a doctorate in polymer science and engineering from the University of Massachusetts in 1991.

Coleman was commissioned as a 2nd lieutenant in the Air Force in 1983 and began graduate work at the University of Massachusetts. In 1988, she entered active duty and was assigned to Wright-Patterson Air Force Base as a research chemist. She did research on new polymer materials and acted as a surface analysis consultant for the Long Duration Exposure Facility. In addition to assigned duties, Coleman was a volunteer test subject for the centrifuge program at the Crew Systems Directorate of the Armstrong Aeromedical Laboratory. She set several endurance and tolerance records during her participation in physiological and new equipment studies.

Coleman was selected as an astronaut in 1992. Her technical assignments have since included working in the Astronaut Office Mission Support Branch and for flight software verification in the Shuttle Avionics Integration Laboratory.

Also making his first flight as Mission Specialist 2 is Navy Lieutenant Commander **Michael Lopez-Alegria**.

Lopez-Alegria, 37, was born in Madrid, Spain, and considers both Madrid and Mission Viejo, CA, to be his hometowns. He earned a bachelor's degree in systems engineering from the U.S. Naval Academy in 1980, and a master's degree in aeronautical engineering from the U.S. Naval Postgraduate School in 1988.

Lopez -Alegria was designated a naval aviator in 1981. He then served as a flight instructor in Pensacola, FL, until March 1983. His next assignment was to a fleet electronic reconnaissance squadron in Rota, Spain, where he served as a pilot and mission commander aboard EP-3E aircraft, flying missions in the Mediterranean Sea, North Atlantic, Baltic Sea and Central America. In 1986, he was assigned to a two-year cooperative program between the Naval Postgraduate School in Monterey, CA, and the U.S. Naval Test Pilot School in Patuxent River, MD. His final tour before being assigned to NASA was at the Naval Air Test Center as an engineering test pilot and program manager.
Lopez-Alegria also was selected as an astronaut in 1992, and has worked with the Space Shuttle Orbiter, Main Engine, Solid Rocket Booster and External Tank projects.

The crew roster for STS-73 also includes two Payload Specialists -- **Fred Leslie**, Ph.D., from the Marshall Space Flight Center, and **Albert Sacco Jr.**, Ph.D., from Worcester Polytechnic Institute.

Leslie, 43, was born in Ancon, Panama. He received a bachelor's degree in engineering science from the University of Texas in 1974, and a master's and doctorate degrees in meteorology with a minor in fluid mechanics from the University of Oklahoma in 1977 and 1979, respectively.

After earning his doctorate, Leslie served as a post doctoral research associate at Purdue University studying fluid vortex dynamics. In 1980, he worked for the Universities Space Research Association as a visiting scientist at the Marshall Space Flight Center.

Since 1983, Leslie has served as a co-investigator for the Geophysical Fluid Flow Cell experiment which flew on the Spacelab 3 mission and is part of the USML-2 payload. He also was a principal investigator for the Fluid Interface and Bubble Experiment examining the behavior of a rotating free surface aboard NASA's KC-135 aircraft. He is the author of 27 journal papers, 45 conference papers, and nine NASA reports involving atmospheric and fluid dynamic phenomena.

In 1987, he became chief of the Fluid Dynamics Branch where he directed and conducted research in both laboratory and theoretical investigations. He was also the mission scientist for the Japanese Spacelab mission, STS-47. STS-73 will be his first space flight.

A native of Boston, MA, **Sacco**, 46, received a bachelor's degree with honors from Northeastern University in 1973 and a doctorate from the Massachusetts Institute of Technology in 1977, both in chemical engineering. Since 1977, Sacco has been on the faculty at Worcester Polytechnic Institute in the Department of Chemical Engineering, splitting his time between research and teaching. He was appointed department head in 1989. He has consulted for numerous companies in the field of catalysis, solid/gas contacting, and equipment design for space applications. Also, with his father and brother, he ran a family restaurant in Boston for more than 20 years.

Sacco has over 70 publications in the areas of carbon filament initiation and growth, catalyst deactivation, and zeolite synthesis. He is the principal investigator for the Zeolite Crystal Growth Experiment and served as an alternate payload specialist on USML-1.

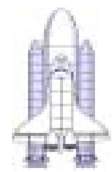
The alternate payload specialists for the USML-2 mission are **Glynn Holt**, a research scientist at NASA's Jet Propulsion Laboratory, and **David Matthiesen**, an assistant professor of Materials Science and Engineering at Case Western Reserve University.

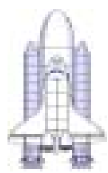
Holt, 35, a native of Plainview, TX, has performed significant research in support of the Drop Physics Module Program. He has authored numerous papers on drop behavior and gas bubble phenomena in both 1-G and microgravity environments. He is a co-investigator for the Drop Physics Module for both USML-1 and USML-2.

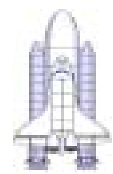
Matthiesen, 37, a native of Blue Island, IL, has conducted extensive material processing research both in the laboratory and in low gravity aboard the KC-136. He was principal investigator on the USML-1 gallium arsenide experiment and will serve as PI for a similar activity on USML-2.

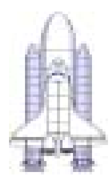
SHUTTLE FLIGHTS AS OF AUGUST 1995

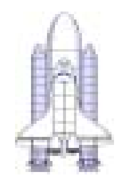
71 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 46 SINCE RETURN TO FLIGHT











		STS-70 07/13/95 - 07/22/95		
		STS-63 02/03/95 - 02/11/95		
		STS-64 09/09/94 - 09/20/94		
		STS-60 02/03/94 - -2/11/94		
STS-65 07/08/94 0 07/23/94		STS-51 09/12/93 - 09/22/93		
STS-62 03/04/94 - 03/18/94		STS-56 04/08/83 - 04/17/93		
STS-58 10/18/93 - 11/01/93		STS-53 12/02/92 - 12/09/92		
STS-55 04/26/93 - 05/06/93		STS-42 01/22/92 - 01/30/92	STS-71 06/27/95 - 07/07/95	
STS-52 10/22/92 - 11/01/92		STS-48 09/12/91 - 09/18/91	STS-66 11/03/94 - 11/14/94	
STS-50 06/25/92 - 07/09/92		STS-39 04/28/91 - 05/06/91	STS-46 07/31/92 - 08/08/92	
STS-40 06/05/91 - 06/14/91		STS-41 10/06/90 - 10/10/90	STS-45 03/24/92 - 04/02/92	
STS-35 12/02/90 - 12/10/90	STS-51L 01/28/86	STS-31 04/24/90 - 04/29/90	STS-44 11/24/91 - 12/01/91	
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STS-28 08/08/89 - 08/13/89	STS-51F 07/29/85 - 08/06/85	STS-29 03/13/89 - 03/18/89	STS-37 04/05/91 - 04/11/91	STS-67 03/02/95 - 03/18/95
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STS-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89	STS-57 06/21/93 - 07/01/93
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88	STS-54 01/13/93 - 01/19/93
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51A 11/08/84 - 11/16/84	STS-61B 11/26/85 - 12/03/85	STS-47 09/12/92 - 09/20/92
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	STS-41D 08/30/84 - 09/05/84	STS-51J 10/03/85 - 10/07/85	STS-49 05/07/92 - 05/16/92
OV-102 Columbia (17 flights)	**OV-099 Challenger (10 flights)**	**OV-103 Discovery (21 flights)**	**OV-104 Atlantis (14 flights)**	**OV-105 Endeavour (9 flights)**