NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE SHUTTLE MISSION
STS-60

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FEBRUARY 1994
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WAKE SHIELD FACILITY
SPACEHAB-2

STS-60 INSIGNIA

STS060-S-001 -- The design of the crew insignia for NASA's STS-60 mission depicts the space shuttle Discovery's on-orbit configuration. The American and Russian flags symbolize the partnership of the two countries and their crew members taking flight into space together for the first time. The open payload bay contains: the Space Habitation Module (Spacehab), a commercial space laboratory for life and material science experiments; and a Getaway Special Bridge Assembly in the aft section carrying various experiments, both deployable and attached. A scientific experiment to create and measure an ultra-vacuum environment and perform semiconductor Material science -- the Wake Shield Facility -- is shown on the Remote Manipulator System (RMS) prior to deployment.

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.

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CONTENTS

GENERAL BACKGROUND

General Release	5
Media Services Information	6
Quick-Look Facts	7
Shuttle Abort Modes	9
Summary Timeline	10
Payload and Vehicle Weights	11
Orbital Events Summary	12
Crew Responsibilities	13

CARGO BAY PAYLOADS & ACTIVITIES

Wake Shield Facility (WSF)	14
Spacehab-2 (SPACEHAB-2)	27
Astroculture®	33
IMMUNE-1	46
Sample Return Experiment	52
Get Away Special (GAS) Payloads	53
Capillary Pump Loop (CAPL) Experiment	56
Orbital Debris Radar Calibration Spheres (ODERACS) Project	57
BREMEN Satellite (BREMSAT)	58

IN-CABIN PAYLOADS

Shuttle Amateur Radio Experiment-II (SAREX-II)	60
Aurora Photography Experiment-B (APE-B)	62

STS-60 CREW BIOGRAPHIES	63

Release: 94-11

FIRST SHUTTLE MISSION OF 1994 TO INCLUDE RUSSIAN COSMONAUT

The first flight of the Space Shuttle in 1994, designated as STS-60, will be highlighted by the participation of a Russian astronaut serving as a crew member aboard Space Shuttle Discovery. The mission also will see the deployment and retrieval of a free-flying disk designed to generate new semiconductor films for advanced electronics and the second flight of a commercially developed research facility.

Leading the six-person STS-60 crew will be Mission Commander Charlie Bolden who will be making his third space flight. Pilot for the mission is Ken Reightler, making his second flight. The mission specialists for STS-60 are Jan Davis, Mission Specialist 1 (MS1) making her second flight, Ron Sega, Mission Specialist 2 (MS2) making his first flight, Franklin Chang-Diaz, the Payload Commander and Mission Specialist 3 (MS3) making his fourth flight and Sergei Krikalev, Mission Specialist 4 (MS4) who is a veteran of two flights in space, both long-duration stays aboard the Russian MIR space station.

Launch of Discovery on the STS-60 mission is currently scheduled for no earlier than February 3, 1994 at 7:10 a.m. EST. The planned mission duration is 8 days, 5 hours and 32 minutes. An on-time launch on February 3 would produce a landing at 12:42 p.m. EST on February 11 at Kennedy Space Center's Shuttle Landing Facility.

A new era of human space flight cooperative efforts between the United States and Russia will begin with the flight of Russian cosmonaut Sergei Krikalev as a member of the STS-60 crew. His flight aboard the Shuttle is the beginning of a three-phased program. Phase one will entail up to 10 Space Shuttle-Mir missions including rendezvous, docking and crew transfers between 1995 and 1997. Phase two is the joint development of the core international space station program. Phase three is the expansion of the space station to include all of the international partners.

The STS-60 mission will see the first flight of the Wake Shield Facility (WSF), a 12-foot diameter, stainless steel disk which will be deployed and retrieved using the Shuttle mechanical arm. While it flies free of the Space Shuttle, WSF will generate an "ultra-vacuum" environment in space within which to grow thin semiconductor films for next-generation advanced electronics. The commercial applications for these new semiconductors include digital cellular telephones, high- speed transistors and processors, fiber optics, opto-electronics and high-definition television.

The commercially developed SPACEHAB facility will make its second flight aboard the Space Shuttle during the STS-60 mission. Located in the forward end of the Shuttle cargo bay, it is accessed from the orbiter middeck through a tunnel and provides an 1100 cubic feet of working and storage space. Experiments being carried in SPACEHAB-2 involve materials processing, biotechnology and hardware and technology development payloads.

NASA's program affords the average person a chance to perform small experiments in space through the agency's Get Away Special (GAS) program. This flight will mark a major milestone because Discovery will fly the 100th GAS payload since the program's inception in 1982. GAS experiments on STS- 60 will attempt to create a new kind of ball bearing, measure the vibration level during normal orbiter and crew operations and understand the boiling process in microgravity.

Two GAS payloads will involve deploying objects from the cargo bay. The Orbital Debris Calibration Spheres (ODERACS) payload will deploy six spheres which will be observed, tracked and recorded by ground-based radars and optical telescopes. The German-built BREMEN Satellite (BREMSAT) payload will conduct scientific activities at various mission phases before and after satellite deployment.

STS-60 crew members will take on the role of teacher as they educate students in the United States and Russia about their mission objectives and what it is like to live and work in space by using the Shuttle Amateur Radio Experiment-II (SAREX-II). Astronauts Bolden, Sega and Krikalev will operate SAREX. Operating times for school contacts are planned into the crew's activities.

STS-60 will be the 18th flight of Space Shuttle Discovery and the 60th flight of the Space Shuttle system.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS.)

MEDIA SERVICES INFORMATION

NASA Select Television Transmission

NASA Select television is now available through a new satellite system. NASA programming can now be accessed on Spacenet-2, Transponder 5, located at 69 degrees west longitude; frequency 3880.0 MHz, audio 6.8 MHz.

The schedule for television transmissions from the orbiter and for mission briefings will be available during the mission at Kennedy Space Center, Fla; Marshall Space Flight Center, Huntsville, Ala.; Dryden Flight Research Center, Edwards, Calif.; Johnson Space Center, Houston and NASA Headquarters, Washington, D.C. 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 Select television schedule will indicate when mission briefings are planned.

STS-60 QUICK LOOK

Launch Date/Site:	Feb. 3, 1994/Kennedy Space Center - Pad 39A
Launch Time:	7:10 a.m. EST
Orbiter:	Discovery (OV-103) - 18th Flight
Orbit/Inclination:	190 nautical miles/57 degrees
Mission Duration:	8 days, 5 hours, 32 minutes
Landing Time/Date:	12:42 p.m. EST Feb. 11, 1994
Primary Landing Site:	Kennedy Space Center, FL.
Abort Landing Sites:	Return to Launch Site - KSC, FL
	Trans-Atlantic Abort landing - Zaragoza, Spain
	Ben Guerir, Morocco
	Moron, Spain
	Abort Once Around - Edwards AFB, CA
Crew:	Charlie Bolden, Commander (CDR)
	Ken Reightler, Pilot (PLT)
	Jan Davis, Mission Specialist 1 (MS1)
	Ron Sega, Mission Specialist 2 (MS2)
	Franklin Chang-Diaz, Payload Commander, (MS3)
	Sergei Krikalev (RSA), Mission Specialist 4 (MS4)
Cargo Bay Payloads:	WSF-1 (Wake Shield Facility-1)
	Spacehab-2 (Space Habitation Module-2)
	CAPL/GAS Bridge experiments (Capillary Pumped Loop Experiment/Get-Away Special canisters)
Spacehab Experiments:	3-DMA (Three-Dimensional Microgravity Accelerometer)
	ASC-3 (Astroculture Experiment)
	BPL (Bioserve Pilot Lab)
	CGBA (Commercial Generic Bioprocessing Apparatus)
	CPCG (Commercial Protein Crystal Growth)
	ECLiPSE-Hab (Equipment for Controlled Liquid Phase Sintering)
	IMMUNE-01 (Immune Response Studies)
	ORSEP (Organic Separations Experiment)
	SEF (Space Experiment Facility)
	PSB (Penn State Biomodule)
	SAMS (Space Acceleration Measurement System)
	SOR/F (Stirling Orbiter Refrigerator/Freezer)
	SRE (Sample Return Experiment)
Get Away Special (GAS) Experiments:	ODERACS (Orbital Debris Radar Calibration Spheres)
	BREMSAT (University of Bremen Satellite)
	G-071 (Ball Bearing Experiment)
	G-514(Orbiter Stability Experiment and Medicines in Microgravity)
	G-536 (Heat Flux)
	G-557 (Capillary Pumped Loop Experiment)

In-Cabin Payloads:	SAREX-II (Shuttle Amateur Radio Experiment-II) APE-B (Auroral Photography Experiment)

Joint U.S.-Russian Investigations:

DSO 200	Radiological Effects
DSO 201:	Sensory Motor Investigation
DSO 202:	Metabolic
DSO 204:	Visual Observations From Space

Other DTOs/DSOs

DTO 623:	Cabin Air Monitoring
DTO 656:	PGSC Single Event Upset Monitoring
DTO 664:	Cabin Temperature Survey
DTO 670:	Passive Cycle Isolation System
DTO 700-2:	Laser Range and Range Rate Device
DTO 700-7:	Orbiter Data for Real-Time Navigation Evaluation
DSO 325:	Dried Blood Method for Inflight Storage
DSO 326:	Orbiter Window Inspection
DSO 901:	Documentary Television
DSO 902:	Documentary Motion Picture
DSO 903:	Documentary Still Photography

SPACE SHUTTLE ABORT MODES

Space Shuttle launch abort philosophy aims toward safe and intact recovery of the flight crew, Orbiter and its payload. Abort modes include:

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

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

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

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

STS-60 contingency landing sites are the Kennedy Space Center, Edwards Air Force Base, Zaragoza, Ben Guerir, or Moron.

STS-60 SUMMARY TIMELINE

Flight Day 1
Ascent
OMS-2 burn (190 n.m. x 190 n.m.)
Spacehab activation
Joint Science Operations
CAPL activation
Group B powerdown
CPCG setup
Vestibular Experiments
Spacehab operations

Flight Day 2
Metabolic investigations
Remote Manipulator System checkout
Vestibular experiments
SAREX setup

Flight Day 3
Wake Shield Facility grapple
Wake Shield Facility unberth
Group B powerup
Wake Shield Facility release (191 n.m. x 189 n.m.)
NC-1 burn (190 n.m. x 189 n.m.)
Group B powerdown
Vestibular Experiments
Spacehab Operations

Flight Day 4
SAREX operations
Vestibular experiments

Flight Day 5
Group B powerup
NC-4 burn (195 n.m. x 191 n.m.)
TI burn (191 n.m. x 188 n.m.)
Wake Shield Facility Plume Impingement Test
Wake Shield Facility grapple (191 n.m. x 189 n.m.)
Group B powerdown

Flight Day 6
Vestibular experiments
Wake Shield Facility operations
Wake Shield Facility berth
Vestibular experiments
Orbit Adjust burn (If required: 191 n.m. x 183 n.m.)

Flight Day 7
SAREX operations
Vestibular experiments
Group B powerup
ODERACS deploy
BREMSAT deploy
Crew press conference
Vestibular experiments
Group B powerdown

Flight Day 8
Reaction Control System hot fire
Flight Control Systems checkout
Vestibular experiments
Spacehab stow
Cabin stow

Flight Day 9
Group B powerup
Spacehab final deactivation
Deorbit preparation
Deorbit burn
Entry
Landing

STS-60 VEHICLE AND PAYLOAD WEIGHTS

	Pounds
Orbiter (Discovery) empty and 3 SSMEs	173,117
Wake Shield Facility (deployable)	3,710
Wake Shield Facility (cargo bay support equipment)	3,770
Capillary Pumped Loop Exp./Gas Bridge Assembly	5,136
Spacehab-2	9,452
SAREX-II	50
DSOs/DTOs	437
Total Vehicle at SRB Ignition	4,507,961
Orbiter Landing Weight	214,832

STS-60 ORBITAL EVENTS SUMMARY

Event	Start Time (dd/hh:mm:ss)	Velocity (fps)	Change Orbit (n.mi.)
OMS-2	00/00:45:00	267	191 x 189
WSF release	02/03:50:00	n/a	191 x 189
WSF thrust (WSF's single thruster will fire to provide separation from Discovery’s vicinity)	02/03:51:00	1.5	190 x 189
NC-1 (fired when Discovery is about 10 n.m. ahead of WSF, begins slow drift over next 12 orbits to a point about 40 n.m. ahead of WSF	02/08:27:00	0.6	190 x 189
NC-2 (if required, maintains Discovery at about 40 n.m. ahead of WSF)	03/01:14:00	TBD	190 x 189
NPC (if required, aligns Discovery's groundtrack with WSF’s groundtrack)	03/07:00:00	TBD	190 x 189
NC-3 (if required, maintains Discovery at about 40 n.m. ahead of WSF)	03/08:00:00	TBD	190 x 189
NC-4 (fired at 40 n.m. ahead of WSF, begins closing in on WSF, initiates closing rate of about 16 n.m. per orbit to arrive at a point 8 n.m. behind WSF after two orbits)	03/23:06:00	9	195 x 189
NH-1 (if required, adjusts Discovery’s altitude as it closes on WSF)	03/23:52:00	TBD	190 x 189
NCC (first burn calculated by onboard computers using onboard navigation derived from orbiter star tracker sightings of WSF; fine-tunes course while orbiter is closing in on a point 8 n.m. ahead WSF)	04/01:12:00	TBD	195 x 191
TI (fired upon arrival at a point 8 n.m. ahead WSF; begins terminal interception of WSF)	04/02:09:00	12	191 x 188
MC1-MC4 (mid-course corrections, if required; calculated by onboard computers, double-checked by ground; designed to fine-tune final course toward WSF, may or may not be required)	TBD	TBD	TBD
MANUAL (Begins about 4 hours, 40 minutes prior to WSF grapple, less than 1 nautical mile from WSF, passing below it. Commander takes manual control of orbiter flight, fires braking maneuvers to align and slow final approach to WSF and begins an almost four-hour long series of proximity operations designed to study the characteristics of Discovery’s thruster exhaust during rendezvous)	04/03:20:00	TBD	TBD
PLUME MNVRS (Commander and Pilot will fire a series of thrusters at differing angles to WSF while flying in front of and behind WSF at ranges of 400, 300 and 200 feet. The thruster firings will gather information on how to avoid contaminating and disturbing rendezvous targets with thruster exhaust during close operations)	04/03:43:00	n/a	n/a
GRAPPLE (WSF is captured using Discovery's mechanical arm)	04/08:00:00	TBD	191 x 189
OA (If required, burn to adjust Discovery's orbit for landing opportunities and deploy of ODERACS and BREMSAT)	05/07:45:00	TBD	TBD
ODERACS (ODERACS spheres are deployed)	06/02:45:00	n/a	191 x 189
BREMSAT (University of Bremen satellite is deployed)	06/07:39:00	n/a	191 x189
DEORBIT	08/04:28:00	335	n/a
LANDING	08/05:32:00	n/a	n/a

NOTE: All planned burns are recalculated in real time once the flight is under way and will likely change slightly. Depending on the accuracy of the orbiter's navigation and course at certain times, some smaller burns listed above may not be required. However, the times for major burns and events are unlikely to change by more than a few minutes.

STS-60 CREW RESPONSIBILITIES

Task/Payload	Primary	Backups/Others
Wake Shield	Facility Sega	Krikalev, Chang-Diaz
Remote Manipulator System	Davis	Krikalev, Sega
ODERACS	Bolden	Reightler
BREMSAT	Bolden	Chang-Diaz
Get-Away Special (GAS) Bridge experiments		
CAPL/GBA	Krikalev	Sega
GAS 514	Davis	Chang-Diaz
GAS 071	Davis	Chang-Diaz
GAS 536	Davis	Chang-Diaz
GAS 557	Davis	Chang-Diaz
Spacehab experiments		
Spacehab systems	Chang-Diaz	Davis, Sega, Krikalev
SAMS	Krikalev	Sega
3-DMA	Krikalev	Chang-Diaz
ORSEP	Bolden	Davis
CPCG	Davis	Chang-Diaz
BPL	Krikalev	Chang-Diaz
CGBA	Davis	Reightler
SEF	Chang-Diaz	Davis
ECLiPSE	Reightler	Sega
IMMUNE	Krikalev	Reightler
ASC-3	Chang-Diaz	Krikalev
PSB	Sega	Bolden
Middeck experiments		
SAREX-II	Krikalev	Bolden, Sega
APE-B	Chang-Diaz	Krikalev
Joint U.S.-Russian medical investigations		
DSO 200 (radiological)	Reightler	Krikalev
DSO 201 (sensory)	Sega	Davis, Krikalev, Reightler
DSO 202 (metabolic)	Chang-Diaz	Bolden, Reightler
DSO 204 (visual obs)	Krikalev	Chang-Diaz
Detailed Test Objectives (DTOs)		
DTO 623 (cabin air)	Sega	Bolden
DTO 656 (PGSC upset)	Sega	Reightler
DTO 664 (cabin temp)	Sega	Davis
DTO 670 (passive cycle)	Sega	Reightler
DTO 700-2 (laser range)	Reightler	Chang-Diaz, Sega
DTO 700-7 (Orbiter Data For Real-Time Navigation Evaluation)	Reightler	Sega, Chang-Diaz
Other Responsibilities		
Photography/TV	Chang-Diaz Davis	
Earth observations	Chang-Diaz	Krikalev
In-flight maintenance	Krikalev	Bolden
Medic	Bolden	Davis
EVA (not planned)	Chang-Diaz (EV1)	Davis (EV2), Reightler (EV3)

WAKE SHIELD FACILITY (WSF)

The Wake Shield Facility (WSF) is a 12-foot diameter, stainless steel disk designed to generate an "ultra-vacuum" environment in space within which to grow thin semiconductor films for next-generation advanced electronics. This mission represents the first time, internationally, in which the vacuum of space will be used to process thin film materials. The STS- 60 astronaut crew will deploy and retrieve the WSF during the 9-day mission. The NASA Office of Advanced Concepts and Technology (OACT) is the sponsor of the WSF-1 flight on this mission of Space Shuttle Discovery.

The WSF is designed, built and managed by the Space Vacuum Epitaxy Center (SVEC) -- a NASA Center for the Commercial Development of Space (CCDS) based at the University of Houston, Houston, Texas -- with its principal industry partner, Space Industries, Inc. (SII), League City, Texas. Six additional corporate partners support the WSF program, including: American X-tal Technology, Dublin, Calif.; AT&T Bell Labs, Murray Hill, N.J.; Instruments, S.A., Inc., Edison, N.J.; Ionwerks, Houston, Texas; Quantum Controls, Houston, Texas; and Schmidt Instruments, Inc., Houston, Texas. In addition, the University of Toronto, NASA Johnson Space Center, the U.S. Air Force Phillips Laboratories and the U.S. Army Construction Engineering Research Laboratory are members of the SVEC consortium.

The principle objectives of the WSF-1 mission include:

- The characterization of the "ultra-vacuum" environment generated by the WSF in low Earth orbit (LEO) space, and the flow field around the WSF, and

- Molecular Beam Epitaxy (MBE) - growth of a thin film of the compound Gallium Arsenide (GaAs).

These objectives may have a significant impact on the microelectronics industry because the use of improved GaAs thin film material in electronic components holds a very promising economic advantage. The commercial applications for high quality GaAs devices are most critical in the consumer technology areas of digital cellular telephones, high-speed transistors and processors, high-definition television (HDTV), fiber optic communications and opto-electronics.

The majority of electronic components used today are made of the semiconductor silicon, but there are many other semiconductors of higher predicted performance than silicon. A current example of this prediction is the material Gallium Arsenide (GaAs). Devices made from GaAs could be about 8 times faster than silicon devices and take 1/10 the power. However, GaAs of high enough quality to reach this predicted performance level does not exist. If high quality GaAs could be produced, the devices made from it would represent nothing less than a technological revolution.

If improved GaAs material were available, it could significantly impact the global semiconductor market. The 1990 worldwide semiconductor consumption was $56.8 billion. Of this amount, about 40% went for computers, 18% for telecommunications and 15% for military applications. The projected market for 1994 is $109 billion. Within this giant market, GaAs currently holds only a 0.5% niche. It is predicted that the niche for GaAs should grow to 2% (or about $2.2 billion) by 1995, which could significantly increase with the availability of improved GaAs material.

A method to generate such advanced material is by thin film growth of the material in a vacuum environment. This technique, known as epitaxy, is limited by the vacuum conditions in vacuum chambers on Earth. To improve the material, the vacuum environment where it is grown must be improved.

Low-Earth orbit (LEO) space can be used to grow GaAs (and other materials) epitaxially, by creating a unique vacuum environment or "wake" ahead an object moving in orbit. There is a moderate vacuum in LEO space with very few atoms present. A vehicle in orbit, such as the WSF, pushes even those few atoms out of the way, leaving fewer atoms, if any, in its wake. This unique "ultra-vacuum" produced in space by the WSF will be 1,000-10,000 times better than the best vacuum environments in laboratory vacuum chambers. Using this unique "ultra-vacuum" property of space, the WSF holds the promise of spawning orbiting factories to produce the next generation of semiconductor materials and the devices they will make possible.

Program Overview

The space "ultra-vacuum" concept was first described within NASA more than twenty years ago, but there was no need identified at that time for the use of an "ultra-vacuum." Recent interest by scientists and corporate researchers in epitaxial thin-film growth has motivated the use of space to create the "ultra-vacuum" in which to grow better thin films.

Recognizing this scientific opportunity as a new economic opportunity, in 1987 SVEC formed a consortium of interested industries, academic institutions and government laboratories to utilize the LEO vacuum environment in thin film growth. In 1989, SVEC partnered with its industry members led by Space Industries, Inc., and with NASA Johnson Space Center to build the WSF using a timely and cost-effective manner required of a commercially-oriented endeavor.

Prior to 1989, preliminary studies indicated that the WSF would be a disk or shield about 12-14 feet in diameter, and would be deployed from the Shuttle payload bay on the Shuttle "arm." The WSF hardware development program was soon projected to be complex, time intensive and quite costly, and it was mutually decided by NASA and SVEC that a more cost-effective and timely approach must be identified. The result was the effort by SVEC, Space Industries, Inc., and the rest of the SVEC industrial partners to create a non-traditional, commercial approach to space hardware development, and hence space infrastructure development. Through this mode of operation, the WSF will fly in nearly 1/2 the time required under a traditional approach, and at less than 1/6 the cost for a traditional aerospace hardware development program.

The primary objectives for the WSF-1 mission (listed above) remain as outlined by SVEC in March 1989. It should be noted that both of these primary objectives will be major "firsts" in space science and technology. The generation and characterization of the "ultra-vacuum" in LEO and its utilization for thin-film growth have never been attempted before, and as a result, represent additional risk for the SVEC-developed space thin film science and technology. These objectives, however, form the foundation of the SVEC principle of taking a basic science concept, identifying an application of it, developing a technology from the application, and identifying and producing a product from that technology.

A major contributor to the success of the WSF program will be Discovery's crew, especially Dr. Ronald Sega. Dr. Sega is a Co-Principal Investigator on the WSF program, with Dr. Alex Ignatiev, SVEC Director. The close SVEC interaction with the crew, pre-flight, has proven extremely beneficial for optimizing the complex WSF operation of unberthing, cleaning, deployment, rendezvous and capture. The crew also has contributed to the tuning of the WSF's science and technology operations for maximized data return from this first mission of the WSF and will play a major role in assuring its success.

Hardware Description

The WSF consists of the Shuttle Cross Bay Carrier (SCBC) and the Free Flyer. The SCBC remains in the Shuttle and has a latch system which holds the Free Flyer to the Carrier. The Shuttle "arm" or Remote Manipulator System (RMS) is attached to the Free Flyer for deployment and free flight in space. The SCBC has an extended-range, stand-alone RF communications system that lets the WSF seem like an attached payload to the Shuttle's systems, even when the Free Flyer is following ahead the Shuttle at its stationkeeping distance of 40 nautical miles.

The Free Flyer is a fully-equipped spacecraft on its own, with cold gas propulsion for separation from the Shuttle and a momentum bias attitude control system (ACS). Forty-five kilowatt-hours of energy, stored in silver-zinc batteries, are available to power the thin film growth cells, substrate heaters, process controllers, and a sophisticated array of characterization devices. Weighing approximately 9,000 lbs. (the Free Flyer alone is 4,000 lbs.), the WSF occupies one quarter of the Shuttle payload bay. Controlling electronics, attitude control system, batteries and solar panels, and MBE process control equipment are on the back (wake side) of the WSF, while the avionics and support equipment are located on the front (ram side).

The commercial approach used to create the WSF has facilitated the development of several critical pieces of supporting hardware which have proven to be extremely useful and valuable in their own right. The development of an inexpensive carrier (the SCBC), a versatile ground link, and an innovative communications link between the Shuttle and the WSF have each been valuable spin-offs from the WSF program.

WSF Physical Characteristics

Free-Flyer Vacuum welded 304L SS structure, UHV finish on wake side, 12 ft. dia. x 6 ft.

Carrier 7075-T73 aluminum alloy, dual trunnion, doubly redundant stand alone latch system

Weight 8,000 lbs. total, 3,800 lbs. deployable

Power Ag-Zn batteries, 45 k-watt-hr. @ 28 Vdc

Attitude Control System Momentum bias (10 ft.-lb.-sec.), horizon scanner, 2-axis magnetometer, 3-axis magnetic torquer

WSF Characterization Equipment

Total Pressure Gauges (TPG) 2 10-5 torr-10-8 torr; 3 10-7 torr-10-10 torr

Mass Spectrometers (TOF-MS) 2 1-150 amu, 2 10-14 torr time-of-flight, programmable data integration time

Retarding Potential Analyzers 3 ram flux plasma diagnostics, 2 wake side Langmuir probe

3-axis Accelerometers 3 1g-10-6g

Wake side video camera Compressed video interleaved with telemetry stream

The WSF as a Versatile Space Platform

As a free-flying platform, the WSF's wake side -- the ultra-clean side -- is used exclusively for ultra-pure thin film growth. The ram side -- the relatively dirty side -- of the 12 ft.-diameter WSF, however, can be used to accommodate other experiments and space technology applications. The ram side has a significant area of high quality "real estate" in the form of the outer shield -- more than 65 sq. ft. -- which can be applied to the support of other space payloads. The ram side contains four payload attach points, each capable of accommodating 200 pounds of experiment hardware.

In addition, since the WSF is mounted horizontally in the Shuttle payload bay, it was obvious early-on that the open volume of the Shuttle payload bay below the WSF could be used effectively by mounting additional payload canisters on the SCBC. The SCBC has power and data capabilities which were extended to the payload canisters, thus prompting their name -- "Smart Cans." The "Smart Cans," based on the NASA Goddard Space Flight Center Get Away Special Canisters (GAS cans), also provide the opportunity for other payloads to fly with the WSF (however, staying inside the Shuttle payload bay during the mission).

What is Epitaxial Thin Film Growth?

Epitaxial thin film growth is an approach to reducing the defects in semiconductor materials, such as GaAs, through the growth of new material on a substrate in a vacuum. In epitaxial growth, atomic or molecular beams of a material, such as arsenic (As) and gallium (Ga), formed in a vacuum are exposed to a prepared surface -- or substrate. The substrate is an atomic template, or pattern, upon which the atoms form thin films. The atoms grow in layers which follow the crystal structure pattern of the substrate. A thin film of new materials then grows on top of the substrate in an atom-by-atom layer, atomic layer-by-atomic layer manner to form a "wafer" with an ultra-high purity top region. This growth technique is defined as Molecular Beam Epitaxy (MBE), and has been used as a laboratory technique for studies in new thin film electronic materials for the past 20 years. It has been shown during this time that the vacuum environment within which the materials are grown is critical to the quality of the thin film grown.

The WSF has the capability of growing epitaxial thin films on seven different substrate wafers. GaAs will be the materials system grown on the WSF-1 flight, with each specific wafer growth tuned for unique thin film parameters. There will be at least one "thick" GaAs film grown (

9 micrometers) for the characterization of ultimate defect densities. In addition, there will be several films grown to exhibit high electron mobility in GaAs and films grown to support the Earth- based fabrication of field effect transistors. Finally, there will be a GaAs film grown by Chemical Beam Epitaxy (CBE) through the use of arsenic (As) and an organometallic compound containing gallium (Ga). The near-infinite vacuum pumping speed of the WSF ultra-vacuum environment should allow for the extremely rapid removal of the residual organic species found during CBE growth, and hence should greatly improve the quality of the grown GaAs film.

Cooperative Experiments

The University of Toronto Institute for Aerospace Studies (UTIAS) will also be performing exposure experiments aboard WSF-1 as a follow-up to its Long Duration Exposure Facility (LDEF) studies.

A NASA CCDS, the Center for Materials for Space Structure (CMSS), based at Case Western Reserve University, Cleveland, Ohio, is conducting an experiment to test different materials and coatings in space to determine how they degrade in the space environment. The experiment is known as MatLab-1, for Materials Laboratory-1. Industrial contributors to the MatLab- 1 experiment include Westinghouse-Hanford, Martin Marietta, TRW, Rosemount, 3M, Dow Corning and McDonnell Douglas. Supporting government organizations include NASA Lewis Research Center and the Jet Propulsion Laboratory.

The MatLab-1 will be on the Materials Flight EXperiment (MFLEX) carrier mounted on the front of the WSF (ram side). Each experiment is considered "active," i.e., the material has an electronic sensor attached to it, which is placed into a tray connected to the electronics equipment. The MFLEX will scan the sensors and relay the information back to Earth via the WSF communications link. Material scientists on Earth can monitor the experiments in real-time and determine the performance of each material and coating interaction with the space environment.

The MatLab-1 experiment will test many materials in the actual environment in which they would be used to ensure "expected" performance. The materials will be tested for thermal cycling, strain, micro-debris, atomic oxygen erosion and its scattering effects, and the effects of ultra-violet rays. These materials may then be used in the construction of products for the space environment.

For example, the materials needed to build a rocket, satellite or space station must meet stringent requirements in weight and durability, given the harsh environment of space. Testing materials onboard the MatLab-1 experiment provides advance information to government and corporate planners about how some materials react in space. In order to reduce launch costs based on a spacecraft's weight, researchers are looking for lighter-weight materials that have the strength to survive a launch into space. Also, they are looking for durable, long- lasting materials that can withstand a lengthy stay in space to reduce replacement costs of valuable assets -- like a satellite that could orbit the Earth for 30 years instead of deteriorating sooner, requiring a new satellite to take its place.

The Geophysics Directorate at the U.S. Air Force Phillips Laboratory located at Hanscom Air Force Base (30 miles NW of Boston, Mass.), working with SVEC, studies the flow fields of charged particles in the Wake Shield's vicinity. AFGL will fly the Charging Hazards and Wake Studies (CHAWS) experiment on the WSF Free Flyer. The general purpose of the experiment is to increase understanding of the interactions of the space environment with space systems and the hazards such interactions pose. The improved understanding of spacecraft environmental interactions derived from CHAWS results will enhance both the commercial and military utilization of space. For instance, CHAWS results may lead to the design and operation of higher powered satellites in orbit.

The two specific goals of the CHAWS experiment are 1) to measure the ambient, low-energy population of positively- charged particles on both the front and back of the WSF, and 2) to study the magnitude and directionality of the current collected by a negatively-charged object in the plasma wake as a function of the ambient-charged particle density and the orientation of the WSF and the Shuttle. The CHAWS experiment data are crucial to achieving part of the primary mission goal of characterizing the neutral and charged particle wake created by WSF-1.

The CHAWS experiment consists of two sensor units and a controller. At the heart of each sensor unit are a series of newly developed, state-of-the-art, compact particle detectors able to measure a wide range of charged particle densities down to low densities previously difficult or impossible to measure. In the spirit of the WSF program, the STS-60 mission will provide the first flight test of this new technology.

The most intensive portion of the CHAWS experiment will be conducted after WSF recapture. With the WSF held by the Shuttle "arm," the Shuttle attitude will be varied with respect to the direction of orbital motion so that the full wake can be mapped by varying the sensor's location in the wake region. In addition, measurement will be made of any optical emissions produced near the sensor during high voltage activities. These measurements will be the first ever made in space of the current collected by a negatively-charged object in the wake of a space structure in low Earth orbit.

Working with NASA Johnson Space Center (JSC) engineers, SVEC is offering the WSF as a testbed for the development of highly sensitive accelerometers, called the Microgravity Measurement Devices (MMD). Accelerometers measure low levels of acceleration by a vehicle in space. Specifically on WSF-1, the accelerometers will characterize the microgravity environment of the WSF Free Flyer. Given the largely passive thin film growth process, the WSF Free Flyer promises to be a "true" microgravity platform, ideal for any number of future materials processing chores. The MMD will be the linchpin for another joint experiment between SVEC and JSC: an ambitious Shuttle Plume Impingement Experiment (PIE) in support of space station development. A critical concern to space station planners is the complex interaction between Shuttle attitude control thruster firings and nearby space structures; however, little information exists in this area. The WSF Free Flyer, loaded with environmental diagnostic equipment, is the ideal target for this study, as a cost-effective means to multiply benefits to differing program goals. A complex and extensive series of thruster firings have been planned to use the WSF's response to measure the characteristics of the Shuttle's thruster plumes.

Two "Smart Cans" will be attached to the WSF's SCBC on this flight to conduct a Containerless Coating Process (CONCOP-1) experiment. The United States Army Construction Engineering Research Laboratory (CERL) in Champaign, Ill., will be using the "Smart Cans" for an investigation of hot filament thin film metals deposition on a variety of materials. The results will give researchers information about applying reflective coatings to space structures while in space. While the Free Flyer is ahead the Shuttle, the crew will activate the CERL experiment for follow-on operations controlled through the payload operations center.

Two student experiments will be a part of WSF-1. "Fast Plants" will be coordinated by Hartman Middle School, Houston, Texas, to study the effects of space radiation on plants' generation. Brassica rapa plants supplied by the University of Wisconsin will be exposed to the entire spectrum of radiation from space while Velcro-mounted to the SCBC.

Brassica rapa's rapid growth rate of 38 days per generation will allow numerous generations to be studied during a single school year following the WSF-1 flight. Six Houston Independent School District middle schools will be involved in the experiment.

Students will not only grow plants and gather data, but will become proficient at controlling variables while learning how to conduct a long-term experiment. Data will be compiled for the purpose of writing and submitting a paper to a scientific publication, rounding out a rich educational experience.

Ninth grade students at the Gregory Jarvis Junior High School, Mohawk, N.Y., will be determining the orbital variation of the Earth's magnetic field from electron diffraction data obtained in the WSF thin film growth experiments. The electron beam used for in situ diffraction measurement of the atomic structure of the growing GaAs films is deflected by the Earth's magnetic field. This deflection can be used to define the magnitude and direction of the Earth's magnetic field as a function of orbital position. The junior high school students will work with SVEC researchers in applying elementary physical laws to directly extract Earth magnetic field information from the WSF data.

Mission Scenario

The Wake Shield Facility will be released from Discovery to fly free for about 48 hours, gathering its experiment information before it is retrieved by the Shuttle. Once it is retrieved, the facility will remain captured at the end of Discovery's remote manipulator system (RMS) mechanical arm overnight, for a total of about 17 hours, to gather further data before it is berthed in the cargo bay for the return to Earth.

Release

On Flight Day 3, the WSF will be grappled by the Shuttle "arm" and removed from the SCBC. The WSF will be positioned by the "arm" to be "cleaned" by the highly reactive atomic oxygen found in low Earth orbit and by the sun's heat. The "cleaning" will last 3 hours. Some tests will be run during this "cleaning," such as radio checks between the SCBC and the Free Flyer, checks of the Free Flyer batteries, and activation of the primary video camera on the wake side of the Free Flyer.

Three successive approximately 45-minute long windows exist for deploying the facility on the third day of STS-60, as well as backup opportunities later in the mission. During the release operations, Commander Charlie Bolden will be at the aft flight deck controls of Discovery, Mission Specialist Jan Davis will operate the mechanical arm, and Mission Specialist Ron Sega will oversee the Wake Shield Facility's systems and experiments. Mission Specialist Franklin Chang-Diaz will use a hand-held laser range-finding device as well as a similar device mounted in Discovery's cargo bay to provide information on the distance and separation rate of the facility. The data supplement information provided by the

Shuttle's rendezvous radar system. Mission Specialist Franklin Chang-Diaz will document the events with still photography, video and film.

After the "cleaning" is done, the "arm" will move the WSF to a position that will allow the formation of a vacuum wake ahead the WSF. There will be approximately one hour of vacuum measurements and checkouts in this position. Then the arm will move the WSF to the release position, over the starboard (right) side of the Shuttle payload bay. The Free Flyer will separate from the arm and move ahead the Shuttle to remove it from Shuttle contamination sources (i.e., water dumps, fuel cell purges and engine firings). The astronauts will fire a thruster if necessary to keep the WSF safely ahead the Shuttle while they are sleeping.

The WSF will stay 40 nautical miles ahead the Shuttle while growing the thin films. The WSF will be operated during this time from the Payload Operations Control Center (POCC) at the NASA Johnson Space Center. The SVEC POCC team will monitor and control all aspects of WSF operations in close cooperation with the astronaut crew.

Rendezvous

On Flight Day 5, the Shuttle will rendezvous with the Free Flyer. Every member of the STS-60 crew has a vital role to play during the WSF rendezvous and capture and the integral plume experiment. Charles Bolden, Commander, and Kenneth Reightler, Pilot, will pilot Discovery through a complex series of maneuvers in approaching the WSF.

The retrieval of the Wake Shield Facility will begin with an engine firing by Discovery that will have the Shuttle leave its stationkeeping position 40 nautical miles ahead to close in on a point about 8 nautical miles behind the facility. Over the next three hours, as Discovery closes in on a point 8 nautical miles ahead the Wake Shield Facility, the Shuttle's navigation will be continually refined as will tracking information on the facility itself. The final engine firing performed will be calculated by the Shuttle's onboard navigation systems, rather than by ground controllers. At a distance of 8 nautical miles ahead the facility, Mission Specialist Sergei Krikalev will power up the mechanical arm and move it into position for the impending capture, and Discovery will fire its engines to perform a terminal interception (TI) burn, a firing that will put the Shuttle on a course directly for the facility. The Shuttle may perform four small course correction firings during its final approach before Bolden takes over manual control of Discovery's flight as the Shuttle passes less than one nautical mile below the facility.

Shuttle Plume Impingement Tests

Ron Sega and Sergei Krikalev will coordinate the plume experiment initiation and data acquisition. Franklin Chang-Diaz will track the WSF position by video and Jan Davis will prepare the Shuttle "arm" for WSF capture.

Bolden and Reightler will brake Discovery's approach to the Wake Shield Facility, eventually flying to about 400 feet directly in front of the facility. At that point, Bolden and Reightler will begin an almost four-hour long series of maneuvers that will have Discovery perform precise steering jet firings at various angles to the Wake Shield Facility. The jet firings comprise a plume impingement test that will help characterize the behavior of the exhaust emitted by Discovery's jets. With its contamination-sensitive experiments already completed at that time, the Wake Shield's instruments can measure the makeup of the exhaust plume, accelerations the plumes cause, and the pressures of the exhaust. During the tests, Bolden will fly Discovery from in front of the facility to pass above and ahead it. The jet firings will be performed in front of the Wake Shield at ranges of 400 feet, 300 feet and 200 feet, and from ahead the facility at a range of 200 feet. Information from these tests will be valuable in planning future retrievals and dockings by the Shuttle with other spacecraft in a method that avoids contaminating or significantly disturbing those spacecraft with the exhaust plumes.

Retrieval

The final approach to within capture range of the Wake Shield Facility will be done from ahead it, with Bolden moving Discovery to within 35 feet of the Free-Flyer. Krikalev will then capture the Wake Shield using the mechanical arm. Krikalev will then place the arm in a parked position with the Wake Shield held above the payload bay during the astronaut sleep period for extended WSF environmental measurement.

On Flight Day 6, the CHAWS experiment will be performed. The astronauts will position the WSF to the point above the overhead windows for maneuvering of the WSF to gather plasma flow data around the WSF. The Air Force Auroral Photography Experiment B (APE-B) camera will be used in support of the plasma flow studies to view the Shuttle glow phenomenon on the CHAWS plasma probe from the Shuttle's aft flight deck windows. Plasma flow data will be acquired for two full orbits, after which the WSF will be re-stowed into the SCBC for return to Earth.

Future Plans for the WSF Program

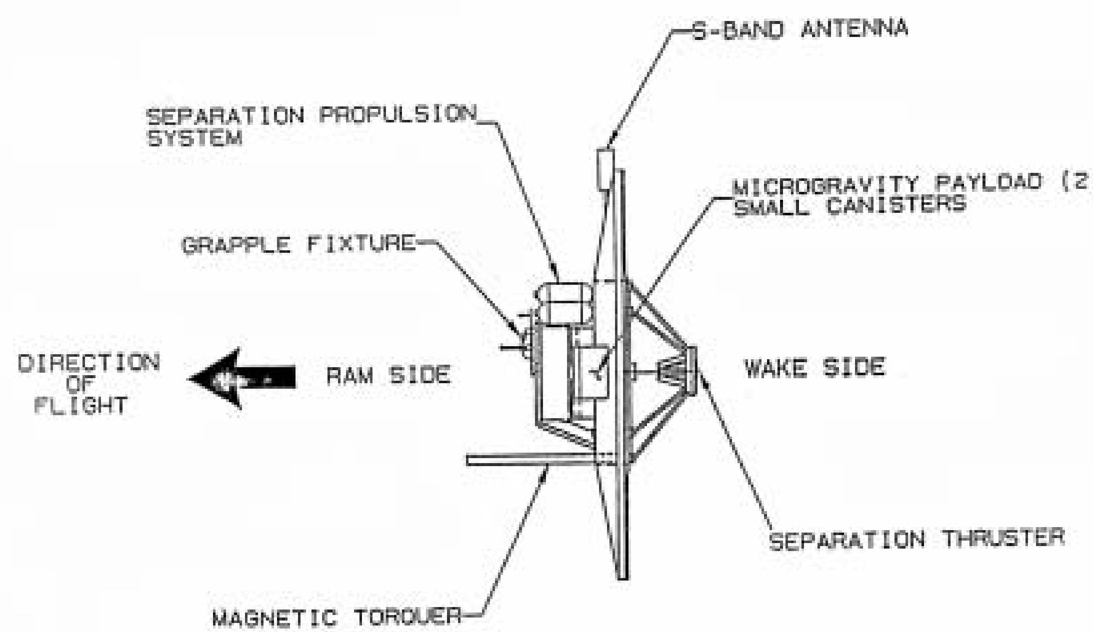
The WSF Program consists of four flights basically flying at one year intervals. During the four flights, the WSF program first will provide the "proof-of-concept" demonstration of thin film growth in space techniques required for industry to fully embrace the space epitaxial growth technology. Second, it will demonstrate the ability to grow commercial quantities of epitaxial thin films in space. To accomplish these goals, the WSF Program is designed to evolve with the WSF-2 flight (1995) expected to show increased capability in number and types of thin films grown, and in command and control of the growth process through ground operations from a commercial payload command and control center (POCC). WSF-3 (1996) is expected to see the addition of solar panels, additional central processing power, and robotic substrate sample manipulation for extended orbital operations. WSF-4 (1997) is expected to have the capability of processing up to 300 epitaxial thin film wafers.

Beyond the first "proof-of-concept" flights of WSF, full commercial use of the WSF is projected. The commercial phase of the program is being termed "Mark II" -- a 5-year orbiting WSF free flyer. Because the weight of the Free Flyer is 4,000 lb., it would not be economically realistic to launch and retrieve the complete WSF for every batch of thin film wafers grown (about 300 wafers per batch). It is clearly more suitable to launch only the raw materials and bring back only the finished wafers, leaving the WSF in space. Therefore, the "Mark II" would be launched into orbit and then be periodically visited by a dedicated service vehicle that would replenish the raw materials and bring back the finished wafers.

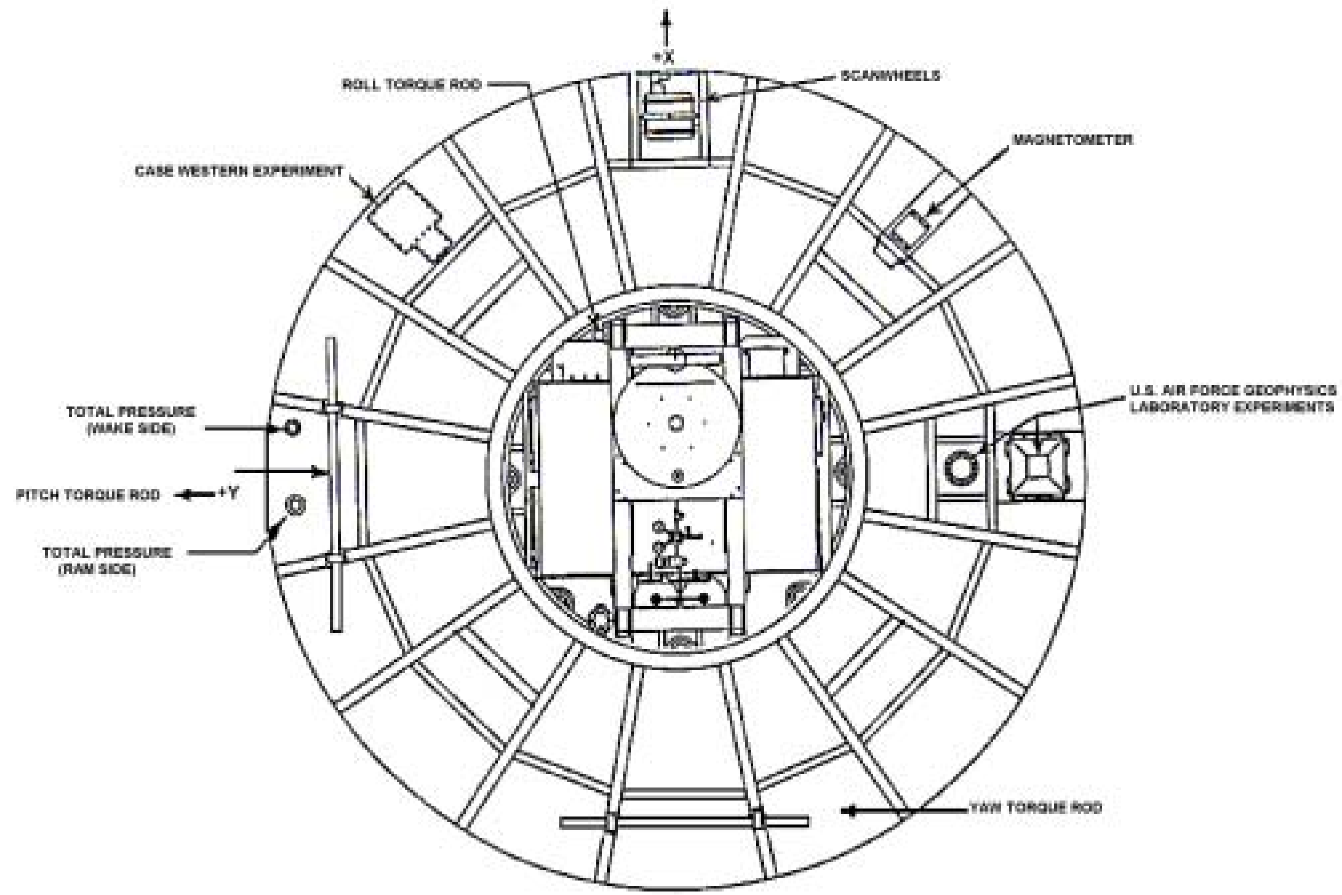
Conclusion

The accomplishment of the objectives of WSF-1 and the three subsequent WSF missions is expected to prove the theory that electronic materials grown in space are of higher quality. The electronics industry's need for high-speed optical and high frequency devices will continue to drive electronics material development and improvement. The ever-increasing use of electronic materials worldwide and the ability to grow them in thin film form in space are expected to give commercial viability to the use of the space "ultra-vacuum" to produce improved and advanced electronic materials.

Space Vacuum Epitaxy Center
University of Houston
NASA Center for the Commercial Development of Space

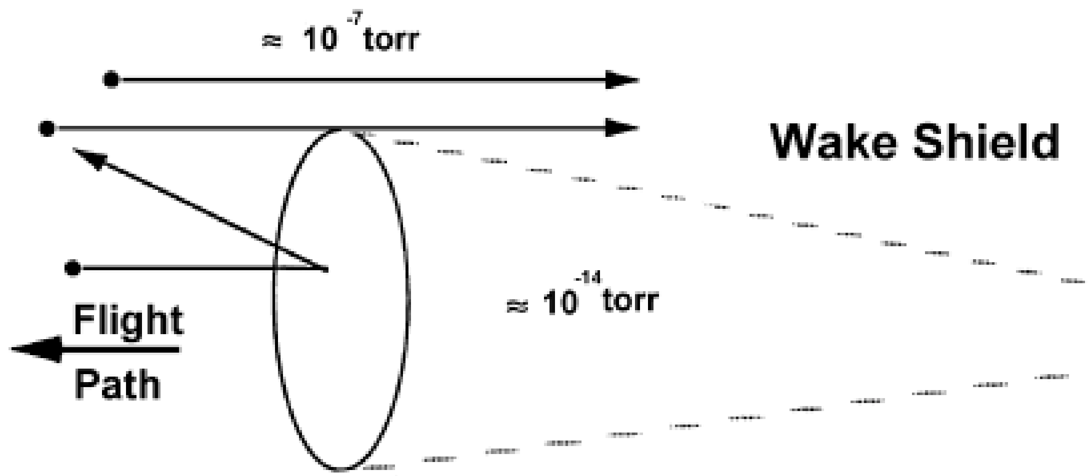


Space Vacuum Epitaxy Center
University of Houston
NASA Center for the Commercial Development of Space



Space Vacuum Epitaxy Center
University of Houston
NASA Center for the Commercial Development of Space

Ultra-Vacuum in Space for thin Film Growth



Wake Shield Facility-1 (WSF-1 Overview)

Facility	Sponsor	Affiliates	Facility Description	Potential Commercial Applications
Wake Shield Facility (WSF)	Space Vacuum Epitaxy Center, University of Houston, Houston, Texas	Space Industries, Inc., League City, Texas; American X-tal; Technology, Dublin, Calif.; AT&T Bell Labs, Murray Hill, N.J.; Instruments, S.A. Inc., Edison, N.J.; Ionwerks, Houston, Texas; Quantum Controls, Houston, Texas; Schmidt Instruments, Inc., Houston Texas	Sensitive vacuum measurement devices aboard the WSDF Free Flyer will characterize the "ultra-vacuum" generated by the 12-foot diameter stainless steel disk. Gallium Arsenide (GaAs) thin films will be grown using Molecular Beam Epitaxy (MBE) and Chemical Beam Epitaxy (CBE) to demonstrate the advantages of material processing in the space vacuum environment	The use of improved GaAs thin film material in electronic components holds a very promising economic advantage. The commercial applications for high quality GaAs devices are most critical in the consumer technology areas of: • Digital cellular telephones • High-speed transistors and processors • High-definition television (HDTV) • Fiber optic communications & • opto-electronics

WSF-1 Experiments

Facility	Sponsor	Affiliates	Facility Description	Potential Commercial Applications
Charging Hazards and Wake Studies (CHAWS)	Space Vacuum Epitaxy Center, University of Houston, Houston, Texas	United States Air Force Philips Laboratory/Geophysics Directorate, Hanscom Air Force Base, Mass.	CHAWS will measure the charged particle environment in the vicinity of the WSF to complete analysis of the wake's "ultra-vacuum" and investigate the behavior of exposed high potentials in a plasma wake.	This experiment will demonstrate the operation of a unique miniaturized plasma detector and provide data to validate Air Force analytical model for spacecraft charging.
Microgravity Measurement Device (MMD)	SVEC, UH	NASA Johnson Space Center (JSC)	JSC will use the WSF as a testbed for the development of highly sensitive accelerometers (MMD) which measure low levels of acceleration by a vehicle in space, specifically the microgravity environment of the WSF Free Flyer.	To support the WSF in commercial operations as a free flying space platform.
Plume Impingement Experiment (PIE)	SVEC, UH	NASA JSC	A complex and extensive series of Shuttle thruster firings will target the WSF during rendezvous, relying on Free Flyer instrumentation to characterize the Shuttle's thruster plumes.	To provide information to space station planners on the complex interaction between Shuttle thruster firings and space structures such as the space station).

WSF-1 Collaborative Experiments

Facility	Sponsor	Affiliates	Facility Description	Potential Commercial Applications
Materials Laboratory-1 -- MatLab-1	Center for Materials for Space Structure (CMSS), Case Western Reserve University, Cleveland, OH	Westinghouse-Hanford, Martin Marietta, TRW, Rosemount, 3M, Dow Corning, McDonnell Douglas, NASA Lewis Research Center, Jet Propulsion Laboratory	The MFLEX (Materials Flight Experiment carrier) will carry the MatLab, housing different materials and coatings on the front of the WSF to determine how they hold up in the space environment.	The results will help to determine which materials to use in construction of products for the space environment (*e.g.*, rockets, satellites, space station), based on the material's qualities (*i.e.*, durable, light-weight).
Containerless Coating Process (CONCOP-1)	United States Army Construction Engineering Research laboratory (CERL), Champaign, Ill.		An investigation of hot filament thin film metals deposition on a variety of materials, conducted in the "Smart Cans" mounted on the Shuttle Cross Bay Carrier (SCBC).	The results will give researchers information about applying metallic and reflective coatings to space structures while in space.

SPACEHAB-2

Evolution of the SPACEHAB Program

The commercial development of space is a NASA objective as directed by legislation and national policy. Through the many facets of its commercial development of space program, NASA has developed and maintains a high level of commitment to this objective. To that end, NASA has actively invested in the continued technological leadership of the United States and its future economic growth through the direct promotion and support of private sector space-related activities.

In the late 1980's, NASA's commercial development of space program identified a significant number of payloads to be flown to further program objectives. To viably sustain this program, the Office of Advanced Concepts and Technology identified a level of flight activity necessary to support the various payload requirements. In September 1989, the office conducted an analysis which revealed that planned Space Shuttle flight activity would not meet middeck-class accommodations needs. Mission experience had already demonstrated the middeck as a very cost-effective area to conduct "crew-tended" scientific and commercial microgravity research. However, the size and number of experiments that can be accommodated in the middeck is severely limited, has conflicting requirements from Shuttle operations and other NASA programs, and is being further constrained by a number of factors such as reduced flight rates.

In order to provide the necessary support for commercial development of space payloads, the Commercial Middeck Augmentation Module (CMAM) procurement was initiated in February 1990, through the Johnson Space Center (JSC). Subsequently, in November 1990, NASA awarded a 5-year contract to SPACEHAB, Inc., of Arlington, Va., for the lease of their pressurized module, the SPACEHAB Space Research Laboratory. This unit provides additional space for "crew-tended" payloads as an extension of the Shuttle orbiter middeck into the Shuttle cargo bay.

This 6-year lease arrangement covers five Shuttle flights and requires SPACEHAB, Inc., to provide for the physical and operational integration of the SPACEHAB Space Research Laboratory into Space Shuttle orbiters, including experiments and integration services, such as safety documentation and crew training.

NASA's primary objective for leasing the SPACEHAB Space Research Laboratory is to support the agency's commercial development of space program by providing access to space to test, demonstrate or evaluate techniques or processes in the environment of space, and thereby reduce operational risks to a level appropriate for commercial development.

NASA's secondary objective in leasing the SPACEHAB Laboratory is to foster the development of space infrastructure which can be marketed by private firms to support commercial microgravity research payloads. It is expected that commercial demand will result from successful demonstrations of SPACEHAB.

The first, and very successful, flight of the SPACEHAB Space Research Laboratory was made on Space Shuttle Mission STS-57, June 21-27, 1993. All systems operated nominally and met 100% of mission success criteria. The 21 NASA-sponsored experiments achieved over 90% of mission success criteria and detailed analyses are underway.

SPACEHAB Laboratory Accommodations

The SPACEHAB Space Research Laboratory is located in the forward end of the Shuttle orbiter cargo bay and is accessed from the orbiter middeck through a tunnel adapter connected to the airlock. It weighs 10,584 pounds, is 9.2 feet long, 11.2 feet high and 13.5 feet in diameter. It increases pressurized experiment space in the Shuttle orbiter by 1100 cubic feet, quadrupling the working and storage volume available. Environmental control of the laboratory's interior maintains ambient temperatures between 65 and 80 degrees Fahrenheit.

The laboratory has a total payload capacity of 3,000 pounds based on operational constraints and, in addition to facilitating crew access, provides the experiments with standard services, such as power, temperature control and command/data functions. Other services, such as late access/early retrieval and vacuum venting also are available.

The SPACEHAB Space Research Laboratory can provide various physical accommodations to users based on size, weight and other user requirements. Experiments are commonly integrated into the laboratory in Shuttle middeck-type lockers or SPACEHAB racks. The laboratory can accommodate up to 61 lockers, with each locker providing a maximum capacity of 60 pounds and 2.0 cubic feet of volume.

The laboratory can also accommodate up to two SPACEHAB racks, either of which can be a "double-rack" or "single-rack" configuration. A "double-rack" provides a maximum capacity of 1250 pounds and 45 cubic feet of volume, whereas a "single-rack" provides half of that capacity. The "double- rack" is similar in size and design to the racks planned for use in the space station.

The use of lockers or racks is not essential for integration into the SPACEHAB Laboratory. Payloads also can be accommodated by directly mounting them in the Laboratory.

Operations Philosophy of the SPACEHAB Program

In order to help keep development costs within levels appropriate to entrepreneurial enterprises, the Office of Advanced Concepts and Technology's (OACT) flight programs accept a certain level of risk in order to approach the payloads from the commercial standpoint, including payload development costs incurred by industry partners. Each of the investigators is aware of and accepts a self-established level of risk for mission success. However, crew and orbiter safety requirements are always fully met.

Some of the payloads associated with this SPACELAB flight are physically located in the orbiter middeck. The middeck space that makes this possible is made available by accommodating in the SPACEHAB module other items such as supplies that are normally stowed in the middeck. This operational approach best provides for the late installation and early retrieval of payloads with time critical requirements such as perishable samples. These payloads remain in the middeck throughout the flight in order to reduce the use of critical on-orbit crew time in moving materials from one location to another. The actual relocation of payloads on- orbit would also introduce undesirable operational risks.

The preparations for the flight of SPACEHAB-2 have included the development of a number of backup and contingency operations for each payload appropriate to that payload's relative design simplicity. These backup procedures include scenarios which might possibly affect crew or orbiter safety, and each payload has procedures associated with it that will deactivate and/or safe the payload. Shuttle crew members are trained in the use of these procedures.

The SPACEHAB-2 Payload Complement

The second voyage of the SPACEHAB Space Research Laboratory will contain 12 payloads conducted under the CMAM contract. Like SPACEHAB-1, SPACEHAB-2 payloads represent a wide range of space experimentation including 9 commercial development of space experiments in materials processing and biotechnology, sponsored by five NASA Centers for the Commercial Development of Space (CCDS). There are also three supporting hardware and technology development payloads, one from a CCDS, one from the Lewis Research Center, and one from the Johnson Space Center. One non-NASA experiment is also on this flight. It is attached to the exterior of the module and will collect cosmic dust and debris.

SPACEHAB-2 will carry seven biotechnology experiments. These experiments range from improving drugs to feeding plants, from splitting cells to studying the immune system disorders. Two materials processing experiments use furnaces to study sintering of metals and the growth of crystals by vapor transport. The third concentration of experiments is in supporting hardware, with two payloads designed to obtain data on the low-gravity environment of this SPACEHAB flight, to support data analysis of the other investigations, and to further characterize SPACEHAB as a carrier for microgravity experiments.

The 12th payload will provide a test and demonstration of technology developed by NASA to support space flight activities with refrigerator/freezer capability requirements such as life sciences and biotechnology.

Each of the commercial development of space payloads has been screened by the NASA Office of Advanced Concepts and Technology (OACT) to review the viability of the commercial aspects of the proposed activity as well as the technical soundness. Most of the SPACEHAB-2 payloads have flown on the Shuttle before, with this flight representing the continuation of industry-driven research toward a new or improved commercial end product or process. Some of the CCDS payloads, including the CCDS-sponsored accelerometer, have participated in the NASA OACT Consort series of suborbital sounding rocket flights to test hardware operation and gain flight worthiness.

NASA Centers for the Commercial Development of Space

The Centers for the Commercial Development of Space (CCDS) program is the cornerstone of NASA's commercial development of space activities, generating 10 of the total of 12 flight hardware packages for which NASA is leasing services on the flight of SPACEHAB-2. NASA's nationwide CCDS network represents a unique example of how government, industry and academic institutions can create partnerships that combine resources and talents to strengthen America's industrial competitiveness. The CCDSs are designed to increase private sector participation and investment in commercial space-related activities, while encouraging U.S. economic leadership and stimulating advances in promising areas of research and development. The CCDSs are based at universities and research institutions across the country and benefit from links with their industrial partners, each other and with NASA field centers.

The CCDSs foster industry-driven, space-based, high- technology research in areas such as: materials processing, biotechnology, remote sensing, communications, automation and robotics, and space power.

NASA OACT provides annual funding of up to $1 million to each center, with additional funding to those centers to cover specific programs or flight activities, as appropriate. NASA offers the CCDSs its scientific and technical expertise through NASA field centers, opportunities for cooperative activities and other forms of continuing assistance. A key facet of the CCDSs is the additional financial and in-kind contributions and capabilities from industry affiliates, state and other government agencies, which, on the average, exceed the NASA funding level.

Through creative and enterprising partnerships with industry, the CCDS program helps move emerging technologies from the laboratory to the marketplace with speed and efficiency. The accomplishments of CCDS participants include significant advances in a number of scientific fields and hundreds of Earth- and space-based applications. As an incubator for future commercial space industries, the CCDS program, since its inception, has facilitated a number of new commercial space ventures and supported a wide range of ongoing efforts.

The CCDS program continues to be the key facilitator for U.S. industry involvement in commercial development of space activities, encouraging and supporting new and ongoing space- related ventures, as well as spawning research and development advancements that promise enormous social and economic benefits for all.

Equipment for Controlled Liquid Phase Sintering Experiments

The Consortium for Materials Development in Space (CMDS) based at the University of Alabama in Huntsville (UAH) has developed the Equipment for Controlled Liquid Phase Sintering Experiments (ECLiPSE). Wyle Laboratories supported the development of ECLiPSE which flew successfully on STS-57 SPACEHAB-01. This furnace was developed in a very rapid and cost-effective manner. ECLiPSE is now available as space- qualified hardware and is a key part of this nation's commercial space infrastructure.

On STS-60, the SPACEHAB-2 ECLiPSE experiment investigates the Liquid Phase Sintering (LPS) of metallic systems. Sintering is a well-characterized process by which metallic powders are consolidated into a metal at temperatures only 50% of that required to melt all of the constituent phases. In LPS, a liquid coexists with the solid, which can produce sedimentation, thus producing materials that lack homogeneity and dimensional stability. To control sedimentation effects, manufacturers limit the volume of the liquid. The ECLiPSE experiment examines metallic composites at or above the liquid volume limit to more fully understand the processes taking place and to produce materials that are dimensionally stable and homogeneous in the absence of gravity.

The ECLiPSE project is focused on composites of hard metals in a tough metal matrix. This composite will have the excellent wearing properties of the hard material and the strength of the tough material. Applications of such a composite include stronger, lighter, more durable metals for bearings, cutting tools, electrical brushes, contact points and irregularly shaped mechanical parts for high stress environments. Kennametal, Inc., is an industry partner of the UAH CMDS participating in the ECLiPSE experiment and has immediate applications for material improvements in the ceramic composites tested. Kennametal, one of the nation's largest cutting tool manufacturers, is developing stronger, more durable tool bits and cutting edges. Other industry partners on the ECLiPSE project are Wyle Laboratories, Automatic Switch Company, Parker Hannifin Corporation, and Machined Ceramics.

Preparation of the ECLiPSE payload begins with the compaction of two or more metal powders under high pressure (11.2 tons/sq. in.) to form a composite. Once compacted, the composites are cleaned and installed into the ECLiPSE high temperature furnace for flight. A Wyle Laboratories-designed Universal Small Experiment Container (USEC) will house the furnace assembly within the SPACEHAB Space Research Laboratory rack. In operation, the ECLiPSE payload is first evacuated, pressurized with argon gas and switched on by the crew. The furnace then autonomously heats to a temperature in excess of 2000{F, which is above the melting point of one of the metals in the composite samples. The samples then undergo the rearrangement and solution re-precipitation stages of LPS. The hardware performs purge, heat-up, processing, quench and cool down cycles. The total time for all operations is slightly more than 10 hours.

ECLiPSE is mounted in a SPACEHAB single rack. During on- orbit operations, a crew member monitors the indicators on the front of the payload to show the health of the hardware and progress of the experiment through the operating cycles. Once the unit has completed all cycles, a crew member connects a Payload General Support Computer (PGSC) to the ECLiPSE, downloads the data stored inside the ECLiPSE process control computer and then shuts down the experiment. The Shuttle flight of the ECLiPSE payload is building on the experience of other ECLiPSE flights on suborbital rockets. Suborbital flights have provided 1-3 minutes of sample processing time and now the longer flight durations possible on the Shuttle are required. Because the hardware was originally designed to fly in suborbital rockets, it is very automated, requiring little crew interaction.

Principal Investigator for ECLiPSE is Dr. James E. Smith Jr., Associate Professor and Chairman, Department of Chemical and Materials Engineering, The University of Alabama in Huntsville.

Space Experiment Furnace

The Space Experiment Facility (SEF) is a space flight furnace system managed by the Consortium for Materials Development in Space (CMDS) based at the University of Alabama in Huntsville (UAH). The SEF was manufactured by Boeing Commercial Space Development Company, Seattle, WA, and is similar to Boeing's Crystals by Vapor Transport Experiment (CVTE) furnace which flew in October 1992 on STS-52.

The initial objective of the SEF project was to provide a vapor transport crystal growth furnace for use by the CCDSs. The SEF system has the capability to carry one, two or three separate furnaces at one time and has room for two samples in each furnace, for a total of up to six samples. The CVTE was designed as a middeck facility while the SEF has been adapted for flight in the SPACEHAB Space Research Laboratory and is mounted in a SPACEHAB single rack. This is the first flight of the SEF.

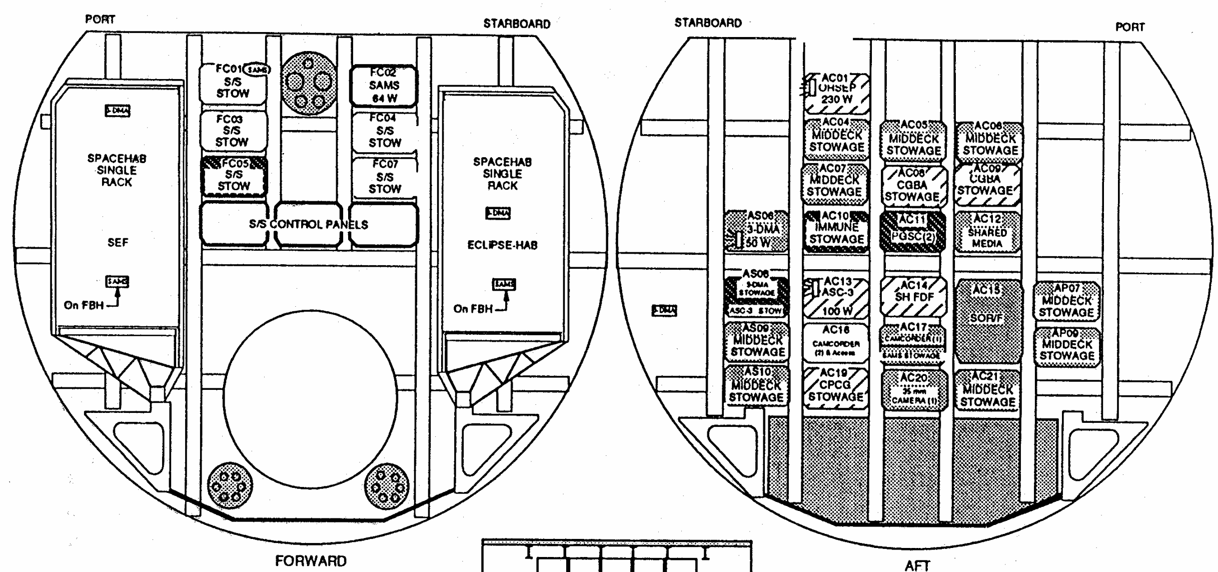
The SEF has two transparent furnaces available for operations at various temperatures up to approximately 800 degrees C, but only one of these will be flown and used aboard SPACEHAB-2. The third furnace has an opaque core design that allows it to reach temperatures up to 1080<C to satisfy higher temperature requirements.

The SEF differs from UAH's other furnace, ECLiPSE, in several ways. First, the SEF can process different types of crystals, notably crystals grown from vapor. Second, the furnace will process the samples in transparent ampoules that can be monitored by the crew and adjusted to optimize crystal growth. Third, the sample ampoules can be translated within the furnace to control the applied temperature gradients. And, fourth, while the opaque furnace can be used for metal and alloy processes, such as liquid metal sintering, it can provide temperature gradients as compared to the isothermal characteristics of ECLiPSE. Thus, although the original CVTE furnace was designed to process crystals, SEF operations are not being restricted to crystal growth. For instance, on SPACEHAB-2, UAH will be using the opaque core for its Sintered and Alloyed Materials project. The Consortium for Commercial Crystal Growth at Clarkson University, another CCDS, will use a transparent furnace for growth of Cadmium Telluride crystals using vapor transport techniques.

The industry affiliates involved in designing, fabricating, and integrating the SEF for SPACEHAB-2 flight are: Boeing Commercial Space Development Company, Seattle, WA; McDonnell Douglas Aerospace - Huntsville, Huntsville, AL; and Wyle Laboratories, Huntsville, AL.

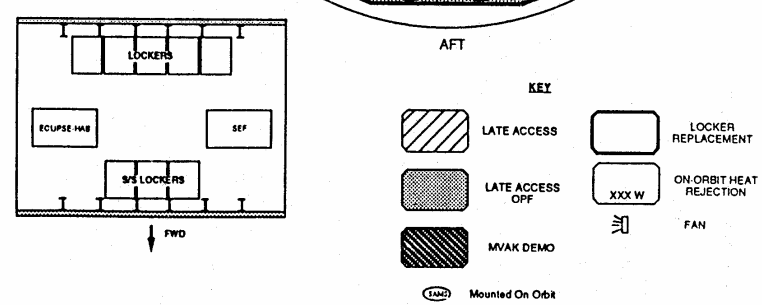
The Principal Investigator for the UAH/CMDS Sintered and Alloyed Materials project which will use the opaque core furnace in the SEF for SPACEHAB-2 is Dr. James E. Smith Jr., Associate Professor and Chairman, Department of Chemical and Materials Engineering, The University of Alabama in Huntsville. Dr. Smith is also the P.I. of the ECLiPSE furnace experiment which will be flying on SPACEHAB-2. The Principal Investigator for the Clarkson-sponsored Cadmium Telluride activity is Professor Herbert Wiedemeier of Rensselaer Polytechnic Institute.

SPACEHAB 02 MODULE LAYOUT



NOTE: The following are located in Orbiter middeck:
- CPCG(2)
- CGBA(3)
- PSB
- IMMUNE(2)
- BPL

SRE is located on top of the module



ASTROCULTURE™

The ASTROCULTURE™ payload is sponsored by the Wisconsin Center for Space Automation and Robotics (WCSAR), a NASA Center for the Commercial Development of Space (CCDS), located at the University of Wisconsin in Madison.

Extended space ventures that involve human presence will require safe and reliable life support at a reasonable cost. Plants play a vital role in the life support system we have here on Earth. Likewise, we can expect that plants will be a critically important part of a life support system in space because they can be a source of food while providing a means of purifying air and water for humans. Currently, no satisfactory plant-growing unit is available to support long-term plant growth in space. Several industry affiliates including Automated Agriculture Assoc., Inc., Dodgeville, WI; Biotronics Technologies, Inc., Waukesha, WI; Orbital Technologies Corp., Madison, WI; and Quantum Devices, Inc., Barneveld, WI, together with WCSAR have embarked on a cooperative program to develop the technologies needed for growing plants in a space environment.

The objective of the ASTROCULTURE™ (ASC) series of flight experiments is to validate the performance of plant growth technologies in the microgravity environment of space. Each of the flight experiments will involve the incremental addition of important subsystems required to provide the necessary environmental control for plant growth. The flight hardware is based on commercially available components, thereby significantly reducing the cost of the hardware. The information from these flight experiments will become the basis for developing large scale plant growing units required in a life support system. In addition, these technologies will also have extensive uses on Earth, such as improved dehumidification/humidification units, water-efficient irrigation systems, and energy-efficient lighting systems for plant growth.

The ASC-1 flight experiment, conducted during the USML-1 mission on STS-50, evaluated the WCSAR concept for providing water and nutrients to plants. The ASC-2 flight experiment, conducted during the SPACEHAB-01 mission on STS-57, provided additional data on the water and nutrient delivery concept, plus an evaluation of the light emitting diode (LED) based plant lighting concept. Results from both these flight experiments indicate that all the goals were achieved and confirmed the validity of these concepts for use in space-based plant growing unit.

The ASTROCULTURE™ (ASC-3) flight experiment included in the SPACEHAB-2 mission is designed to validate a WCSAR developed concept for controlling temperature and humidity in a closed air loop of the plant growth chamber. This unit is capable of both humidifying and dehumidifying the air and does not require a gas/liquid separator for recovery of the condensed water as do all other systems now being used for dehumidification in space. This condensed water can be used as a source of cooking and drinking water. Demonstration of the successful performance in space of this humidity and temperature control technology will represent a major advance in our ability to provide superior environmental control for plant growth in an inexpensive and reliable space flight package.

The flight hardware for this mission is accommodated in a SPACEHAB locker located in the module and weighs approximately 50 pounds. The ASC-3 flight unit includes the water and nutrient delivery unit, the LED-based plant lighting unit, the temperature and humidity control unit, and a microprocessor unit for control and data acquisition functions. These subsystems, or units, provide essentially all the environmental regulation needed for plant growth. It is expected that the next ASC flight experiment beyond SPACEHAB-2 will include plants as a test of the operational effectiveness of the units to support plant growth.

The Principal Investigator on ASTROCULTURE™ is Dr. Raymond J. Bula, WCSAR.

Penn State Biomodule

The Penn State Biomodule (PSB) payload will test the hypothesis that exposure to near zero gravity (microgravity) can alter microbial gene expression in commercially useful ways. The payload was developed by the Center for Cell Research (CCR), a NASA CCDS based at The Pennsylvania State University, and its commercial partner, Novo Nordisk Entotech, Inc. Novo Nordisk Entotech, Inc., is located in Davis, California, and is part of Denmark-based Novo Nordisk A/S, a global company with diverse business anchored primarily in biotechnology, serving the health care, industrial and agricultural sectors.

Novo Nordisk Entotech develops bioinsecticides, naturally occurring microbes that produce products that are toxic to certain insects, but are non-toxic to non-target pests, people and the environment. The company is interested in determining if exposure to microgravity can enhance microbial expression, altering the growth, toxin production and potency of these environmentally friendly pest-control agents.

The microbes scheduled to be tested aboard STS-60, Bacillus thuringiensis var. tenebrionis, are known to be specifically effective against the Colorado potato beetle. They will be carried in the Penn State Biomodule which is being used for the first time aboard the Shuttle. The biomodule is a computer-controlled, fluid-transfer, mixing device developed by the Center for Cell Research. It was flight tested and developed aboard the Consort sounding rocket series.

Eight Biomodules, each containing eight microbial samples, will be housed in a sealed containment vessel within a Commercial Refrigeration/Incubation Module (CRIM) located in the middeck. The containment vessel was also designed and developed by the Center for Cell Research in conjunction with Commercial Payloads, Inc., of St. Louis, MO.

In its STS-60 configuration, the Biomodule needs no hands- on attention from the astronauts. The device automatically provides dynamic temperature regulation, three levels of liquid containment and the ability to add two different fluids to each sample at different time intervals during the spaceflight.

To accelerate postflight data analyses, the CCR has developed a gel encapsulation procedure for bacteria that enables quick, efficient, automated, identification of microbes that display altered patterns of gene expression. In this technique, individual bacteria are trapped inside tiny (30 micron) gel beads. Using fluorescent markers and a flow cytometer, the researchers can quantify bacterial growth and product formation within each individual bead. In this way, altered bacteria that over- or under-produce insect toxins can be quickly identified, isolated and cultured as part of the postflight analysis.

CCR scientific affiliates Dr. Zane Smilowitz, Penn State professor of entomology, and Dr. William McCarthy, Penn State associate professor of entomology, are co-principal investigators. Penn State graduate student Bryan Severyn, an M.S. candidate in entomology, is assisting them. Dr. Chi-Li Liu, Manager of Microbiology, is Entotech's representative. Dr. William W. Wilfinger is CCR Director of Physiological Testing and principal investigator on the gel encapsulation project. Dr. W. C. Hymer is Director of the Center for Cell Research. Dr. Pamela Marrone is President of Novo Nordisk Entotech, Inc.

BioServe Pilot Laboratory

The BioServe Pilot Laboratory (BPL) is sponsored by BioServe Space Technologies, a NASA Center for the Commercial Development of Space (CCDS) based at the University of Colorado in Boulder.

The BPL will play an important role in providing the commercial and scientific communities affordable access to space for material and life sciences research. The main focus of the project is to provide a "first step" opportunity to companies interested in exploring materials processing and life science experiments in space. The notion ahead the project is to allow industry a mechanism for entry level "proof of concept" flights. Thus, the BPL is a crucial screening device for more complex, targeted space research and development activities.

The BPL payload has been designed to support investigations in a wide variety of life sciences areas with primary emphasis on cellular studies. Following a successful flight on STS-57 SPACEHAB-01, this second BPL flight on SPACEHAB-2 consists of investigations on bacterial products and processes.

One investigation examines Rhizobium trifolii behavior in microgravity. Rhizobia are special bacteria that form a symbiotic relationship with certain plants. The bacteria infect the plants early in seedling development to form nodules on the plant roots. The bacteria in these nodules derive nutritional support from the plant while in turn providing the plant with nitrogen fixed from the air. Plants that form such relationships with rhizobia are called legumes and include alfalfa, clover and soybean. Such plants do not require synthetic fertilizers to grow. In contrast, many important crop plants such as wheat and corn are dependent on synthetic fertilizers since they do not form symbiotic relationships with rhizobia.

The experimental system employing Rhizobium trifolii is a model that can be used to better understand the multi-step process associated with rhizobia infection of legumes. Once understood, it may become possible to manipulate the process to cause infection of other crop plants. The potential savings in fertilizer production would be tremendous.

One of the commercial goals of the BioServe Center is to determine whether microgravity might be exploited as a tool for rhizobial infection of significant crop plants. This BPL investigation along with complementary investigations in BioServe's Commercial Generic Bioprocessing Apparatus (CGBA) also flying in the SPACEHAB Space Research Laboratory should provide data needed to address this goal.

Another investigation being flown in the BPL concerns bacteria.

E. coli. These bacteria are normally found in the gastrointestinal tracts of mammals, including humans. E. coli have been well studied as a model system for bacterial infection and population dynamics and in genetics research. With regard to commercial application, the genetic material in E. coli has been manipulated to produce bacteria capable of secreting important pharmaceutical products. These bacteria also serve as a model for bacteria used in waste treatment and water reclamation.

For STS-60, these bacteria are being studied to determine changes in growth and behavior that occur as a consequence of exposure to microgravity. The commercial objectives for this investigation include understanding and controlling bacterial infection in closed environments, exploiting bacteria and other micro-organisms in the development of ecological life support systems and waste management, and determining the opportunity for enhanced genetic engineering and enhanced pharmaceutical production using bacterial systems.

Yet another BPL investigation examines a biomedical test model based on cells derived from frog kidney. This investigation is intended to provide insight into effects of microgravity on cell behavior -- especially cell division. Gravitational effects on such cell systems may be used as models of diseases or disorders that occur on Earth. For STS- 60, the kidney cell system is being examined to determine feasibility for use as such a test model.

On STS-60, the BPL will consist of 40 Bioprocessing Modules (BPMs) stowed in a standard middeck locker. The BPMs will contain the biological sample materials. The stowage locker will also contain an Ambient Temperature Recorder (ATR) which will provide a temperature history of the payload throughout the mission.

Each BPM consists of three syringes held together on an aluminum tray. Generally, the center syringe in each BPM will be loaded with the cell culture system. Adjacent syringes will contain process initiation and termination fluids, respectively. A three-way valve is mounted on the trays which permits fluid transfer from one syringe to the next. The syringes, valve tubing and fittings provide for containment of the sample materials. The hardware is further enclosed in heat-sealed plastic bags to provide additional levels of containment.

Some of the BPMs will be fitted with a special filter at the front of the center syringe. This filter allows fluids, but not cells, to pass in and out of the center syringe. With these special BPMs, products secreted by the cells under study can be separated from the cells on orbit and preserved, without the need for a fixative that would damage the secreted products.

Approximately 26 hours after reaching orbit, a crew member will initiate the various investigations within the BPMs. Typically, this is done by removing each BPM from stowage, turning the three-way valve and pushing a syringe plunger to transfer the initiation solution into the center syringe.

The BPMs will be terminated at predetermined time points throughout the mission. Similar to initiation, the three-way valve is turned and the plunger on the center syringe is pushed to transfer cell materials into the termination solution. In some instances, only part of the contents of the center syringe will be transferred. This will effectively produce two samples for analysis, one that is terminated and another that continues to develop during the balance of operations.

For most of the investigations, simultaneous ground controls will be run. Using similar hardware and identical sample fluids, ground personnel will activate and terminate BPMs in parallel with the flight crew. Synchronization will be accomplished based on voice downlink from the crew. Ground controls will be conducted at the SPACEHAB Payload Processing Facility at Cape Canaveral, Fla.

After the orbiter has landed, the stowage locker containing the BPMs will be turned over to BioServe personnel for deintegration. Some sample processing will be performed at the landing site. However, most BPMs will be shipped or hand- carried back to the sponsoring laboratories for detailed analysis.

Dr. Marvin Luttges, Director of the BioServe CCDS, is Program Manager. Drs. Louis Stodieck and Michael Robinson, also of BioServe, are responsible for mission management.

Commercial Generic Bioprocessing Apparatus

The Commercial Generic Bioprocessing Apparatus (CGBA) payload is sponsored by BioServe Space Technologies, a NASA Center for the Commercial Development of Space (CCDS), located at the University of Colorado, Boulder. The purpose of the CGBA is to allow a wide variety of sophisticated biomaterials, life sciences and biotechnology investigations to be performed in one device in the low gravity environment of space.

During the STS-60 mission, the CGBA will support 32 separate commercial investigations, which can be classified in three application areas: biomedical testing and drug development, controlled ecological life support system (CELSS) development and agricultural development and manufacture of biological-based materials. These areas and investigations are shown in the following three tables.

Biomedical Testing and Drug Development -- To collect information on how microgravity affects biological organisms, the CGBA will include twelve biomedical test models. Of the twelve test models, four are related to immune disorders: one will investigate the process in which certain cells engulf and destroy foreign materials (phagocytosis); another will study bone marrow cell cultures; two others will study the ability of the immune system to respond to infectious-type materials (lymphocyte and T-cell induction); and one will investigate the ability of immune cells to kill infectious cells (TNF-Mediated Cytotoxicity).

The other eight test models -- Which are related to bone and developmental disorders, toxicological wound healing, cancer and cellular disorders -- will investigate bone tissue, miniature wasp development testing, brine shrimp development, inhibition of cell division processes, stimulation of cell division processes and the ability of protein channels to pass materials through cell membranes.
Test model results will provide information to better understand diseases and disorders that affect human health, including cancer, osteoporosis and AIDS. In the future, these models may be used for the development and testing of new drugs to treat these diseases.

Closed Agricultural Systems Development -- To gain knowledge on how microgravity affects micro-organisms, small animal systems, algae and higher plant life, the CGBA will include 11 ecological test systems. One of the test systems will examine miniature wasp development. Five separate studies will concern seed germination and seedling processes related to CELSS development. Another four test systems will investigate bacterial products and processes and bacterial colonies for waste management applications. Finally, another system will study new materials to control build-up of unwanted bacteria and other micro-organisms.

Test system results will provide research information with many commercial applications. For example, evaluating higher plant growth in microgravity could lead to new commercial opportunities in controlled agriculture applications. Test systems that alter micro-organisms or animal cells to produce important pharmaceuticals could later be returned to Earth for large-scale production. Similarly, it may be possible to manipulate agricultural materials to produce valuable seed stocks.

Biomaterials Products and Processes -- The CGBA also will be used to investigate nine different biomaterials products and processes. Two investigations will attempt to grow large protein and RNA crystals to yield information for use in commercial drug development. A third investigation will evaluate the assembly of virus shells for use in a commercially-developed drug delivery system. Two other investigations will use fibrin clot materials and collagen as a model of potentially implantable materials that could be developed commercially as replacements for skin, tendons, blood vessels and even cornea. Three investigations will focus on drug development. One will be using plant tissue cultures to create the anti-cancer drug taxol. The second will be looking at the bacteria E. coli and its resistance to drugs in microgravity. The third investigation will be looking at yeast reproduction as a drug production process.

Results from the 32 investigations will be carefully considered in determining subsequent steps toward commercialization. STS-60 marks the fourth of six CGBA flights. Future flights will continue to focus on selecting and developing investigations that show the greatest commercial potential.

The CGBA consists of 432 Fluids Processing Apparatuses (FPAs) packaged in 54 Group Activation Packs (GAPs). Each GAP will house eight FPAs. The FPAs will contain biological sample materials which are mixed on-orbit to begin and end an experiment. Individual experiments will use two to 24 FPAs each. 192 FPAs in 24 GAPs will be stored in the SPACEHAB Space Research Laboratory in two standard stowage lockers; these samples are less time critical than the others with regard to installation or retrieval. 240 FPAs in 30 GAPs will be stored on the middeck of the orbiter in 3 standard stowage lockers or locker equivalents. 144 FPAs will be kept at a temperature of 37{C throughout the mission, while 288 FPAs will be kept at ambient temperature. Those lockers containing FPA at ambient temperature will also contain ambient temperature records (ATRs) which will provide a temperature history of the payload throughout the mission.

Fluids Processing Apparatus (FPA) -- Sample materials are contained inside a glass barrel that has rubber stoppers to separate three chambers. For each investigation, the chambers will contain precursor, initiation and termination fluids, respectively. The loaded glass barrel will be assembled into a plastic sheath that protects the glass from breakage and serves as a second level of sample fluid containment.

The FPAs are operated by a plunger mechanism that will be depressed on-orbit, causing the chambers of precursor fluid and the stoppers to move forward inside the glass barrel. When a specific stopper reaches an indentation in the glass barrel, initiation fluid from the second chamber is injected into the first chamber, activating the biological process.

Once processing is complete, the plunger will again be depressed until the termination fluid in the third chamber is injected across the bypass in the glass barrel into the first chamber.
Group Activation Packs (GAP) -- The GAP consists of a 4- inch diameter plastic cylinder and two aluminum endcaps. Eight FPAs will be contained around the inside circumference of the GAP cylinder. A crank mechanism extends into one end of the GAP and attaches to a metal pressure plate. By rotating the crank, the plate will advance and depress the eight FPA plungers simultaneously, significantly facilitating crew handling of the FPAs.

Upon reaching orbit, the crew will initiate the various investigations by attaching a crank handle to each GAP. Turning the crank will cause an internal plate to advance and push the plungers on the contained FPAs. This action, in turn, causes the fluids in the forward chambers of each FPA to mix. Most of the GAPs will be activated on the second flight day.

The crew will terminate the investigations in a manner similar to activation. Attaching and turning the GAP crank will cause further depression of the FPA plungers which will cause the fluid in the rear chamber to mix with the processed biological materials. This fluid will typically stop the process or "fix" the sample for return to Earth in a preserved state. Each of the 54 GAPs will be terminated at different time points during the mission. In this manner, sample materials can be processed from as little as one hour to nearly the whole mission duration.

For most of the investigations, simultaneous ground controls will be run. Using identical hardware and samples fluids and materials, ground personnel will activate and terminate FPAs in parallel with the flight crew. Synchronization will be accomplished based on indications from the crew as to when specific GAPs are operated. A temperature- controlled environment at the SPACEHAB Payload Processing Facility (SPPF), Cape Canaveral, Fla., will be used to duplicate flight conditions.

After the orbiter has landed, the stowage lockers will be retrieved and turned over to BioServe personnel for deintegration. Some sample processing will be performed at the SPPF; however, most FPAs will be shipped or hand-carried back to the sponsoring laboratories for detailed analysis.

Dr. Marvin Luttges, Director of the BioServe CCDS, is program manager for CGBA. Drs. Louis Stodieck and Michael Robinson, also of BioServe, are responsible for mission management.

SPACEHAB-2 COMMERCIAL GENERIC BIOPROCESSING APPARATUS INVESTIGATIONS
Biomedical Testing and Drug Development

These investigations will provide information to develop a better understanding of diseases and disorders that affect human health including cancer, osteoporosis and AIDS. These models may be used for the development and testing of new drugs to treat these diseases.

Commercial Opportunity	PI Affiliation	Process/Product Development	Experiment Description
Immune Disorders	University of Alabama, Huntsville	Lymphocyte Induction Process	Examines immune system's ability to respond to infectious-type materials.
	Kansas State University	T-Cell Induction Test	Examines immune system's ability to respond to infectious-type materials.
		TNF-Mediated Cytotoxicity Test Model	Examines immune cell's ability to kill infectious cells.
		Bone Marrow Cell Culture Test System	Studies bone marrow cultures in microgravity.
Bone Disorders	Kansas State University	Bone Organ Culture Test Model	Studies the effects of microgravity on bone development.
Development Disorders	Kansas State University	Pancreas and Lung Development Tests	Examines organ development in microgravity.
		Brine Shrimp Test System	Examines brine shrimp development in microgravity.
Cancer	Kansas State University	Inhibitor Protein Test Model	Studies inhibition of cell division processes.
Cellular Disorders	Kansas State University	Gap Junction Processes	Investigates ability of protein channels to pass materials through cell membranes.
	University of Colorado	Cell Division Processes	Studies stimulation of cell division processes
Toxicological Testing	Kansas State University	Brine Shrimp test System Model	Examines ability of brine shrimp to be used for toxicity tests.
	University of Colorado	Miniature Wasp Test System Model	Examines ability of miniature wasps to be used for toxicity tests

ECOLOGICAL TEST SYSTEMS

These investigations could lead to new commercial opportunities in controlled agriculture applications, large scale production on Earth of important pharmaceuticals, and production of valuable seed stocks by manipulation of agricultural materials.

Commercial Opportunity	PI Affiliation	Process/Product Development	Experiment Description
Closed Agriculture Systems	University of Colorado	Seed Germination Products	Studies seed germination in microgravity
	Kansas State University	Seedling Processes	Examines seeding processes in microgravity.
	University of Colorado	Miniature Wasp Test System	Investigates miniature wasp development in microgravity.
	Kansas State University	Bacterial Nitrogen Fixation Model	Studies important symbiotic relationships between bacteria and plants.
	University of Colorado	Plant Tissue Culture Processes	Studies secondary metabolic production during spaceflight.
	University of Colorado	Plant Bacterial Infection Processes	Studies important symbiotic relationships between bacteria and plants
Waste Management	University of Colorado	Bacterial products and Processes	Studies bacterial products and processes in microgravity.
	Kansas State University	Bacterial Products and Processes	Studies bacterial products and process I microgravity.
	Kansas State University	Bacterial Products and Processes	Studies important symbiotic relationships between bacteria and plants.
	University of Colorado	Bacterial Colony Test System	Studies bacterial colony products and processes in microgravity.
Microbial Controls	Kansas State University	Zirconium Peroxide product Testing	Examines effectiveness of Zirconium Peroxide as a decontaminant.

BIOMATERIALS PRODUCTS AND PROCESSES

Potential applications of these investigations include commercial drug development and a drug delivery system, and the development of potentially implantable materials used commercially as replacements for skin, tendons, blood vessels and cornea.

Commercial Opportunity	PI Affiliation	Process/Product Development	Experiment Description
Drug Delivery System	Kansas State University	Virus Capsid Product	Evaluates assembly of virus shells.
Drug Development	University of Colorado	Protein Crystal Morphology Products	Growth of large protein crystals.
		RNA Crystal Growth Products	Growth of large RNA crystals.
Data mass Storage	Syracuse University	Bacteriorhodopsin Biomatrix Products	Formation of more homogeneous bacteriorhodopsin gels for use as mass data storage devices.
Synthetic Implants	University of Colorado	Fibrin Clot Materials	Use of fibran clot materials as a model of potentially implantable materials.
		Collagen Materials	Use of collagen as a model of potentially implantable materials.
Pharmaceutical Development	University of Colorado	Taxol Culture Model	Investigates the production of taxol in microgravity.
Drug Development	University of Colorado	Bacterial Drug Resistance	Investigates the effects of microgravity on drug resistance.
		Yeast Reproduction	Investigates the use of yeast as drug producers.

SPACEHAB-2 COMMERCIAL BIOTECHNOLOGY EXPERIMENTS OVERVIEW

Experiment	Sponsor	Affiliates	Experiment Description	Potential Commercial Applications
ASTROCULTURE ™	Wisconsin Center for Space Automation and Robotics, Madison, Wis. (CCDS)	Automated Agriculture Asssoc., Inc.; Biotronics Technologies, Inc.; Quantum Devices, Inc.; Orbital Technologies Corp.	Validates technologies for supplying water and nutrients to plants growing in microgravity and providing a controlled environment.	Development of an enclosed environmental system with earth-based and space-based uses, including improved dehumidification/humidification and energy efficient lighting.
Penn State Biomodule	Center for Cell Research (CCR), St. College, Pa. (CCDSW)	Novo Nordisk Entotech, Inc.	The Biomodule is a computer-controlled, fluid-transfer, mixing device. The microbes studied in the Biomodule are specifically effective on the Colorado Potato Beetle.	Improvement of environmentally friendly pest-control agents.
BioServe Pilot Laboratory (BPL)	BioServe space Technologies, Boulder Colorado (CCDS)	Abbott Labs, Alza, Aquatic Products, Chiron, Martin Marietta, Spaceport Florida Authority, Synchrocell	Determines the response of cells to various hormones and stimulating agents in microgravity.	Development of next-generation drugs and space-grown polymers.
Commercial Generic Bioprocessing Apparatus (CGBA)	BioServe space Technologies, Boulder Colorado (CCDS)	Abbott Labs, Alza, Aquatic Products, Chiron, Martin Marietta, OmniData, Spaceport Florida Authority, Synchrocell, Water Technologies	Processes biological fluids by mixing components in a microgravity environment.	Improvement of bio-implantable products, immune disease research and water management systems.
IMMUNE	BioServe Space Technologies, Boulder, Colorado (CCDS)	Chiron Corporation	The IMMUNE-1 experiment is a study of 12 rats. The drug PEG-IL2 will be used in an attempt to alleviate the immunosuppression induced by the environment.	The experiment may provide a new therapy to treat the effects of spaceflight on the human immune system, as well as on physiological systems effected by the immune system.
Organic Separation (ORSEP)	Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)	Interfacial Dynamics Corp., Space Hardware Optimization Technology, Inc.	Explores the use of phase separation techniques in microgravity conditions to separate cells, cell fragments and heavy molecules.	Improvement of techniques for processing pharmaceutical and biotechnology products.
Commercial Protein Crystal Growth (CPCG)	Center for Macromolecular Crystallography, Birmingham, Ala. (CCDS)	Medical Foundation of Buffalo	Growth of high quality protein crystals in microgravity using temperature as the primary controlling factor in crystallization; one of the two systems flying uses laser light scattering techniques to monitor crystallization for enhanced control	Acceleration or enabling of drug research and development using or requiring crystallography to determine molecular structure.

SPACEHAB-2 SUPPORTING HARDWARE OVERVIEW

<table>
<tr><th>Hardware</th><th>Sponsor</th><th>Hardware Operation</th><th>Potential Applications</th></tr>
<tr><td>3-Dimensional Microgravity Accelerometer (3-DMA)</td><td>Consortium for Materials Development in Space, Huntsville, Ala. (CCDS)</td><td rowspan="2">Measures accelerations in three axes within the SPACEHAB to record the microgravity levels experienced during the flight.</td><td rowspan="2">Characterization of low-gravity environment of the SPACEHAB Space Research Laboratory, and the acquisition of acceleration data to support experiment data analysis.

Two different systems are flown to satisfy different program objectives and to correlate the data obtained by the two systems. This also allows the comparison of such data with that gathered on other flights where only one or the other system has flown.</td></tr>
<tr><td>Space Acceleration Measurement System (SAMS</td><td>NASA Lewis Research Center, Cleveland, OH</td></tr>
</table>

SPACEHAB-2 TECHNOLOGY DEVELOPMENT OVERVIEW

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

SPACEHAB-2 COMMERCIAL MATERIALS PROCESSING EXPERIMENTS OVERVIEW

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

IMMUNE-1

The IMMUNE-1 experiment is a middeck payload sponsored by BioServe Space Technologies. BioServe is a NASA Center for the Commercial Development of Space (CCDS) at the University of Colorado, Boulder, and Kansas State University, Manhattan. The corporate affiliate leading the IMMUNE-1 investigation is Chiron Corporation, Emeryville, Calif., with NASA's Ames Research Center, Mountain View, Calif., providing payload and mission integration support.

The goal of IMMUNE-1 is to reduce or prevent the changes seen in the immune system of rats after space flight. The experiment may provide a new therapy to treat the effects of space flight on the human immune system, as well as on physiological systems affected by the immune system.

Hardware for the IMMUNE-1 experiment consists of two Commercial Animal Enclosure Modules (CAEMs). The CAEM is a copy of the Animal Enclosure Module (AEM) developed by the Ames Research Center. The CAEM provides life support for the rats.

IMMUNE-1 is the second experiment to use the CAEM in support of activities to develop the commercial uses of space. (The first was the Physiological Systems Experiment, conducted with the Center for Cell Research, another NASA CCDS.) The AEM has a considerable successful flight history in support of other NASA investigations.

Each of the two CAEMs in the Shuttle's middeck area will hold six rats. Six of the rats will be treated pre-flight with a prescribed dosage of a compound similar to the commercially available recombinant Interleukin-2, which is known to stimulate the immune system. The compound used in IMMUNE-1 -- polyethylene glycol-modified recombinant human Interleukin-2 (PEG-IL-2) -- is longer-lasting than recombinant Interleukin-2. It will be used in an attempt to reduce or prevent the suppression of the immune system seen in rats flown in space. The other six rats will receive a placebo.

The rats will live in an environment similar to that of the astronauts in terms of launch stress, length of exposure to microgravity, and the forces of Shuttle re-entry and recovery. These conditions are known to result in a suppression of the immune system similar to "shipping fever" in cattle. The utility of PEG-IL-2 in preventing spaceflight-induced effects on the immune system may lead to its use as a therapeutic treatment for shipping fever in animals on Earth.

The longer-lasting PEG-IL-2 probably will be useful in clinical settings in which patients could receive less frequent injections, perhaps once a week instead of up to three times a day, as is necessary with recombinant IL-2. The development of recombinant IL-2 for treatment of some human cancers is still being investigated, although it is licensed for high-dose therapy of kidney cancer in humans.

Based on recent experimental findings, PEG-IL-2 (and recombinant IL-2) appears to have potential as an antiviral, as well as an antibacterial, agent. As such, PEG-IL-2 may become a part of a therapy used to treat various opportunistic infections associated with AIDS and other non-AIDS related infectious diseases.

It also may become part of a standard treatment for the nation's aging population, because aging individuals demonstrate decreased levels of Interleukin-2. The PEG-IL-2 treatment could accompany flu shots to bolster the immune system of the elderly. These important applications present exciting commercial opportunities for Chiron Corp.

The science team will be led by principal investigator Dr. Robert Zimmerman of Chiron Corp. Co-principal investigators are Drs. Marvin Luttges and Keith Chapes of BioServe and Dr. Gerald Sonnenfield of the Carolinas Medical Center, Charlotte, N.C. Other investigators include Drs. Richard Gerren, Steven Simske and Louis Stodieck, BioServe; Ed Miller, Harrington Cancer Center/Texas Tech University, Amarillo, Texas; and Jason Armstrong and Mary Fleet, BioServe.

Organic Separations

The Consortium for Materials Development in Space (CMDS) based at the University of Alabama in Huntsville has developed the Organic Separations (ORSEP) payload for flight on STS-60.

ORSEP offers the commercial and scientific communities the opportunity to separate cells and particles based on their surface properties using a process known as counter current phase partitioning. Such separations cannot be carried to equilibrium on Earth because sedimentation influences the separation before partitioning equilibrium can be established. It is hoped that equilibrium separations will produce subpopulations with nearly identical surface properties rather than with some contamination of surface and density that is presently the case with Earth-based users. The potential commercial value of separations includes the opportunity to identify subpopulations, to study the purified samples and to culture cell subpopulations for cell product.

The ORSEP hardware was built by Space Hardware Optimization Technology (SHOT), Inc. Floyd Knobs, Ind. It is considerably lower cost than existing phase partitioning devices, and SHOT may be able to capture a good portion of the commercial market on Earth. The hardware is a modular design which can be configured for use with Shuttle middeck, Spacelab, the SPACEHAB Space Research Laboratory, and sounding rockets. On this flight, ORSEP will be accommodated in a standard-sized locker located in the module.

It is a multi-sample, multi-step, fully automated device that separates non-biological particles, as well as biological cells, particles, macromolecular assemblies and organelles in low gravity via partitioning in liquid polymer two-phase systems. The hardware has been designed to perform partitioning in microgravity for a long duration because two to three hours are required for each separation step. Commercial interests were factored into the hardware design in its multi- sample capability that offers temperature control and sterility. On STS-60, the SPACEHAB Space Research Laboratory makes available continuous power, which allows for constant heating/cooling for the experiment while the vacuum of space provides thermal insulation. As a result of these design features, four samples can be processed through 12 steps while being held at selected temperatures in a sterile environment.

The samples that will be processed on STS-60 in the ORSEP apparatus include growth hormone vesicles supplied by the Penn State Center for Cell Research along with inert particles for equilibration and diagnostics. On STS-60, a new use for the ORSEP hardware as a low-gravity cell culturing facility will be demonstrated. The ability of the ORSEP hardware to mix a culture medium with various activators and fixture agents in a controlled manner offers several unique advantages over other flight-qualified cell culturing hardware. Lymphocytes and bone-marrow cells will be provided by Dr. Marian Lewis at UAH. ORSEP has flown on 9 prior Shuttle missions and two suborbital flights as a part of its development. The UAH CMDS plans to continue development of ORSEP on additional suborbital rocket flights and SPACEHAB missions.

ORSEP is designed to be capable of fully-automated operations but it relies on crew interaction to maximize its results. Full function digital display and interaction controls allow the crew to monitor and control the vacuum which will modify the temperature of the experiment. The crew can also control both the initiation and operation of the four experiments which provide for potential variations in mission operations. The next planned generation of ORSEP is to be designed for use on space station. New samples in sterile cassette devices will be launched in the Shuttle.

The principal investigator of ORSEP is Dr. Robert J. Naumann, University of Alabama in Huntsville.

Commercial Protein Crystal Growth

The Center for Macromolecular Crystallography (CMC), based at the University of Alabama in Birmingham (UAB), is sponsoring Commercial Protein Crystal Growth (CPCG) experiments on STS-60. The CMC is a NASA Center for the Commercial Development of Space (CCDS), which forms a bridge between NASA and private industry to stimulate biotechnology research for growing protein crystals in space and offers other protein crystallography services to a wide range of pharmaceutical, chemical and biotechnology companies.

The objective of space-based protein crystal growth experiments on STS-60 SPACEHAB-2 is to produce large, well- ordered crystals of various proteins. These crystals are to be used in ground-based studies to determine the three-dimensional structures of the proteins. These experiments also continue to investigate how to control and optimize protein crystal growth in order to reduce uncertainties or risks associated with using this space-based process as a vital and enabling technology for many critical areas. The SPACEHAB-01 protein crystal growth experiments were extremely successful. Three of the seven proteins flown produced superior data when compared to the very best crystals ever obtained by Earth-grown methods using any other method of crystallization.

The technique most-widely used to determine a protein's three-dimensional structure is X-Ray crystallography, which requires large, well-ordered crystals for analysis. Crystals produced on Earth often are large enough to study, but they usually have numerous gravity-induced flaws. However, space-produced crystals tend to have more highly-ordered structures that significantly facilitate X-Ray diffraction studies.

Since proteins play an important role in everyday life -- from providing nourishment to fighting diseases -- research in this area is quickly becoming a viable commercial industry. Scientists need large, well-ordered crystals to study the structure of a protein and to learn how its structure determines a protein's functions.

Studies of such crystals not only can provide information on basic biological processes, but they may lead to the development of food with higher protein content, the production of highly resistant crops and, of great importance, the development of more effective drugs. By studying the growth rates of crystals under different conditions, scientists can find ways to improve crystal growth in microgravity, thus providing higher-quality crystals for study and the ability to produce satisfactory protein crystals that are hard or impossible to grow on Earth. For these reasons, the CMC will have conducted protein crystal growth experiments on 19 Shuttle missions after completion of STS-60.

The CPCG experiments are contained in two thermal control enclosures called Commercial Refrigerator/Incubator Modules (CRIM) both located in the middeck. Each CRIM contains a Protein Crystallization Facility (PCF), and one has been modified with a light scattering (LS) system and is called PCFLS.

The PCF has been successful in inducing crystallization of human insulin by lowering the temperature of one end of a cylindrical crystallization chamber from 40{C to 22{C over a period of 24 hours. Since the rest of the chamber takes time to match the temperature of the controlled end, the crystals are formed within a temperature gradient.

The light scattering system is designed to detect crystals at the nucleation stage, before they would be visible by ordinary microscopy. The information is to be used to alert the astronauts of initial crystal formation. After they know that crystals have formed they will decrease the rate at which the temperature of the controlled end is changing. This will allow the crystals that have formed to grow more slowly and more perfectly in the weightlessness of space.

The light scattering system consists of a laser beam from a laser diode delivered into the sample chamber and a photo detector viewing the beam from an angle of 30{. As the protein molecules begin to collect into small nuclei, they become larger, hence more efficient, scattering particles, and the laser beam becomes brighter. This principle is demonstrated when large dust particles appear brighter than small ones in a sunbeam shining through a household window. The increased brightness is seen by the detector, and the information is sent to a Macintosh Powerbook computer. This information is graphed on the screen of the Powerbook for the astronauts to view and react to.

The computer evaluates the scattering information and has an alarm that alerts the astronauts of crystal formation, but the astronauts must still evaluate the scattering curve to confirm that nucleation has actually occurred before modifying the rate of temperature change. Human insulin is the protein to be crystallized in this flight of the PCFLS system.

Due to each protein's short lifetime and the crystals' resulting instability, the protein crystal growth experiments will be retrieved within 3 hours of the Shuttle landing and will be returned to the CMC for post-flight analyses. This early retrieval is made possible by the quick access to the SPACEHAB laboratory after landing.

The CMC has flown over 50 different types of proteins in space, seeking protein structure data and techniques for predictable enhancement by growth in microgravity. Crystallographic analysis has revealed that on average 20% of proteins grown in space are superior to their Earth-grown counterparts. As a result of advances made by the CMC in its microgravity crystallographic technologies, 40% of the proteins flown on the first United States Microgravity Laboratory (USML- 1) mission in July 1992, yielded diffraction size crystals, several of which were superior to any previously grown on Earth.

With continued research, the commercial applications developed using protein crystal growth have phenomenal potential, and the number of proteins that need study exceeds tens of thousands. Current research with the aid of pharmaceutical companies may lead to a whole new generation of drugs, which could be able to help treat diseases such as cancer, rheumatoid arthritis, periodontal disease, influenza, septic shock, emphysema, aging and AIDS. These possibilities plus drugs and other products for agriculture, proteins for bioprocessing in manufacturing processes and waste management, and other biotechnical applications, represent critical capabilities for dealing with the future of our world.

A number of companies are participating in the CMC's protein crystal growth projects including: BioCryst Pharmaceuticals, Inc., Eli Lilly & Co., Schering-Plough Research, Du Pont Merck Pharmaceuticals, Sterling Winthrop Inc., Eastman Kodak Co., The Upjohn Co., Smith Kline Beecham Pharmaceuticals, and Vertex Pharmaceuticals, Inc. Principal Investigator for the STS-60 protein crystal growth experiments is Dr. Charles E. Bugg, Director of the CMC.

Three-Dimensional Microgravity Accelerometer

The Consortium for Materials Development in Space (CMDS), is sponsoring the Three-Dimensional Microgravity Accelerometer (3-DMA) on the STS-60 mission. The CMDS is a NASA Center for the Commercial Development of Space (CCDS) based at the University of Alabama in Huntsville (UAH).

The acceleration measurements system will help chart the effects of deviations of zero gravity on the experiments conducted in space. The microgravity environment inside the SPACEHAB Space Research Laboratory will be measured in three dimensions by the 3-DMA at different locations, allowing researchers to review experiment results against deviations from zero gravity. This information will be used to determine the degree of microgravity achieved inside the SPACEHAB Space Research Laboratory. 3-DMA will measure disturbances caused by operating various experiments in SPACEHAB and the residual microgravity resulting from orbiter rotational motions and by the resistance of extreme upper atmosphere fringes. The 3-DMA experiment was successful on the SPACEHAB-01 STS-57 flight; all twelve accelerometers situated at four different locations worked well and continuously generated data. All data desired for the technology development were obtained.

The 3-DMA hardware consists of four accelerometer assemblies to be located in different parts of the SPACEHAB Space Research Laboratory. The accelerometer package is comprised of three remotely located standard three-dimensional systems and three new invertible accelerometers in the central unit. The signal processing system and the new, unique invertible feature permit measurements of absolute microgravity and low-level, quasi-steady, residual accelerations. Those extremely low frequency disturbances are particularly detrimental to space processes such as crystal growth and have proven difficult to measure in the past. The accelerometers provide the acceleration data to a central control unit located in a single locker. The data are recorded in flight on three two-gigabyte magnetic hard drive devices.

A potential application of 3-DMA would be to characterize the microgravity environment of space station in support of experiments, research and commercialization activities. Principal Investigator for 3-DMA is Jan Bijvoet of the UAH CMDS.

Space Acceleration Measurement System

NASA's Microgravity Science and Applications Division at the Lewis Research Center is sponsoring the Space Acceleration Measurement System (SAMS) on the STS-60 mission. The SAMS is designed to measure and record low-level accelerations during experiment operations. The signals from these sensors are amplified, filtered and converted to digital data before being stored on optical disks and sent via downlink to the ground control center. SAMS has flown successfully on seven previous Shuttle flights and acquired nearly 15 gigabytes of data which represents 50 days of operation. Approximately two gigabytes of data will be acquired on the SPACEHAB-2 mission.

The capacity of SAMS' double-sided optical disk used on Shuttle missions is 400 megabytes. This compares to approximately 400 high density floppy disks, or forty standard boxes of ten disks. All the data will fit on one optical disk measuring about 5 inches square.

Three sensors will be flown. One sensor will measure the disturbances near an Environmental Control Support System. Another sensor will be located on the support structure of the SPACEHAB Space Research Laboratory. The third sensor will be attached to a locker door to determine the level of disturbances experienced by experiments in the locker and nearby. Data from all three sensors will be used to further characterize the SPACEHAB Space Research Laboratory microgravity environment. SAMS data will be compared with data from the Three-Dimensional Microgravity Accelerometer (3-DMA.)

Scientists may use the SAMS data in different ways, depending on the nature of the science experiment and the principal investigators' experience and ground-based testing results. The principal investigators will typically look for acceleration events or conditions that exceed a threshold where the experiment results could be affected. This may be, for example, a frequency versus amplitude condition, an energy content condition or simply an acceleration magnitude threshold. Data from previous missions were used to characterize the Shuttle middeck and Spacelab microgravity environment, including disturbances caused by thruster firings and crew exercise with the treadmill and bicycle ergometer.

SAMS flight hardware was designed and developed in-house by the NASA Lewis Research Center. Ronald Sicker is the SAMS Project Manager and Richard Delombard is responsible for analyzing SAMS data.

Stirling Orbiter Refrigerator/Freezer

The flight of the Stirling Orbiter Refrigerator/Freezer (SOR/F) on SPACEHAB-2 is a demonstration to obtain necessary information and characterization about the operation of Stirling refrigerator/freezer technology in microgravity. If proven successful, this technology will be targeted to replace the current vapor compression systems, which historically have had marginal reliability and lower theoretical efficiencies.

The Stirling system in the SOR/F uses environmentally benign helium as a working fluid, has an easily variable capacity, a quick chill capacity, long life gas bearings, and a motor hermetically sealed within the fluid loop, thus avoiding leakage.

Refrigerator/freezer technology for support of on-orbit investigations has been identified by the NASA Office of Life and Microgravity Sciences and Applications, the SOR/F sponsor, as one of its highest priority technologies for development. Since microgravity operation of the SOR/F Stirling unit has not been proven on orbit, this flight test requirement was established as a requirement before the unit can become operational.

SOR/F is a system the size of two standard lockers and was developed under the auspices of the Life Sciences Project Division at the Johnson Space Center. It weighs a total of nearly 100 pounds (97.8 kilograms) and consumes 50 watts of electricity at refrigerator conditions and 70 watts at freezer conditions, with cold set points ranging from -22<C to +10<C. The volume within the refrigerator/freezer unit is slightly less than one cubic foot.

SAMPLE RETURN EXPERIMENT

Principal Investigator: Peter Tsou, Jet Propulsion Laboratory Co-investigator: Donald E. Brownie, University of Washington

The Sample Return Experiment sits on top of the Spacehab Module poised to capture intact cosmic dust particles as they come in contact with the 160 capture cells. The capture cells consist of transparent silica aerogel with a density of 0.02/ g/cm^3. Silica aerogel is the lowest density known solid material and has extremely fine structure, about 50A.

Cosmic dust particles come from other planetary bodies, remnants of the formation of our solar system, or materials of other stellar systems. Capturing them allows detailed laboratory studies needed to gain understanding of their composition, type of cosmic processing and even the age. The information will contribute to answering the questions pertaining to the origin and development of our solar system and life itself. Along with the cosmic dust, space debris and other hypervelocity materials will be captured to provide detailed tracing of the sources of these other particles as well.

GET AWAY SPECIAL (GAS) PAYLOADS

STS-60 is especially significant to the Get Away Special (GAS) program because Discovery will fly the 100th GAS payload since the program's inception. NASA began flying small self- contained payloads in 1982. The program, managed by the Goddard Space Flight Center (GSFC), Greenbelt, Md., fully utilizes the Shuttle's capacity not used by major payloads. It affords the average person a chance to perform small experiments in space. The program enhances education with hands-on space research opportunities and generates new activities unique to space. Customers also are able to inexpensively test ideas that could later grow into major space experiments. The first GAS payload reservation was purchased by R. Gilbert Moore. Moore enthusiastically advocated the GAS program throughout aerospace circles. Soon, others began depositing money for GAS payload reservations. When Moore, a Martin Thiokol Corporation executive, donated the first GAS payload to Utah State University (USU), he presented USU students with a new world of hands-on space research.

USU's first payload was very ambitious. Students put ten experiments into a 5 cubic-foot (.14 cubic-meter) GAS container. One experiment grew successive generations of fruit flies to see if microgravity would affect their genetic structure. Other tests examined the effects of microgravity on epoxy resin-graphite composite curing, brine shrimp genetics, duckweed root growth, soldering, homogeneous alloy formation, surface tension, growth rate of algae, and thermal conductivity of a water and oil mixture.

From this first payload a scholarship program emerged in which undergraduate students could design and build experiments to be flown in GAS payloads. Students have since generated payloads totaling numerous experiments, while assisting other universities and institutions with their GAS projects.

Since the program's early days, the GAS team at Goddard have relied on numerous NASA and contractor personnel at the Johnson and Kennedy Space Centers. Without their active support, GAS payloads never would have left the ground. GAS team members at Johnson helped establish simplified integration, operational, and safety documentation procedures. Personnel at Kennedy streamlined techniques and procedures for processing payloads from arrival at Kennedy to installation in the orbiters and from their postflight removal to their shipment back to the experimenters. As well, Kennedy team members found a home for the GAS program on Cape Canaveral.

An unusual feature of the GAS program is that experimenters are not required to furnish postflight reports to NASA. NASA feels that GAS customers can best speak for their own experiments. The payloads results can be reviewed in detail by obtaining papers presented by the experimenters at NASA's Get Away Special Experimenter's Symposiums.
To date, 97 payloads have flown on 19 Shuttle missions. STS-60 will fly four GAS experiments as well as three other payloads on the GAS bridge. Clarke Prouty is GAS Mission Manager and Lawrence R. Thomas is Customer Support Manager for the Shuttle Small Payloads Project at Goddard. The following is a brief description of the payloads that will fly on Discovery:

G-071 The Orbiter Ball Bearing Experiment

Customer: California State University, Northridge
Customer Manager: Joan Yazejian
NASA Technical Manager: Dave Peters

A team of researchers from California State University, Northridge, have built an experiment apparatus called the OBBEX (Orbital Ball Bearing Experiment), to test the effects of melting cylindrical metal pellets in microgravity. If successful, this experiment may produce a new kind of ball bearing, which has never before been built.

One of the goals of the OBBEX experiment is to create the world's first seamless, hollow ball bearing. The hollow characteristic of the ball can improve the service-life rating of a ball bearing. This permits higher speeds and higher load applications, and may reduce the friction encountered in normal operation.

The OBBEX is a self-contained package that provides its own energy needs and is controlled by an on-board computer. The system will be activated by one of the Space Shuttle's crew members at a pre-determined time during the flight, starting with a 90-minute process to melt several metal alloy pellets.

G-514 The Orbiter Stability Experiment

Customer: Dr. Werner Neupert
Customer Manager: James Houston
NASA Technical Manager: Charlie Knapp

The primary scientific objective of this experiment is to measure the vibration spectrum of the orbiter structure that is present during normal orbiter and crew operations. The information received as a result of this measurement is valuable for any fine-pointed optical instrument mounted in the orbiter bay, as even small orbiter disturbances, such as those that may result from normal crew activity, could have an impact on the line-of-sight stability of sensitive optical systems. The net effect is that the vibration spectrum acts as a low level acceleration spectrum that may influence experiments requiring a low gravity environment.

This primary experiment consists of rapid and accurate measurements of the direction of the Sun while the orbiter is oriented with the bay (-Z axis) pointed to the center of the Sun with a nominal deadband. It also measures the effects of exposure to space environment on over-the-counter medicines and plant seeds.

Piggy-backing on this experiment are: Morgan State University, Baltimore, Md., Howard University, Washington, D.C., and native-American high school students from South Dakota. They are participants in the Scientific Knowledge for Indian Learning and Leadership (SKILL) program.

G-536 The Pool Boiling Experiment

Customer: NASA Headquarters, Office of Space Science and Applications,
Microgravity Sciences Division, Washington, D.C.
Customer Manager: Warren Hodges
NASA Technical Manager: Tom Dixon, GSFC

The Pool Boiling Experiment marks the 100th GAS payload to fly since the program's inception. The objective of this experiment is to improve the understanding of the boiling process in microgravity. This involves putting a pool of liquid in contact with a surface that can supply heat to the liquid. The experiment will observe heating and vapor bubble dynamics associated with bubble growth/collapse and subsequent bubble motion. The lack of gravity driven motion makes the boiling process easier to study in microgravity.

This will be the third flight of this payload. The two previous flights have been extremely successful. The data in each flight have been used to improve the science return on the next flight.

G-557 The Capillary Pumped Loop Experiment

Customer: The European Space Agency, The Netherlands
Customer Manager: Dr. G. Reibaldi
NASA Technical Manager: Rich Hoffman

This experiment gives an in-orbit demonstration of the working principle and performances of a two-phase Capillary Pumped Loop (CPL), a two-phase Vapor Quality Sensor, and a two- phase multi-channel Condenser Profile. It also compares data on CPL behavior in a low-gravity environment with analytical predictions resulting from modeling and on-Earth performance.

THE CAPILLARY PUMPED LOOP (CAPL)

The CAPL payload is sponsored by the Goddard Space Flight Center Earth Observing System project and will fly as a Hitchhiker payload on the Space Shuttle. The CAPL experiment will provide a microgravity test of a full sized prototype for a capillary pumped thermal control system. This two-phase system utilizes an ammonia working fluid to transfer large amounts of heat over long distances at nearly constant temperature. Capillary pumped systems will be used for thermal control on Earth Observing System satellites and other future missions.

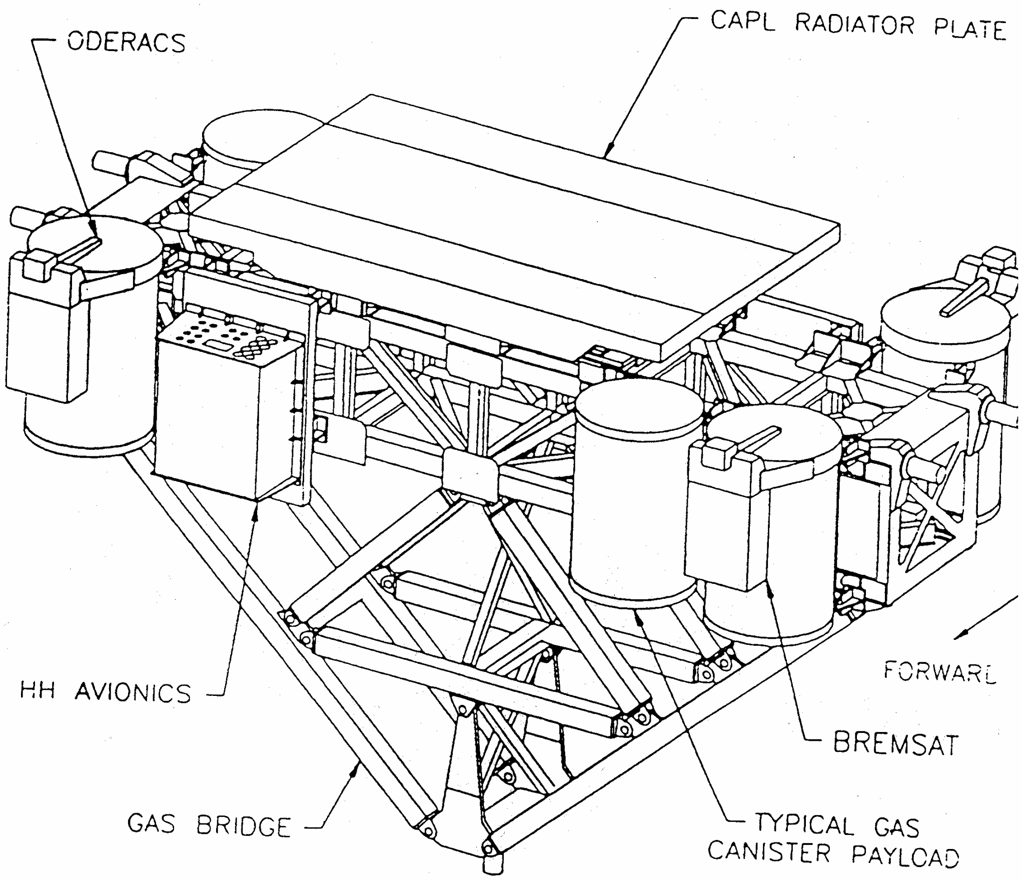
ORBITAL DEBRIS RADAR CALIBRATION SPHERES (ODERACS)

ODERACS is a project of the Space Sciences Branch of the Solar System Exploration Division at the Johnson Space Center, Houston, Texas and NASA Headquarters, Washington, D.C. This experiment deploys six spheres of three different sizes from the orbiter payload bay. The spheres range in size from two to six inches in diameter (five to 15.2 centimeters). The spheres will be observed, tracked, and recorded by ground-based radars and optical telescopes. ODERACS enables end-to-end calibration of the radar facilities and data analysis systems. This calibration is particularly geared toward the small debris size range. Additionally, ODERACS enables the correlation of controlled empirical optical and radar debris signatures to the spheres which have physical dimensions, compositions, albedos, and electromagnetic scattering properties.

THE UNIVERSITY OF BREMEN SATELLITE (BREMSAT)

BREMSAT is a 140 lb. (63 kilogram) small satellite built by the University of Bremen's Center of Applied Space Technology and Microgravity (ZARM) under sponsorship of the German Space Agency (DARA). This 480 mm (19 inch) deployable satellite is contained in a GAS canister with a Standard Door Assembly and a modified GAS Carrier Ejection System. BREMSAT performs the following scientific activities at various mission phases before and after satellite deployment:

- Measures heat conductivity.
- Measures residual acceleration forces by acceleration sensors to estimate the in-orbit microgravity quality onboard BREMSAT.
- Investigates the density distribution and dynamics of micrometeorites and dust particles in low-Earth orbit.
- Maps atomic oxygen.
- Measures the exchange of momentum and energy between the molecular flow and the rotating satellite.
- Measures pressure and temperature during satellite re-entry.



CAPL/GBA/ODERACS/BREMSAT

PAYLOAD CONFIGURATION

(Forward Face)

SHUTTLE AMATEUR RADIO EXPERIMENT (SAREX)

Students in the U.S. and Russia will have a chance to speak via amateur radio with astronauts aboard the Space Shuttle Discovery during STS-60. Ground-based amateur radio operators ("hams") will be able to contact the Shuttle through automated computer-to-computer amateur (packet) radio link. There also will be voice contacts with the general ham community as time permits.

Shuttle commander Charles Bolden (license pending) and mission specialists Ronald Sega (license pending) and Sergei K. Krikalev (call sign U5MIR) will talk with students in 5 schools in the U.S. and Russia using "ham radio."

Students in the following schools will have the opportunity to talk directly with orbiting astronauts for approximately 4 to 8 minutes:

- Boise Senior High School, Boise, Idaho (WA7QKD)
- Chariton High School, Chariton, Iowa (KB0IWE)
- James Bean School, Sidney, Maine (N1IFP)
- Mars Area Middle School, Mars, Penn (N3HKN
- House of Science and Technology for Youth, Central Moscow, Russia (UA3CR)

The radio contacts are part of the SAREX (Shuttle Amateur Radio EXperiment) project, a joint effort by NASA, the American Radio Relay League (ARRL), and the Radio Amateur Satellite Corporation (AMSAT)

The project, which has flown on 11 previous Shuttle missions, is designed to encourage public participation in the space program and support the conduct of educational initiatives through a program to demonstrate the effectiveness of communications between the Shuttle and low-cost ground stations using amateur radio voice and digital techniques.

Information about orbital elements, contact times, frequencies and crew operating schedules will be available during the mission from NASA, ARRL (Steve Mansfield, 203/666- 1541) and AMSAT (Frank Bauer, 301/ 286-8496). AMSAT will provide information bulletins for interested parties on INTERNET and amateur packet radio.

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

There will be a SAREX information desk during the mission in the Johnson Space Center newsroom. Mission information will be available on the computer bulletin board (BBS). To reach the bulletin board, use JSC BBS (8 N 1 1200 baud): dial 713- 483-2500, then type 62511.

The amateur radio station at the Goddard Space Flight Center, (WA3NAN), will operate around the clock during the mission, providing SAREX information and retransmitting live Shuttle air-to-ground audio.

STS-60 SAREX Frequencies

Routine SAREX transmissions from the Space Shuttle may be monitored on a worldwide downlink frequency of 145.55 MHz.

The voice uplink frequencies are (except Europe):
144.91 MHz
144.93
144.95
144.97
144.99

The voice uplink frequencies for Europe only are:
144.70
144.75
144.80

Note: The astronauts will not favor any one of the above frequencies. Therefore, the ability to talk with an astronaut depends on selecting one of the above frequencies chosen by the astronaut.

The worldwide amateur packet frequencies are:

Packet downlink 145.55 MHz
Packet uplink 144.49 MHz

The Goddard Space Flight Center amateur radio club planned HF operating frequencies:

3.860 MHz 7.185 4.295 21.395 28.650

AURORAL PHOTOGRAPHY EXPERIMENT (APE-B)

The objectives of the Auroral Photography Experiment-B (APE-B) is to obtain spectral images of orbiter thruster emissions, Shuttle glow, air glow and auroral glow. This will be accomplished by photographing these phenomena with the on board CCTV cameras and recording the information on two video cassettes.

Still photos will be taken with a spectrometer assembly consisting of a 35 mm camera, intensifier assembly, 55 mm lens, clamp and spectrometer section. The experiment will be operated by the flight crew at pre-determined times throughout the mission.

STS-60 CREWMEMBERS

STS060-S-002 -- *Five NASA astronauts and a Russian cosmonaut take a break from training for their scheduled flight in space to pose for the traditional crew portrait. In the front (left to right) are astronauts Kenneth S. Reightler Jr. and Charles F. Bolden Jr., pilot and commander, respectively. In the middle row are astronauts Franklin r. Chang-Diaz and N. Jan Davis, mission specialists. In the back row are astronaut Ronald M. Sega (left) and Russia cosmonaut Sergei K. Krikalev, both mission specialists.*

BIOGRAPHICAL DATA

CHARLES F. BOLDEN, 47, Col., USMC, is the commander (CDR) of STS-60. A native of Columbia, S.C., Bolden was selected as an astronaut in 1980 and will be making his fourth Space Shuttle flight.

Bolden graduated from C.A. Johnson High School in Columbia in 1964; received a bachelor's degree in electrical science from the Naval Academy in 1968; and received a master's in systems management from the University of Southern California in 1977.

After flying more than 100 sorties in Vietnam as a Marine Corps aviator, Bolden graduated from the Naval Test Pilot School in 1979. Following his selection by NASA, Bolden's first flight was as pilot of Shuttle mission STS-61C in January 1986. His second flight was as pilot of Shuttle mission STS-31 in April 1990, and his third flight was as commander of STS-45 in March 1992. His technical assignments with NASA have included service as a Special Assistant to the Johnson Space Center Director in Houston and as an Assistant Deputy Administrator at NASA Headquarters in Washington, D.C.

Bolden has logged more than 481 hours in space.

KENNETH S. REIGHTLER Jr., 42, Capt., USN, is the pilot (PLT) of STS-60. Selected as an astronaut in 1987, Reightler considers Virginia Beach, Va., his hometown and will be making his second space flight.

Reightler graduated from Bayside High School in Virginia Beach in 1969; received a bachelor's degree in aerospace engineering from the Naval Academy in 1973; received a master's in aeronautical engineering from the Naval Postgraduate School in 1984; and received a master's in systems management from the University of Southern California in 1984.

As a Naval aviator, Reightler attended the Naval Test Pilot School in 1978, and, following service as a test pilot for a variety of Naval aircraft, later was serving as chief instructor at the test pilot school when selected by NASA. His first Shuttle flight was as pilot of STS-48 in September 1991. Reightler has logged more than 128 hours in space and 4,500 hours flying time in over 60 different types of aircraft.

DR. N. JAN DAVIS, Ph.D., 40, is mission specialist 1 (MS1) on STS-60. Selected as an astronaut in 1987, Davis considers Huntsville, Al., her hometown and will be making her second space flight.

Davis graduated from Huntsville High School in 1971; received bachelors' degrees in applied biology from the Georgia Institute of Technology and in mechanical engineering from Auburn University in 1975 and 1977, respectively; and received a master's and a doctorate in mechanical engineering from the University of Alabama in Huntsville in 1983 and 1985, respectively.

Davis joined NASA's Marshall Space Flight Center in 1979 as an aerospace engineer, where, in 1986, she was named team leader in the Structural Analysis Division. Projects with which Davis was involved during her tenure at Marshall included structural analysis of the Hubble Space Telescope, the Advanced X-Ray Astrophysics Facility and the redesign of the Shuttle solid rocket booster external tank attach ring. After her selection as an astronaut, she first flew aboard Endeavour in September 1992 on Shuttle mission STS-47.

Davis has logged more than 188 hours in space.

BIOGRAPHICAL DATA

DR. RONALD M. SEGA, Ph.D., 41, is mission specialist 2 (MS2) on STS-60. Selected as an astronaut in 1991, Sega considers Northfield, Ohio, and Colorado Springs, Co., his hometowns, and he will be making his first space flight.

Sega graduated from Nordonia High School, Macedonia, Ohio, in 1970; received a bachelor's degree in mathematics and physics from the Air Force Academy in 1974; received a master's in physics from Ohio State University 1975; and received a doctorate in electrical engineering from the University of Colorado in 1982.

Sega completed Air Force pilot training in 1974 and served as an instructor pilot in the Air Force from 1976-1979. From 1979-1982, he was on the faculty of the Air Force Academy's Dept. of Physics, and, from 1982 through 1990 was actively on the faculty of the University of Colorado in Colorado Springs, from which he is currently on a leave of absence. From 1989- 1990, while on leave from the University of Colorado, Sega served as research associate professor of physics at the University of Houston and is a co-principal investigator of the Wake Shield Facility.

Sega has logged more than 4,000 hours flying time in aircraft as of Jan. 27, 1994.

DR. FRANKLIN R. CHANG-DIAZ, Ph.D., 43, is payload commander and mission specialist 3 (MS3) on STS-60. A native of San Jose, Costa Rica, Chang-Diaz was selected as an astronaut in 1980 and will be making his fourth space flight.

Chang-Diaz graduated from Colegio De La Salle in San Jose in 1967 and from Hartford High School, Hartford, CT., in 1969. He received a bachelor's degree in mechanical engineering from the University of Connecticut in 1973; and received a doctorate in applied plasma physics from the Massachusetts Institute of Technology in 1977.

Chang-Diaz has been a visiting scientist with the MIT Plasma Fusion Center since 1983, working with the institute to develop a future propulsion system for spacecraft based on magnetically confined high temperature plasmas. As an astronaut, his non-flight assignments have included starting the Astronaut Science Colloquium Program and the Astronaut Science Support Group, implementing closer ties between the astronaut corps and the scientific community.

Chang-Diaz first flew on STS-61C in January 1986 as a mission specialist. His second flight was on STS-34 in October 1989, and his third Shuttle flight was on STS-46 in August 1992.

Chang-Diaz has logged more than 457 hours in space.

SERGEI KONSTANTINOVICH KRIKALEV, 35, a Russian Space Agency cosmonaut, is mission specialist 4 (MS4) on STS-60. A native of St. Petersburg, Russia, Krikalev is one of two candidates named by the Russian Space Agency to fly on the Space Shuttle. Krikalev is a veteran of two flights in space, both long-duration stays aboard the Russian Mir Space Station.

Krikalev graduated from high school in 1975 and received a mechanical engineering degree from the Leningrad Mechanical Institute, now renamed the St. Petersburg Technical University, in 1981.

Krikalev joined NPO Energia, the Russian industrial organization responsible for manned space flight activities in 1981, and his duties included testing space flight equipment, developing space operations methods, and ground control operations. He worked with the rescue team for the Salyut 7 space station failure in 1985, developing methods for docking with the uncontrolled station and for repair of the station.

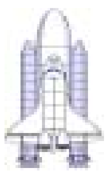
Krikalev was selected as a cosmonaut in 1985 and first flew aboard Soyuz TM-7 as a flight engineer. The Soyuz TM-7 mission was launched Nov. 26, 1988, and the crew stayed aboard the Mir space station until their return on April 27, 1989.

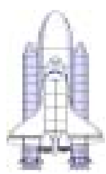
His next flight was as flight engineer aboard Soyuz TM-12, the ninth Mir mission, launched on May 19, 1991. Krikalev remained aboard the Mir station, performing seven spacewalks during his stay, until his return on March 25, 1992.

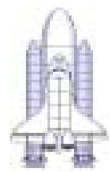
Krikalev has logged a total of more than 1 year and three months in space.

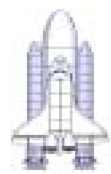
SHUTTLE FLIGHTS AS OF FEBRUARY 1994

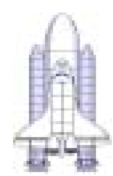
59 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 34 SINCE RETURN TO FLIGHT











		STS-51 09/12/93 - 09/22/93		
		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-52 10/22/92 - 11/01/92		STS-48 09/12/91 - 09/18/91		
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	
STS-32 01/09/90 - 01/20/90	STS-61A 10/30/85 - 11/06/85	STS-33 11/22/89 - 11/27/89	STS-43 08/02/91 - 08/11/91	
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-61C 01/12/86 - 01/18/86	STS-51B 04/29/85 - 05/06/85	STS-26 09/29/88 - 10/03/88	STS-38 11/15/90 - 11/20/90	
STS-9 11/28/83 - 12/08/83	STS-41G 10/05/84 - 10/13/84	STS-51-I 08/27/85 - 09/03/85	STS-36 02/28/90 - 03/04/90	
STS-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	STS-51G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89	STS-61 12/02/93 - 12/13/93
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 (15 flights)	**OV-099 Challenger (10 flights)**	**OV-103 Discovery (17 flights)**	**OV-104 Atlantis (12 flights)**	**OV-105 Endeavour (5 flights)**