

NASA-TM-108742

# SPACE STATION FREEDOM UTILIZATION CONFERENCE

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VON BRAUN CIVIC CENTER  
HUNTSVILLE, ALABAMA  
AUGUST 3-6, 1992

(NASA-TM-108742) SPACE STATION  
FREEDOM UTILIZATION CONFERENCE  
(NASA) 553 p

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*Sponsored by:*

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*Space Station Freedom Program  
NASA Headquarters  
Washington, D.C.*





National Aeronautics and  
Space Administration

Washington, D.C.  
20546

Reply to Attn of MG

Dear Conference Participant:

I am pleased to present you with the proceedings of the first Space Station Freedom Utilization Conference held August 3-6, 1992. The conference is part of NASA's ongoing efforts to better inform current and prospective space researchers about the research potential of Space Station Freedom.

Freedom will be a world-class facility, an on-orbit laboratory which will support research and discovery in a variety of science and technology disciplines by those in academia, industry and government. We held the Utilization Conference to present Freedom's research capabilities, to describe current plans for research and to establish a forum for direct interaction between the Space Station Freedom Program and the research community.

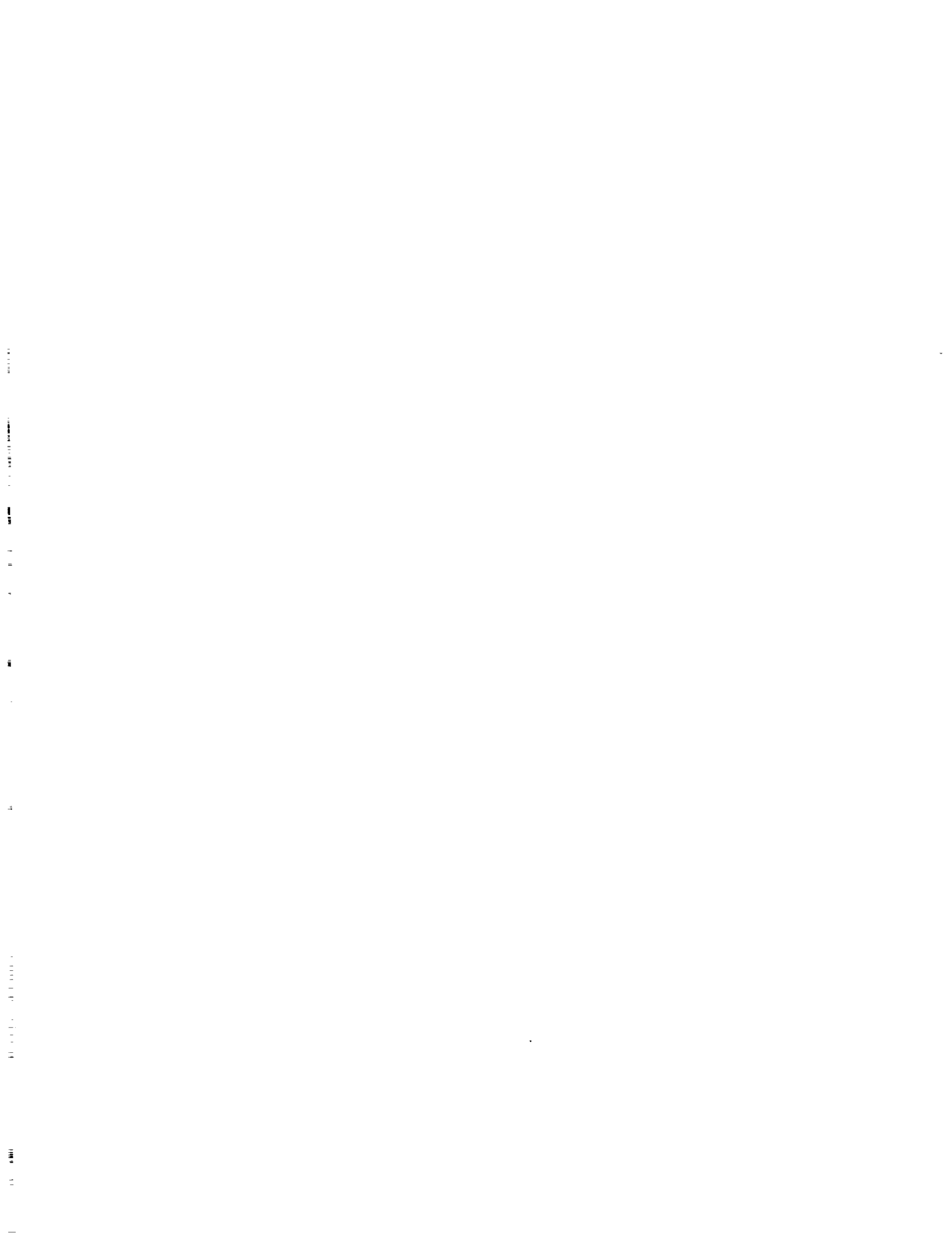
We thank all participants for helping to make this a successful conference. It is clear that there is strong interest in the results of our nation's space research and in research opportunities aboard Freedom.

We take your comments to heart. Many of your suggestions for improving the program format and content are being used in our planning for the 1993 Utilization Conference. In particular, the next conference agenda will include more in-depth discussion of research results between the audience and "hands-on" space researchers. We will also present more detailed information about the many different experiment accommodations which will be available on Space Station Freedom. Please feel free to contact me at (202) 453-1180 if you have any further questions or comments.

Thank you again for contributing to the success of the 1992 Space Station Freedom Utilization Conference. We look forward to expanding our dialogue with the prospective Space Station Freedom research community and hope to see you at our next conference.

Sincerely,

John-David F. Bartoe  
Director, User Integration Division  
Spacelab/Space Station Utilization Program  
Office of Space Flight





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# *SPACE STATION FREEDOM UTILIZATION CONFERENCE*

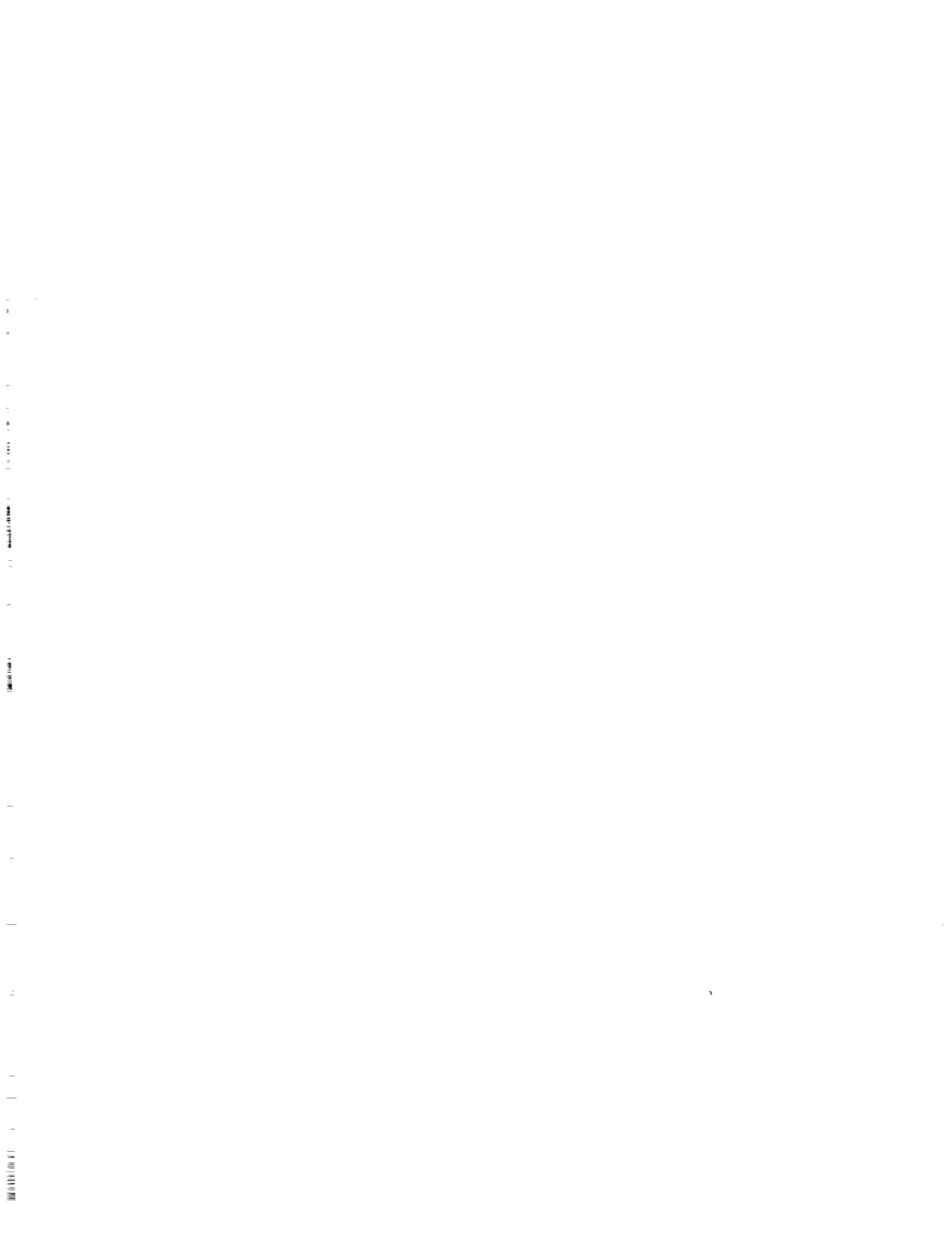
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*VON BRAUN CIVIC CENTER  
HUNTSVILLE, ALABAMA  
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*EXECUTIVE SUMMARY*

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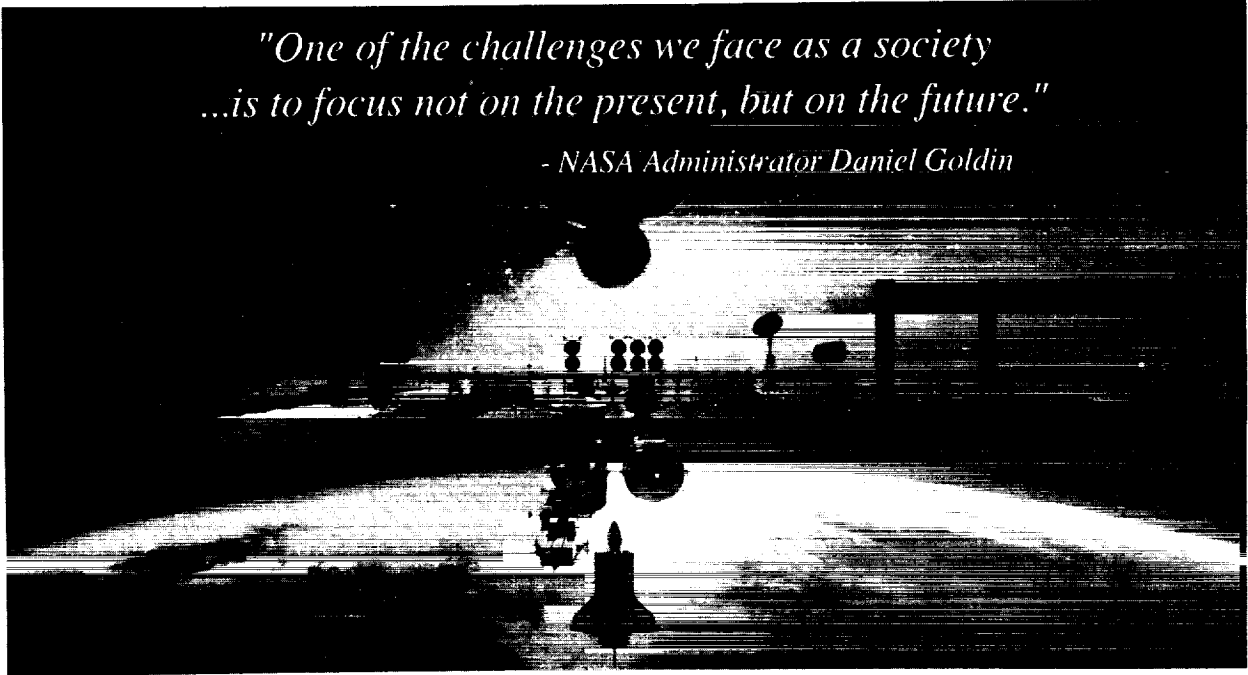


# EXECUTIVE SUMMARY

## SPACE STATION FREEDOM UTILIZATION CONFERENCE

*"One of the challenges we face as a society  
...is to focus not on the present, but on the future."*

*- NASA Administrator Daniel Goldin*



### Introduction

From August 3-6, 1992, Space Station Freedom Program (SSFP) representatives and prospective Space Station Freedom researchers gathered at the Von Braun Civic Center in Huntsville, Alabama, for NASA's first annual Space Station Freedom (SSF) Utilization Conference.

Conference Chairman John-David Bartoe, Director of User Integration for the Spacelab/Space Station Utilization Program in NASA's Office of Space Flight, told attendees that the purpose of the conference was to bring together prospective space station researchers and the people in NASA and industry with whom they would be working to exchange information and discuss plans and opportunities for space station research.

The conference was the first annual meeting that NASA organized for space station researchers. Almost 700 people attended, including 500 who participated in the utilization conference and 200 who participated in a

concurrent Space Station Freedom Payload Data Services Workshop. The attendees included approximately 100 researchers and 100 experiment hardware developers.

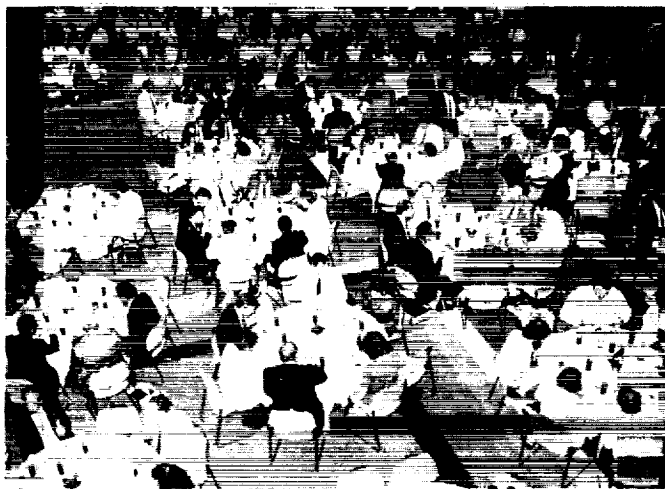
The conference featured more than three dozen exhibits sponsored by private companies, NASA offices, and foreign space agencies. The exhibits included mock-ups of hardware and potential experiments and provided information on equipment and services available to researchers on Space Station Freedom. (See List of Exhibitors, Appendix C.)

In a keynote address to participants, NASA Administrator Daniel Goldin said the conference was a needed and timely effort to spur the development of a space station research community. Freedom should be thought of as an international research center in space where researchers will be able to share facilities to do basic research in such disciplines as materials processing and biotechnology. Moreover, it will allow scientists to perform life sciences research necessary for

missions to the Moon and Mars. He urged those in attendance to spread the word about research opportunities on Freedom, with the aim of doubling or tripling the number of researchers at next year's utilization conference.

In plenary and splinter sessions, speakers described space station capabilities, plans and opportunities for research. Freedom will accommodate experiments in its laboratory modules and observational payloads mounted external to the modules. It will provide researchers access to the microgravity environment of space, with resources such as power, communications and crew time to perform experiments. In addition, laboratory support equipment such as refrigerators and gloveboxes will be available to support experiments. NASA research organizations also will be developing facilities that will support a broad range of research. Such facilities include the Fluid Physics Dynamics Facility, Advanced Protein Crystal Growth Facility and a 2.5 meter Life Sciences Centrifuge.

Opportunities for flying space station precursor experiments were also detailed — for instance, Get Away Special payloads, the Office of Commercial Programs' Wakeshield Facility for high-vacuum research, Spacelab missions, and the Office of Aeronautics and Space Technology's In-Space Technology Experiment Program (IN-STEP). Researchers with space flight experience described what it is like to work in space and what kinds of services crew members can offer to investigators.



Participants enjoyed the Welcome Lunch.

NASA officials told attendees that the first research initiatives on Space Station Freedom may be flying just five years from now. Investigators associated with the Spacelab Life Sciences 1 (SLS-1) mission launched on the Space Shuttle in June 1991 and the U.S. Microgravity Laboratory 1 (USML-1) mission launched in June 1992 spoke at the conference. They reported on the results of space station precursor experiments in life sciences and materials processing that were conducted on these flights. Crew members of other Space Shuttle missions dedicated to science told researchers how to make the most of human presence in orbit.

NASA officials explained the kinds of research that the agency's various "user" organizations support, so that prospective space station researchers could determine where to seek sponsorship. These organizations — the NASA program offices that sponsor space-based research — are the Office of Aeronautics and Space Technology, Office of Commercial Programs, Office of Space Flight, and Office of Space Science and Applications. Representatives of these organizations explained how NASA announces research opportunities and how researchers obtain sponsorship.

Representatives of the international partners in Space Station Freedom — the Canadian Space Agency, European Space Agency, and National Space Development Agency of Japan — told conference attendees about their plans for research on Freedom. These presentations made it clear that international cooperation in space research is not an option; it is a given.

### *Welcome Lunch*

"We're building the space station for you." This conference theme was articulated by Spacelab/Space Station Utilization Division Director Robert Parker of NASA's Office of Space Flight.

Now is the right time for members of the research community to gather together and discuss what they want to do and how they want to do it, NASA Associate Administrator for Space Systems Development Arnold Aldrich told attendees. Aldrich discussed NASA's plans for extended-duration (up to 14 days) and

long-duration (14-28 days) Space Shuttle missions that will serve as space station precursor missions.

Plans are now in the works for joint U.S.-Russian missions in space, including the flight of a U.S. astronaut on a long-duration mission to the Russian space station Mir. He also reported that NASA is considering the purchase of Russian Soyuz spacecraft used to transport crews to and from the Mir space station. These spacecraft could serve as Assured Crew Return Vehicles (ACRVs), or "lifeboats," for Space Station Freedom crews.

### **Session 1: Overview and Research Capabilities**

*Space Station Freedom Director Richard Kohrs, Office of Space Systems Development, NASA Headquarters:*

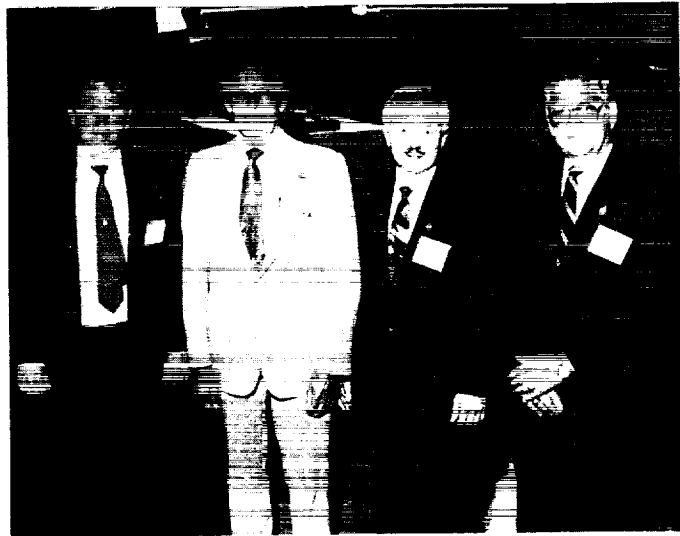
NASA field centers and contractors are organized to develop "work packages" for Space Station Freedom. Marshall Space Flight Center and Boeing are building the U.S. laboratory and habitation modules, nodes, and environmental control and life support system; Johnson Space Center and McDonnell Douglas are responsible for truss structure, data management, propulsion systems, thermal control, and communications and guidance; Lewis Research Center and Rocketdyne are developing the power system.

The Canadian Space Agency (CSA) is contributing a Mobile Servicing Center, Special Dextrous Manipulator, and Mobile Servicing Center Maintenance Depot. The National Space Development Agency of Japan (NASDA) is contributing a Japanese Experiment Module (JEM), which includes a pressurized module, logistics module, and exposed experiment facility. And the European Space Agency (ESA) is contributing the Columbus laboratory module.

NASA ground facilities that are now in various stages of development to support Space Station Freedom include: Marshall Space Flight Center's Payload Operations Integration Center and Payload Training Complex (Alabama), Johnson Space Center's Space Station Control Center and Space Station Training Facility (Texas), Lewis Research Center's Power System Facility

(Ohio), and Kennedy Space Center's Space Station Processing Facility (Florida).

In Fiscal Year 1988, Congress appropriated only half of the funds that NASA requested for the space station program (\$393 million vs. \$767 million). In FY 89, NASA sought \$967



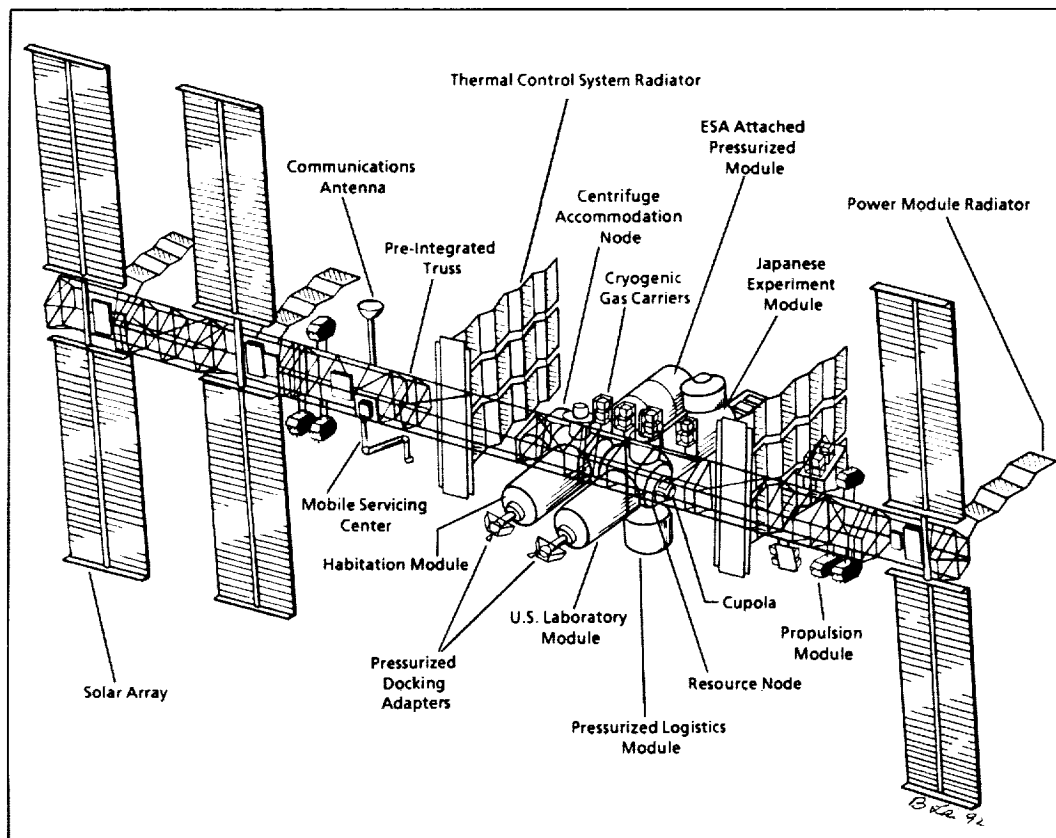
*Opening Plenary Speakers: Robert Moorehead, Robert Phillips, John-David Bartoe and Richard Kohrs.*

million for the program, and Congress appropriated \$900 million. NASA's FY 90 request was \$2.05 billion compared to an appropriation of \$1.75 billion; the FY 91 request was \$2.45 billion, and the appropriation was \$1.9 billion.

After NASA restructured the Space Station Freedom program in response to directions from Congress, the agency's full budget request of \$2.029 billion for Space Station Freedom in FY 92 was appropriated. For FY 93, NASA is seeking \$2.25 billion for the program; the planned budget for FY 94 is \$2.5 billion. Further alterations to the hardware configuration for Freedom would be a serious setback; NASA intends "to stick with the current baseline" and continue planning for utilization.

*Space Station Freedom Program and Operations Deputy Director Robert Moorehead, Office of Space Systems Development, NASA Headquarters:*

NASA's plan for building up space-based research capabilities begins with extended-duration Space Shuttle missions that will



Permanently Manned Capability (PMC).

double the research capability currently provided by Spacelab and culminate in Space Station Freedom. The 14-day USML 1 mission flown on the Space Shuttle in June 1992 was a space station precursor mission, dedicated to microgravity and life science research.

Freedom will be a permanent space-based research facility, providing a working environment nearly free of buoyancy-driven convection, sedimentation, and hydrostatic pressure and featuring access to the ultra-high vacuum of space (for external payloads). In its crew-tended phase, Space Station Freedom will provide 40 times Spacelab's capability, and in its permanently occupied phase, Freedom will provide 110 times Spacelab's capability. (The Russian space station, Mir, offers 26 times Spacelab's capabilities.)

According to NASA's current schedule, the first launch of a space station element will take place in November 1995, with permanently occupied capability planned for September 1999. This year, NASA will conduct space station critical design reviews (CDRs). Work

package design reviews will take place from February to April 1993, followed by a systems CDR.

**Space Station Freedom Program Chief Scientist, Robert Phillips, Office of Space Systems Development, NASA Headquarters:** NASA has allocated research accommodations on Freedom (equipment, utilities, etc.) to the program offices that sponsor space-based research and development as follows: Space Science and Applications (OSSA) — 52 percent, Commercial Programs (OCP) — 28 percent, Aeronautics and Space Technology (OAST) — 12 percent, and Space Flight (OSF) — 8 percent.

Most of OSSA's allocation will be used for microgravity and life science experiments, although OSSA's space physics, astrophysics, earth science and applications, and solar system exploration divisions also will use some of this allocation.

Other Federal agencies have expressed interest in using Space Station Freedom. They



include the National Institutes of Health (NIH), U.S. Geological Survey, National Science Foundation, National Oceanic and Atmospheric Administration, and U.S. Departments of Agriculture and Energy. NIH and NASA have already signed a memorandum of understanding regarding joint space research.

Payload interfaces with space station lab support equipment must be simple, and experiment packages must be highly contained. Freedom's research facilities will feature International Standard Payload Racks (ISPRs), experiment racks that are about twice the size of a Spacelab rack. ESA's Columbus lab will feature 20 racks, the U.S. lab will have 12 racks, and the Japanese lab will have 10. Thus Freedom will have a total of 42 racks versus 8 for Spacelab.

NASA is considering outfitting some rack space to accommodate small, self-contained payloads similar to the Get-Away-Special canisters and middeck-locker experiment packages flown on Space Shuttle missions. Because of the large number of planned experiments, crew time allotted to experiments on Freedom at permanently occupied capability will average 25 minutes per rack per day, compared to six hours per rack per day on Spacelab missions. Hence, telescience — the remote operation of space-based experiments by researchers on the ground — will play a very important role in space station research.

Plans for supporting life sciences research on Freedom focus on the two basic goals of NASA's space life sciences program: to ensure the health, safety, and productivity of humans in space and to acquire fundamental knowledge of biological processes. Today, "there are no known factors" that will limit long-duration human stays in space.

Space-based research has already shown that people and plants respond the same way to the microgravity environment: they lose structure. However, the mechanisms by which they respond are different, and researchers do not yet know much about these mechanisms. Life science research accommodations on Freedom will include facilities for experiments designed to address this and other questions, in fields such as gravitational

biology, space physiology, and biomedical monitoring and countermeasures research.

**User Integration Division Director John-David Bartoe, Spacelab/Space Station Utilization Program, Office of Space Flight, NASA Headquarters:**

Researchers who want to use NASA facilities must find a NASA sponsor. The agency's program offices periodically issue announcements of opportunity (AOs) for research proposals involving major hardware procurements and NASA research announcements (NRAs) for proposals involving existing hardware or minor hardware procurements.

<b>MICROGRAVITY RESEARCH</b>
<ul style="list-style-type: none"> <li>• Materials Science                             <ul style="list-style-type: none"> <li>- Electronic and photonic materials</li> <li>- Metals, alloys and composites</li> <li>- Glasses and ceramics</li> </ul> </li> <li>• Fundamental sciences                             <ul style="list-style-type: none"> <li>- Fluid dynamics and transport phenomena</li> <li>- Combustion science</li> <li>- Gravitational physics</li> </ul> </li> <li>• Biotechnology Experiments                             <ul style="list-style-type: none"> <li>- Macromolecular crystal growth</li> </ul> </li> </ul>
<b>LIFE SCIENCES RESEARCH</b>
<ul style="list-style-type: none"> <li>• Crew health, safety and productivity                             <ul style="list-style-type: none"> <li>- Monitor crew health</li> <li>- Develop countermeasures to adverse effects of prolonged exposure to low gravity</li> </ul> </li> <li>• Basic and applied research                             <ul style="list-style-type: none"> <li>- Study effects of gravity on living systems</li> <li>- Cell and tissue growth</li> <li>- Biologically based support systems</li> </ul> </li> </ul>
<b>TECHNOLOGY RESEARCH</b>
<ul style="list-style-type: none"> <li>• Space Construction</li> <li>• Structural dynamics and control</li> <li>• Space materials and environmental effects</li> <li>• Space power systems</li> <li>• Thermal management</li> <li>• Fluid management</li> <li>• Propulsion</li> <li>• Automation and robotics</li> <li>• Sensors</li> <li>• Information systems</li> <li>• Human systems engineering</li> </ul>

*Long-Term Research Objectives.*

OSSA's Microgravity Science and Applications Division is in the process of releasing a series of discipline-oriented NRAs for fundamental physics and chemistry, materials science, and biotechnology investigations to fly on Freedom. OSSA's Life Sciences Division plans to release its first NRA for space station investigations in about two years.

SPACE STATION RESEARCH CAPABILITIES AT PERMANENTLY MANNED CAPABILITY ( ~2000)
<ul style="list-style-type: none"> <li>• 3 Laboratory Modules</li> <li>• 1 Habitation Module</li> <li>• 2.5 m (8.2 ft) Centrifuge Facility</li> <li>• Pressurized working environment</li> <li>• 42 International Standard Payload Racks</li> <li>• For Payloads:                             <ul style="list-style-type: none"> <li>- Power - 30 kW</li> <li>- Thermal Control - 30 kW</li> <li>- Data Transmission Rate - 50 Mbps</li> </ul> </li> <li>• A permanent crew of 4 with 2 dedicated to research</li> <li>• 4 attachment points to truss for external payloads</li> <li>• 10 locations for external payloads on JEM Exposed Facility (zenith, nadir, wake viewing)</li> </ul>

NASA's Office of Aeronautics and Space Technology plans to release an NRA shortly for robotics, life support, thermal management, and other technology development and validation experiments that require some sort of flight testing. The Office of Commercial Programs seeks cooperative research proposals in which NASA provides space flights in return for access to experimental data. A national network of 17 Centers for the Commercial Development of Space, cosponsored by NASA and private-sector partners, provides a way for prospective commercial users of space to work with the agency.

NASA is developing a policy that will establish the price commercial reimbursable researchers will pay for access to Freedom's accommodations, resources, and standard services. Space requirements, energy consumption, crew time needs, and length of stay in space will be considered in establishing the prices. The space station pricing policy will be based on the agency's existing Space Shuttle and Spacelab pricing policy.

NASA is planning Space Station Freedom flights using a five-year planning horizon, but

researchers will not get involved in the flight planning process this far in advance unless their payloads are very complex.

All space station researchers will be assigned payload accommodations managers to work with them throughout the payload integration process. This process encompasses analytical integration — "a paper process" addressing detailed payload requirements, physical integration (including optional functional testing), and operations integration (compatibility, interface with crew, uplink commands).

Because 60 percent of payloads proposed for Space Station Freedom thus far require less than one rack of space, NASA wants to be able to handle small payloads in a fast, simple fashion. "The payload integration process is being streamlined to better accommodate researchers"; NASA's goal is to complete space station payload integration in less than a year.

## Session 2: Research Plans and Opportunities

*Deputy Assistant Administrator Ray Arnold, Office of Commercial Programs, NASA Headquarters:*

Between now and the time that Space Station Freedom is available, NASA's Office of Commercial Programs (OCP) can arrange for the launching of commercial experiments on facilities ranging from sounding rockets to expendable launch vehicles to Spacelab and Spacehab (a commercial pressurized lab module designed to fly in the Space Shuttle cargo bay) and a Wakeshield Facility being developed to accommodate high-vacuum research. Toward creating an industry-driven research environment in space, OCP is focusing its resources on NASA's national network of Centers for the Commercial Development of Space (CCDSs).

Joint endeavor agreements (JEAs) are among the means by which OCP currently arranges to fly commercial experiments on NASA missions; OCP is working on new legal instruments that will further ease commercial access to space. OCP's Space Station Freedom utilization flight plan shows seven racks in use for commercial research by 1997. OCP has a

commercial Space Station Freedom planning team in place, including CCDS representatives and JEA partners.

**Director for Space W. Ray Hook, NASA Langley Research Center:**

Over the last 25 years, NASA's Office of Aeronautics and Space Technology has logged quite a bit of space flight experience that will aid in planning space station research: 26 experiments on Skylab missions, 8 on expendable launch vehicles (ELVs), and 12 on the Space Shuttle. OAST technology initiatives begin with basic research and proceed to proof of feasibility, technology development, subsystem and system development, and system testing, launch, and operations.

OAST's current activities include a research and technology (R&T) program, the Civil Space Technology Initiative, and the In-Space Technology Experiments Program (IN-STEP). IN-STEP sponsors the design, development, and flight of technology experiments for private-sector, academic, and NASA researchers on ELV, Space Shuttle, and Space Station Freedom missions.

Some of OAST's most recent technology investigations include a tank-pressure-control experiment flown as a Get Away Special payload on the Space Shuttle in August 1991, a middeck zero-gravity experiment flown in September 1991 to measure truss-structure and fluid-slosh dynamics, and an orbital acceleration research experiment flown in June 1992.

This summer, OAST plans to release a new AO that will solicit proposals for space technology experiments to fly on Space Station Freedom beginning in 1997. OAST will select 50 proposals for concept development in the areas of space materials and coatings, cryogenic fluid handling, human support, space power, vibration isolation, space communication, in-space construction and repair, and sensors.

**Space Station Utilization Branch Chief Philip Cressy, Flight Systems Division, Office of Space Science and Applications, NASA Headquarters:**

NASA's Office of Space Science and Applications (OSSA) will use Space Station Freedom to further its goal of studying physical,

chemical, and biological processes in the space environment. OSSA's goals are to advance knowledge of the Earth, the solar system, and the universe; use the unique qualities of the space environment to advance research; and expand human presence into the solar system.

OSSA's strategic plan includes a Space Shuttle-to-Space Station Freedom transition plan, focused on the use of Freedom to support preparations for long-duration human missions in space. OSSA's strategy for using Freedom calls for ensuring a range of utilization options, from small self-contained or rapid-response payloads to attached payloads and facility-class payloads.

For facility-class payloads, OSSA will solicit research proposals three years before flight and assemble science teams for investigations two years before flight. OSSA's Life Sciences Division has developed a strategy for using Freedom as follows: Phase 1, Biomedical



*Inside the U.S. Laboratory Module.*

Monitoring and Countermeasures (BMAC) Program; Phase 2, building of a national/international life science research capability; and Phase 3, establishment of an international life science facility for in-depth studies of medical issues related to long-duration human missions in space.

The Microgravity Science and Applications Division has outlined its utilization strategy as follows: Phase 1, provision of transitional

hardware for use during crew-tended stage; Phase 2, provision of facility-class hardware during crew-tended stage; and Phase 3, onboard research during permanently occupied capability and evolution to crew-tended free flyers.

Prospective researchers asked whether crew movements on Space Station Freedom would disturb experiments requiring a carefully controlled microgravity environment. NASA officials reported that the effects of crew movements are being monitored on Space Shuttle missions, but thus far it has been difficult to separate the effects of crew movements from other factors in play. Researchers have nothing conclusive to report on how crew movements might affect the microgravity environment.

***U.S. Microgravity Laboratory 1 Payload Specialist Larry DeLucas (associate director for protein crystal growth, Center for Macromolecular Crystallography, University of Alabama in Birmingham):***

Protein crystallography — a research tool used to study the structure of the complex building blocks of living systems — has a lot to gain from space-based research. In order to know how a protein works in the human body, researchers must understand its molecular structure. Researchers have identified 150,000 different proteins in the body, but they know the structure of fewer than a third of them.



*Payload Specialist Larry DeLucas working at the Multipurpose Glovebox.*

The only viable technique for analyzing the structure of these proteins is x-ray diffraction of the proteins in their crystal form. The better the quality of a protein crystal, the more useful it is to researchers who are trying to delineate its structure. The microgravity environment of space allows protein crystals to grow nearly undisturbed by convection and other gravity-driven forces that cause flaws to form in them on the ground. In space, lack of convection enables protein crystals to grow more slowly than they do on Earth, and the slower a protein crystal grows, the fewer flaws it will have.

Protein crystal growth experiments have already flown on 14 Space Shuttle missions. This year's USML-1 Spacelab mission included protein crystal growth experiments conducted for commercial researchers.

*[DeLucas, the first payload specialist with expertise in protein crystal growth research, performed protein crystal experiments on USML-1.]* The results of protein crystal experiments flown thus far have been larger crystals with more uniform morphologies.

The Center for Macromolecular Crystallography (a NASA-cosponsored CCDS) currently builds flight hardware to meet researchers' needs and handles sample loading and retrieval for flight experiments. "The sample approval process is rapid"; NASA will approve a change in sample material in a matter of days. The results of commercial experiments are not made public.

Protein crystallography enables "rational drug design": the development of drugs that bind only with the target protein and, hence, do not cause side effects. For example, pharmaceutical companies presently are interested in developing drugs that can inhibit purine nucleoside phosphorylase (PNP), a protein that plays a role in auto-immune diseases. To continue these kinds of investigations, researchers need a constant supply of protein crystals that are as free of flaws as possible.

Space Station Freedom will provide the kind of research environment that will enable the production of such supplies. In addition, Freedom will provide the kind of long-duration facility required by protein crystal researchers: 40 percent of proteins require more than two weeks to crystallize. And

finally, "to try to automate this process would be fruitless": a permanently occupied facility is required for the conduct of this kind of research.

The Center for Macromolecular Crystallography is now working on a thermal enclosure system for crystal growth investigations in the Space Shuttle middeck and on Space Station Freedom; this system will have a 50-pound payload capacity and feature a hermetically sealed, controlled temperature environment. Ultimately, installing an x-ray generator on Freedom would enable scientists to analyze the results of crystal growth experiments in orbit, reducing the loss of samples due to deterioration or the stresses of reentry.

### **Keynote Address: NASA Administrator Daniel Goldin**

*(In an address to conference attendees, NASA Administrator Goldin urged prospective space station researchers to recruit their colleagues for next year's utilization conference: "the more you learn about possibilities on Space Station Freedom, the more you get excited." Citing Freedom as an example of "how nations can work together on projects of peace instead of weapons of war," he urged the research community to think of Freedom as NASA's newest field center and "the first international research center in orbit." The text of Goldin's speech follows):*

One of the challenges we face as a society — certainly in this period of slow economic growth — is to focus not on the present, but on the future. I believe one of the reasons we're having problems with our economy is that we're not investing in our future to the degree we should.

When I was born in 1940, there were about two billion people on Earth. Today, that's more than doubled to 5.5 billion. And when I'm 100 years old, there'll be almost 10 billion. The people alive during my life have consumed more of the world's resources than all those living in prior generations of human history. We've already used more than we deserve, and now we're stealing from the future to buy the creature comforts of today.

We see it in government, where we have big deficits year after year. We see it in the

corporate world, where the focus is on short-term profits, not long-term investment. Last year, the aerospace companies that invested the least in research and development saw their stock prices go up the most. While the rest of the world gears up for the economic



NASA Administrator Daniel Goldin presenting his Keynote Address.

competition of the post-Cold War era, America is chowing down on its seed corn to feed its belly today.

NASA scientist Rick Chappell, who works at Marshall, recently had an experience that illustrates this quite clearly. As he jogged through the wildlife refuge that surrounds the launch pads at Cape Canaveral, he noticed an armadillo by the trail. Later, he looked up and saw an eagle.

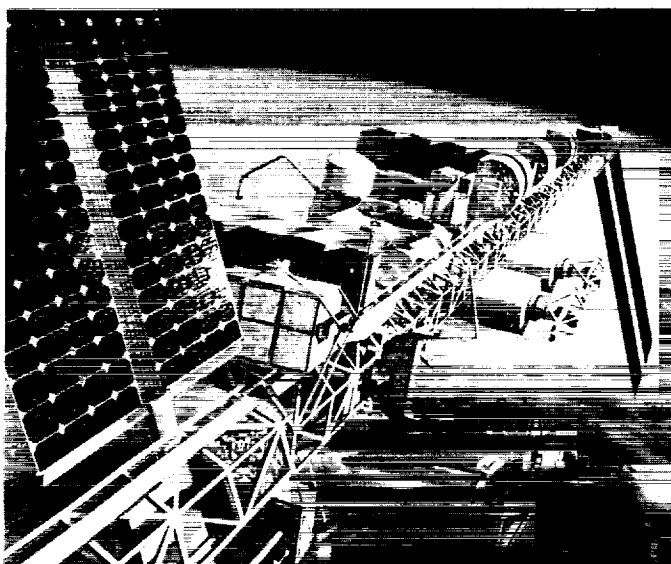
He wrote later on, "I was struck by the contrast of their different approaches to life. Where the armadillo never looks up — concentrating only on its next meal, and oblivious to the world around it — the eagle soars quietly and majestically. It is not rooting around the ground, but is striving for the high ground — seeking a vantage point from which to see the horizon and beyond."

America's first spacecraft that landed on the Moon wasn't called the armadillo; it was the Eagle — the symbol of America. This nation didn't become the greatest in the world by keeping its eyes on the ground. We are about broad visions, about looking over the horizon

to see the future, and then blazing the trail for others to follow.

Technology is the fuel in our economic furnace. Technology creates growth. It creates whole new industries and new jobs — high paying, high quality jobs that add value to our economy.

NASA's research and development of advanced technology reaches out into the future to bring back opportunities to the world of today. Between 1979 and 1986, the new products generated from NASA science and



*Artist's Concept of Space Station Freedom and Space Shuttle.*

engineering created over 350,000 new jobs. And believe me, this is a very conservative estimate, because once NASA invents something and makes it available to industry, we lose track of the many by-products that build on our pioneering work.

NASA has been driving technology forward ever since it was created. Apollo brought us untold bounty — especially in medical technology. Pacemakers, CAT scans, magnetic resonance imaging, intensive care monitoring equipment — all got their start because of research NASA needed to go into space. Mission Control's computer networks and software are the great grandfathers of what runs America's telephone system, banking and credit card networks, and airline computer networks.

But we can't keep living off Apollo's bounty. Currently, the hair of a scientist can turn gray waiting to get his or her first experiment on the shuttle, let alone the necessary follow-up research. A researcher can't make much progress doing one experiment every few years or so. We can't keep attracting good people to do space science if the research they need for their Ph.D.s takes decades to complete.

The House of Representatives took a giant leap in the right direction last week when they voted to continue building Space Station Freedom. As I listened to the debate in the House Chamber and watched the vote tally grow, I was proud that in these difficult economic times, Congress saw the wisdom in investing in our future. It was not just a victory for NASA, but a victory for America and its international partners, who desperately need the research and technology that will come from a permanent facility in space.

Space Station Freedom will revolutionize our way of life in the 21st century the same way the Apollo program did in the 20th century.

A permanent space station will be the place where we become a true space-faring nation — the place where we learn how to live and work in space. And it will be an example of how nations can unite and work together on projects of peace. All of our plans to build an outpost on the Moon and explore Mars depend on using Space Station Freedom to conduct the necessary life science research to protect astronauts' health from the effects of long-duration space travel.

While these studies are going on, the space station will have dual use lab equipment where scientists can systematically study how living organisms and other materials behave without gravity. Essentially, the space station should be thought of as an international research center in orbit. Researchers from universities and the private sector, such as pharmaceutical companies, and our international partners will be able to share facilities on Freedom to facilitate basic research in materials processing, biotechnology, and life sciences.

Biotechnology, for instance, is expected to be the big business of the 90s, going from \$4 billion a year currently to \$50 billion by the

end of the decade — revolutionizing everything from agriculture to pollution control to health care. The commercial possibilities of biotechnology research in microgravity are mind-boggling. Product improvements developed from this research can fuel the furnace of our economy, creating new jobs and saving lives with new drugs and medical knowledge.

The stunning success of the U.S. Microgravity Lab on the last shuttle flight showed the vast potential of Space Station Freedom. On that flight was Astronaut Larry DeLucas of the University of Alabama at Birmingham, who's an expert in growing protein crystals, which are key to developing new drugs. The protein crystals grown on that flight were some of the largest and best-formed ever. Drug companies and other researchers had attempted to grow some of them on Earth to no avail. One drug company said they accomplished in two weeks an experiment that would have taken two years on the ground.

Yet despite this successful shuttle mission, DeLucas reached two conclusions: 1) that even a 14-day shuttle flight was not enough time for some of the experiments, and 2) a lab is needed in which scientists can interact and manipulate the experiments on a day-to-day basis.

That's why we need Space Station Freedom. The tidal wave of research that's waiting to be flown in space is what can let us live longer lives, in a cleaner environment, with a higher standard of living.

Clearly investing in the future is worth it, but at what cost? Many people don't realize that NASA receives only 1 percent of the federal budget. Space Station Freedom's yearly cost is about one-seventh of that — literally two cents a day for every American citizen. When you consider the enormous return on investment a space station will yield, Americans will get far more than their two cents' worth. For that small amount, the dividends we pay are enormous.

Life on Earth is better because of the lives we've sent into space. Thank goodness we have a president that understands how important space is to the strength, and competitiveness, and future economic growth

of America. George Bush and Dan Quayle support a robust civil space program because they've seen how science and technology drives this nation forward. Our international partners know this as well, which is exactly why they've joined us.

Every time we have gone to the frontier, we've brought back more than we could ever imagine. Space is no longer just an experiment or a symbol. It's no longer a "luxury," the way automobiles and air travel were once viewed. Space is an essential part of our future in medicine, science, and technology.

We have to get bold again. We have to take risks and make investments so our children will have a better future. By reaching for the stars, we bring inspiration, hope, and opportunity back to Earth.

The "armadillos" of the world cannot defeat those of us who choose to be eagles. By flying higher, and seeing farther, we will use our vision to lead the way for the benefit of all humanity.

Let me leave you with a vision of what the space station could mean. It's early in the next century, and a woman in Montgomery, Alabama goes to her doctor to receive a hormone shot to prevent osteoporosis. That night, she sees on TV that a young astronaut at Kennedy Space Center just received the same shot to prevent bone loss before blasting off on the long journey to Mars.

That young astronaut grew up in Huntsville, where decades before, her father was a builder of Space Station Freedom, on which the life science research for long-term space flight uncovered the hormone that prevents osteoporosis. Her father's work on Space Station Freedom had inspired her to study organic chemistry so that when the time came, she'd be qualified to go search for signs of ancient life on Mars.

Space Station Freedom isn't just a job, or a chance to make money. It's a mission to move the human species into breaking the chains of gravity and becoming a multi-planetary society. Pursuing a mission of this monumental importance will lift civilization on Earth to new heights of health, wealth, and knowledge.

The exploration of space is the most inspirational adventure of all time. Our work offers hope that our children's world will be a better place than our own. Join me as we make this vision a reality.

**Session 2: Research Plans and Opportunities (continued)**

*Space Station Program Deputy Director Toshio Mizuno, National Space Development Agency of Japan (NASDA):*

The National Space Development Agency's contribution to the Space Station Freedom Program is the Japanese Experiment Module (JEM). The agency's JEM utilization policy calls for a national research program to promote utilization, the development of multipurpose facilities, space station precursor missions, and the release of announcements of opportunity to solicit experiment proposals.

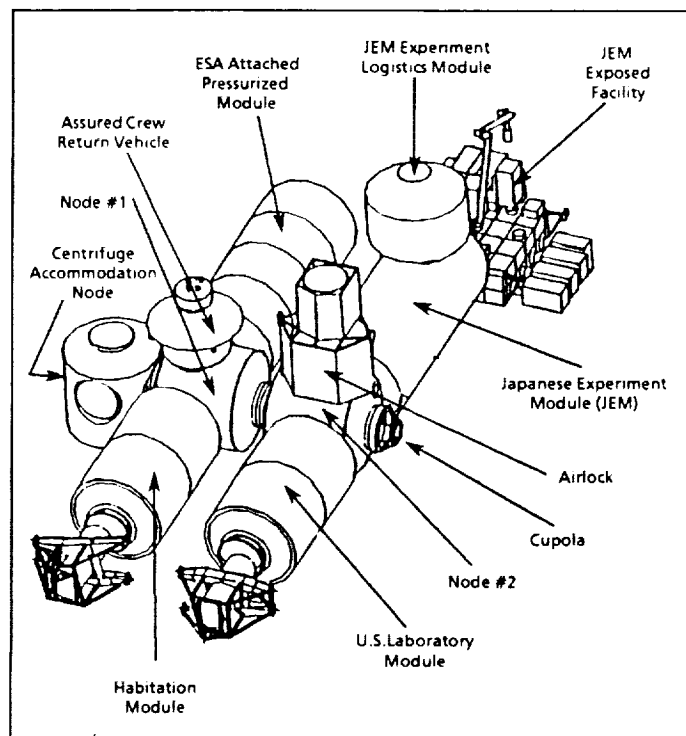
Japan is in the process of implementing a joint research plan under which core research institutes such as the Institute for Space and Astronautical Science (ISAS) will manage space-based investigations, with NASDA providing flight hardware and flight opportunities.

As part of its effort to develop generic JEM experiment support technology, NASDA is conducting microgravity investigations using drop tubes (one operational since 1991, another to become operational in 1993), parabolic aircraft flights (since 1990), and suborbital rockets (five materials processing and fluid physics experiments per flight, one flight per year from 1991 to 1993).

In addition, NASDA has flown two experiments on the International Microgravity Laboratory (IML-1) mission of January 1992 and has booked 12 more experiments on IML-2, to be launched in July 1994. A dedicated Spacelab Japan (SL-J) mission to be launched on the Space Shuttle in September 1992 will carry 34 experiments developed by Japan.

A Japanese space experiment data base has been in operation since January 1992; it will be translated into English by mid-1993. NASDA has installed a telescience test bed at its Space Experiment Laboratory, which became operational at the Tsukuba Space Center in June 1992; a JEM telescience demonstration is scheduled there for November 1992.

A wet-environment training facility for JEM crew candidates is under construction. A JEM



Pressurized Elements (PMC).



mission specialist candidate was selected in April 1992, and a JEM system review is scheduled for October 1992. Eight multi-user facilities for JEM are now in the design study phase. JEM technology development will continue until early 1993.

**Manager of Space Station Operations and Utilization James Faulkner, Canadian Space Agency:**

The Canadian Space Agency (CSA) plans to use its three percent allocation of space station resources for materials science and life science investigations. Research plans encompass exploratory, fundamental, and applied science.

CSA's first solicitation of interest in space station research drew more than 130 responses, including 52 percent for materials science investigations and 17 percent for biology and life science experiments. In evaluating these proposals, discipline review panels will consider factors such as commercial potential, cost, and national and scientific value. A Canadian Space Station Program Allocation Board will select experiments for flight.

Investigators will cover some payload development costs, and CSA will cover payload integration, launch, and recovery. CSA currently supports four test facilities for space station researchers: a laser test system, large motion isolation mount, float zone furnace, and protein crystallization apparatus.

CSA's space station user support program ultimately will include technical support centers, a payload integration center, and payload operations and payload support centers. The latter two facilities will be part of a new space center at St.-Hubert, Quebec, scheduled for completion in November 1993.

**Head of Microgravity and Columbus Utilization Jean-Jacques Dordain, European Space Agency:**

The European Space Agency (ESA) plans to use any and all facilities available for space-based research — Spacelab, Spacehab, and the Russian space station, Mir, as well as ESA's Columbus laboratory module for Space Station Freedom. The Columbus module will feature 20 racks; half will be for ESA researchers. Six racks will be integrated with the



*International Standard Payload Rack.*

Columbus module before it is launched to Space Station Freedom so that research can begin immediately.

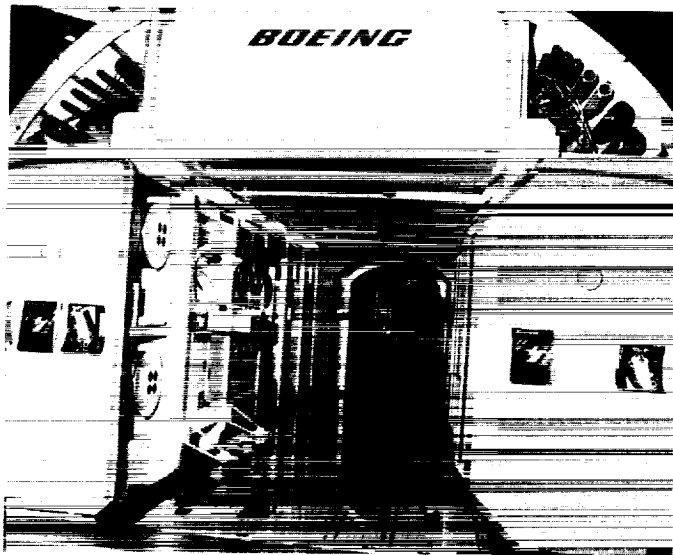
ESA is considering the addition of an external viewing platform to Columbus for attached payloads: the structure will be based on that of ESA's Eureka free-flying platform. As part of its plans for developing space-based investigations so that they will not burden crew members with routine tasks, ESA already is operating telescience and robotics test beds in the Netherlands; these facilities are available free to any researchers interested in using them.

**Spacelab Life Sciences 2 Payload Specialist Candidate Laurence Young:**

Long-duration investigations and experiments using multiple generations of plants and animals are necessary to address key questions in the space life sciences. Space Station Freedom will enable researchers to fly a

sufficient number of experimental subjects to produce statistically significant results.

The fact that Freedom will be permanently occupied means that crew members can redesign experiments on the spot, an option especially important to the life sciences. Life science requirements for Space Station Freedom include two-way communication



Mock-up of U.S. Laboratory Module presented by Boeing Corporation.

links, sample return, onboard analysis, bioisolation, and normal atmospheric conditions.

Equipment planned to support life science research on Freedom includes a glovebox to protect crew and samples, animal and plant holding facilities, a 2.5-meter-diameter centrifuge, and a health maintenance facility. The centrifuge is especially important because it will provide a one-g control environment as well as a range of microgravity environments for investigations.

Space physiology investigations thus far have shown that fast-twitch muscle fibers gradually replace slow-twitch fibers in the absence of gravity, bones lose calcium and overall mass, blood cell count and plasma volume decreases, the immune system changes, and the neurovestibular system adapts to the microgravity environment. The mechanisms by which all of these changes take place are not understood. More frequent and longer-

duration flight opportunities are needed to pursue this line of research.

*Director Liya Regel, International Center for Gravity Materials Science and Applications, Clarkson University (former head, material science department, Institute for Space Research, Soviet Union):*

Materials science experiments flown on the Soviet Salyut space stations and Russia's present-day Mir have yielded interesting results. Crystal growth experiments on the Salyuts and Mir have yielded zeolite crystals several times larger than the largest produced on Earth and the first crystals produced by rapid mixing of two solutions.

The latter result has helped to optimize terrestrial crystal growth. During the first year of operations on Mir's Kristall materials processing laboratory module, researchers produced 100 kilograms of high-quality semiconductor material. Materials processing hardware currently installed on the Kristall module includes the Gallar and Crater tube furnaces, the Splav gradient furnace, and the Optizone mirror furnace for float-zone melting of silicon.

However, problems such as insufficient power, mass restrictions, inadequate operating time, and limited space-to-ground communications have affected materials science investigations on Soviet/Russian space station facilities, because engineers have designed experiments without input from the research community.

Other problems affecting Russian microgravity research include a lack of accelerometer data, lengthy delays in sample and data returns, excessive paperwork, unknown experiment selection criteria, and insufficient preflight training of cosmonauts with experiment hardware.

Replication of experiments is rarely possible in the Russian space program, and researchers do not receive support for thorough analyses of flight test results. Mir hardware is already old, and its solar power system is inadequate: for instance, the conduct of a materials processing experiment may require the diversion of power for hot water and cooking.

In addition, foreign investigators can get experiments on the Mir faster than Russian investigators can. And finally, Russian investigators cannot accompany their experiments to the launch site but must deliver them to NPO Energia in Moscow for delivery by Energia officials.

### **Session 3: Life Sciences Research**

*Session Chairman Larry Chambers (Space Station Life Sciences Program Manager, Life Sciences Division, NASA Headquarters):* NASA's Life Sciences Division sponsors investigations that fulfill the goals and objectives of ensuring the health, safety, and productivity of humans in space; acquiring fundamental scientific knowledge in the space biological sciences; expanding our understanding of life in the universe; and better understanding the role of gravity in living systems. NASA has identified life sciences research priorities for Space Station Freedom in consultation with a number of expert advisory groups such as the Committee on the Future of the U.S. Space Program and the NASA Advisory Council.

Spacelab-class life sciences investigations will be conducted during the crew-tended phase of Space Station Freedom. Once Freedom is permanently occupied (ca. 2000), NASA's Life Sciences program will provide a suite of five discipline-focused "common-core" life sciences research facilities for investigations of up to six months: the Biomedical Monitoring and Countermeasures Facility (four racks, 1997 launch); Gravitational Biology Facility (two racks, 1998 launch); Centrifuge Facility (2.5-meter centrifuge plus habitat racks, late 1999 launch); Gas Grain Simulation Facility (one rack, 1998 launch); and Controlled Ecological Life Support System (CELSS) Test Facility (two racks, 1999 launch). All dates are for planning purposes.

NASA's Office of Space Science and Applications and Office of Space Flight will provide lab support equipment for life sciences and other investigations. European, Japanese, and Canadian facilities on Freedom will be available to support life sciences investigations as well. In addition, the Italian Space Agency is negotiating with NASA to build a

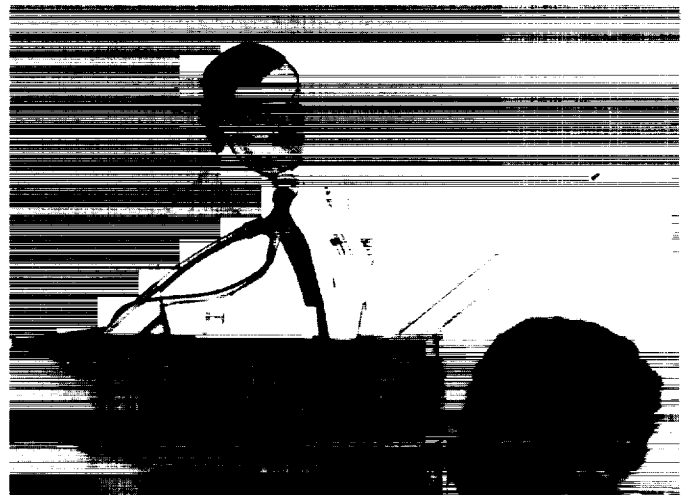
mini-life science laboratory module to be installed at a space station node.

*Space Station Life Sciences Program Scientist Richard Keefe, Life Sciences Division, NASA Headquarters:*

NASA's Life Sciences Division has consulted with the NASA Advisory Council's Aerospace Medicine Advisory Committee and a network of 13 Discipline Working Groups (DWGs) to identify space life science initiatives that should be pursued and plan solicitations of space station life science investigations. The DWGs, comprising mostly non-NASA researchers, have developed implementation plans prioritizing scientific questions to be addressed in the various life science disciplines (e.g., neuroscience, radiation health, plant biology).

The Life Sciences Division's strategy for using Space Station Freedom is to establish and maintain an international research laboratory there, provide routine access to this facility by regularly issuing discipline-focused NRAs and AOs (approximately every two years), and create an international life sciences archive and data base to facilitate research.

NRAs are used to solicit proposals for ground-based research and flight projects using existing hardware; AOs are used to solicit proposals for flight projects requiring major hardware development. The Life Sciences Division also accepts unsolicited proposals for experiments that would use existing hardware.

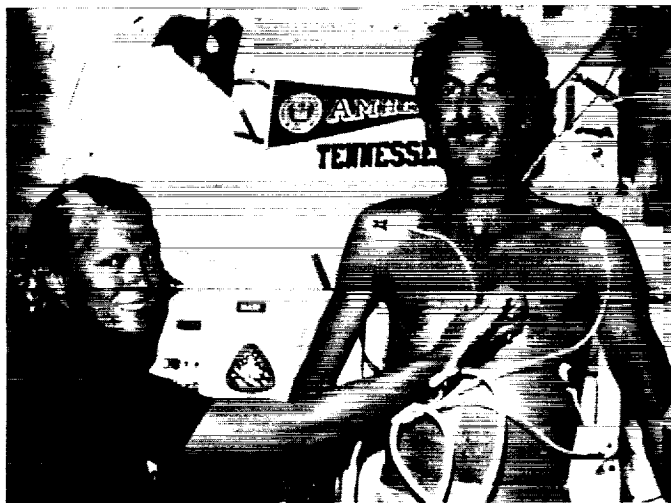


*Life Sciences Research Splinter Session Chairman Larry Chambers.*

All proposals are subject to peer review. Evaluation criteria include scientific merit, relevance to NASA's mission, technical requirements, hardware availability, and cost. NASA's life sciences research budget is \$55 million for the current fiscal year; about half of those funds are granted to non-NASA researchers. The average grant or contract for a space life science experiment will be \$60,000-\$100,000 per year.

On Space Station Freedom, life science flight opportunities will include nominal use of core facilities (time from solicitation to flight is approximately two years), investigations requiring experiment-unique equipment (time from solicitation to flight is more than two years), and small, rapid-response payloads (six months for payload integration).

An International Life Sciences Strategic Planning Working Group, including representatives of NASA, the European Space Agency, the Canadian Space Agency, the National Space Development Agency of Japan, the



*Life Sciences research aboard the Space Shuttle.*

French space agency CNES, and the German space agency DARA, is working on collaborative plans for space station life sciences research.

**Biomedical Monitoring and Countermeasures Program Manager Donald Stewart, Life Sciences Division, NASA Headquarters:** To study ways of combatting human physiological deconditioning in space, NASA is

planning a Biomedical Monitoring and Countermeasures (BMAC) Program for Space Station Freedom. Space flights to date have not produced sufficient data to enable scientists to understand "the full extent of human risk associated with space flight"; hence, the BMAC Program is necessary if human missions in space are to last more than 16 days.

The BMAC Program will establish health and performance standards for human missions in space. Questions to be addressed by BMAC investigations include: what are the optimal biomedical monitoring scenarios? What changes might limit mission duration? Are there limits to the number of missions an individual can fly? What countermeasures are required, and when? Is there an optimum mission duration?

BMAC investigations will involve operational biomedical monitoring, functional monitoring, and risk assessments. Specific test protocols have not yet been determined. BMAC feasibility studies are complete, and design studies are about to begin. Four racks of hardware are planned for Space Station Freedom, offering opportunities "for rigorous involvement" of the science community.

**Gravitational Biology Facility (GBF) Project Scientist Katherine Allen, NASA Ames Research Center:**

NASA is developing a Gravitational Biology Facility (GBF) for Space Station Freedom comprising a set of generic laboratory equipment that will accommodate cell and developmental biology and plant biology experiments. This facility will be available as soon as Freedom is available for research. A Science Working Group (SWG) will identify equipment to be included in the GBF. The SWG also will identify design requirements for the facility so that it will meet the needs of researchers.

The GBF will accommodate a wide variety of species, several methods of observation, and many different methods of sample collection, preservation, and storage. Equipment for manipulating samples will include a compound microscope and radioisotope handling equipment. The GBF also will feature a small centrifuge for one-g control studies.

**Gas Grain Simulation Facility (GGSF)**  
**Scientist Ken Greenwald, NASA Ames**  
**Research Center:**

A Gas Grain Simulation Facility (GGSF) being developed for Space Station Freedom will accommodate investigations of fundamental physical and chemical processes (nucleation, condensation, aggregation, etc.) involving suspended particles in the sub-micron to micron range. Such experiments are relevant to NASA studies of the origin and evolution of the solar system, the universe, and life therein. The GGSF also will accommodate experiments in other fields such as planetary science, astrophysics, and earth science.

Researchers have gone as far as they can on Earth with studies of the processes by which the solar system and the universe were formed. The microgravity environment of Space Station Freedom will increase particle suspension times, reduce interference from buoyancy-driven convection, and enable the study of gravitationally unstable objects and low-energy interactions that are masked by gravity.

The GGSF will offer investigators four experiment chambers and a broad variety of particle-generation and diagnostic methods. A current list of candidate GGSF experiments includes a Titan atmospheric aerosol simulation, a study of airborne bacteria in microgravity, and an investigation of planetary ring dynamics. The first GGSF science workshop took place this year; next year, NASA will hold a GGSF technology workshop and a second science workshop.

**Senior Scientist Glenn Funk, GE Government**  
**Services:**

The Centrifuge Facility Project (CFP) for Space Station Freedom will include a 2.5-meter-diameter centrifuge for plant and animal experiments at a range of 0.01 to 2.0 gs, modular habitats, and a glovebox for handling samples. The CFP will accommodate cardiopulmonary, musculoskeletal, neuroscience, plant biology, cell development, regulatory physiology, environmental health, radiation exposure, and behavior and performance investigations requiring long-duration exposures and the testing of multiple generations or space-adapted subjects.

The CFP will accommodate rats and mice and later will be upgraded to handle squirrel monkeys. Coriolis forces will render the one g to be generated by the space station centrifuge different from the one g here on Earth. NASA has considered a human-rated centrifuge but does not plan to build one at this time.



*A Space Station node will accommodate the 8.2 ft. diameter centrifuge.*

The CFP is generic hardware, but it is being designed to accommodate experiment-unique equipment such as special specimen chambers or video cameras. However, CFP experiment proposals, to be solicited by NRA, must minimize experiment-unique equipment needs. CFP design studies are complete. Engineering and construction will begin next year.

Early CFP experiments must produce data that meet NASA's flight-verification needs. An NRA for experiments to fly during this flight verification period is due out in 1994; experiments will be selected for flight in 1995. An NRA for ongoing CFP science investigations will be issued in 1997, with experiment development beginning in 1998.

**Senior Research Associate John Tremor,**  
**Bionetics Corporation:**

A Controlled Ecological Life Support System (CELSS) Test Facility (CTF) being developed for Space Station Freedom will accommodate plant-growth experiments with a variety of food crops under carefully controlled environmental conditions (temperature, humidity, oxygen and carbon dioxide levels, light intensity).

The CTF will include two racks of equipment, one for experiments and one for support hardware such as nutrient delivery and condensate recovery systems. The productivity of plants in space is currently a major unknown.

A CTF science and technology working group has met three times since the fall of 1991. A NASA request for proposals (RFP) to build the CTF is due out in 1994, to be followed by a solicitation for investigations. Experiments will be selected and a CTF Investigators Working Group (IWG) formed by 1996.

*Space Shuttle Payload Specialist Byron Lichtenberg (STS-9, the Spacelab 1 microgravity science mission of 1983, and STS-45, the Atlas 1 earth science mission in 1992):*

Space Station Freedom researchers requiring crew support for their space investigations should keep several points in mind. Maintaining bioisolation is important. Including crew members as members of science teams, and involving them in preparations for flight investigations as early as possible, is also important.

Investigators also should note that, for now, life science investigations involving crew members as subjects are generally invasive activities; hence, the crew should know in advance exactly what is going to occur in space. Further, pre-flight and post-flight data collection is required, and crew members are very busy before a flight and very tired after a flight.

Crew time requirements for space-based experiments tend to double from the time



*Technology Research Splinter Session Co-Chairman  
M. Frank Rose.*

plans are set to the time the investigations are conducted. Exact replicas of flight hardware are a necessity for pre-flight crew training. Science payloads requiring crew involvement should be designed so that crew members can observe experiments and access the hardware if repair or intervention is required.

*Medical Operations Branch Chief Roger Billica, NASA Johnson Space Center:*

NASA's plans for accommodating operational medicine on Freedom focus on a Crew Health Care System (CHeCS) including a health maintenance facility, environmental health system, and exercise countermeasures facility. Space station operational medicine will involve establishing norms for humans in space, developing monitoring and countermeasures practices, gaining experience in remote health care (telemedicine), and operating as a test bed for crew health maintenance on the Moon and Mars.

NASA is looking for ideas in the field of space-station-era operational medicine research such as non-invasive health monitoring and diagnostic techniques, circadian shifting, telemedicine, decontamination strategies, extended-life pharmaceuticals, radiation protection, and crew selection. Radiation exposure is a major concern for long-duration human missions in space, and largely an unknown today.

### **Session 3: Technology Research**

*Session Co-chairman M. Frank Rose (Director, Space Power Institute, Auburn University):*

Space Station Freedom will be an engineering experiment station, a laboratory for qualifying new technologies in the near term. No roadblocks based on physical laws stand in the way of using space. The only roadblocks are related to engineering and technology issues. For instance, high levels of space power will be required to support orbital operations in the future.

Space Station Freedom has great utility for space technology qualification, process development, in-space satellite repair, and materials engineering. Further, Freedom itself is an elaborate engineering experiment that

will address space power, large space structures, and life support systems.

The planning cycle for space experiments has to be streamlined and made user friendly. The planning cycle for research access to Freedom must be reduced from the current five years down to one to three years. In addition, the cost of space transportation must come down (\$500 per kilogram is a goal). Current space transportation costs vary depending on the accounting method used. However, Space Shuttle costs are quoted at up to \$10,000 per kilogram.

To cut transportation costs NASA could pursue an aggressive development program for heavy lift launch vehicles and shift more payloads to lower cost expendable launch vehicles (ELVs). Another way to cut the cost of working in space would be to trim the amount of red tape and paperwork required to space-qualify experiments.

**Session Co-chairman Roger Breckenridge (Deputy Manager, Space Station Freedom Office, NASA Langley Research Center):** Reported on Precursor Space Station Experiments for Sherwin M. Beck. The Office of Aeronautics and Space Technology's (OAST) In-Space Technology Experiments Program (IN-STEP) is developing space station precursor investigations. IN-STEP experiments are small (fitting into a middeck locker or Get Away Special canister), low-cost (less than \$5 million), and solicited by AO from NASA, industry and university researchers. Program performance to date shows a good trend — technology research is expanding and the planning cycle of flight experiments is accelerating.

A 1992 IN-STEP AO is ready to be issued. OAST plans to accept approximately 50 Phase A proposals. These experiments should be ready for flight starting in 1997, using any suitable carrier, including Space Station Freedom. In fact, this AO is the first from OAST that shows Freedom as a carrier.

**Professor Edward F. Crawley, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology:**

The OAST-sponsored Middeck 0-g Dynamics Experiments (MODE) are an example of IN-STEP space station precursor research. The

purpose of the MODE experiments, flown on the Space Shuttle, was to conduct engineering research that would promote technology development for space applications.

Researchers must have a clear idea of why the space environment is necessary to conduct their experiments. Many years of ground test work culminated in a one and one half day experiment in orbit. The MODE experiments produced valuable engineering data on technology issues that industry researchers had not previously considered.

The MODE flight experiments used a structural test article (STA) and a fluids test article (FTA) — scaled-down hardware that cost a fraction of the price for full-scale items. Doing the research in scale and then using scaling laws to interpret the data was very effective. The STA experiment, a scaled-down section of a generic space truss structure, was assembled and conducted in the shuttle middeck. Space Station Freedom will be able to accommodate larger test articles.



*Technology Research Splinter Session Co-Chairman Roger A. Breckenridge.*

Lessons learned from the IN-STEP Program are that low cost experiments are possible; integrating a space experiment is an art, not a science; the flight crew can be an important part of an experiment's success if properly trained (the crew needs as much hardware interaction during training as possible); and investigators need to become familiar with real-time operations before their experiments fly.

Current estimates for crew time available for space station experiments are based on 100 percent utilization of all available payload

racks. It is likely that Freedom will carry substantially fewer than the maximum number of experiments in its early phases. Crew time allocations are still "to be determined."

**Technology Experiments Manager Don Avery, Space Station Utilization Office, NASA Langley Research Center:**

The proposed traffic model for Space Station Freedom includes categories for attached and pressurized technology payloads, for Freedom itself as an instrumented experiment test article, and for a guest investigator program



*Mission Specialist James Buchli operates the Middeck 0-gravity Dynamics Experiment (MODE) aboard the Space Shuttle.*

enabling researchers to use data from existing experiments and space station subsystem instruments.

In planning space station attached-payload experiments, technology researchers should consider the following design issues: environment, carrier, payload accommodations, and integration. Investigators will be assisted in designing technology payloads by a technical interchange process that includes space station subsystem and utilization experts. Solid object modeling and animation techniques are being employed early in the design of attached payloads to identify problems during the conceptual phase.

Designers of attached payload experiments should assume robotic installation with contingency plans for extravehicular activity (EVA). EVA capability will be available, but it

is very time consuming and expensive. A Mobile Transporter will be used to manipulate external payloads. Because Mobile Transporter operations will affect the space station microgravity environment, they will be scheduled to minimize disturbances.

Technology researchers interested in flying experiments on Space Station Freedom can contact Langley Research Center's Space Station Utilization Office during the conceptual stages of a Phase A proposal. OAST AOs are open to U.S. researchers only. However, the international partners in Space Station Freedom will be cooperating on many investigations.

**Raymond Kvaternik, Spacecraft Dynamics Branch, Structural Dynamics Division, NASA Langley Research Center:**

A Modal Identification Experiment (MIE) being developed by OAST will use Space Station Freedom itself as a test article for a large space structure investigation. This experiment also will contribute to on-orbit space station verification.

The MIE will provide the first opportunity to obtain vibration data for the fully assembled space station structure, which is too large and flexible to be tested as a single unit on the ground. MIE researchers have conducted extensive simulations of on-orbit tests, as well as exploratory laboratory simulations using small-scale models, to evaluate potential performance.

**Richard DeLombard, In-Space Technology Experiments Program, NASA Lewis Research Center:**

The Tank Pressure Control Experiment (TPCE) is an OAST-sponsored cryogenic fluid dynamics investigation that will yield information useful to the design and operation of future onboard cryogenic fluid storage systems. The Thermal Energy Storage Flight Project (TES) is an OAST-funded thermal management experiment that will aid in the design of solar dynamic power systems.

OAST's Solar Array Module Plasma Interaction Experiment (SAMPIE) will determine the environmental effects of low Earth orbit on solar cells. SAMPIE will provide information necessary for optimum module design. A Vibration Isolation Advanced Technology



Development initiative funded by OSSA will provide the technology necessary to maintain a stable microgravity environment for sensitive payloads on spacecraft.

The OSSA-funded Space Acceleration Measurement System (SAMS) is an instrument designed to measure the microgravity acceleration environment for Space Shuttle and space station payloads. The SAMS has cost \$12 million from concept definition to on-orbit use in the Shuttle middeck. This instrument will be used on Space Station Freedom.

***Technology Experiments Manager Don Avery, Space Station Utilization Office, NASA Langley Research Center:***

Long-term exposure in low Earth orbit can enhance our understanding of what might happen to materials and coatings used on extended space missions. The results of materials exposure experiments flown on NASA's Long-Duration Exposure Facility (LDEF) are already being applied to space station design.

Long-duration exposures on Space Station Freedom will further benefit spacecraft materials and coatings research. Current plans call for materials exposure experiments to be launched with the first space station element.

***David Allen, Center on Materials for Space Structures, Case Western Reserve University:***

The Center on Materials for Space Structures, a NASA-cosponsored CCDS, is working on long-duration space materials exposure experiments intended to evaluate new materials for space structures and develop passive and active facilities for materials exposure and analysis in space. A major facility for materials exposure is planned for mounting on the space station truss structure.

Samples will be rotated once a year, allowing commercial researchers to obtain information promptly on materials survivability in the low Earth orbit environment. The space station environment will not necessarily be pristine; hence, the results of these experiments may be different from those flown on the LDEF. This 30-year research program will provide information on how to manage the environment around a space station structure.

***Theodore Swanson, Advanced Development and Flight Experiment Section, NASA Goddard Space Flight Center:***

The biggest differences between ground- and space-based tests show up with fluids systems, especially two-phase flow systems. Generic microgravity fluids research is needed to create a data base from which researchers can develop reliable analytical models of fluid behavior in space. Space Station Freedom will support high-quality heat transfer experiments and long-term data collection.

Several new capabilities will be available to fluids researchers on Freedom. The microgravity environment will simplify experiments because most nonlinearities in fluid behavior are attributable to Earth's gravity. Fluids in space should exhibit linear behavior that will enable the development of new models.

Researchers must take into account the steady state accelerations that will occur on Freedom ( $10^{-5}$  to  $10^{-6}$  gs) in designing fluids experiments. In addition, space station safety concerns will limit the use of fluids and require safety features in experimental hardware.



*MSFC exhibit presenting space station payload operations.*

***Matthew Kolodney, Lockheed Corporation:***

Optimal design of spacecraft environmental control and life support systems (ECLSS) for long-duration missions requires an understanding of microgravity and its long-term influence on system performance. Short-

duration testing on KC-135 or Space Shuttle flights is not sufficient. Hence, experiments are planned for Space Station Freedom to study fundamental processes associated with air and water recycling in microgravity. Long term testing of life support hardware under microgravity conditions is required as well.

**Jim Scheib, McDonnell Douglas:**

Space Station Freedom's truss structure will feature four sites for external attached payloads. Volume limits for attached payloads are usually not physical but related to performance parameters such as antenna viewing requirements. Payload sponsors must provide their own thermal control. Payload thermal analysis will be time and site dependent. Investigators will have to provide their own structural support for space station external payloads.

Although attached payload Site 1 is located next to the U.S. laboratory module, lab venting should not pose problems for experiments there. Venting contamination from Space Shuttle docking will be a significantly greater hazard to external payloads than allowable limits from the lab module. External payload sites can be covered during Shuttle maneuvers, but venting from the lab module cannot be predicted.

Pointing and viewing capabilities at attached payload sites are passive; no pointing capability is provided. Therefore, experiment

designers will have to provide their own pointing if required. Potential interference with communications antennas or solar or radiator arrays will be evaluated on a case by case basis. Interference with space station subsystem viewing requirements will not be allowed. Site viewing angle measurements are not yet approved for release to investigators.

### **Session 3: Microgravity Research and Biotechnology**

**Session Co-chairman Robert Bayuzick, Vanderbilt University (former Visiting Senior Scientist, Microgravity Science and Applications Division, NASA Headquarters):**

NASA's microgravity science program has two elements: the Microgravity Science and Applications Division, which sponsors basic and applied research, and the Office of Commercial Programs, which sponsors flight projects that will stimulate private sector involvement and investment in space. The two programs share flight hardware and cooperate on some research initiatives. Many space station precursor experiments are being planned to prepare for microgravity research on Space Station Freedom.

The goal of NASA's microgravity research program is to study fluids science, combustion science, materials science, biotechnology, and fundamental physics for the purpose of attaining a structured understanding of gravity-dependent phenomena and physical phenomena usually masked by the effects of gravity. In short, this field of research uses gravity (or the absence of it) as an experimental parameter.

Plans for space station based microgravity research facilities include Spacelab to space station transition hardware as well as hardware designed specifically for Space Station Freedom. The Microgravity Science and Applications Division also will offer flight opportunities for small and rapid response payloads that will allow researchers to get experiments aboard Space Station Freedom in two years. The division periodically will release NASA Research Announcements (NRAs) to solicit new experiment proposals.



*Microgravity Research Splinter Session Co-chairman Robert Bayuzick.*

The division is sponsoring the development of major microgravity research hardware for Space Station Freedom: an Advanced Protein Crystal Growth Facility, Space Station Furnace Facility, Modular Combustion Facility, Fluid Physics Dynamics Facility, Modular Containerless Processing Facility, and Biotechnology Facility. A glovebox will be available for crew handling of research samples.

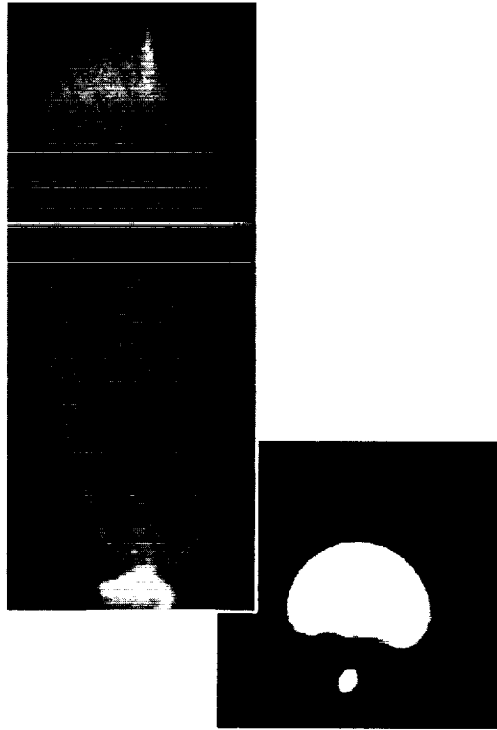
A payload adapter may be available to accommodate small- to moderate-scale microgravity experiments. NASA will begin operating microgravity research facilities during space station assembly (crew tended capability). NASA's research program will involve significant collaboration with the international science community through the sharing of research facilities.

Access to space for microgravity researchers is growing, with a heavy load of flight activity planned for the coming decade. Space Station Freedom's research accommodations will surpass those of all other space research facilities, particularly in the areas of power and available pressurized experiment volume.

**NASA Microgravity Combustion Discipline Working Group Chairman Gerard Faeth (University of Michigan, Department of Aerospace Engineering):**

Combustion science is relevant to the study of pollution, energy utilization, waste incineration, power and propulsion systems, and fire and explosion hazards, among other things. The implications of microgravity combustion experimentation are as important as the development of computers and optical diagnostics. Gravity has impeded fundamental understanding of combustion more than most areas of science; therefore, access to microgravity should yield major breakthroughs.

Microgravity eliminates the effects of buoyancy on combustion; scientists have never observed some of the most fundamental combustion phenomena without substantial buoyancy disturbances. Buoyancy inhibits research relating to propagating flames, motionless flames, flammability limits, flame spread along solid surfaces, convecting flames, convection drop combustion and turbulent combustion. This problem stands in



*Compare the spherical shape of a flame in microgravity (right) with that of a flame on Earth (left).*

the way of a rational merging of theory, in which buoyancy is of little interest, and experimentation, which always is contaminated by buoyancy.

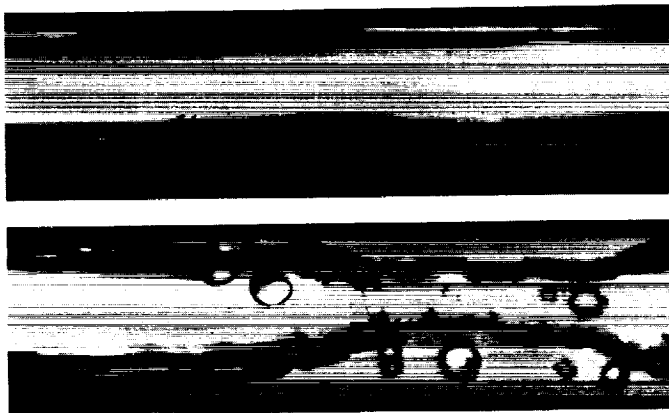
NASA-sponsored microgravity combustion investigations are using both ground- and space-based facilities. Experiments planned for space-based facilities involve laminar premixed flames, soot processes in laminar jet diffusion flames, the structure of laminar and turbulent jet diffusion flames, solid surface combustion, one-dimensional smoldering, ignition and flame spread of liquids, drop combustion, and the quenching of particle-air flames.

Combustion research in orbit is important for spacecraft fire safety because the microgravity environment can introduce new fire and explosion hazards that have no counterpart on earth. No fire-safe atmospheres have been provided on spacecraft as yet. Microgravity broadens flammability limits, creates novel regimes of flame spread, enhances flame radiation effects, slows down fire detector response, and enhances combustion upon injecting fire extinguishing agents.

On the other hand, the controlled environment of a spacecraft can offer a fire-safe atmosphere. Investigation of these problems is just beginning, with fire safety experiments supplementing fundamental combustion experiments. It is possible that fire hazards in space can be entirely eliminated, but not in the near term because of systems complications and a lack of understanding regarding human response to such an environment.

**Fluids Science Program Scientist Bradley Carpenter, Microgravity Science and Applications Division, NASA Headquarters:**

NASA's microgravity fluids science program currently supports research in multi-phase flows and heat transfers, behavior of granular media and colloids, interface dynamics, morphological stability, and contact line phenomena. Advances in these areas will enhance understanding of materials processing in space and on Earth and contribute to diverse technologies such as oil and chemical extraction.



*Air rises above flowing water on Earth (top); in microgravity, air bubbles remain mixed with the liquid (bottom).*

NASA's Fluid Physics Dynamics Facility will be the primary platform for microgravity fluid physics on Space Station Freedom. Experiment-unique equipment will be changed out once a year. NASA is evaluating 207 proposals received in response to fluid physics research announcements. NASA will fund experiments in six research areas: capillary phenomena, multiphase flow and heat transfer, diffusive transport, magneto/electrohydrodynamics, colloids and nucleation phenomena, and solid-fluid interface; 40 to 50 proposals will likely be funded. Addi-

tional solicitations will be issued for flight and ground-based research proposals.

**NASA Materials Science Discipline Working Group Chairman John Perepezko (University of Wisconsin-Madison):**

The goals of materials science research in microgravity are to understand relationships between materials microstructure and properties during processing and to apply process modeling and advanced processing concepts toward achieving designed microstructures.

The objective is to use microgravity to advance understanding of materials processing, including phase transformations during solidification and deposition, transport phenomena, and structure-property relationships. Technological applications of microgravity materials science include containerless processing, directional solidification and crystal growth, and casting.

Extended-duration space flights offer new opportunities to control the microstructure, processing, and properties of materials. First, minimizing gravitational effects reduces buoyancy-driven convection. Flows caused by density differences, due to composition or temperature gradients, will then be reduced or eliminated, permitting more precise control of the temperature and the composition of a melt (critical to achieving high-quality crystal growth of electronic materials or alloys).

Operating in microgravity will facilitate containerless processing by doing away with the limitations of containment for reactive melts. Non-contacting electromagnetic, electrostatic, or acoustic fields can be used to position samples. Containerless processing minimizes contamination, enabling the study of reactive melts and eliminating extraneous crystal nucleation so that novel crystalline structures and new glass compositions may be produced.

To take full advantage of the microgravity environment, materials researchers will need reliable processing models based on sound ground-based experimental experience and established thermophysical property data.

***Biophysics Branch Chief Daniel Carter, NASA Marshall Space Flight Center:***

NASA's biotechnology program uses the microgravity environment to investigate bioprocessing phenomena. The program currently supports research in the areas of crystal growth of biological macro-molecules and cell and molecular science. In the latter area, research on tissue cultures is under way at NASA's Johnson Space Center, using bioreactors for processing.

One objective of protein crystal growth research in space is to identify optimal conditions for nucleating and growing crystals. Another objective is to identify optimal methods of manipulating crystals in microgravity. By determining the structure of protein crystals, scientists may be able to develop dramatically improved medical and agricultural products. It can take up to three months to grow a protein crystal in space, due to slow growth or delayed initiation of growth.

Long-duration experiments on Space Station Freedom will enable researchers to learn more about optimum mixing times and solution concentrations. Longer periods on orbit can be beneficial because scientists cannot predict how long it will take to grow a particular crystal. Several crystal structures grown in Space Shuttle experiments have been refined to significantly higher resolution than obtainable on the ground.

***Session Co-chairman Jim Fountain (Program Manager, Commercial Use of Space Station Freedom, Office of Commercial Programs, NASA Headquarters):***

NASA's Office of Commercial Programs supports space research that meets the needs of U.S. industry, mainly through cosponsorship of a national network of Centers for the Commercial Development of Space (CCDSs). A major objective of the CCDSs is to produce a body of knowledge and experience that will allow U.S. industries to make informed decisions regarding participation in commercial space endeavors. Companies that wish to work more independently with NASA may negotiate Joint Endeavor Agreements or commercial reimbursable agreements. Each type of agreement entails different types and levels of risks for the parties to it.

OCP-sponsored investigations use a variety of flight hardware and transportation methods for gaining microgravity experience. Experiment carriers range from KC-135 aircraft and sounding rockets to the Space Shuttle, giving researchers the flexibility to vary payload complexity and cost. OCP has sponsored the building of 32 payload hardware elements that have flown in space a total of 73 times.

In 1993, two new capabilities will be available to accommodate microgravity experiments. COMET, a recoverable experiment capsule to be launched by expendable launch vehicle, can keep experiments in orbit for extended periods; and Spacehab, a pressurized module, will expand the Shuttle's middeck payload accommodations. In addition, OCP is supporting the development of a Wakeshield Vacuum Facility by Space Industries Inc. and the University of Houston's Center for the Commercial Development of Space. OCP is planning a number of space station experiments for launching in 1996 and 1997.

***Commercial Development Associate Director Marianna Long, Center for Macromolecular Crystallography (University of Alabama in Birmingham):***

The Center for Macromolecular Crystallography (CMC) is sponsoring research into the large-scale crystallization of proteins in microgravity via temperature change. The major objective is temperature-driven growth of protein crystals in large batches in the microgravity environment. Another objective is to use temperature to initiate and control protein crystal growth. The results of this



*Protein crystals grown on Earth.*

research may be beneficial in developing pharmaceutical products such as human insulin, human growth hormone, interferons, and tissue plasminogen activator.

Crystal growth can proceed unhindered in microgravity due to lack of surface effects. Initiating protein crystal growth via temperature enables dynamic control and eliminates the need for seeding. Because crystallization is also a procedure for purifying organic materials, microgravity crystallization could be used to remove trace impurities from high-value protein pharmaceutical products.

In two insulin-crystal-growth experiments using a Protein Crystal Growth Facility (PCF) on the Space Shuttle, the hardware performed perfectly, and many crystals were produced that were much larger than ground-grown controls. Crystal size was a function of container volume. X-ray analysis showed that the bigger space-grown insulin crystals diffracted to higher resolution than their ground controls. When the data were normalized for size, they still indicated that the space crystals were better than the ground crystals. Researchers do not yet know why crystal size is linked to container or whether the temperature gradient within a container affects crystal size.



*Protein crystal grown in microgravity.*

**Center for Cell Research Director Wesley Hymer (Penn State University):**

The goal of the Center for Cell Research (CCR) is to encourage industry-driven

biomedical/biotechnology space projects. The CCR focuses on commercial product- and process-oriented biomedical/biotechnology projects in physiological testing, bioseparations, and illumination. Space-based physiological testing involves animal subjects, tissues or cells for pharmaceutical testing, and research into ground-based health problems.

The CCR's bioseparations program offers industry access to continuous flow electrophoresis and aqueous two-phase partitioning in space. This program is the first to include ground-based mathematical modeling services that enable preflight evaluations of performance. The center's illumination studies program aims to develop photometric equipment for biological experimentation and lighting for space- and ground-based biological experiments.

Through its commercial partner program, the CCR offers access to flight, experiment planning and post-flight analysis, payload integration, and mission management, as well as expertise in intellectual property agreements. The CCR is working with Genentech Inc. on the first commercial physiological experiment to be flown in space; it will measure the effects of microgravity on a number of proteins.

The center is developing equipment to accommodate experiments on sounding rocket and COMET missions. A robotic minilab called the Penn State Biomodule, developed for cellular and crystal growth studies, will be launched on a CONSORT sounding rocket. In addition, Penn State is working with a CCR industry affiliate, Corabi International Telemetrics, to market a telepathology instrument for long distance transmission and control of microscope images. The instrument is also being developed for use on Space Station Freedom.

**Director Charles Lundquist, Consortium for Materials Development in Space:**

The Consortium for Materials Development in Space (CDMS) focuses on commercial materials development projects that benefit from the unique attributes of space and rely on innovative applications of physical chemistry and materials transport and their interactions. In addition to sponsoring research, the Consortium is also developing space processing

equipment, launch vehicles for access to space, and hardware and techniques to measure spacecraft environments.

The Sintered and Alloyed Materials Project is a CMDS initiative that could benefit from operating on Space Station Freedom. Two furnace systems are candidates for this project: the Space Experiment Facility and the Equipment for Controlled Liquid Phase Sintering Experiment (ECLiPSE). Hardware could be left on orbit for extended periods of time.

However, crew interaction with such equipment could be valuable; the carrier for the ECLiPSE will be compatible with Spacehab, Freedom, and other systems. Other hardware being developed by the CDMS that is of potential interest to space station researchers includes accelerometer systems and atomic oxygen flux measurement systems.

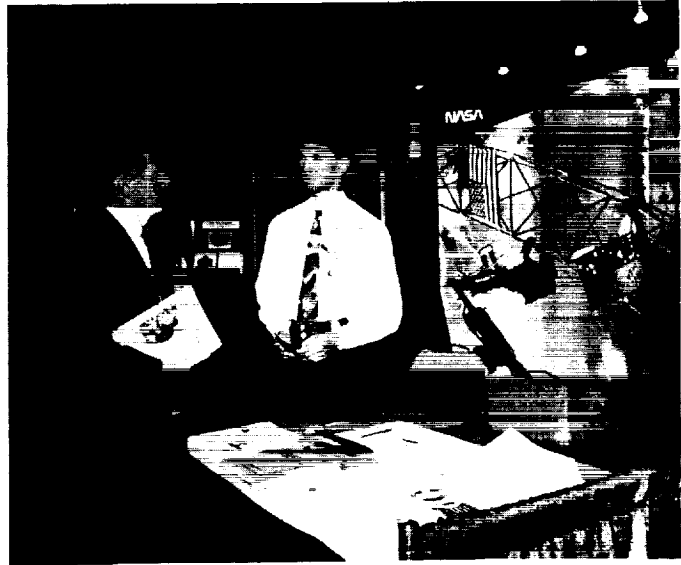
***Materials Dispersion and Biodynamics Manager Marian Lewis, Consortium for Materials Development in Space:***

The CMDS's Materials Dispersion and Biodynamics Project (MDBP) focuses on the dispersion and mixing of various biological materials and the dynamics of cell-to-cell communication and intracellular molecular trafficking in microgravity. Research encompassed by this project includes biomedicine, cell biology, biotechnology, protein crystal growth, ecological life support (involving algae and bacteria), drug delivery, biofilm deposition by living organisms, and hardware development to support living cells on Space Station Freedom.

MDBP experiments will be launched on sounding rockets, the Space Shuttle, and COMET capsules. Ultimately, larger-scale commercial operations will be launched on Space Station Freedom. The consortium is working to inform prospective space station researchers about potential commercial medical applications of microgravity research and to solicit involvement in the consortium's activities.

The objectives of the MDBP are to raise private-sector awareness of the research potential of space, facilitate private-sector development of hardware for microgravity research, and develop cell cultures, crystals, and processes in space that will yield commer-

cial products. The project is a collaboration among industry, university and government researchers. The consortium is contacting potential researchers in the biotechnology and pharmaceutical industries.



*Conference participants at NASA's Office of Commercial Programs exhibit.*

***Project Manager, Barbara Heizer, Crystals by Vapor Transport Experiment (CVTE) and Space Experiment Facility (SEF), Boeing Aerospace Corporation:***

The Crystals by Vapor Transport Experiment (CVTE) and Space Experiment Facility (SEF) are materials processing facilities built for use on the Space Shuttle middeck. Boeing is pursuing these projects because space systems are a major Boeing product area, materials processing is a prime element of commercial space activities, and potential markets exist for space materials processing facilities.

The CVTE, which took six years to develop, is scheduled to fly on the Space Shuttle in October 1992, under a Joint Endeavor Agreement between NASA and Boeing. Boeing is building the SEF under a contract with the Center for Macromolecular Crystallography at the University of Huntsville; it is designed to fly on an early Spacehab mission, and it is currently undergoing environmental testing.

Boeing took the following steps in developing these projects: development of cooperative agreements with researchers, selection of

appropriate vapor transport crystal growth process, identification of candidate materials for space processing, and design and development of hardware.

It is vital to name a chief scientist early for a project like the CVTE. The chief scientist develops an experiment plan that will shape hardware and software design, runs ground and flight research, and interfaces with the scientific community. The Chief Scientist must have authority equal to that of the Chief Engineer. A Mission Manager is needed to represent the payload through integration and serve as an advocate.

Investigators should get involved in the process early to ensure that their experiments are compatible with ground and flight hardware. Time must be allowed for confidence building between investigators and the resident science and engineering team. All parties must be prepared to compromise and recognize that the experiment flown may differ from the original concept because of incompatible requirements.

#### **Session 4: Closing Plenary**

The final session of the conference began with reports on discussions in the previous day's splinter sessions, delivered by session chairpeople (*see above*) and closed with presentations by an astronaut who is a veteran of three Space Shuttle missions and a staff representative of the NASA authorization committee on the U.S. House of Representatives.

Questions that arose during the splinter sessions and throughout the plenary sessions included: How much funding will be available to researchers? How many years of funding will NASA provide for a single research project? Will crew activities on Freedom disturb the stable microgravity environment required for certain types of experiments? Will investigators have a role in choosing the crew members who will work on their experiments? How can researchers ensure that they are informed of NASA research opportunities?

NASA officials explained that funding for space research varies from year to year and

project to project; proposals are usually funded for no more than two years. It does not appear that crew activities will affect the microgravity environment on Freedom, but NASA is still studying the issue. Investigators will have a say in crew assignments for space station research projects. To ensure that they are informed of all upcoming NASA research opportunities, researchers should give their names and addresses to NASA to be added to a mailing list. (See inside back cover for contacts.)

**NASA Astronaut Bonnie Dunbar (crew member, Space Shuttle mission USML 1):** Space Shuttle crews train for 18 months per mission; they are assigned to science missions according to their background. Training encompasses preparations for troubleshooting. Astronauts often need to make judgment calls about how investigations will proceed in space; they want to work with investigators on preparing payloads and planning science operations so they will be as familiar as possible with the experiment. "We're here to serve you.... We're your heads, eyes, and ears in orbit."

The astronaut office at Johnson Space Center has organized an ad hoc science support group to keep abreast of the state of the art in science. The activities of this group support the work of the astronaut office's mission development group.

Astronauts are already testing space station precursor hardware on Space Shuttle missions, including two types of gloveboxes, and studying onboard vibration disturbances. Thus far, vibration caused by crew exercise has been indistinguishable from the background vibration of 5-10 micro-gs.

**Science Advisor Richard Obermann, Subcommittee on Space, House Committee on Science, Space, and Technology:**

Thus far, Congress has not approved the transfer of funds allotted for defense to the Government's discretionary spending account, from which NASA's budget comes. Thus, with budget deficit reduction a pressing need, increasing funds for one discretionary program (such as NASA) requires cutting funds for another.



NASA's Fiscal Year 1993 budget request is "a modest one" — 4.8 percent accounting for inflation. But Congress likely will approve a FY 93 NASA budget that is 1-5 percent less than NASA's FY 92 budget. With regard to Space Station Freedom, Congress has two major concerns. First, NASA must make Freedom as accessible as possible to all prospective researchers. Second, NASA must structure space station operations in a way that minimizes costs over the project's 30-year life. ♦



*Astronaut Bonnie Dunbar and Congressional Science Advisor Richard Obermann.*

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*SPACE STATION FREEDOM  
UTILIZATION CONFERENCE*

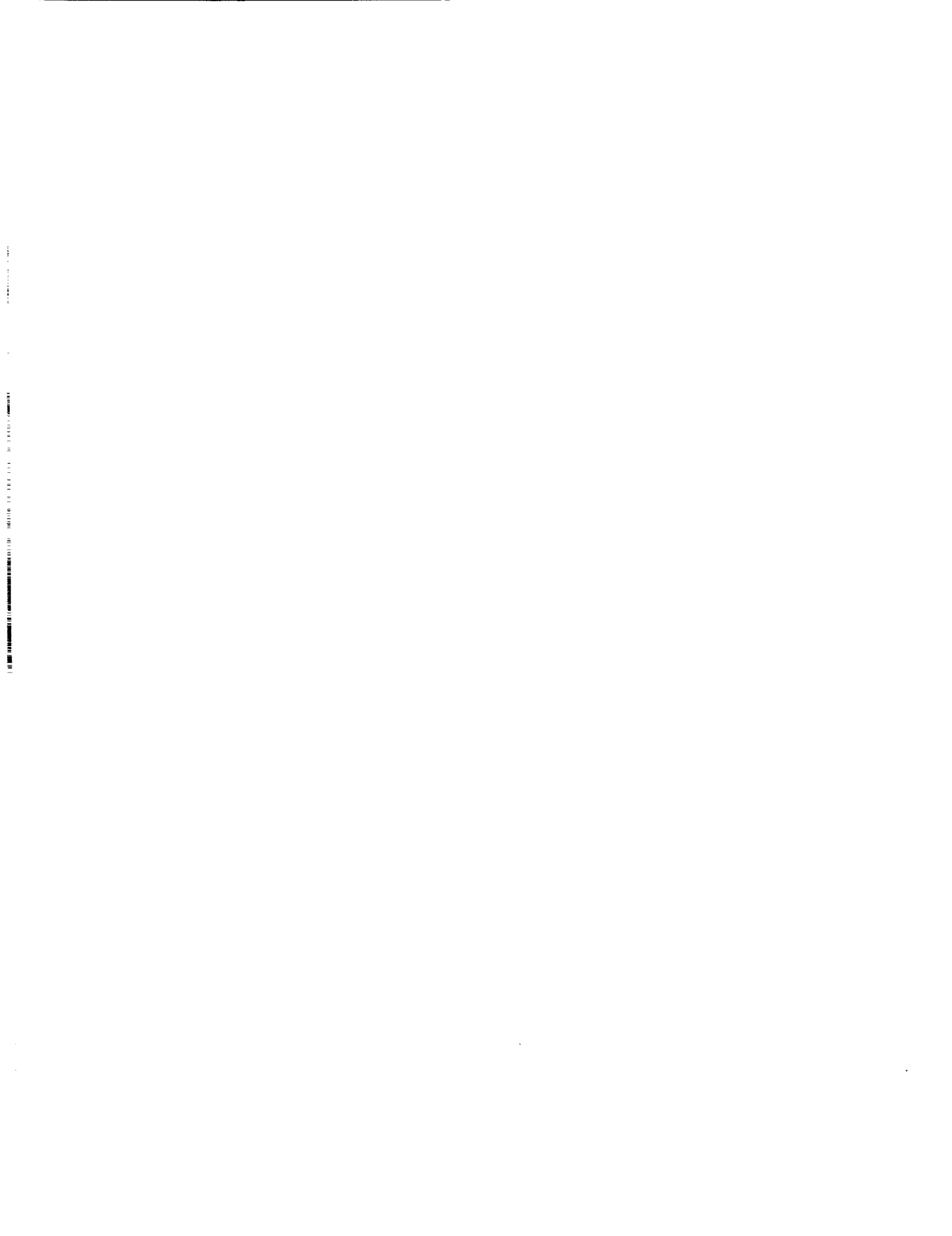
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*VON BRAUN CIVIC CENTER  
HUNTSVILLE, ALABAMA  
AUGUST 3-6, 1992*

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*CONFERENCE PROCEEDINGS*

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# AGENDA

## SPACE STATION FREEDOM UTILIZATION CONFERENCE

### **SESSION 1: Monday, August 3**

#### **Welcome Lunch**

- Welcoming Remarks  
Jack Lee, Director, NASA Marshall Space Flight Center

#### **Space Station Freedom Overview and Research Capabilities**

- Introduction to Space Station Freedom  
Richard Kohrs, Director, Space Station Freedom (SSF),  
NASA Office of Space Systems Development
- Space Station Freedom Research Capabilities  
Robert W. Moorehead, Deputy Director, Space Station Freedom Program and Operations,  
NASA Office of Space Systems Development
- Opportunities for Research on Space Station Freedom  
Dr. Robert W. Phillips, Chief Scientist, Space Station Freedom,  
NASA Office of Space Systems Development
- How To Get On Board Space Station Freedom  
Dr. John-David Bartoe, Director, User Integration,  
Spacelab/Space Station Utilization, NASA Office of Space Flight

### **SESSION 2: Tuesday, August 4**

#### **Space Station Freedom Research Plans and Opportunities**

- Commercial Research Plans and Opportunities  
Ray J. Arnold, Deputy Assistant Administrator,  
NASA Office of Commercial Programs
- Space Technology Research Plans  
W. Ray Hook, NASA Office of Aeronautics and Space Technology,  
(Director for Space, NASA LaRC)
- OSSA Space Station Freedom Science Utilization Plans  
Dr. Philip J. Cressy, Chief, Space Station Utilization Branch,  
NASA Office of Space Science and Applications (OSSA)
- Commercial Researcher Perspective  
Dr. Larry DeLucas, Associate Director, Protein Crystal Growth,  
University of Alabama at Birmingham, Center for Macromolecular Crystallography
- Japanese Plan for Space Station Freedom Utilization  
Toshio Mizuno, Deputy Director of the Space Station Program,  
National Space Development Agency of Japan
- Canadian Space Agency Research Plans  
James Faulkner, Manager, Space Station Operations and Utilization, Canadian Space Agency

# SPACE STATION FREEDOM UTILIZATION CONFERENCE

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- **European Research Plans**  
Jean-Jacques Dordain, Head of Microgravity and Columbus Utilization Department, European Space Agency
- **Space Life Sciences Perspectives for Space Station Freedom**  
Dr. Laurence R. Young, Professor of Aeronautics and Astronautics, MIT and Payload Specialist in Training, Spacelab Life Sciences Mission 2
- **Research Experiences on Materials Science in Space Aboard Salyut and Mir**  
Dr. Liya L. Regel, Director, International Center for Gravity Materials Science and Applications, Clarkson University (Former Head, Materials Science Department, Institute for Space Research, USSR Academy of Sciences)

## **Keynote Address**

- Daniel S. Goldin, NASA Administrator

## **SESSION 3: Wednesday, August 5**

### **Life Sciences Research on Space Station Freedom**

- **Life Sciences Utilization of Space Station Freedom**  
Lawrence Chambers, Manager, Space Station Life Sciences Program, NASA Office of Space Science and Applications
- **Life Sciences Recruitment Objectives**  
Dr. J. Richard Keefe, Program Scientist, Space Station Life Sciences Program, NASA Office of Space Science and Applications
- **Biomedical Monitoring and Countermeasures Facility**  
Donald F. Stewart, M.D., Manager, BMAC, NASA Office of Space Science and Applications
- **Gravitational Biology Facility on Space Station Freedom**  
Katherine Allen, Project Bioengineer, NASA Ames Research Center
- **Gas Grain Simulation Facility**  
Dr. Ken Greenwald, Facility Scientist, NASA Ames Research Center
- **Research Opportunities with the Centrifuge Facility**  
Dr. Glenn Funk, Senior Scientist, NASA Ames Research Center
- **CELSS Test Facility**  
Dr. Robert MacElroy, Project Manager, NASA Ames Research Center  
(Presented by Dr. John Tremor)
- **An On-Orbit Viewpoint of Life Sciences Research**  
Byron Lichtenberg, former NASA Payload Specialist Astronaut and Life Sciences Researcher
- **Crew Health**  
Dr. Roger D. Billica, Chief, Medical Operations Branch, NASA Johnson Space Center

## ***Technology Research on Space Station Freedom***

- Space Station Freedom as an Engineering Experiment Station  
Dr. M. Frank Rose, Director, Space Power Institute, Auburn University
- Precursor Space Station Freedom Experiments  
Sherwin M. Beck, Systems Analysis and Engineering Office, Space Station Freedom Office, NASA LaRC  
(Presented by Dr. Roger A. Breckenridge)
- Middeck 0-gravity Dynamics Experiment (MODE)  
Professor Edward F. Crawley, Department of Aeronautics and Astronautics, MIT
- Utilization of Space Station Freedom for Technology Research  
Don E. Avery, Space Station Utilization Office, Space Station Freedom Office, NASA LaRC
- Modal Identification Experiment  
Raymond G. Kvaternik, Spacecraft Dynamics Branch, Structural Dynamics Division, NASA LaRC
- Experiment Activities in Support of Space Station Freedom  
Richard DeLombard, In-Space Technology Experiments, NASA LeRC
- Spacecraft Materials and Coatings Experiments  
Wayne S. Slemple, Senior Researcher, Materials Division, NASA LaRC  
(Presented by Don E. Avery)
- Long Duration Space Materials Exposure (LDSE)  
David Allen (Allen Aerospace), Center for Materials and Structure, Case Western Reserve University
- Potential Pressurized Payloads; Fluid and Thermal Experiments  
Theodore D. Swanson, Advanced Development and Flight Experiment Section, NASA Goddard Space Flight Center
- 0-gravity Life Support for Space Station Freedom  
Matthew Kolodney, Lockheed Corporation
- Space Station Freedom Attached Payload Accommodations  
Jim Scheib, McDonnell Douglas Corporation

## ***Microgravity Research and Biotechnology on Space Station Freedom***

- Research Objectives, Opportunities and Facilities  
Dr. Robert Bayuzick, Visiting Senior Scientist, Department of Material Science, Vanderbilt University on Sabbatical to Microgravity Sciences and Applications Division, NASA Office of Space Science and Applications
- Combustion Research  
Professor Gerard Faeth, Department of Aerospace Engineering, University of Michigan, Chairman of the Combustion Discipline Working Group
- Microgravity Fluid Physics Research  
Dr. Bradley Carpenter, Program Scientist, Microgravity Sciences and Applications, NASA Office of Space Sciences and Applications

## ***SPACE STATION FREEDOM UTILIZATION CONFERENCE***

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- **Materials Science Research in Microgravity**  
Professor John H. Perepezko, Department of Metallurgical and Materials Engineering, University of Wisconsin, Chairman of the Materials Science Discipline Working Group
- **Protein Crystal Growth**  
Dr. Daniel Carter, Chief of Biophysics Branch, NASA Marshall Space Flight Center, Vice Chairman of the Biotechnology Discipline Working Group
- **Office of Commercial Programs' Research Activities**  
James Fountain, Program Manager, Commercial Utilization of Space Station Freedom, NASA Office of Commercial Programs
- **Large Scale Crystallization of Protein Pharmaceuticals in Microgravity via Temperature Change**  
Dr. Marianna Long, Associate Director, Commercial Development, Center for Macromolecular Crystallography
- **Commercial Opportunities in Bioseparations and Physiological Testing Aboard Space Station Freedom**  
Dr. Wesley Hymer, Director, Center for Cell Research
- **Consortium for Materials Development in Space (CMDS)**  
Dr. Charles Lundquist, Director, Consortium for Materials Development in Space (CMDS)
- **Materials Dispersion and Biodynamics Project Research**  
Dr. Marian Lewis, Manager of Materials Dispersion and Biodynamics, CMDS
- **Space Experiments Facility and Crystals by Vapor Transport Experiment**  
Barbara Heizer, Project Manager, Boeing Aerospace Corporation

### ***SESSION 4: Thursday, August 6***

#### ***Closing Plenary***

- **A Congressional Perspective on the Space Station Program**  
Dr. Richard Obermann, Science Advisor, Space Subcommittee, Committee on Science, Space and Technology, U.S. House of Representatives
- **Crew Experience in Space Research**  
Bonnie J. Dunbar, Mission Specialist - Payload Commander for the U.S. Microgravity Laboratory
- **Open Forum with Audience Participation on Selected Issues and Topics**  
Dr. Robert Bayuzick, Dr. Judith Ambrus, Lawrence Chambers and James Fountain
- **Closing Remarks**  
Dr. John-David Bartoe



*SESSION 1:  
OVERVIEW AND RESEARCH CAPABILITIES*

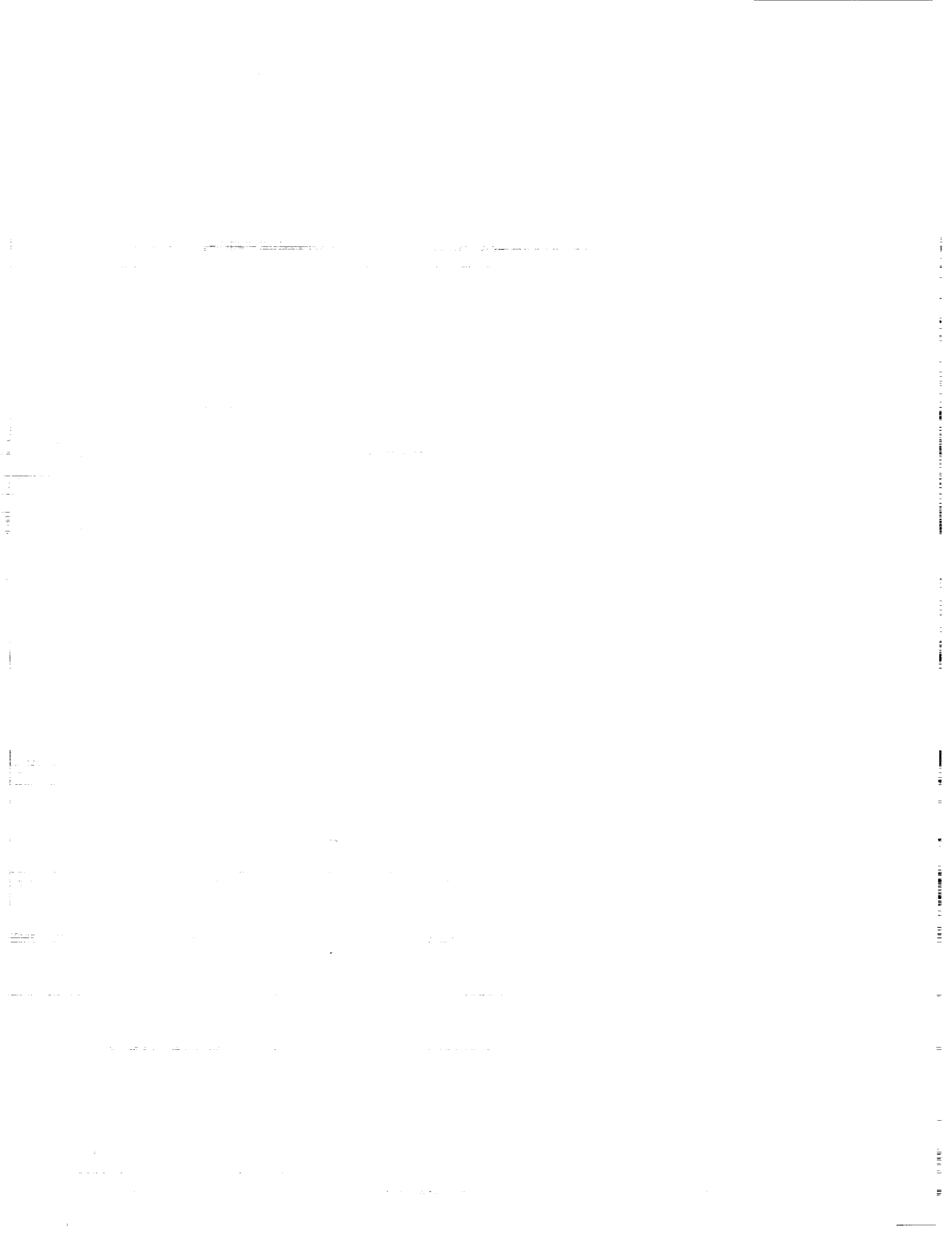
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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 3, 1992*

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**INTRODUCTION TO SPACE STATION FREEDOM**

Presented by Richard Kohrs  
NASA Office of Space Systems Development  
NASA Headquarters

**ABSTRACT**

NASA field centers and contractors are organized to develop "work packages" for Space Station Freedom. Marshall Space Flight Center and Boeing are building the U.S. laboratory and habitation modules, nodes, and environmental control and life support system; Johnson Space Center and McDonnell Douglas are responsible for truss structure, data management, propulsion systems, thermal control, and communications and guidance; Lewis Research Center and Rocketdyne are developing the power system. The Canadian Space Agency (CSA) is contributing a Mobile Servicing Center, Special Dextrous Manipulator, and Mobile Servicing Center Maintenance Depot. The National Space Development Agency of Japan (NASDA) is contributing a Japanese Experiment Module (JEM), which includes a pressurized module, logistics module, and exposed experiment facility. The European Space Agency (ESA) is contributing the Columbus laboratory module.

NASA ground facilities, now in various stages of development to support Space Station Freedom, include: Marshall Space Flight Center's Payload Operations Integration Center and Payload Training Complex (Alabama), Johnson Space Center's Space Station Control Center and Space Station Training Facility (Texas), Lewis Research Center's Power System Facility (Ohio), and Kennedy Space Center's Space Station Processing Facility (Florida).

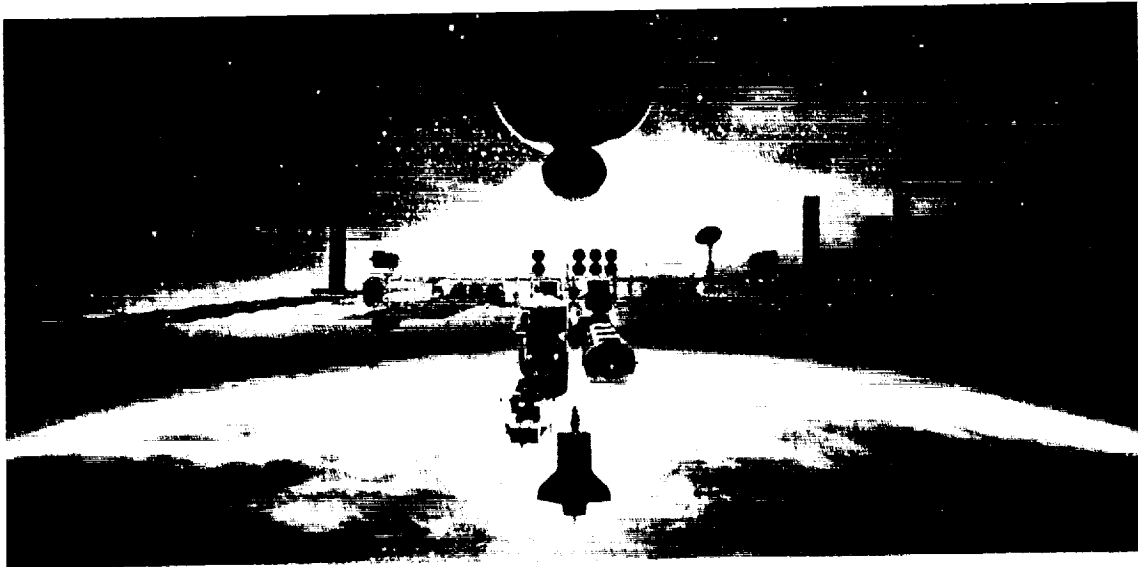
Budget appropriations impact the development of the Space Station. In Fiscal Year 1988, Congress appropriated only half of the funds that NASA requested for the space station program (\$393 million vs. \$767 million). In FY 89, NASA sought \$967 million for the program, and Congress appropriated \$900 million. NASA's FY 90 request was \$2.05 billion compared to an appropriation of \$1.75 billion; the FY 91 request was \$2.45 billion, and the appropriation was \$1.9 billion.

After NASA restructured the Space Station Freedom program in response to directions from Congress, the agency's full budget request of \$2.029 billion for Space Station Freedom in FY 92 was appropriated. For FY 93, NASA is seeking \$2.25 billion for the program; the planned budget for FY 94 is \$2.5 billion. Further alterations to the hardware configuration for Freedom would be a serious setback; NASA intends "to stick with the current baseline" and continue planning for utilization.



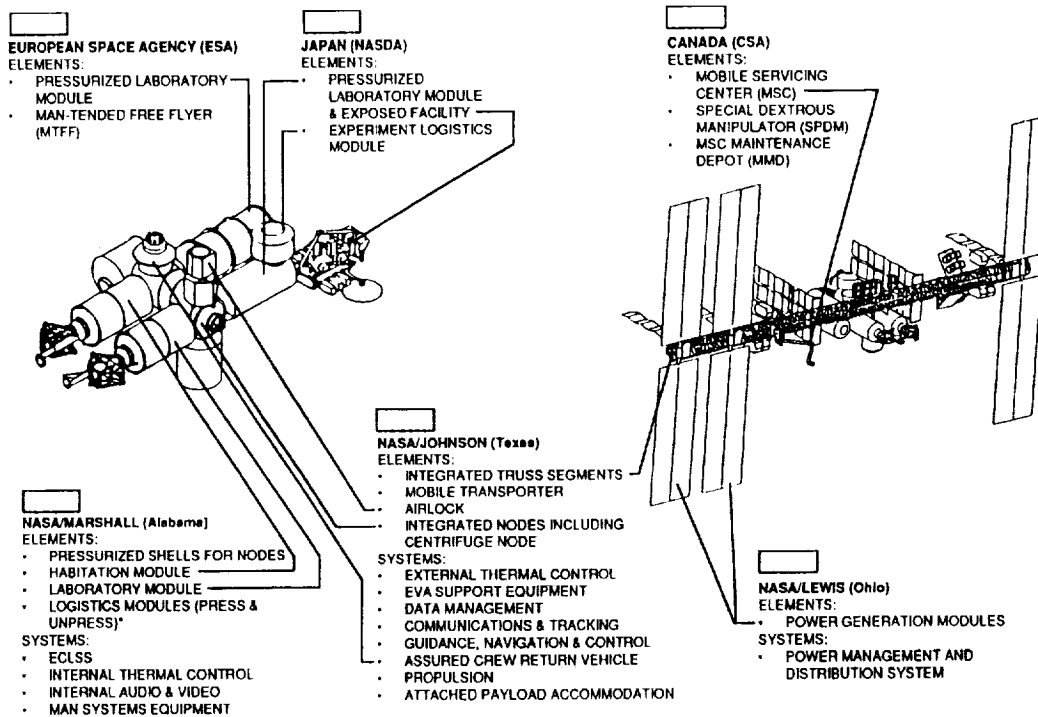
# SPACE STATION FREEDOM

## Great Nations Dare To Explore



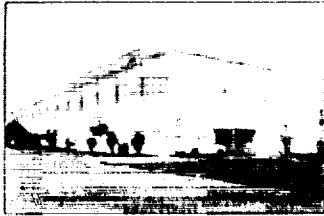
It's Time For America To Take Its Place On The Final Frontier

## SPACE STATION FREEDOM PERMANENTLY MANNED CONFIGURATION



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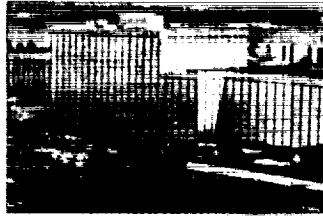
# SPACE STATION FREEDOM GROUND FACILITIES



**Marshall**

**Payload Operations Integration Center**

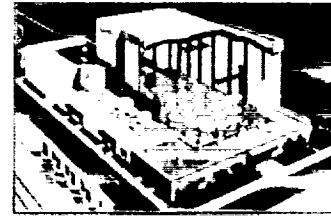
- Payload (cargo) control
- Mission management
- Science operations and integration
- Engineering Support Center for MSFC



**Johnson**

**Space Station Control Center**

- Command and control of operations
- Operations planning and analysis
- Systems monitoring and data processing
- Voice communications and video processing
- Orbit determination and planning



**Lewis**

**Power System Facility**

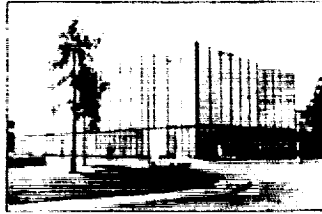
- Development/testing of
  - Power system components and control software
  - Rechargeable battery system
  - Expert automated control system
- Troubleshooting power and control system
- Analysis of electrical power system in orbit



**Marshall**

**Payload Training Complex**

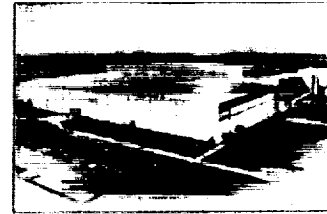
- Provides payload crew training
  - Individual payload launch
  - Integrated payload launch with support systems
  - Ground support



**Johnson**

**Space Station Training Facility**

- Provides flight crew and mission control training
- Simulation of onboard and ground procedures
- Individual/team training for Station crews and ground controllers
- Development of new operations procedures



**Kennedy**

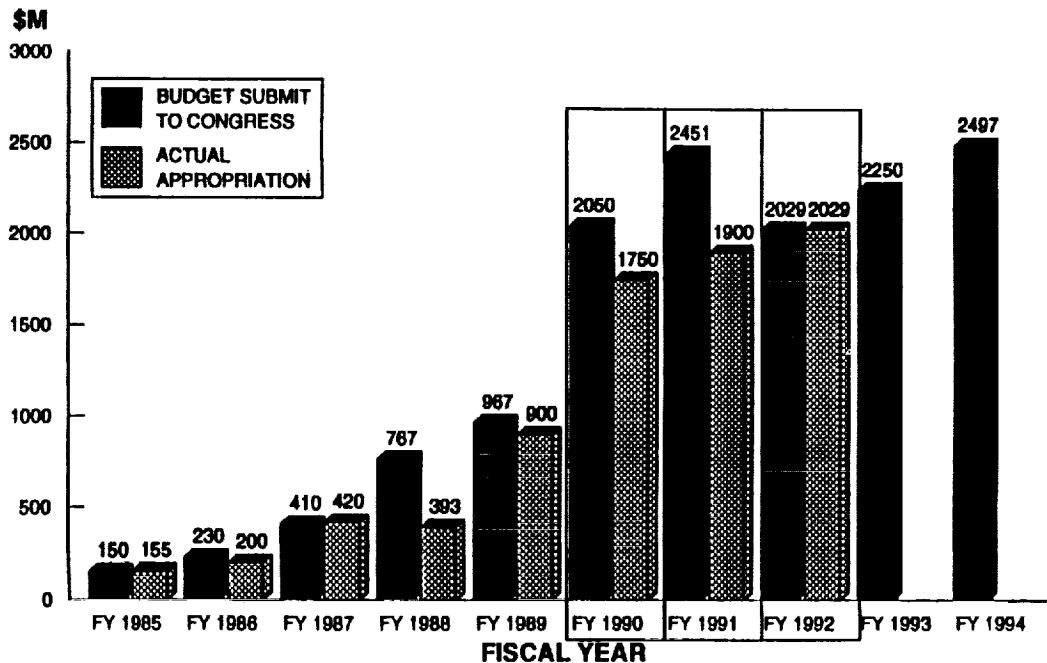
**Space Station Processing Facility**

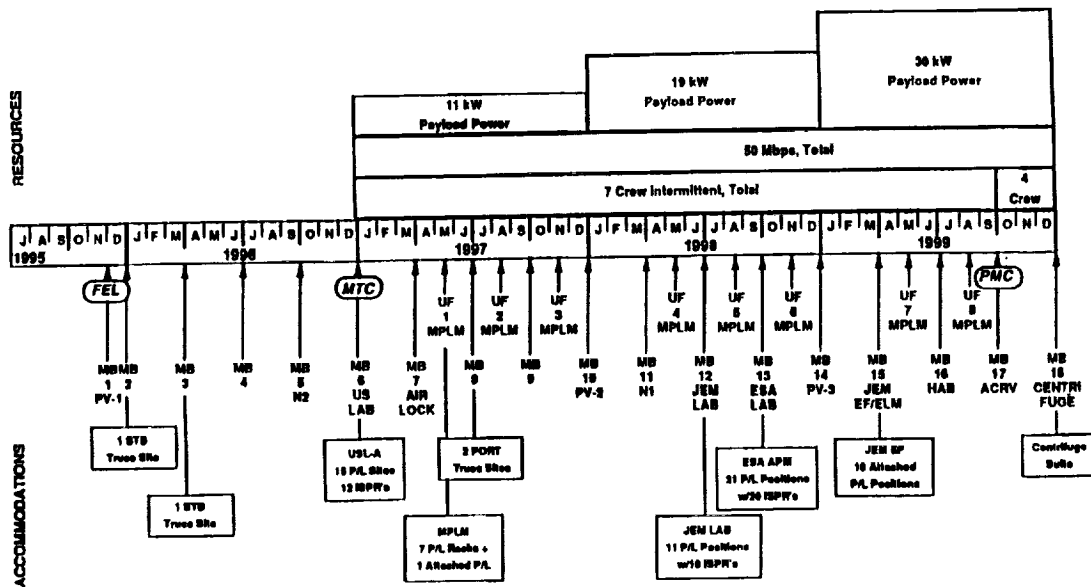
- Prelaunch/postlanding processing of non-hazardous components and supplies
- Receipt, inspection, verification of hardware
- Prepare/load elements, experiments, launch packages
- Final testing prior to launch
- Element turn-around and resupply operations

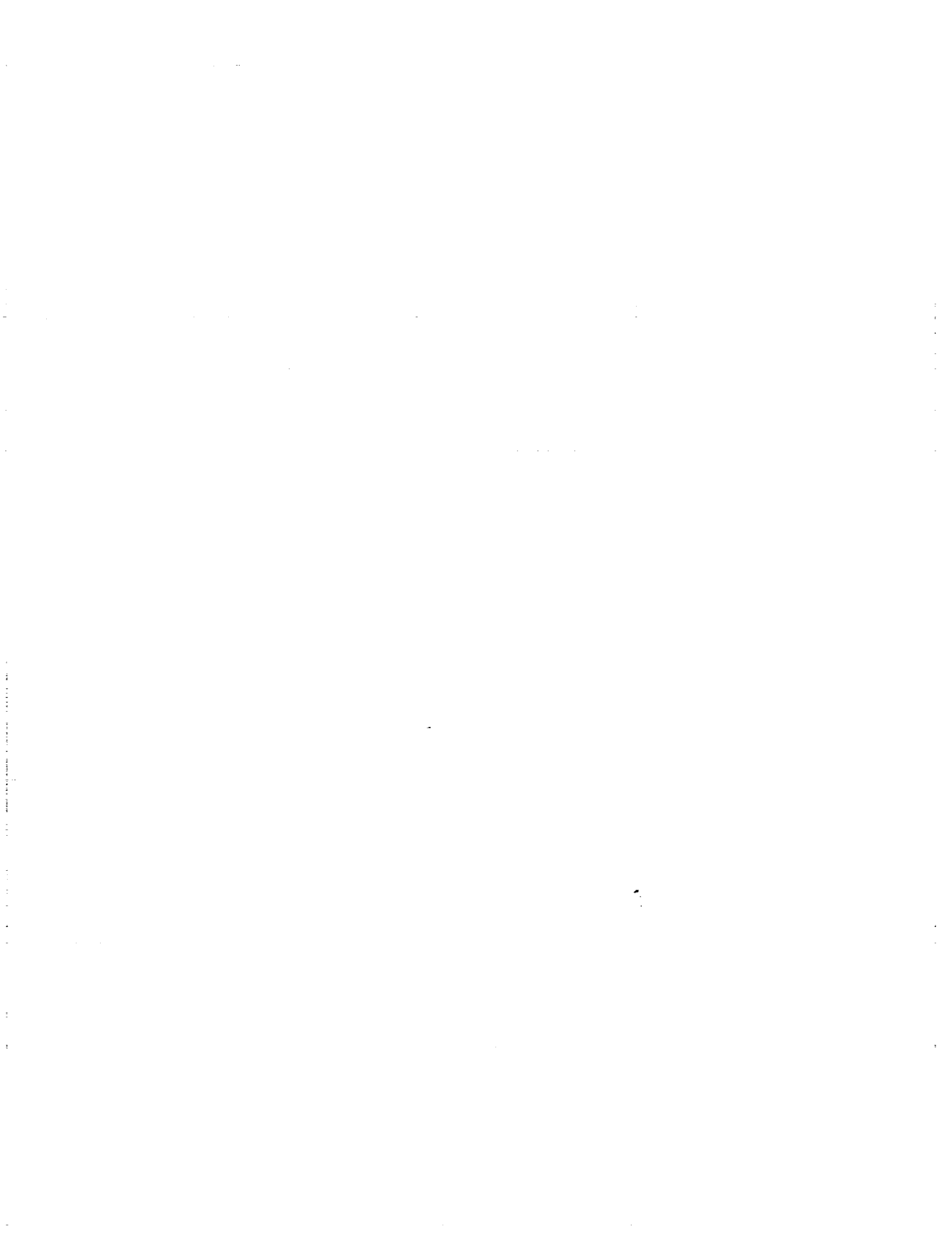


## Budget Comparisons

### Total Program Budget Authority (RY\$M)









**SPACE STATION FREEDOM RESEARCH CAPABILITIES**

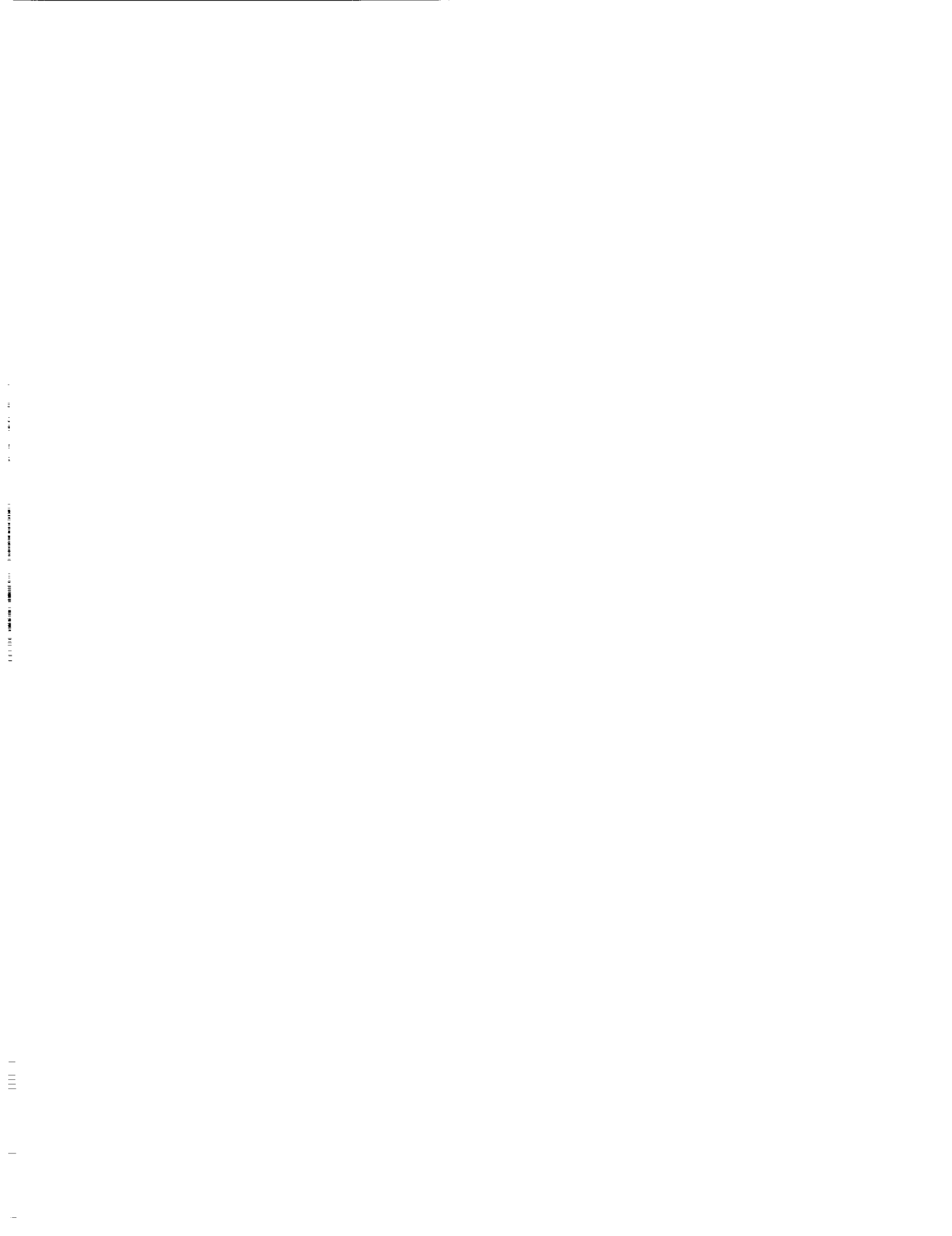
Presented by Robert Moorehead  
Space Station Freedom Program and Operations  
NASA Office of Space Systems Development

**ABSTRACT**

NASA's plan for enhancing space-based research capabilities begins with extended-duration Space Shuttle missions that will double the research capability currently provided by Spacelab and culminate in Space Station Freedom. The 14-day USML 1 mission flown on the Space Shuttle in June 1992 was a space station precursor mission, dedicated to microgravity and life science research.

Freedom will be a permanent space-based research facility, providing a working environment nearly free of buoyancy-driven convection, sedimentation, and hydrostatic pressure and featuring access to the ultra-high vacuum of space (for external payloads). In its crew-tended phase, Space Station Freedom will provide 40 times Spacelab's capability, and in its permanently occupied phase, Freedom will provide 110 times Spacelab's capability. (The Russian space station, Mir, offers 26 times Spacelab's capabilities.)

According to NASA's current schedule, the first launch of a space station element will take place in November 1995, with permanently occupied capability planned for September 1999. This year, NASA will conduct space station critical design reviews (CDRs). Work package design reviews will take place from February to April 1993, followed by a systems CDR.



# Space Station Freedom

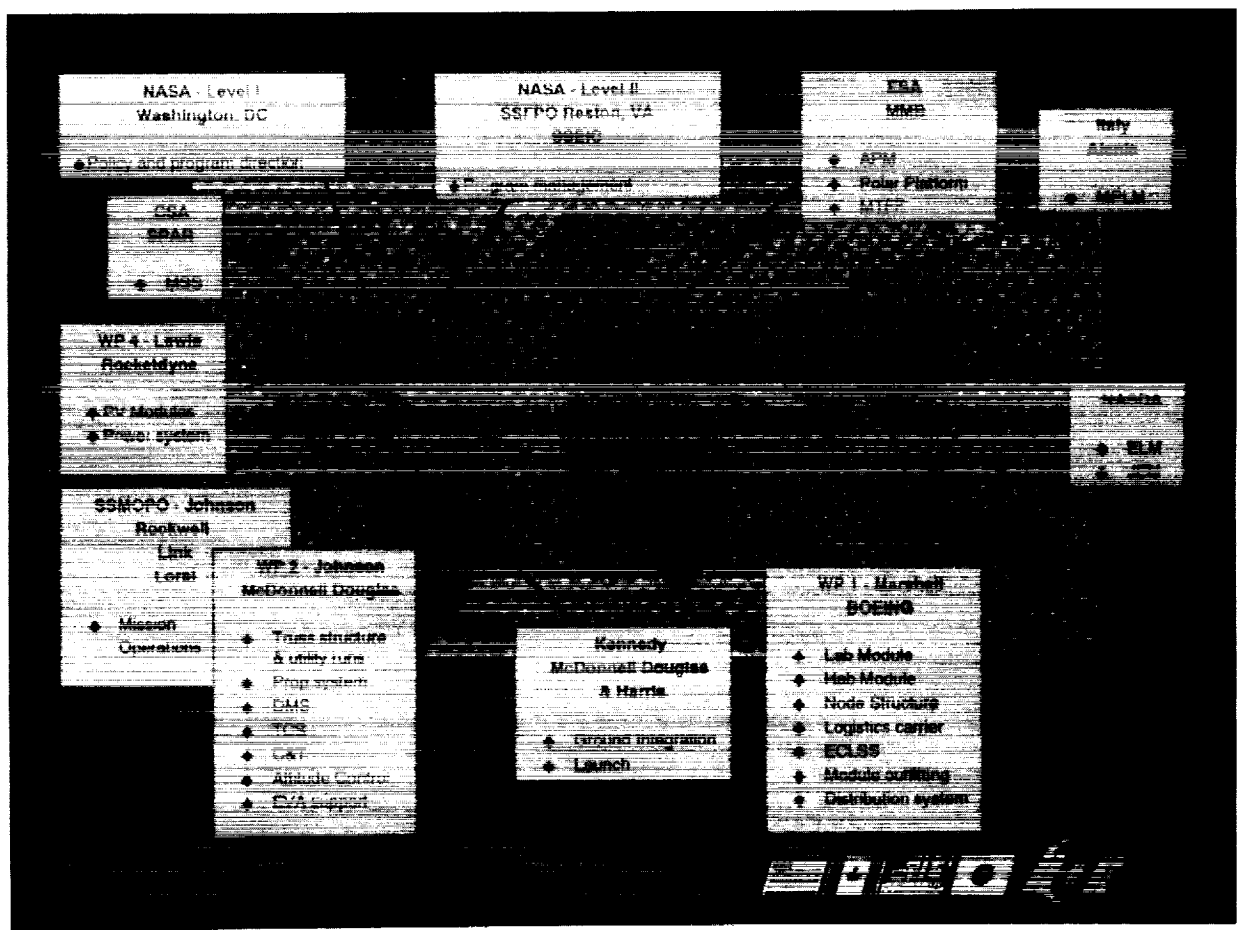
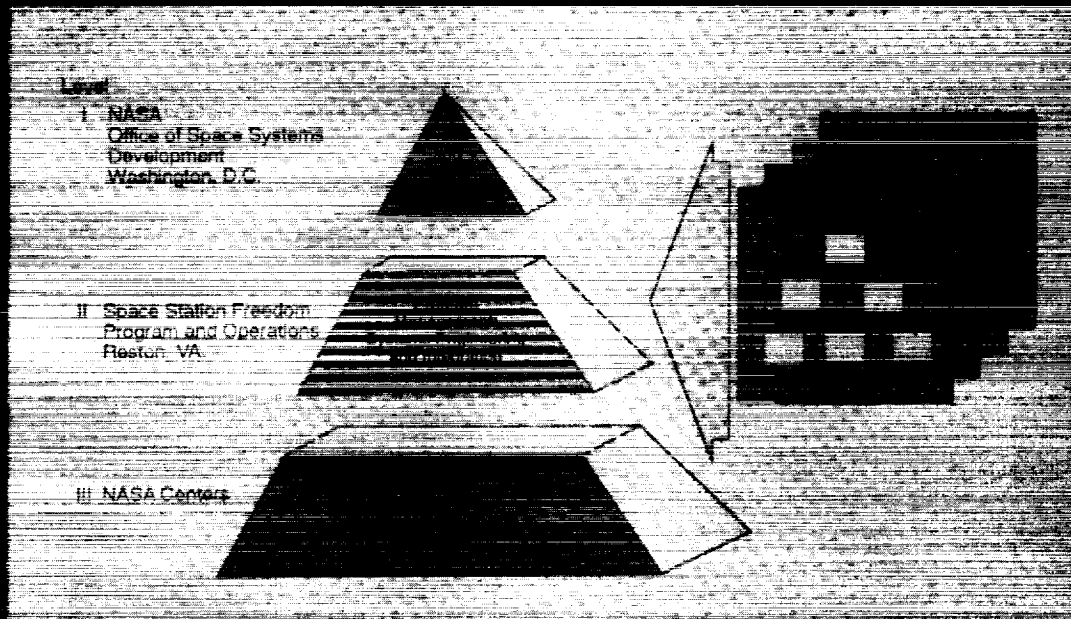


## Objectives

- ┌ Establish preeminent manned space laboratory:
  - ◆ Life & material sciences
  - ◆ Technology advancement
  - ◆ Earth & space observation
- ┌ Build infrastructure for man's evolving space exploration
- ┌ Expand our nation's leadership in civil space programs
- ┌ Promote international participation and cooperation
- ┌ Develop commercial opportunities and applications



# Space Station Freedom Program Organization



# Space Station Freedom: Scope

## Flight System

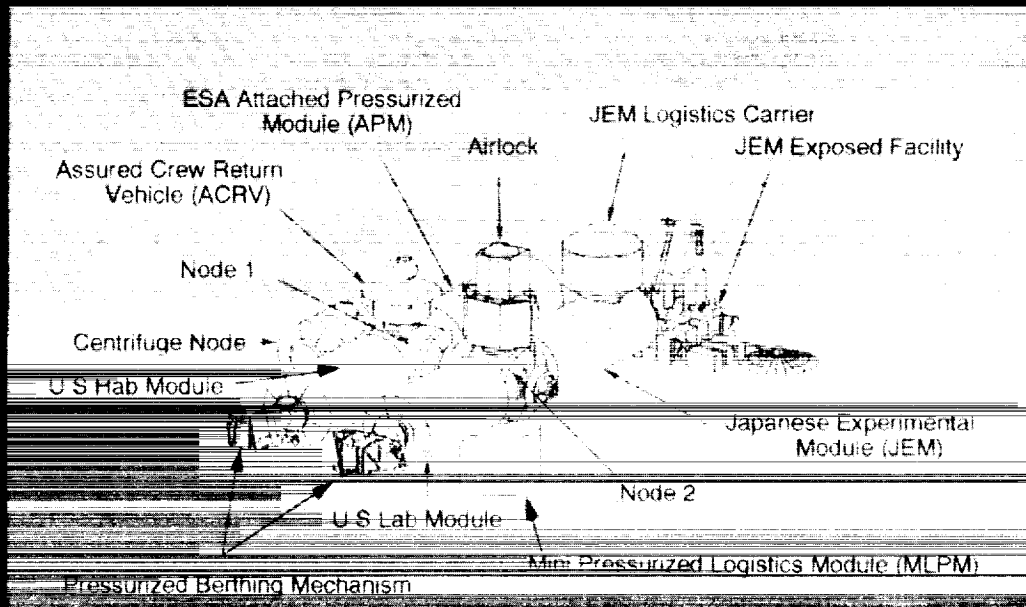
- **Architectural Elements**
  - ◆ US Laboratory
  - ◆ European Laboratory
  - ◆ Japanese Laboratory & Exposed Facility
  - ◆ Habitat Module
  - ◆ Resource Nodes
  - ◆ Centrifuge Node
  - ◆ Pre-integrated Truss
  - ◆ Logistics Carriers
  
- **Distributed Systems**
  - ◆ Electric Power
  - ◆ Thermal Control
  - ◆ Data Management
  - ◆ Guidance, Navigation & Control
  - ◆ Communication & Tracking
  - ◆ EVA Support Equipment
  - ◆ Environmental Control
  - ◆ Fluids Management
  - ◆ Propulsion

## Ground System

- **Facilities**
  - ◆ Space Station Control Center
  - ◆ Payload Operations Integration Center
  - ◆ Space Station Processing Facility
  - ◆ Space Station Training Facility
  - ◆ Payload Training Complex
  - ◆ Engineering Support Centers
  
- **Adjuncts**
  - ◆ Test Checkout and Monitoring System
  - ◆ Mission Planning System
  - ◆ Trajectory, Command, Analysis and Timeline System



## Key Elements



**PMC Module Cluster**



# Research Objectives Overview

## Design Drivers

### Life Sciences

- Space Biology
- Space Medicine
- Exobiology and Biospherics

### Material Sciences

- Fundamental Mass Transport
- Inorganic Materials
- Organic Materials

## Inherent Capabilities

### Earth Sciences

- Global Hydrology
- Climatology
- Geophysics

### Astronomical Sciences

- Plasma Physics
- Solar Physics
- Astrometric Observations



## MTC Capability

- 18.75 kW power

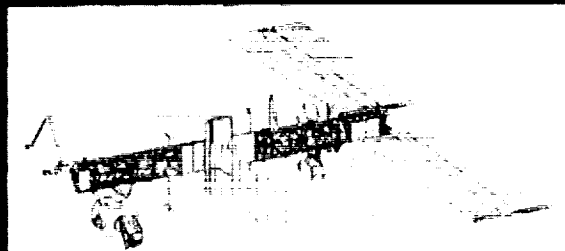
- ◆ 11 kW to users

- Pressurized volume

- ◆ US Lab - 12 racks

- ◆ Node - 4 racks

- Man-tended operations

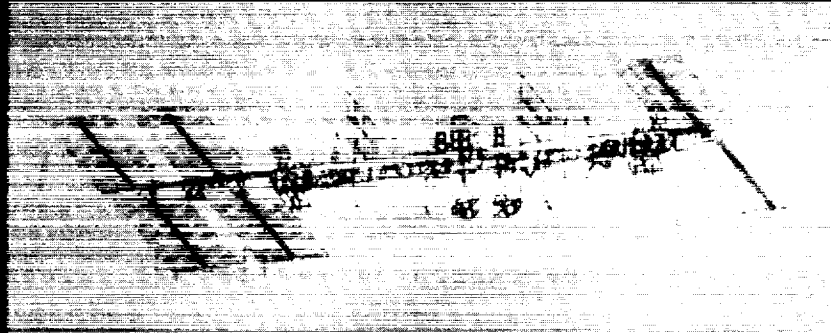


- SSRMS control
- High and low data rate communication
- Orbiter berthing with pressurized crew transfer



## PMC Capability

- ▣ 56.25 kW power
  - ◆ 30 kW to users
- ▣ Pressurized volume
  - ◆ US Lab
  - ◆ ESA ARM
  - ◆ NASDA JEM
  - ◆ US Hab
  - ◆ 2 Nodes
- ▣ Continuous manned presence
  - ◆ 4 person crew
- ▣ Redundant orbiter berthing locations
- ▣ Full MSC capability
- ▣ Crew return capability
- ▣ Centrifuge



## Payload Resources Overview

- PRESSURIZED VOLUME:** 15 Payload Racks at MTC  
46 Payload Racks at PMC
- ATTACHED PAYLOAD ACCOMMODATIONS:** 2 sites at MTC  
4 sites at PMC
- LAUNCH CAPACITY:** 8 Utilization Flights deliver 64 Payload Racks and 80,000 lbsms  
3 Mission Build flights provide accommodations for an additional 25 Payload Racks
- POWER:** 10 kW with 1 Photovoltaic Array  
15 kW with 2 Photovoltaic Arrays  
30 kW with 3 Photovoltaic Arrays
- CREW-TIME:** 4 Payload Crew per 16-Day Utilization Flight  
2 Payload Crew Planned at PMC
- DOWNLINK:** 50 Megabits / Second at MTC



## Attached Payload Accommodations

### Four Payload Accommodation Sites with Resource Ports

- Zenith, nadir, ram, and wake viewing
  - ◆ Nadir sites support equatorial and Earth limb remote sensing
- 120 vdc, 3.0 kW, at each site
- 1000 - 3000 cubic feet clearance envelope
- 400 - 700 kbps data downlink, scarred for growth to 10 Mbps



## Payload Resource Allocations

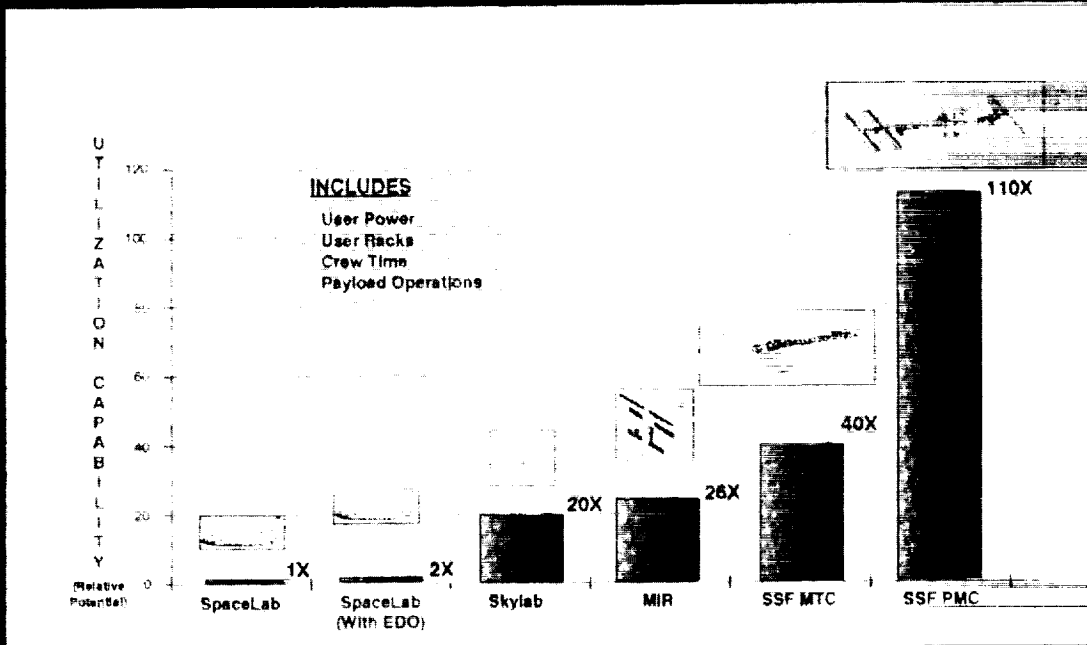
- Establishes Top-Level Allocation of both Resources and Accommodations Among the Four Partners
- Applicable to "Utilization" Resources Only  
(i.e., does not apply to "housekeeping" resources for respective station elements)

	NASA U.S.	MOSST Canada	ESA Europe	STA Japan
1. Utilization Resources	71.4%	3.0%	12.8%	12.8%
2. User Accommodations				
a. NASA Lab Module	97%	3%		
b. NASA Attached Payload Accommodations	97%	3%		
c. ESA Attached Pressurized Module (APM)	46%	3%	51%	
d. Japanese Experiment Module Pressurized Module Exposed Facility Experiment Logistics Module	46%	3%		51%





## Greater Utilization Capabilities



## Benefits of the Space Environment

- Absence of buoyancy-driven convection
- Absence of sedimentation
- Absence of hydrostatic pressure
- Presence of ultra-high vacuum

### Research Objective:

Technology advances through improved control of process variables, such as temperature, composition and flows



## ***Absence of Buoyancy-Driven Convection***

- Microgravity conditions eliminate convective flows in molten metals, liquids and gases due to density differences**
- Diffusion becomes the primary mechanism for thermal and mass transport**
- Diffusion processes can be accurately predicted and controlled**
- Important applications:**
  - Dopant distribution in crystal growth
  - Identification of mechanisms for segregation in alloys
  - Prevention of mixing in purification processes
  - Understanding of fluid dynamic effects in systems undergoing phase changes



## **Absence of Sedimentation**

- In Earth gravity it is possible to maintain a suspension of particles in a fluid if the particles are  $< 1 \mu\text{m}$**
- Microgravity conditions permit suspensions involving particles  $\gg 1 \mu\text{m}$**
- Important applications:**
  - Chemical refinement of glasses
  - Preparation of unique foams (ultra-light structures)
  - Control of flocculation processes
  - Preparation of immiscible alloys
  - Improved polymerization processes



## Absence of Hydrostatic Pressure

- Microgravity conditions eliminate the tendency for a liquid or solid to deform under its own weight
  
- Important applications:
  - Modification of critical points in solid, liquid, and gas phase transitions
  - Ability to form stable floating zones large in length and diameter (an important crystal growth technique)
  - Formation of thin oxide skins to produce intricate casting molds
  - Growth of large complex macromolecules, such as proteins, for structural analysis and drug design



## Presence of Ultra-High Vacuum

- Vacuum chambers on earth approach  $10^{-13}$  torr, however, pumping capacity is limited unless large cryogenic panels are used (incompatible with high heat loads in molten systems)
  
- Space vacuum approaches  $10^{-18}$  torr with virtually infinite pumping capability
  
- Important applications:
  - High temperature materials purification
  - Vapor deposition on ultraclean surfaces
  - Preparation of thin single crystal films
  - Use of container less techniques to avoid container contamination



## Near Term Milestones

- September 1992 Canadian Mobile Servicing Center (MSC) Phase 1 CDR
- 2nd Qtr 1993 Man Tended Capability (MTC) Critical Design Review (CDR)
- 4th Qtr 1993 Permanently Manned Capability (PMC) CDR
- October 1993 Canadian MSC Phase 2 CDR
- November 1994 European Space Agency (ESA) Attached Pressurized Module (APM) CDR
- December 1994 Japanese Experimental Module (JEM) CDR
- 4th Qtr 1995 First Element Launch (FEL)



## Summary

- Space Station Freedom satisfies our manned space research objectives
  - ◆ Life & material sciences
  - ◆ Technology advancement
  - ◆ Earth & space observation
- Space Station Freedom represents man's evolving exploration in space
- Space Station Freedom demonstrates our nation's leadership in international space programs
- Space Station Freedom can serve as a model for all future multi-national space endeavors



# ***Great Nations Dare To Explore***

***It's Time For America To Take Its Place On The Final Frontier***





**OPPORTUNITIES FOR RESEARCH ON SPACE STATION FREEDOM**

Presented by Dr. Robert Phillips  
NASA Office of Space Systems Development  
NASA Headquarters

**ABSTRACT**

NASA has allocated research accommodations on Freedom (equipment, utilities, etc.) to the program offices that sponsor space-based research and development as follows: Space Science and Applications (OSSA) — 52 percent, Commercial Programs (OCP) — 28 percent, Aeronautics and Space Technology (OAST) — 12 percent, and Space Flight (OSF) — 8 percent.

Most of OSSA's allocation will be used for microgravity and life science experiments; although OSSA's space physics, astrophysics, earth science and applications, and solar system exploration divisions also will use some of this allocation.

Other Federal agencies have expressed an interest in using Space Station Freedom. They include the National Institutes of Health (NIH), U.S. Geological Survey, National Science Foundation, National Oceanic and Atmospheric Administration, and U.S. Departments of Agriculture and Energy.

Payload interfaces with space station lab support equipment must be simple, and experiment packages must be highly contained. Freedom's research facilities will feature International Standard Payload Racks (ISPRs), experiment racks that are about twice the size of a Spacelab rack. ESA's Columbus lab will feature 20 racks, the U.S. lab will have 12 racks, and the Japanese lab will have 10. Thus, Freedom will have a total of 42 racks versus 8 for Spacelab.

NASA is considering outfitting some rack space to accommodate small, self-contained payloads similar to the Get-Away-Special canisters and middeck-locker experiment packages flown on Space Shuttle missions. Crew time allotted to experiments on Freedom at permanently occupied capability will average 25 minutes per rack per day, compared to six hours per rack per day on Spacelab missions. Hence, telescience — the remote operation of space-based experiments by researchers on the ground — will play a very important role in space station research.

Plans for supporting life sciences research on Freedom focus on the two basic goals of NASA's space life sciences program: to ensure the health, safety, and productivity of humans in space and to acquire fundamental knowledge of biological processes.

Space-based research has already shown that people and plants respond the same way to the microgravity environment: they lose structure. However, the mechanisms by which they respond are different, and researchers do not yet know much about these mechanisms. Life science research accommodations on Freedom will include facilities for experiments designed to address this and other questions, in fields such as gravitational biology, space physiology, and biomedical monitoring and countermeasures research.





# **OPPORTUNITIES FOR RESEARCH ON SPACE STATION FREEDOM**

**ROBERT W. PHILLIPS  
CHIEF SCIENTIST  
SPACE STATION FREEDOM**

## **SPACE STATION FREEDOM WILL BE:**

- **A WORLD CLASS MICROGRAVITY LABORATORY**
- **AN INTERNATIONAL FACILITY DESIGNED TO  
ADVANCE SCIENCE AND TECHNOLOGY IN  
THE SPACE ENVIRONMENT**
- **A TEST BED FOR DEVELOPING THE EXPERIENCE  
AND TECHNOLOGIES TO EXPLORE THE MOON  
AND MARS**

# **USER ORGANIZATION SUBALLOCATIONS**

<b><u>ORGANIZATION</u></b>	<b><u>SUBALLOCATION OF RESOURCES</u></b>
<b>OFFICE OF SPACE SCIENCE AND APPLICATIONS (OSSA)</b>	<b>52%</b>
<b>OFFICE OF COMMERCIAL PROGRAMS (OCP)</b>	<b>28%</b>
<b>OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY (OAST)</b>	<b>12%</b>
<b>OFFICE OF SPACE FLIGHT (OSF)</b>	<b>8%</b>

## **OFFICE OF SPACE SCIENCE AND APPLICATIONS**

- DIVISION OF LIFE SCIENCES**
- DIVISION OF MICROGRAVITY SCIENCES**
- DIVISION OF EARTH SCIENCE AND APPLICATIONS**
- DIVISION OF SPACE PHYSICS**
- DIVISION OF ASTROPHYSICS**
- DIVISION OF SOLAR SYSTEM EXPLORATION**

**NATIONAL INSTITUTE OF HEALTH (NIH)**

**NATIONAL SCIENCE FOUNDATION (NSF)**

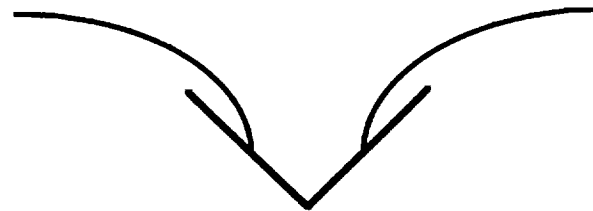
**NATIONAL OCEANIC & ATMOSPHERIC  
ADMINISTRATION (NOAA)**

**DEPARTMENT OF AGRICULTURE (DA)**

**NATIONAL TELECOMMUNICATIONS AND  
INFORMATION ADMINISTRATION (NTIA)**

**DEPARTMENT OF ENERGY (DOE)**

**UNITED STATES GEOLOGICAL SURVEY (USGS)**

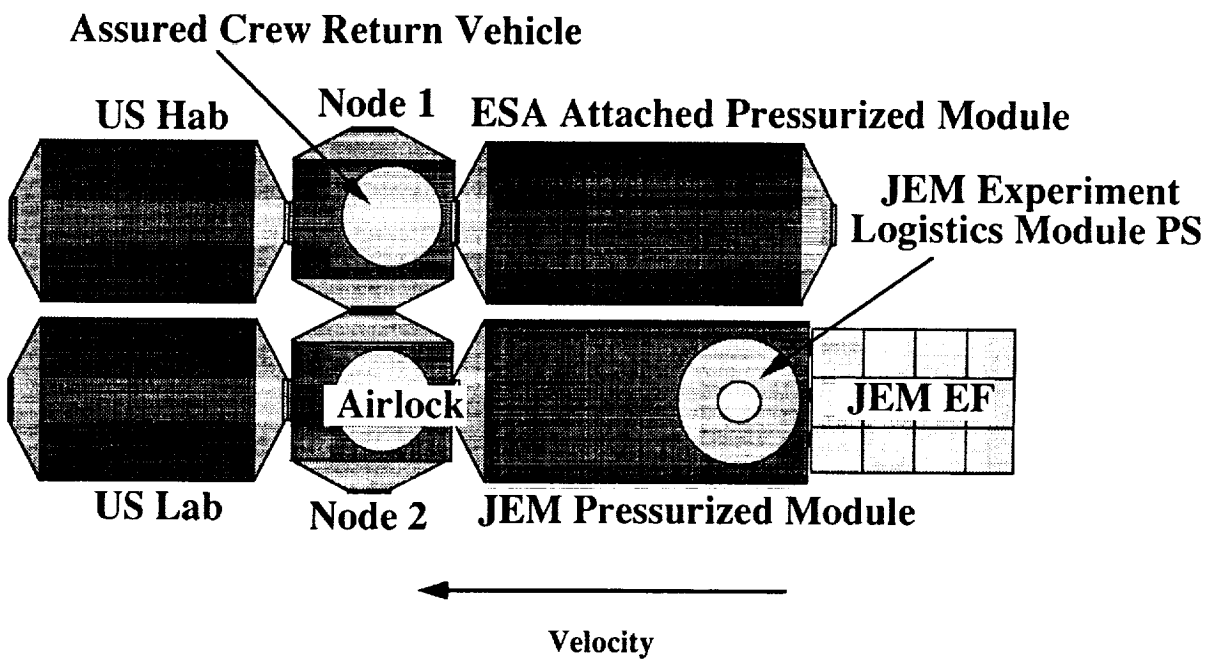


**OSSA**

**SSF WILL HOUSE  
DEDICATED CORE  
RESEARCH FACILITIES  
IN THE PRESSURIZED  
VOLUME**

- **USER-PROVIDED CORE FACILITIES CAN BE SUPPLEMENTED BY EXPERIMENT-UNIQUE EQUIPMENT AND GENERAL LABORATORY SUPPORT EQUIPMENT.**
- **SSF WILL PROVIDE THE BASIC UTILITIES NEEDED TO SUPPORT EXPERIMENT OPERATION (DATA MANAGEMENT, POWER, COOLING, ETC.).**

**Space Station Freedom Module Cluster**



## Spacelab/Space Station Resource Comparison

Resource	SSFP @ PMC	Spacelab
<b>Payload racks</b>	<b>44</b>	<b>8</b>
<b>Payload Power (kW)</b>	<b>30</b>	<b>3.4</b>
<b>Power per Rack (kW)</b>	<b>.68</b>	<b>.42</b>
<b>Crew</b>	<b>2+</b>	<b>4+</b>

## Crew Time Available for Payload Operations

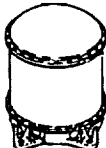
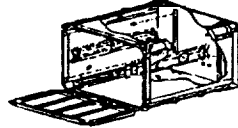
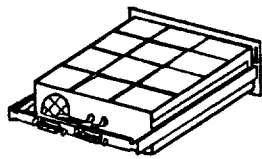
- **The large payload complement on Space Station Freedom will make crew time a valuable resource.**
- **Crew hours per payload rack comparison with Spacelab:**
  - **Spacelab typically offers about 6 hours per (double) rack per day;**
  - **At PMC, Space Station will offer about 25 minutes per rack per day.**

**(One Space Station rack is equivalent to a Spacelab double rack)**

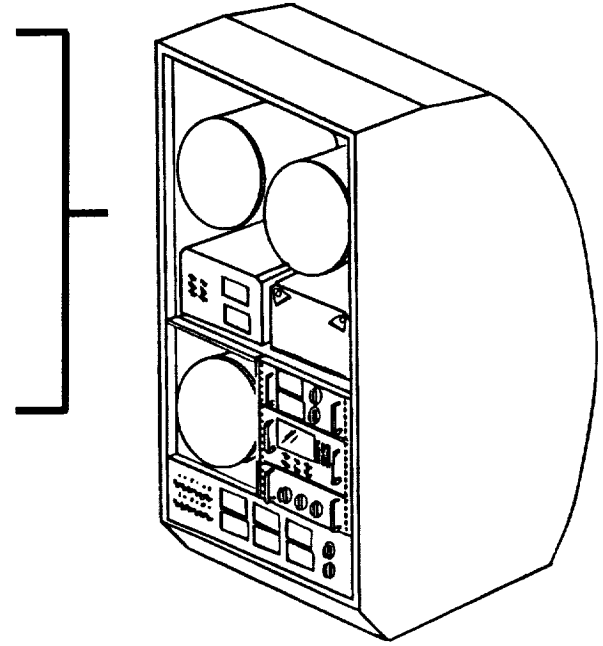
- **Reduced crew time available for each rack mandates an increase in the use of automation and/or telepresence in payload design.**

# DEDICATED SMALL PAYLOAD ACCOMMODATIONS RACK CONCEPT

## Existing Container Hardware:

- EAC 
- Middeck Locker 
- Slide-in Drawer 

## Integrated Small Payload System



**LIFE SCIENCES**

**MICROGRAVITY SCIENCES**

**ATTACHED PAYLOADS**

# **LIFE SCIENCES ON SPACE STATION FREEDOM**

**WILL PROVIDE THE OPPORTUNITY  
TO STUDY MULTIGENERATIONAL  
EFFECTS OF SPACE EXPOSURE ON  
PLANTS AND ANIMALS**

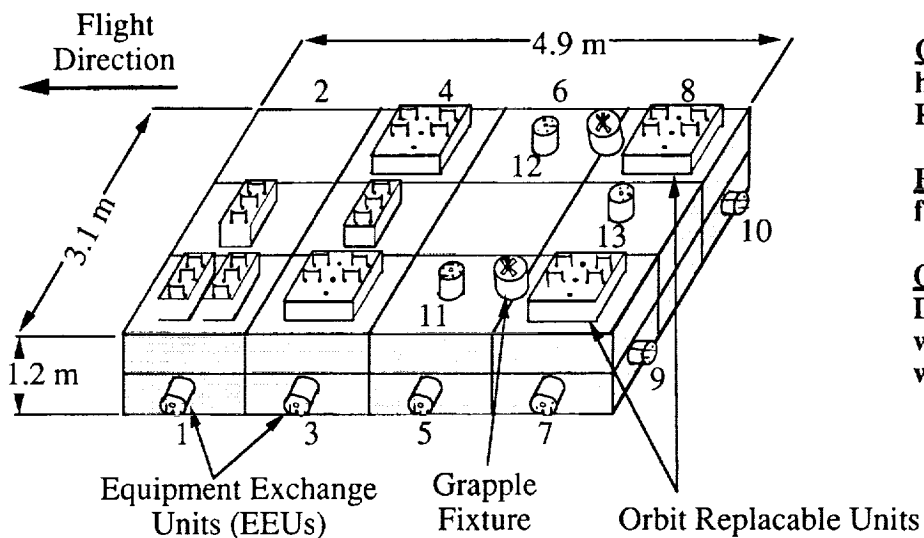
## **MICROGRAVITY SCIENCE FACILITIES**

- **ADVANCED PROTEIN CRYSTAL GROWTH**
- **SPACE STATION FURNACE**
- **COMBUSTION**
- **FLUID PHYSICS DYNAMICS**
- **CONTAINERLESS PROCESSING**
- **BIOTECHNOLOGY**

# ATTACHED PAYLOADS WILL PROVIDE THE OPPORTUNITY:

- TO STUDY THE SPACE ENVIRONMENT
- TO OBSERVE THE EARTH'S TROPICAL REGIONS
- TO OBSERVE OUTWARD

## Japanese Experiment Module - Exposed Facility (JEM - EF)



**Grapple Fixture** - allows handling of JEM - EF by RMS

**EEU** - Attachment point for JEM - EF payloads

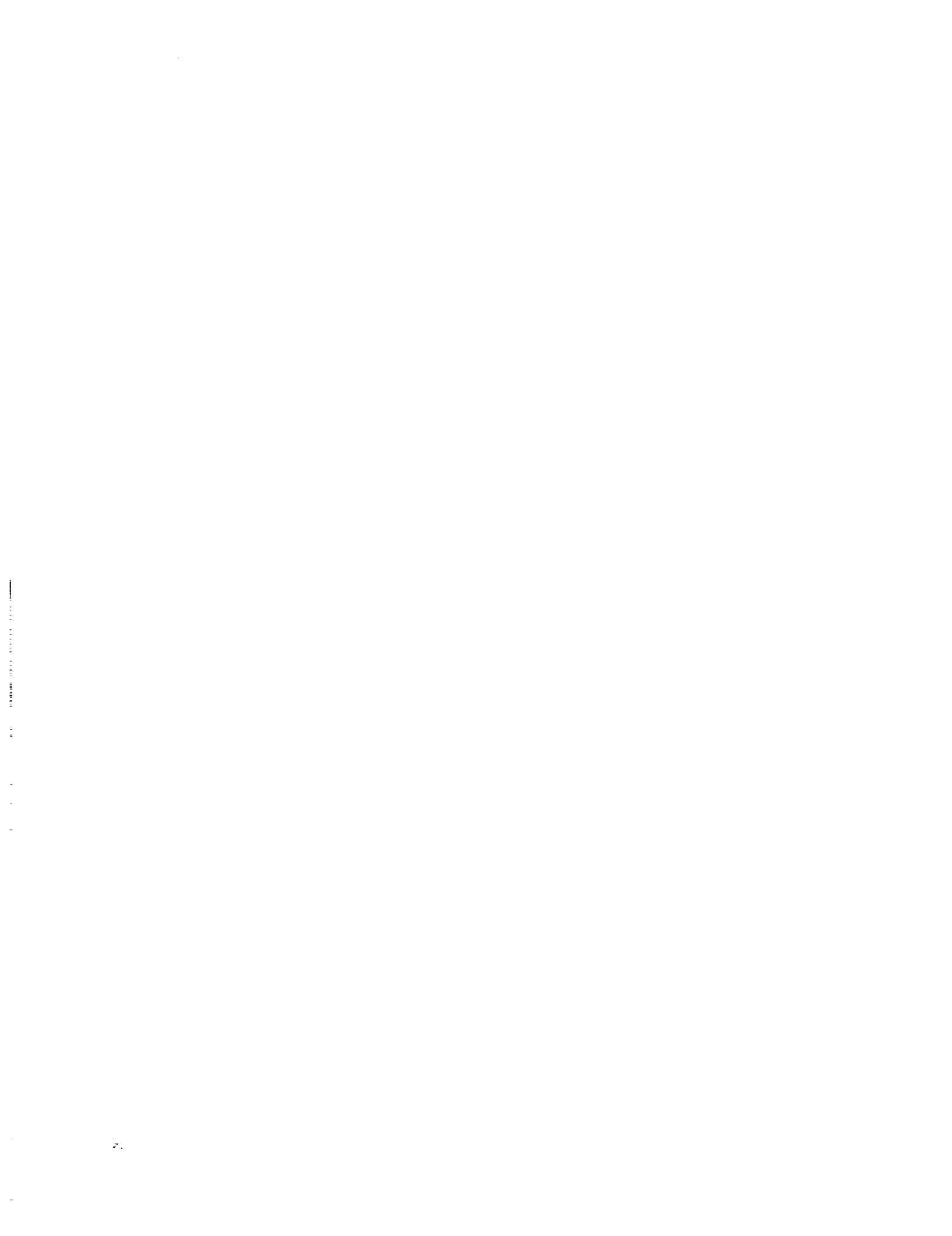
**ORUs** - equipment such as DC to DC Converter Units which can be replaced while on-orbit



**SPACE STATION FREEDOM  
REPRESENTS THE FIRST  
OPPORTUNITY TO DEVELOP  
A PROGRAM TO UNDERSTAND  
AND EXPLAIN MICROGRAVITY  
EFFECTS AND THE SPACE  
ENVIRONMENT.**

**IT IS, HOWEVER, A BEGINNING,  
NOT AN END.**

**WE URGE YOU TO JOIN IN THIS  
ADVENTURE!**



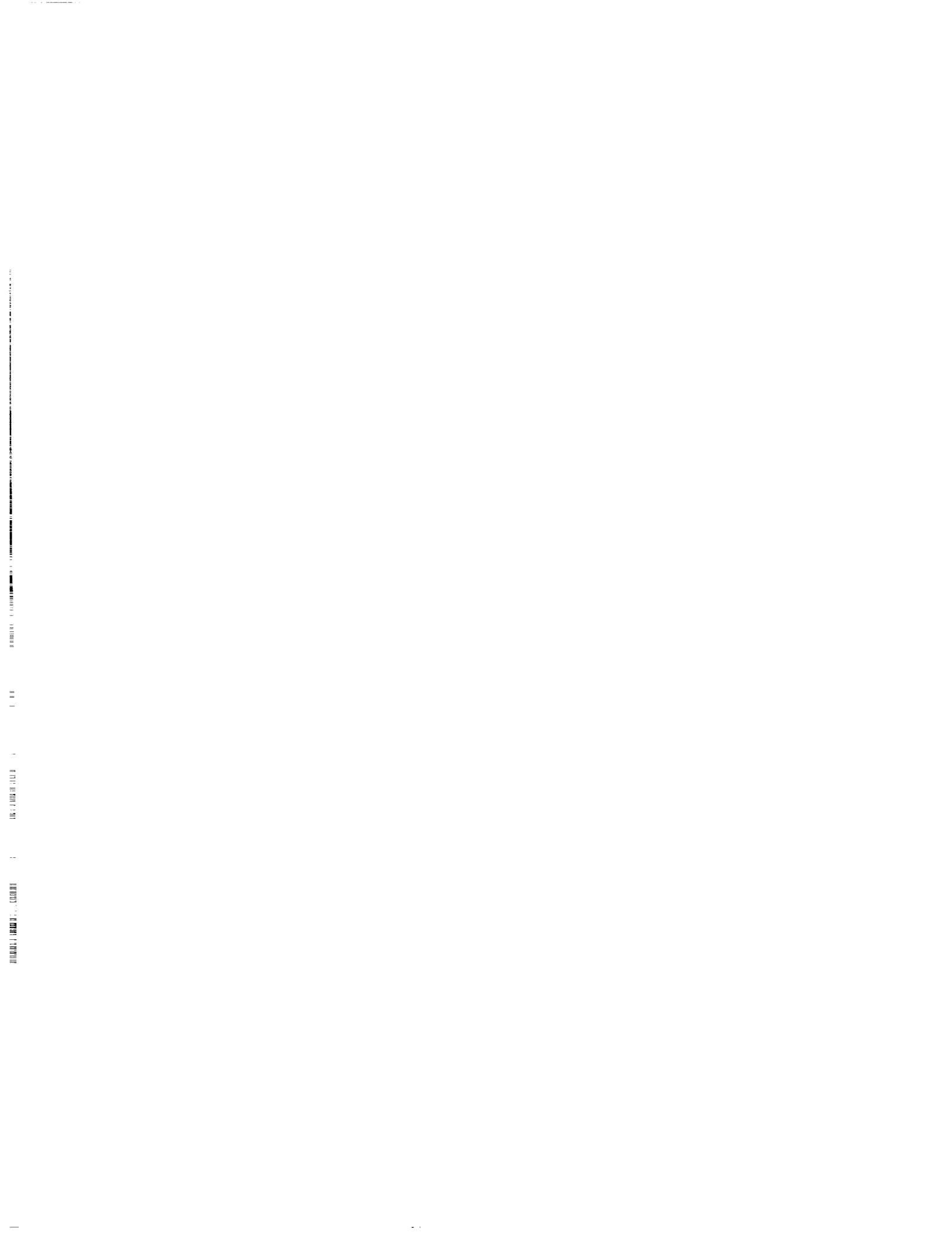
**HOW TO GET ON BOARD SPACE STATION FREEDOM**

Presented by Dr. John-David Bartoe  
User Integration Division  
Spacelab/Space Station Utilization Program  
NASA Headquarters

**ABSTRACT**

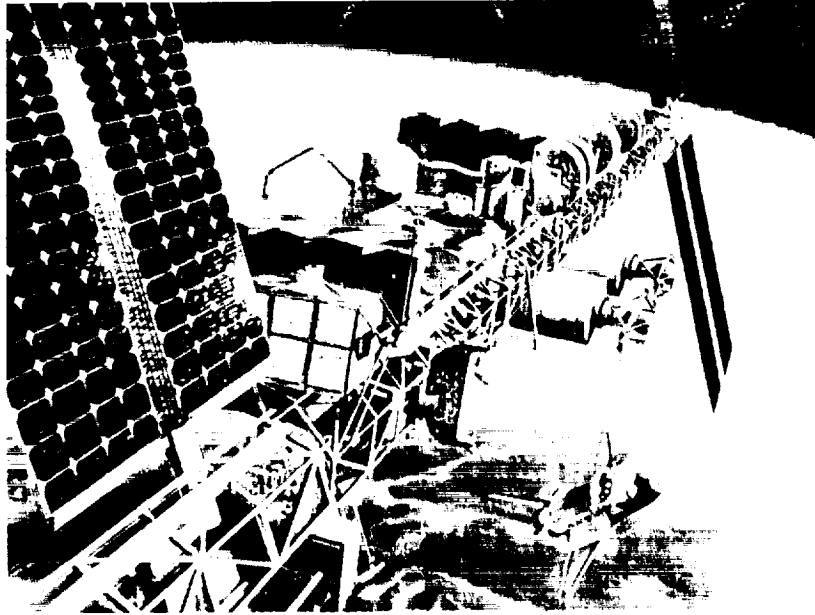
Space Station Freedom will accommodate researchers with interests in science, technology and commercial applications. NASA sponsors will be responsible for selecting the U.S. researchers for Space Station Freedom. The four NASA sponsors are: Office of Space Science and Applications (OSSA), Office of Aeronautics and Space Technology (OAST), Office of Commercial Programs (OCP), and the Office of Space Flight (OSF). The areas of research responsibility for each sponsor are presented. The researcher solicitation vehicles used by OSSA and OAST and the methodology for researchers seeking sponsorship from OCP and OSF as well as the pricing policy are discussed.

Descriptions of flight planning, payload integration and operations functions are presented. Three categories of payloads and their respective payload integration times are discussed. Researchers are advised to contact a NASA sponsor and a source which lists the points of contact for the NASA sponsors is noted.





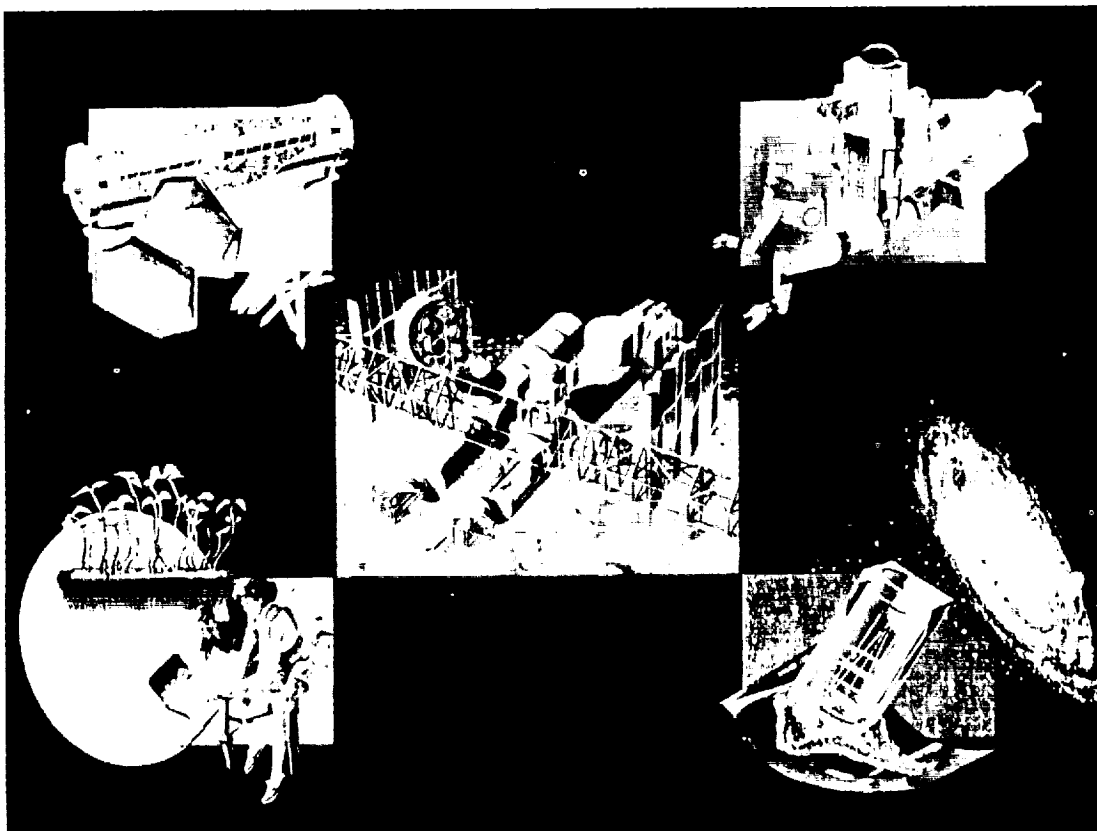
# HOW TO GET ON BOARD SPACE STATION FREEDOM



Presentation to the  
Space Station Freedom  
Utilization Conference  
Huntsville, AL  
August 3-6, 1992

Dr. John-David Bartoe  
Director  
User Integration Division  
Spacelab/Space Station  
Utilization Program

## SPACE STATION FREEDOM RESEARCH





## CONTENTS

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- **GETTING A SPONSOR**
- **FLIGHT PLANNING**
- **PAYLOAD INTEGRATION AND OPERATIONS**

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## GETTING A SPONSOR

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- **Space Station Freedom research capabilities are shared by Canada, ESA, Japan and NASA**
- **Researchers who wish to use NASA's share enter the program through a NASA sponsor**
- **NASA sponsoring organizations are the primary agents for initiating, selecting and implementing research**
- **Each NASA sponsoring organization is allocated a block of Freedom's accommodations and resources**

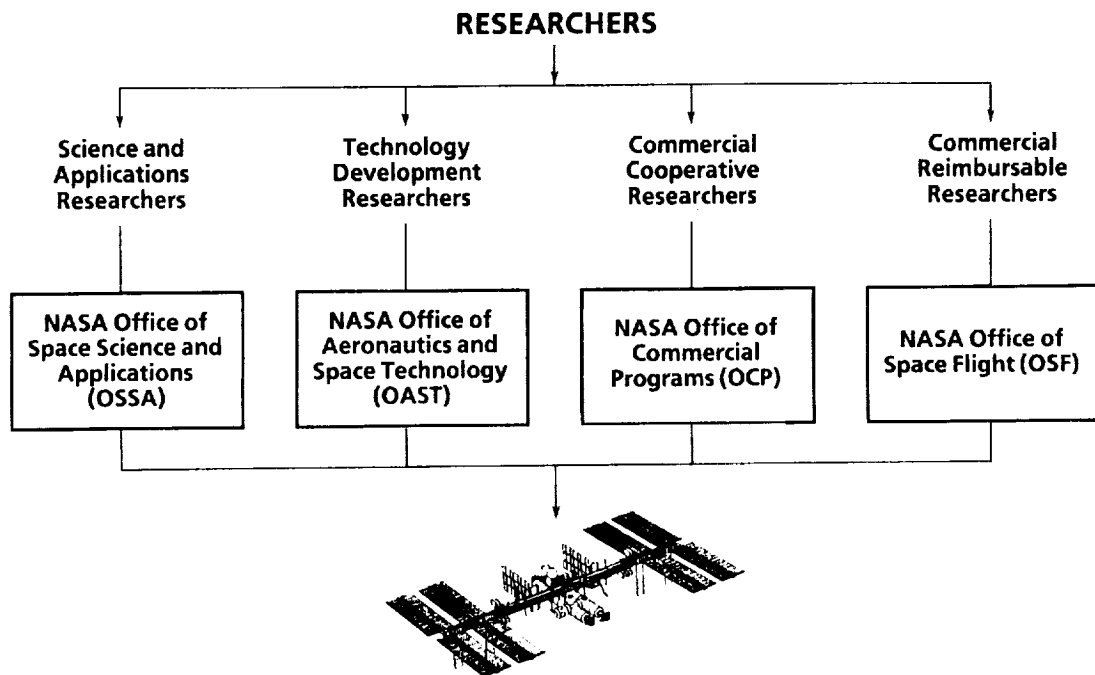


## GETTING A SPONSOR (Continued)

- The sponsor develops research plans:
  - Within the sponsor's mandate
  - Responsive to its research community
- To achieve their goals, sponsors:
  - Perform outreach to their constituencies
  - Develop mechanisms to select payloads for flight
  - Advocate for their research needs within the agency
  - Manage their research program, including payload development, integration and operations
  - Fund research, as appropriate to their mandate



## NASA SPONSORING ORGANIZATIONS





## SCIENCE AND APPLICATIONS RESEARCHERS

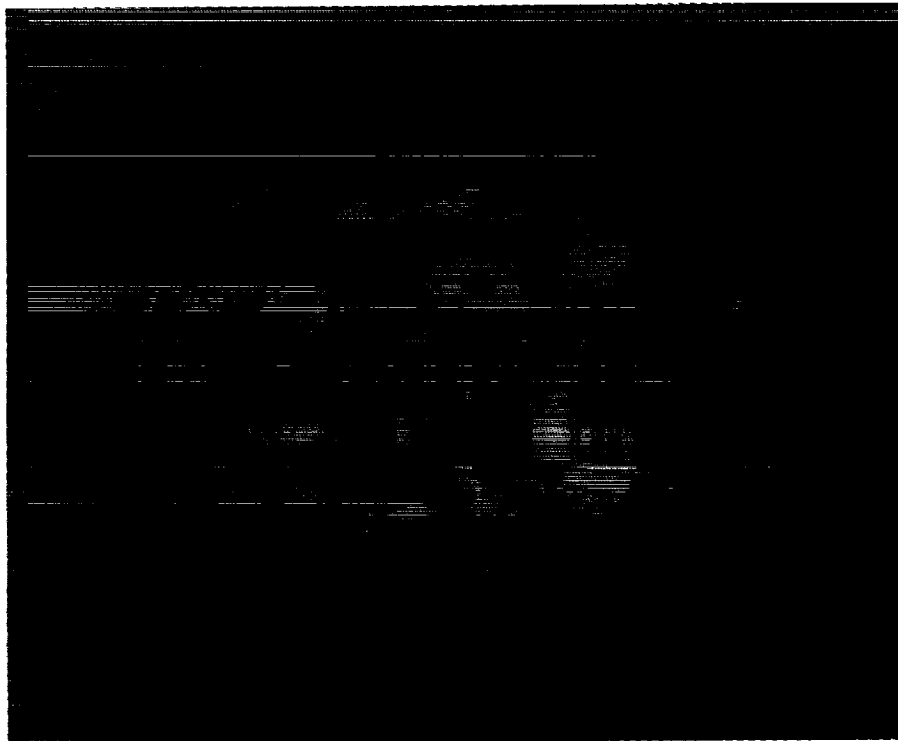
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- Sponsored by Office of Space Science and Applications (OSSA)
- Includes research by other government agencies, such as NIH, NSF, etc.
- Life Sciences Research
  - Ensure the health, safety and productivity of humans in space
    - Monitor crew health
    - Develop countermeasures to adverse effects of prolonged exposure to low gravity
  - Acquire fundamental scientific knowledge in space life sciences
    - Study the effects of gravity on living systems

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### LIFE SCIENCES RESEARCH







## SCIENCE AND APPLICATIONS RESEARCHERS

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- **Microgravity Science and Applications**
  - **Materials Science**
    - Electronic and photonic materials
    - Metals and alloys
    - Glasses and ceramics
  - **Fundamental sciences, including the study of**
    - Fluid dynamics and transport phenomena
    - Combustion science
    - Gravitational physics
  - **Biotechnology experiments**
    - Macromolecular crystal growth
    - Cell and molecular science

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## MICROGRAVITY SCIENCE & APPLICATIONS



Protein Crystal Growth Facility



Insulin Crystal



## SCIENCE AND APPLICATIONS RESEARCHERS

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- OSSA issues Announcements of Opportunity (AOs) and NASA Research Announcements (NRAs)
- AOs solicit proposals which involve major hardware procurements
- NRAs solicit proposals for utilizing existing hardware or involving minor hardware development
- AOs and NRAs solicit proposals for ground-based and research in space (e.g., Spacelab and Space Station)
- Four NRAs for Microgravity Science and Applications have already been released. Future NRAs will be released on a regular schedule.
- First AO/NRA for Life Sciences to be released approximately 2 years before First Element Launch (first AO/NRA expected 1994)

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## TECHNOLOGY RESEARCHERS

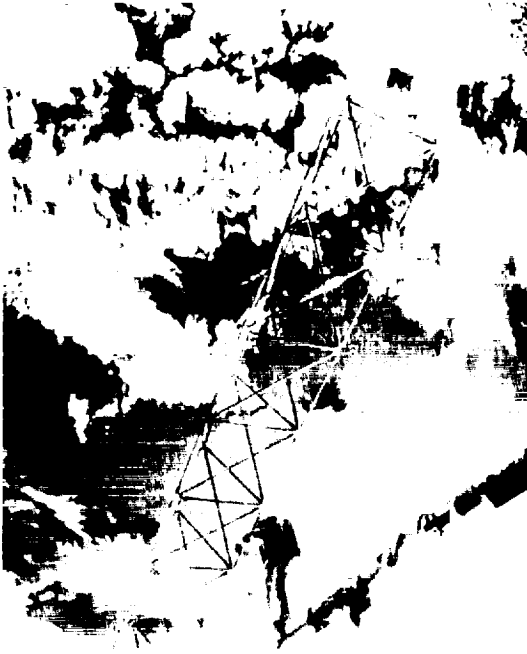
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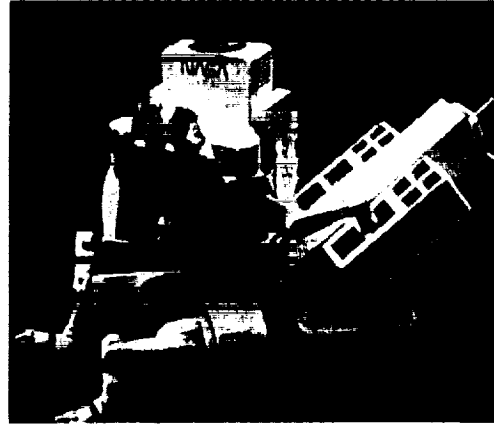
- Sponsored by Office of Aeronautics and Space Technology (OAST)
- OAST is responsible for the development of enabling and enhancing technologies for the Nation's future space missions
- Includes technology experiments by other government agencies, such as DOD R&D
- Flight experiment program objective is to:
  - Validate technology in space
  - Obtain data which are unobtainable on the ground
- OAST emphasizes small and inexpensive experiments
- OAST solicits proposals through the periodic release of AOs
- Next OAST AO expected to be released within next few weeks

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# TECHNOLOGY RESEARCH



Structure



Automation & Robotics



## TECHNOLOGY RESEARCHERS

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- **Technology Development Areas:**
  - **Structural Dynamics**
  - **Robotics**
  - **Sensors and Information Systems**
  - **Life Support Systems**
  - **Materials and Environmental Effects**
  - **Fluid Transfer and Storage**
  - **Thermal Management**
  - **Power Systems**
  - **Propulsion**



## COMMERCIAL COOPERATIVE RESEARCHERS

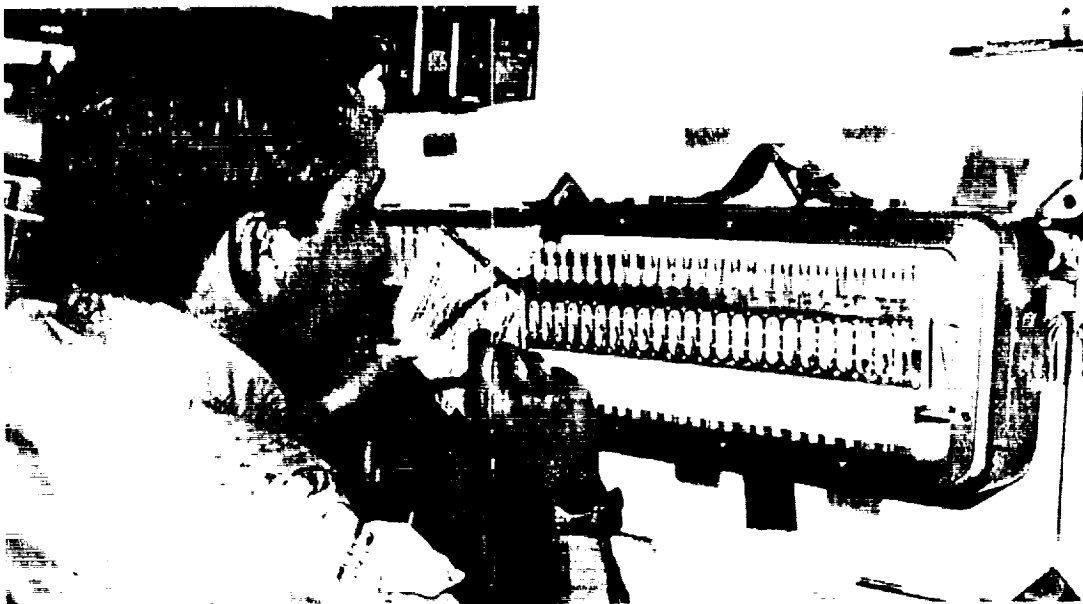
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- Sponsored by the Office of Commercial Programs (OCP)
- Objective of commercial cooperative research is for NASA to provide industry assistance, services, and access to facilities to encourage the commercial use of space
- Commercial cooperative researchers are those who are partially funded by NASA
- Commercial cooperative researchers generally provide some type of compensation or *quid pro quo*
- Agreements between OCP and researcher dependent upon degree of risk researcher is willing to take

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### COMMERCIAL RESEARCH



Protein Crystal Growth Experiment



## COMMERCIAL COOPERATIVE RESEARCHERS

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- Centers for the Commercial Development of Space (CCDSs) are the primary commercial cooperative user entry points
- Seventeen CCDSs focus on the following disciplines
  - Automation and robotics
  - Remote sensing
  - Biotechnology
  - Materials processing in space
  - Space power
  - Space structures
  - Communications

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## COMMERCIAL REIMBURSABLE RESEARCHERS

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- Sponsored by the Office of Space Flight (OSF)
- Researcher who pays the established price for use of Space Station (including *pro rata* Space Shuttle transportation to and from Freedom)
- Submits request for flight and earnest money to OSF
- Negotiates agreement with OSF
- The point of contact is NASA OSF Policy and Plans Division

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# COMMERCIAL REIMBURSABLE RESEARCH



## REIMBURSABLE PRICING POLICY

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- **Cost to reimbursable researcher will be dependent upon two factors:**
  - Pricing policy
  - Cost basis
- **Pricing policy defines the algorithm for charging for use of the Station:**
  - Accommodations
  - Resources
  - Standard services
- **Cost basis defines the dollar cost for each "unit of use"**
- **Pricing policy and cost basis are under agency development and review**
- **Pricing policy will be set by the Administrator and reviewed by Congress**
- **Public review and comment period required**
  - Will be announced in Federal Register
  - Current plan for release early 1993



## REIMBURSABLE PRICING POLICY CONCEPT

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- Reimbursable pricing policy concept currently under development
- Shuttle and Spacelab policies used as a base
- Two standard service packages
  - Round-trip transportation and integration
  - On-orbit operations
- Round-trip transportation and integration price based on:
  - Weight
  - Volume
  - Length

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(1 OF 2)  
7/30/92



## REIMBURSABLE PRICING POLICY CONCEPT (Continued)

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- On-orbit operations price based on:
  - Space
  - Energy
  - Crew time
  - Length of stay
- Optional services available
- Final pricing structure (i.e., policy) will be determined after a thorough management review
- Cost basis to be defined based upon degree of cost recovery

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(2 OF 2)  
7/30/92



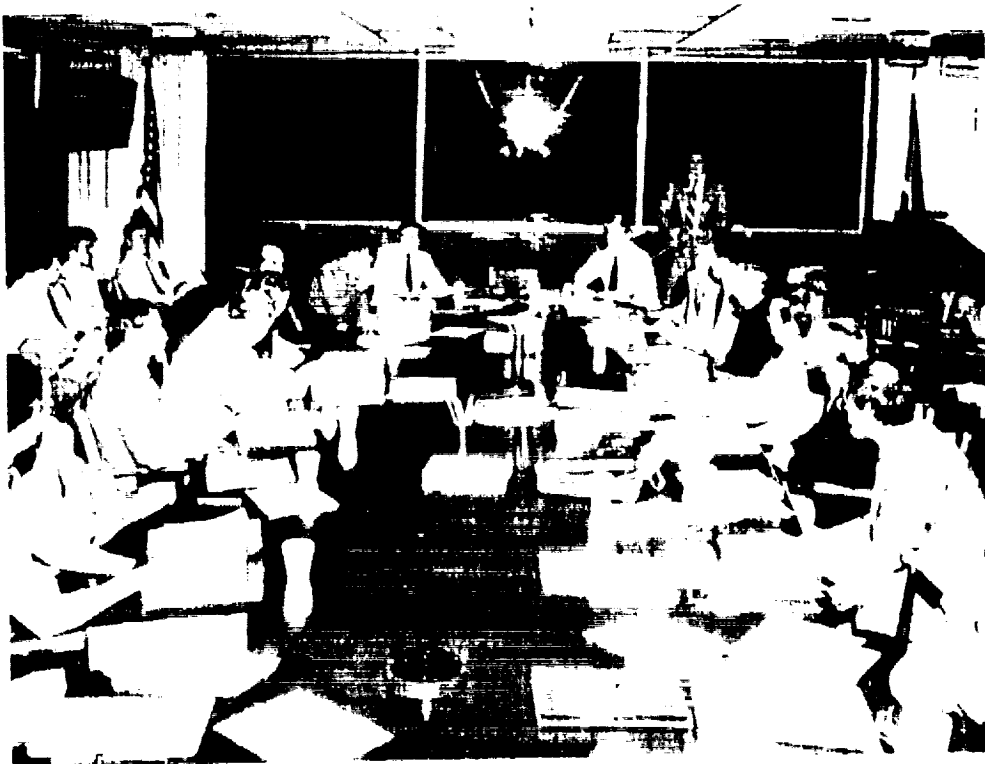
## FLIGHT PLANNING

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- The Space Station Freedom program has developed a planning process that identifies when a payload flies
- Flight planning provides the researcher with a commitment to fly
- The process uses a 5 year planning horizon
  - Researchers are not directly involved this far in advance unless the payload is very complex

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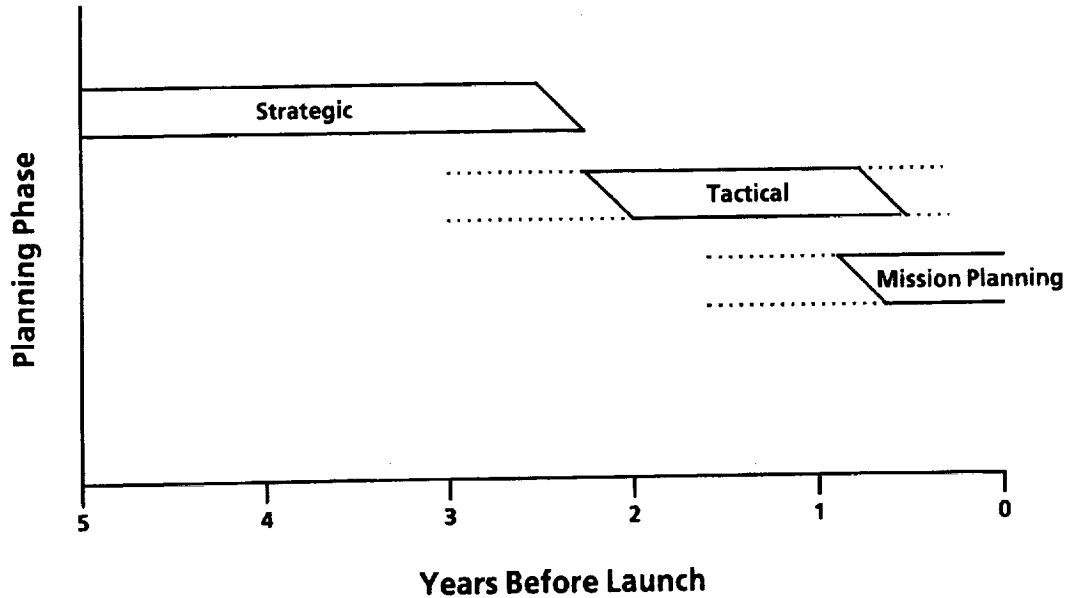
## FLIGHT PLANNING







## FLIGHT PLANNING

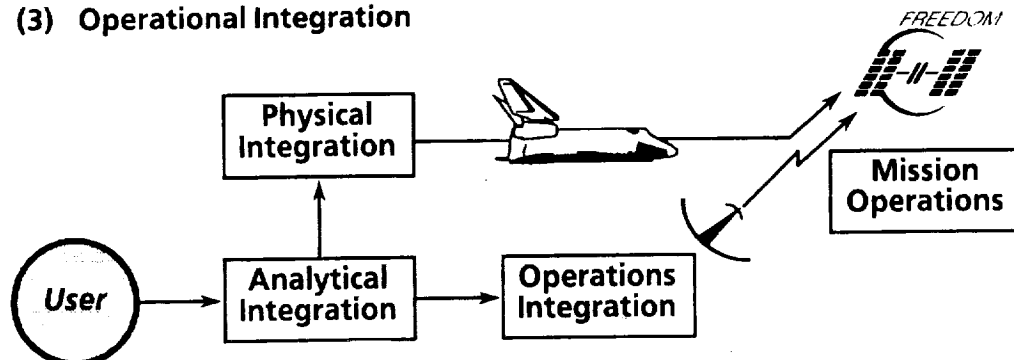


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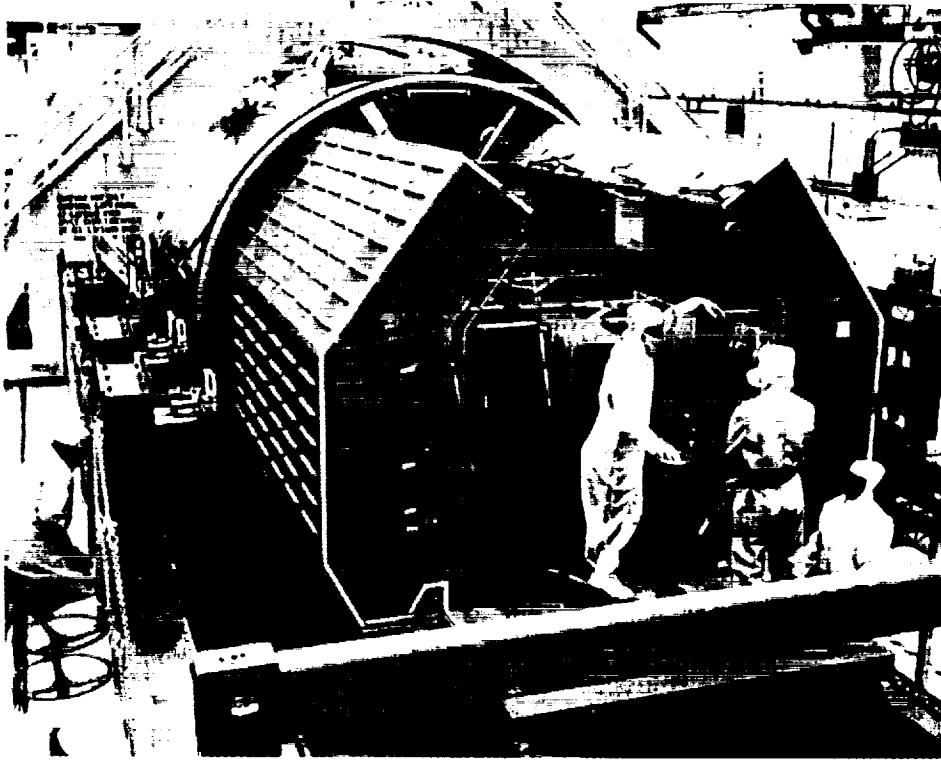
## WHAT IS PAYLOAD INTEGRATION?

- Payload integration is the process used to assemble a complement of payloads for flight on Space Station Freedom and return to Earth
- The payload integration process can be characterized by three individual integration functions:
  - (1) Analytical integration
  - (2) Physical integration
  - (3) Operational Integration

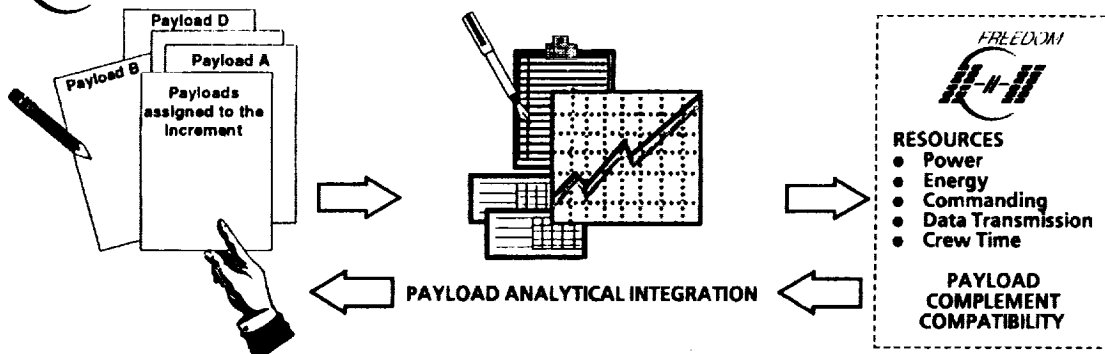


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# PAYLOAD INTEGRATION



## PAYLOAD ANALYTICAL INTEGRATION



- The Payload Analytical Integration function includes:
  - Technical assistance and support to the user
  - Assurance that user and program requirements are met
  - Assurance of compatible interfaces
  - Verification of the safety of the payload and payload complement for launch and on-orbit operation



## PAYLOAD PHYSICAL INTEGRATION

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- The Payload Physical Integration function includes:
  - (1) Development of procedures for physical integration and testing
  - (2) Functional testing of the payload (optional service)
  - (3) Integration of payloads into carriers
  - (4) Performance of final pre-launch interface verification testing for the integrated payload carrier
  - (5) Support to on-orbit payload integration and deintegration
  - (6) Performance of post-landing physical deintegration

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## PAYLOAD OPERATIONS INTEGRATION

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- The Payload Operations Integration function includes:
  - (1) Operations planning for payloads
    - Assurance of operational compatibility of payload complements
    - Generation of payload operations agreements
    - Development and management of payload operations timelines
  - (2) Training and simulation exercises for flight and ground crew

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7/31/92



## PAYLOAD OPERATIONS

- The Payload Operations functions:
  - Provide interface to crew
  - Build and uplink commands
  - Build and uplink crew procedures
  - Payload replanning
    - Research support
    - Hardware malfunctions
    - Other anomalies
    - Update orbital conditions
    - Update resource consumption
  - Data Management
    - Process and provide payload data
    - Provide video/data playback
  - Support payload performance assessments

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7/30/92

## PAYLOAD OPERATIONS





## PAYLOAD INTEGRATION AND OPERATIONS

**PROGRAM PROVIDES**

- ✓ Strategic Planning
- ✓ Accommodations/resources
- ✓ Roadmap of information required to be provided by users
- ✓ Analytical Integration Services
  - Design evaluation
  - Safety evaluation
- ✓ Integration process: rack integration into log module, SSF, and return
- ✓ Payload operations support
- ✓ Payload Accommodation Manager

**USER PROVIDES**

- ✓ Payload requirements
- ✓ Safety, integration, and operational documentation
- ✓ Data and support in reviews
  - Design data
  - Safety data
- ✓ Payload
- ✓ Payload operations support
- ✓ Principal Investigator

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7/31/92



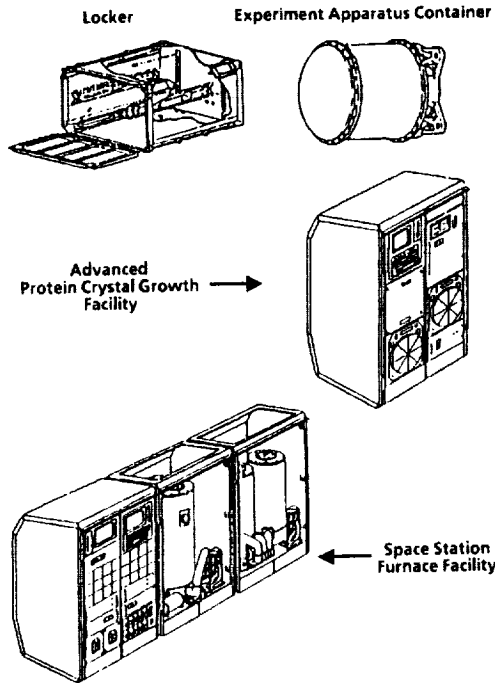
## SPACE STATION FREEDOM PAYLOAD INTEGRATION PROCESS STATUS

- The payload integration process is currently under study to better reflect the changing requirements of the payload community and support more flexibility within the process
  - The payload trend is moving toward the smaller, simpler payloads
  - The aim is to define a process that will accommodate a large number of payloads with a wide range of requirements while minimizing cost and allowing quick integration

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## PAYLOAD



### Sub-Rack Payloads:

- Existing flight-qualified containers
- Simple interfaces and operations
- Standard integration agreements

### Rack Payloads:

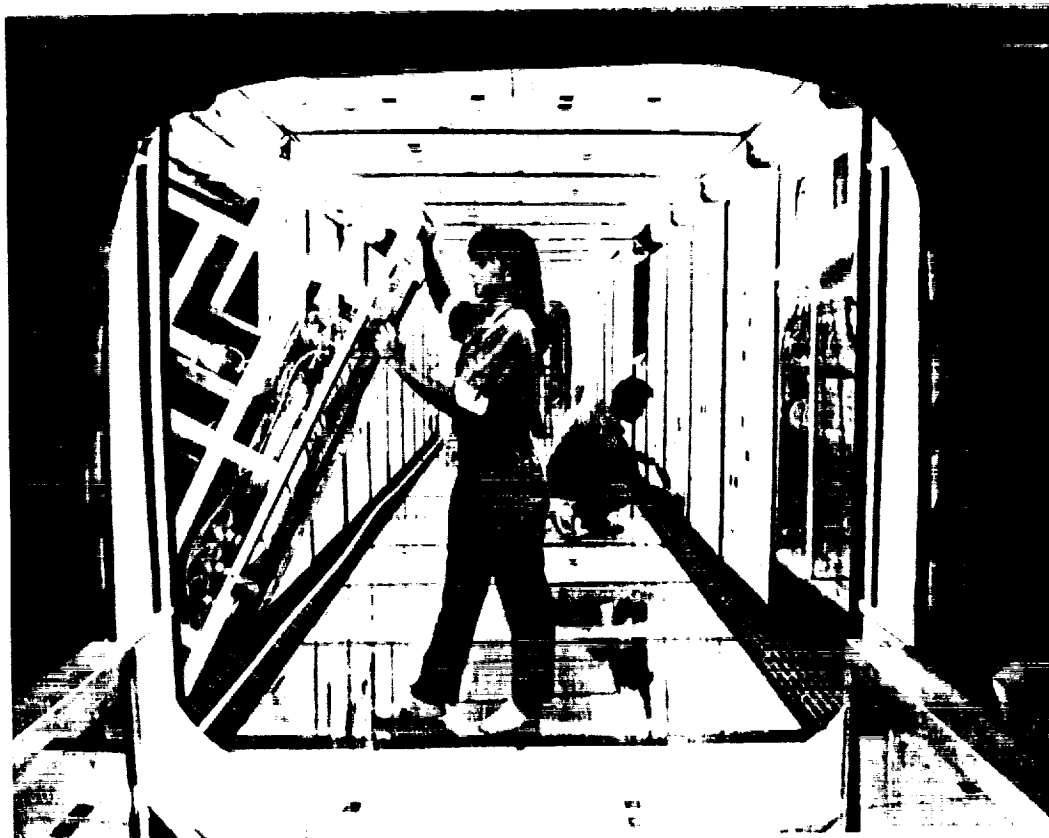
- Unique user-provided and integrated
- International Standard Payload Rack interfaces
- Moderately complex operations
- Standard integration agreements

### Multi-Rack Payloads:

- Unique user-provided racks
- Integrated on orbit
- Non-standard interfaces
- Complex operations
- Non-standard agreements

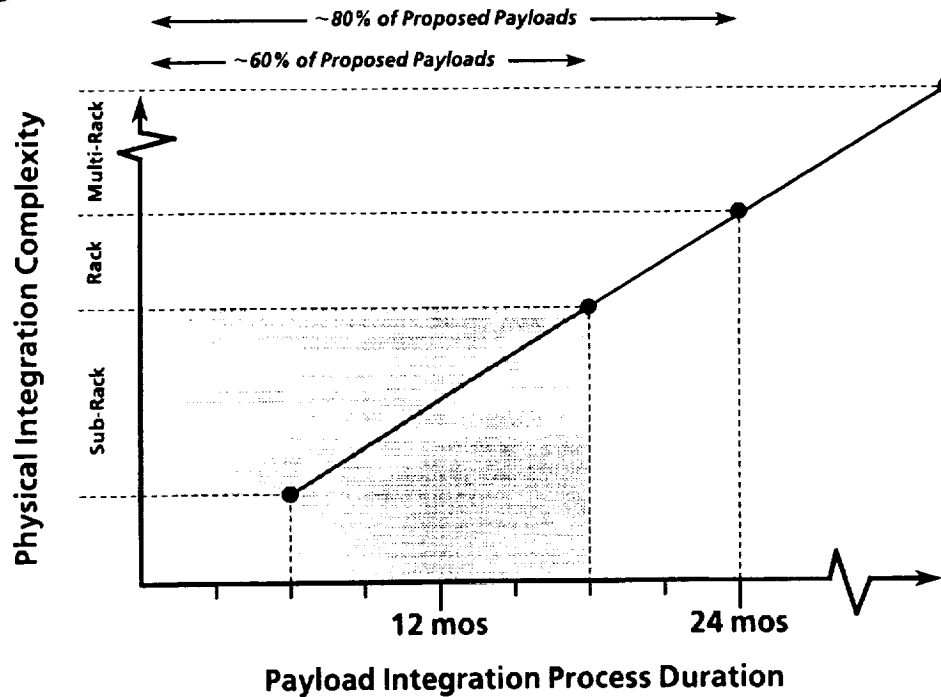
OSS 18635  
7/30/92

## A SPACE STATION FREEDOM RACK





## INTEGRATION TIME VS. COMPLEXITY



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## SUMMARY

- Those who wish to perform research on Freedom may contact one of the four NASA sponsoring organizations
- The payload integration process is being streamlined to better accommodate researchers
- The points of contact for each of the NASA user sponsoring organizations are identified in article available at the NASA Headquarters booth:  
"How to Get On Board Space Station Freedom"
- Contact NASA Headquarters if you have any questions:

Dr. John-David Bartoe, Director, User Integration Division  
Barry Epstein, User Development Program Manager  
(202) 453-1181

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7/31/92



# HOW TO GET ON BOARD SPACE STATION FREEDOM

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## Points of Contact

### Science and Applications Opportunities

Dr. Roger Crouch  
Microgravity Science & Applications Division  
Office of Space Science & Applications  
NASA Headquarters/Code SN  
Washington, DC 20546

### Commercial Cooperative

James Fountain  
Office of Commercial Programs  
PS05  
George C. Marshall Space Flight Center  
Huntsville, AL 35812

Dr. J. Richard Keefe  
Life Sciences Division  
Office of Space Science & Applications  
NASA Headquarters/Code SB  
Washington, DC 20546

### Commercial Reimbursable Opportunities

Office Space Flight  
NASA Headquarters/Code MB  
Washington, DC 20546

### Technology Development Opportunities

Dr. Judith H. Ambrus  
Space Experiments Office  
Office of Aeronautics and Space Technology  
NASA Headquarters/Code RSX  
Washington, DC 20546

### For General Information about Space Station Freedom Research Capabilities and Opportunities:

Dr. John-David Bartoe, Director  
User Integration Division  
Spacelab/Space Station Utilization Program  
NASA Headquarters/Code MG  
Washington, DC 20546  
(202) 453-1181

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*SESSION 2:  
RESEARCH PLANS AND OPPORTUNITIES*

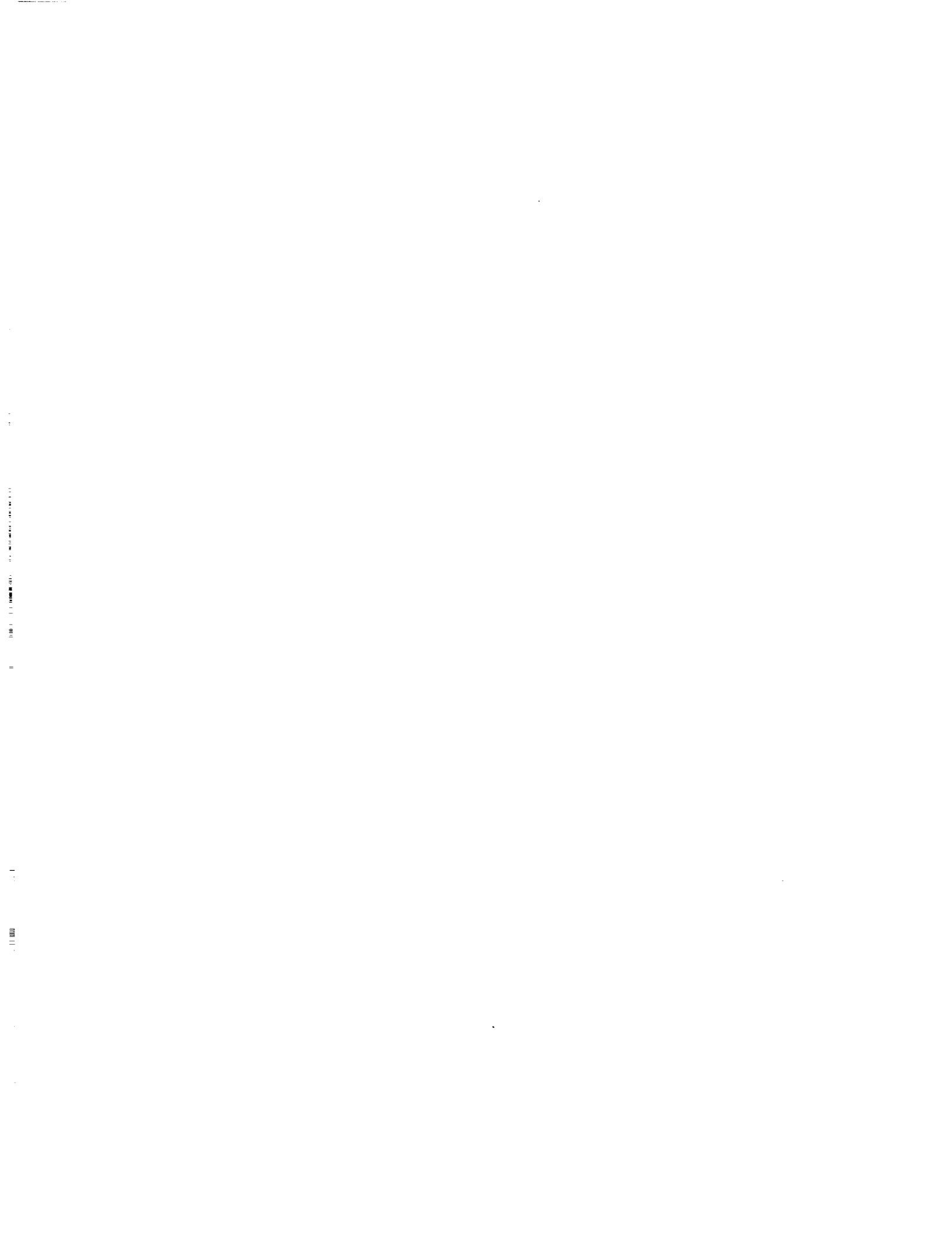
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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 4, 1992*

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**NASA'S COMMERCIAL RESEARCH PLANS AND OPPORTUNITIES**

Presented by Ray J. Arnold  
Office of Commercial Programs  
NASA Headquarters

**ABSTRACT**

One of the primary goals of the National Aeronautics and Space Administration's (NASA) commercial space development plan is to encourage the development of space-based products and markets, along with the infrastructure and transportation that will support those products and markets. A three phased program has been instituted to carry out this program. The first phase utilizes government grants through the Centers for the Commercial Development of Space (CCDS) for space-related, industry driven research; the development of a technology data base; and the development of commercial space transportation and infrastructure. The second phase includes the development of these technologies by industry for new commercial markets, and features unique industry/government collaborations such as Joint Endeavor Agreements. The final phase will feature technical applications actually brought to the marketplace. The government's role will be to support industry required infrastructure to encourage start-up markets and industries through follow-on development agreements such as the Space Systems Development Agreement.

The Office of Commercial Programs has an aggressive flight program underway on the Space Shuttle, suborbital rockets, orbital expendable launch vehicles, and the Commercial Middeck Accommodation Module with SPACEHAB Inc.

The Office of Commercial Program's has been allocated 35% of the U.S. share of the Space Station Freedom resources for 1997 utilization. A utilization plan has been developed with the Centers for the Commercial Development of Space and has identified eleven materials processing and biotechnology payloads occupying 5 double racks in the pressurized module as well as two payloads external to the module in materials exposure and environment monitoring. The Office of Commercial Programs will rely on the Space Station Freedom to provide the long duration laboratory component for space-based commercial research.



## **Office of Commercial Programs**

### **Presentation to Space Station Freedom Utilization Conference**

*Mr. Ray Arnold  
Deputy Assistant Administrator  
for Commercial Programs  
August 4, 1992*



**Office of Commercial Programs • National Aeronautics and Space Administration**

### **Opportunities for Commercial Research in Space**

- Objective
  - Conduct industry driven, space based, high technology, applied research and to allow U.S. industry to develop new or improved commercial products
- Goal
  - Increase the private sector participation and investment while diminishing the associated up-front financial and technical risks



**Office of Commercial Programs • National Aeronautics and Space Administration**

CE-0064-4 07/26/92

## ***Commercial Research Plans and Opportunities***

- The Office of Commercial Programs relies on the Space Station Freedom to provide the long duration laboratory component for space-based commercial research
- The Office of Commercial Programs is creating all of the ingredients in the recipe for the success of U.S. private sector leadership in space by providing:
  - Opportunities for focused research
    - Centers for the Commercial Development of Space
  - Basic experimental apparatus
    - Material science furnaces
    - Commercial refrigerator/incubator modules
    - Thermal enclosure systems
  - Precursor experimental space flights
    - Space Shuttle
    - SPACEHAB
    - COMmercial Experiment Transporter
    - Wakeshield Facility



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CE-9064-3 07/28/92

## ***Mechanisms for Commercial Research Relationships with Industry are in Place***

- Affiliation with the Centers for the Commercial Development of Space
- Collaborative agreements with NASA  
(Joint Endeavor Agreement, Technical Exchange Agreements)
- Reimbursable flight agreements  
(Space Systems Development Agreement)



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CE-9064-2 07/28/92

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## **The Office of Commercial Programs encourages and supports U.S. private sector leadership in space-related commerce**



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CE-9064-1 07/22/92

### ***Centers for the Commercial Development of Space (CCDS) Program***

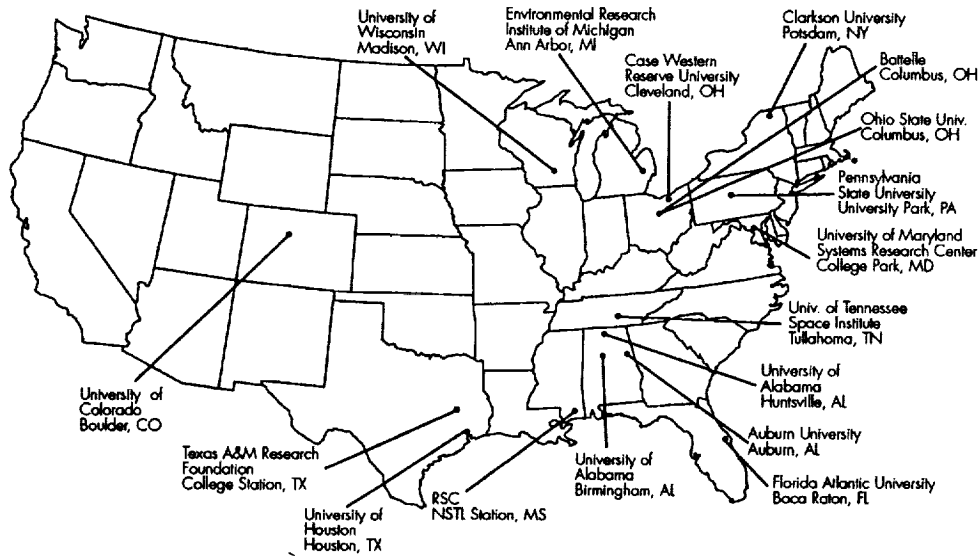
- Non-profit consortia of industry, academia and government
- Conduct industry driven space-based, high-technology research and development
- Research areas include materials processing, biotechnology, remote sensing, automation and robotics, space power, space propulsion, space structures and communications
- Created in 1985 to maximize U.S. industry leadership in commercial space-related activities
- Designed to increase private sector participation and investment in the commercial development of space
- Provide a way for U.S. companies to pool resources and expertise while diminishing the associated costs and risks
- To participate in the CCDS program, a company should contact the appropriate CCDS Center Director



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# Centers for Commercial Development of Space (CCDS)



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## Current CCDS Commercial Technologies

### **Auburn**

Solar Furnace Satellite  
Crystal Growth of Electronic Materials  
Computational Modeling of Casting Processes

### **Battelle**

Solution Crystal Growth  
Polymer Composites  
Float Zone Crystal Growth - CdTe  
Zeolite Crystal Growth  
Doped Non-Linear Optic Substrates  
Investigations into Polymer Membranes

### **Bioserve**

Plant Growth Apparatus  
Blood Rheology Experiment  
Generic Bioprocessing Module  
Autonomous Biomedical Test Apparatus

### **Case Western**

Materials Exposure - Basic, Advanced, & Applied

### **Clarkson**

Zeolite Crystal Growth  
Low-Temp Solidification  
Liquid Encapsulated Melt Zone  
Directional Solidification - CdTe  
Chemical Vapor Transport - CdTe  
Commercial Solution Growth Facility

### **CSTAR**

Cryogenic Fluid Management  
Electric, Chemical Propulsion  
Industrial Laser System Applications

### **Florida Atlantic**

Transmission Techniques

### **Ohio State**

Remote Sensing & Mapping

### **Penn State**

Biomodule  
Telemedicine  
Bioseparations  
Bone Densitometry  
Physiological Systems Experiment  
Light Stimulator & Photon Detector  
Commercial Electrophoresis System

### **SpARC**

Autonomous Rendezvous & Docking  
Automated Microgravity Materials Processing

### **SRSC**

Remote Sensing & Applications

### **SVEC**

Chemical, Molecular Beam Epitaxy Growth

### **Texas A&M**

Micro Heat Pipe Evaluation  
Frozen Startup of Heat Pipe  
Microwave Power Transmission

### **University of Alabama-Birmingham**

Protein Crystal Growth

### **University of Alabama-Huntsville**

Polymer Foam  
Atomic Oxygen  
Electrodeposition  
3-D Accelerometer  
Immiscible Polymers  
Nuclear Track Detectors  
Space Experiment Facility  
Non-Linear Optical Materials  
Sintered & Alloyed Materials  
High-Temp Superconductors  
Materials Dispersion Apparatus

### **University of Maryland**

Hybrid Networks

### **WCSAR**

Astroculture™  
Bioregenerative Water System



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# Active Commercial Agreements

<i>Company</i>	<i>Venture</i>	<i>Status</i>	<i>Requirement</i>	<i>Flights Completed</i>
<b>Joint Endeavor Agreements</b>				
Instrumentation Technology Associates	Standardized Experiments Carrier	Hardware under development, first flight TBD	2 flights (cross-bay carrier)	0
3M (10 years)	Research in organic and polymer chemistry	First payload (pm) STS-34 (Oct 1989)	62 flights (20 middeck; 42 cargo bay)	3
Boeing Aerospace Company (BAC)	Crystal growth experiments on the shuttle	Hardware under development, first flight planned for STS-52 (Sept. 1992)	3-5 flights (Mar)	0
<b>Technical Exchange Agreements</b>				
Autometric, Inc.	High resolution handheld remote sensors	Signed 4/2/91	Access to NASA Imagery from the Electronic Still Camera developed by JSC	2
<b>Other Cooperative Agreements</b>				
University of Alabama - Huntsville Instrumentation Technology Associates	Materials processing using a minimal dispersion apparatus	First flight planned for STS-52 (Sept. 92)	5 flights 1 locker	0



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CE-9025 7/28/92

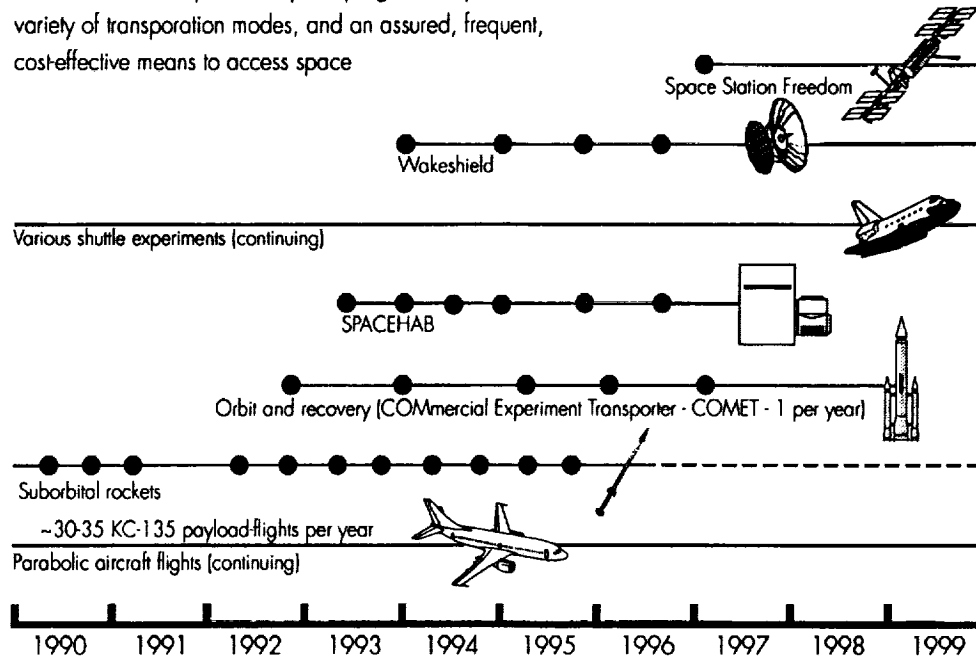
## Flight Planning



Office of Commercial Programs • National Aeronautics and Space Administration

# Commercial Transportation Modes

Commercial development of space programs require a variety of transportation modes, and an assured, frequent, cost-effective means to access space



\* Many carrier and interface configurations not highlighted here



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CE-9067 07/27/92

# Flights of U.S. Commercial Payloads

	Payload Name	No. of Flights	Missions
1	Astroculture		STS 50
2	Automated Generic Bioprocessing Apparatus	2	Consort 3,4
3	Biomodule	2	Consort 3,4
4	Bioserve Instrumentation Materials Dispersion App.	2	STS 37,43
5	Continuous Flow Electrophoresis (I, II, & III)	7	STS 4, 6, 7, 8, 12, 16, 23
6	Demixing of Immiscible Polymers Mixer	2	Consort 1,3
7	Diffusive Mixing of Organic Solutions	2	STS 14,23
8	Directed Polymerization Apparatus (USML-1 GBX exper.)	1	STS 50
9	Elastomer-Modified Epoxy Resins Heaters	2	Consort 1,3
10	Electrodeposition Cells	4	Consort 1,3,4, STS 40 (GAS 105)
11	Equipment for Controlled Liquid Phase Sintering	1	Consort 4
12	Fluid Experiment Apparatus	2	STS 30,32
13	Foam-Formation Device	2	Consort 1,3
14	Gelation of SOLS: Applied Microgravity Research	1	STS 42
15	Generic Bioprocessing Apparatus	1	STS 50
16	Protein Crystal Growth (Hand-Held, VDA, PCF, CRIM)	14*	STS 16, 19, 23, 24, 26, 29, 32, 31, 37, 43, 48, 42, 50
17	Investigations into Polymer Membrane Processes	2	Consort 3,4
18	Investigations into Polymer Membrane Processing	7	STS 31, 41, 43, 48, 42, 45, 50
19	Materials Dispersion Apparatus	3	Consort 1,3,4
20	Metal Sintering Furnace	1	Consort 1
21	Non-Linear Optical Crystal Growth (DAN)-UAH/IBM	1	STS 40 (GAS 105)
22	Non-Linear Optical Crystal Growth (DAN)-UAH/IBM	1	STS 40 (GAS 105)
23	Physical Vapor Transport of Organic Solids	2	STS 20, 26
24	Physiological Systems Experiments	1	STS 41
25	Plasma Particle Generation	1	Consort 3
26	Polymer Curing Experiment	1	Consort 4
27	Polymer Morphology	1	STS 34
28	Polymer Thin Films	2	Consort 3, STS 40 (GAS 105)
29	Separation of Aqueous Phases	1	STS 40 (GAS 105)
30	Space Formed Structural Beam (Foam Foundation Device)	1	Consort 4
31	Yeast Experiment	1	STS 40 (GAS 105)
32	Zeolite Crystal Growth	1	STS 50

Total number of payloads flown - 73\*\* Hardware Items - 32

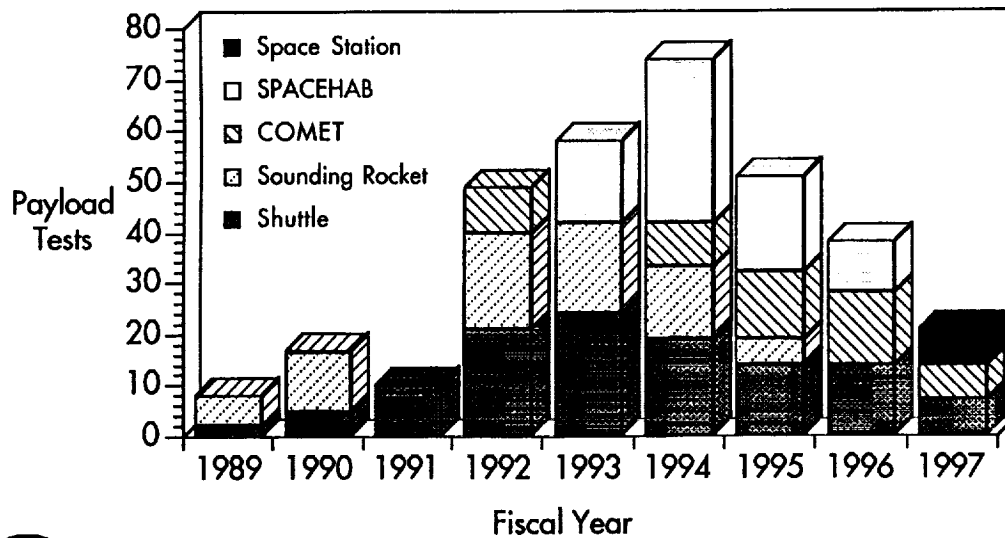
\* The Protein Crystal Growth experiments were shared between the OCP and OSSA  
 \*\* A payload-flight = one flight of one payload. Therefore, one flight with = 3 payload-flight



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CE-9073 07/23/92

# Flight Profile



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CE-9032-1 07/28/92

## Office of Commercial Programs Near Term Flight Projection

Flight	Sponsor	Payload	Launch Date
STS-46	Case Western UAH/Los Alamos Natl Labs UAH/Teledyne Brown	Limited Duration Candidate Materials Exposure (3)* CONCAP-II* (CONsortium Complex Autonomous Payload) CONCAP-III* (CONsortium Complex Autonomous Payload)	Jul 1992
CONSORT-05	Penn State UAH  Wisconsin	Penn State Biomodule* Organic Separation* Polymer Beam* Equipment for Controlled Liquid Phase Sintering Experiment* Materials Dispersion Apparatus* Polymer Foams and Films* Sintered and Alloyed Materials* Electrodeposition* Performance of Light-Emitting Diodes in Microgravity*	Sept. 1992
STS-47	UAB	Protein Crystal Growth**	Sept 1992
STS-52	Boeing UAB Penn State Univ UAH/ITA	Crystals by Vapor Transport Experiment* Protein Crystal Growth* Physiological Systems Experiment* Commercial ITA Materials Dispersion Experiment*	Oct 1992
STS-54	Bioserve	Generic Bioprocessing Apparatus*	Dec 1992

\* Assigned

\*\* OSSA Sponsored - Joint Flight Activity

Note: Shuttle flight dates are based on internal manifest planning on 6/4/92



Office of Commercial Programs • National Aeronautics and Space Administration

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CE-9086-1 7/28/92

# Office of Commercial Programs Near Term Flight Projection (continued)

Flight	Sponsor	Payload	Launch Date
COMET-01	Bioserve UAH  Penn State UAB ERIM FAU Texas A&M	Autonomous Biomedical Test Apparatus* Plant Growth Apparatus* Materials Dispersion Investigations* Non-Linear Optical Materials * Atomic Oxygen* 3-Dimensional Microgravity Accelerometer* Biomodule* Protein Crystal Growth* Autonomous Rendezvous Docking* Motorola Communications Experiment* Frozen Startup of a Heat Pipe in Microgravity*	Mar 1993
STS-51	Case Western  UAB Battelle/Amoco	Advanced Communications Technology Satellite Limited Duration Candidate Materials Exposure (2) * Commercial Protein Crystal Growth* Investigations into Polymer Membrane Processing*	Mar 1993
STS-56	UAH/ITA	Commercial ITA Materials Dispersion Experiment	Apr 1993



\* Assigned  
\*\* OSSA Sponsored - Joint Flight Activity  
Note: Shuttle flight dates are based on internal manifest planning on 6/4/92

Office of Commercial Programs • National Aeronautics and Space Administration

CE-0006-2 7/27/92

# Office of Commercial Programs Near Term Flight Projection (continued)

Flight	Sponsor	Payload	Launch Date
STS-57	Battelle  Bioserve  Clarkson Penn State Univ UAB  UAH  Wisconsin LeRC JSC  LeRC UAH UAH	Spacehab-01 Investigations into Polymer Membrane Processing* Solution Crystal Growth* Zeolite Crystal Growth* Bioserve Pilot Laboratory* Commercial Generic Bioprocessing Apparatus* Liquid Encapsulated Melt Zone-1 * Physiological Systems Experiment* Commercial Protein Crystal Growth* Advanced Protein Crystal Growth* Equipment for Controlled Liquid Phase Sintering* Organic Separation* 3-Dimensional Microgravity Accelerometer* Astraculture* Gas Permeable Polymer Material* Application Specific Preprogrammed Experimental Culture (plus other Space Life Sciences activities)* Space Acceleration Measurement System* CONCAP II CONCAP IV	May 1993



\* Assigned  
\*\* OSSA Sponsored - Joint Flight Activity  
Note: Shuttle flight dates are based on internal manifest planning on 6/4/92

Office of Commercial Programs • National Aeronautics and Space Administration

CE-0006-3 7/27/92

# ***Commercial Utilization of Space Station Freedom***



**Office of Commercial Programs • National Aeronautics and Space Administration**

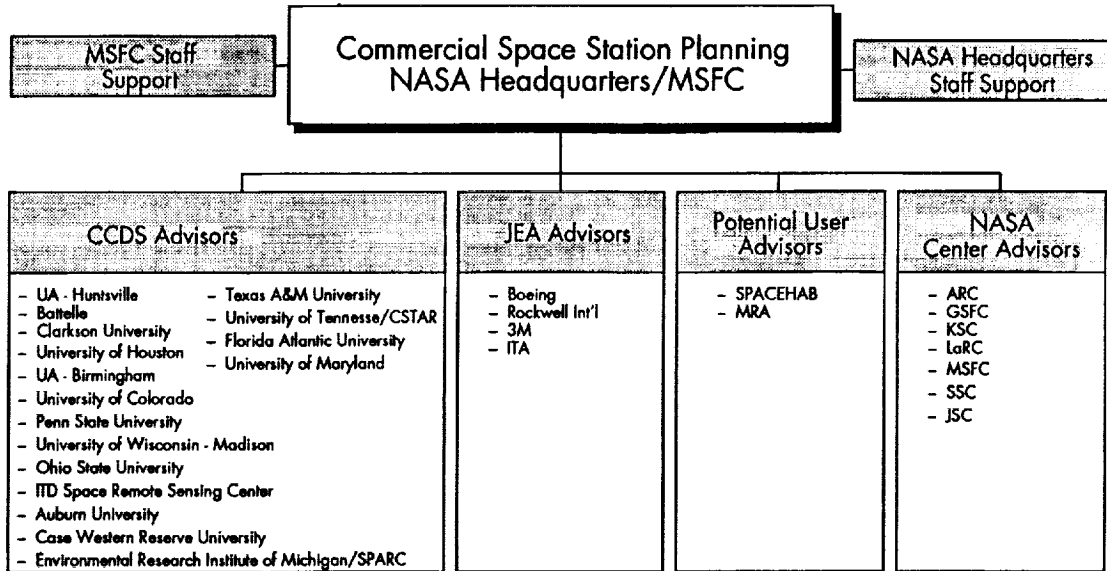
## ***Rationale for Commercial Space Station Involvement***

- Provides the important long duration laboratory component which will enable commercial technologies to transition to new, space-based markets
- Provides natural evolution from shuttle experience for commercial payloads
- Adequate rack volume and power to support commercial payloads
- Most commercial payloads can operate within Space Station microgravity levels
- Payloads can take advantage of untended periods - free flyer environment
- Allows for commercial infrastructural considerations



**Office of Commercial Programs • National Aeronautics and Space Administration**

# Commercial Space Station Freedom Planning Team



Office of Commercial Programs • National Aeronautics and Space Administration

CE-9088 07/29/92

## Space Station Freedom Resource Allocations

	NASA U.S.A.	MOSST Canada	ESA Europe	STA Japan
Utilization Resources	71.4%	3%	12.8%	12.8%

### 1997 OCP SSF Resources

OSSA - Science: 65%*	<p>Pressurized Up Mass: 4,352 kg            Pressurized Down Mass: 3,784 kg            Unpressurized Up Mass: 4,209 kg            Unpressurized Down Mass: 7,073            Volume Up: 9.5 DRE            Volume Down: 7.1 DRE            Power: 3 kW            Downlink: 10,472 kb/s            Crew Time: 436 hours            Data Storage: 92 Mbytes            Racks Occupied On-Orbit: 5 DRE            Truss Attach Points: 0.7 APs</p>
OCP - Commercial: 35%*	
OAST - Technology: 15%*	
OSF/OSSD - Other: 10%*	

\* Utilization planning guidelines allow the total resources used by NASA's User Sponsors to equal 125%, for the launch minus 5 year timeframe.

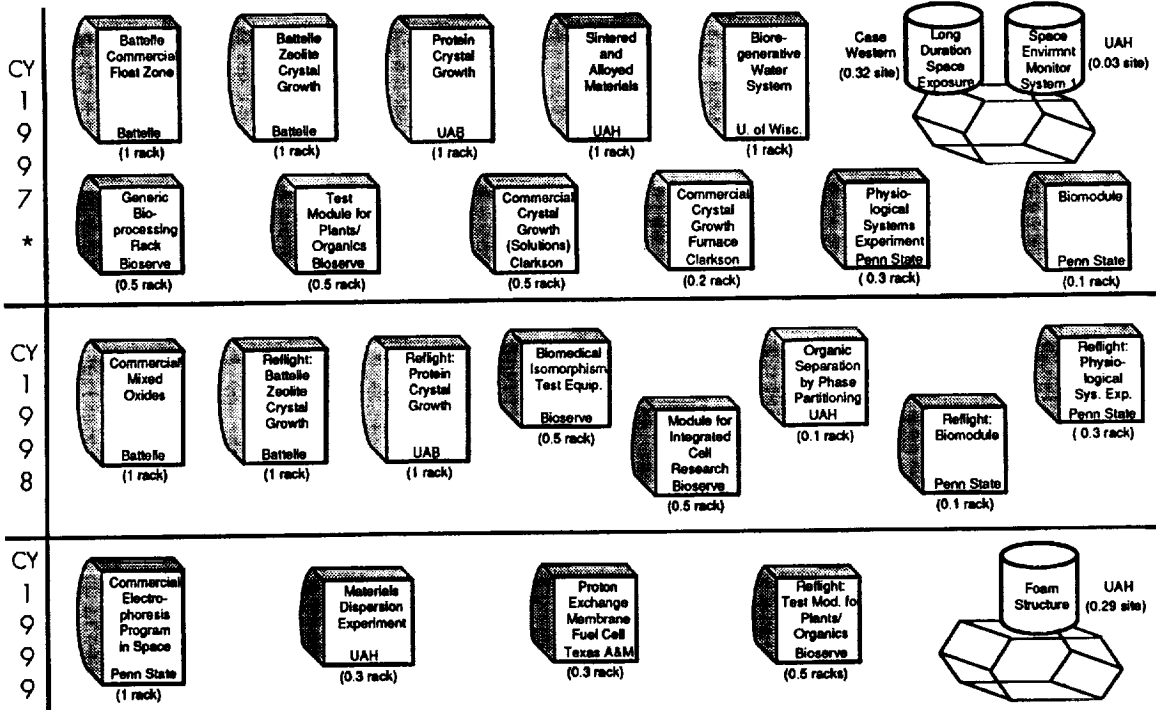


Office of Commercial Programs • National Aeronautics and Space Administration

CE-9070 07/29/92

# OCP SSF Utilization Traffic Model

Draft



\* Includes payloads on Mission Build flight 6, currently scheduled for launch in December 1996.

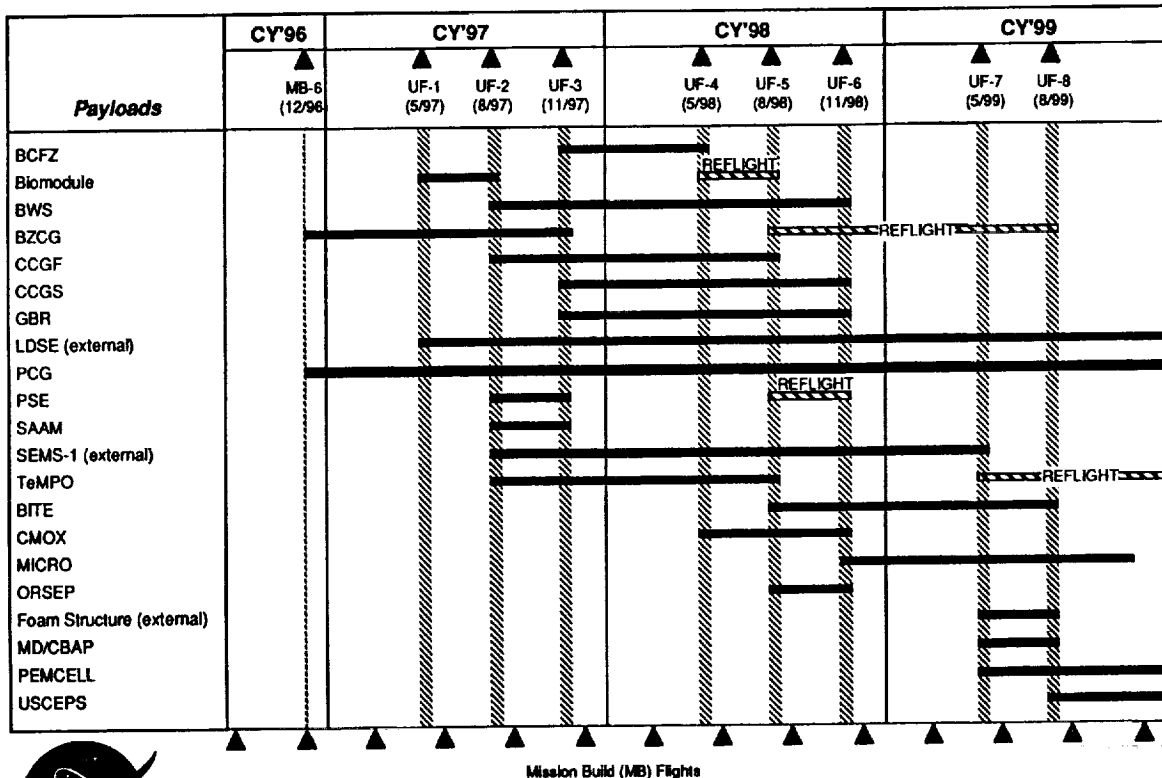


Office of Commercial Programs • National Aeronautics and Space Administration

CE-9071 07/29/92

# Space Station Freedom Flight Manifest

Draft



Office of Commercial Programs • National Aeronautics and Space Administration 109

CE-9072 07/29/92

# Office of Commercial Programs Space Station Freedom Payload Heritage

Space Station Freedom Payload	Precursor Flights					
	1991	1992	1993	1994	1995	1996
<b>Zeolite Crystal Growth (ZCG)</b> Battelle • Applications: Kidney dialysts, radioactive waste cleanup, petroleum processing • Affiliates: Amoco Chemical Co., DuPont, Intek, Teledyne Brown						
<b>Protein Crystal Growth (PCG)</b> UAB • Applications: Human gamma-interferon, Isocitrate lyase • Affiliates: Schering-Plough, Burroughs Wellcome, DuPont, Genentech, Vertex, SmithKline & French, Upjohn, Eli Lilly, Eastman Kodak, Biocryst, Space Industries, Inc.						
<b>Bioregenerative Water System (BWS)</b> WSCAR • Applications: Controlled plant growth environments, water regeneration for space application • Affiliates: Quantum Devices, Inc., Phyto farms of America, Inc., Automated Agriculture Assoc., Inc.						
<b>Module for Integrated Cell Research In Orbit (MICRO)</b> Bioserve • Applications: Membrane formation, crystal growth, cell cultures, organism growth • Affiliates: Alaza, Ball, Boeing, Central Biomedica, DuPont, Omni Data, Juvenile Diabetes Foundation						



Legend: - Middeck - SPACEHAB/Spacelab X-Bay - Space Station Freedom - COMET - Sounding Rocket - Gas Can

Office of Commercial Programs • National Aeronautics and Space Administration

CE-9038-1 07/22/92

## OCP Payload Development and Transition to Space Station Freedom

- OCP has an active flight program using Middeck, sounding rockets, gas cans, and KC-135s to develop experiments
- OCP intends to extend the flight experiments which are successful on these carriers to the Space Station Freedom
- OCP has a draft traffic model and a flight plan for development flights of payloads on various carriers to get us from the present to the Space Station Freedom time frame
- OCP will rely heavily on the existing carriers plus COMET and SPACEHAB for payload development and transition to Space Station Freedom



Office of Commercial Programs • National Aeronautics and Space Administration

CE-9064-6 07/22/92



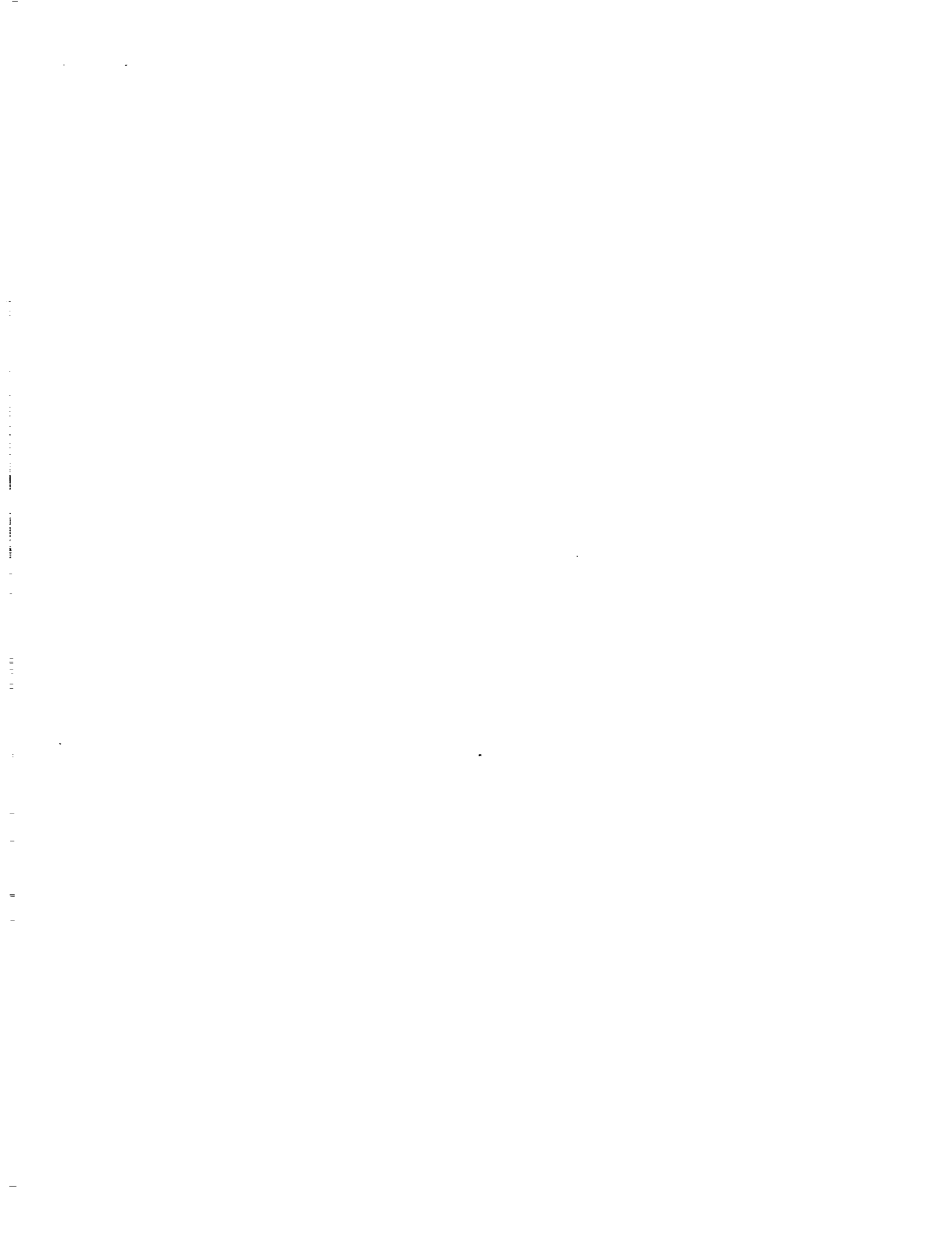
## ***Vision***

- **Stimulating private sector involvement in space-related activities to enhance the competitiveness of U.S. industry, promote the nation's economic well-being, and improve the overall quality of life**



**Office of Commercial Programs • National Aeronautics and Space Administration**

CE-9064-7 07/28/92



**SPACE TECHNOLOGY RESEARCH PLANS**

Presented by W. Ray Hook  
Director for Space  
NASA Langley Research Center

**ABSTRACT**

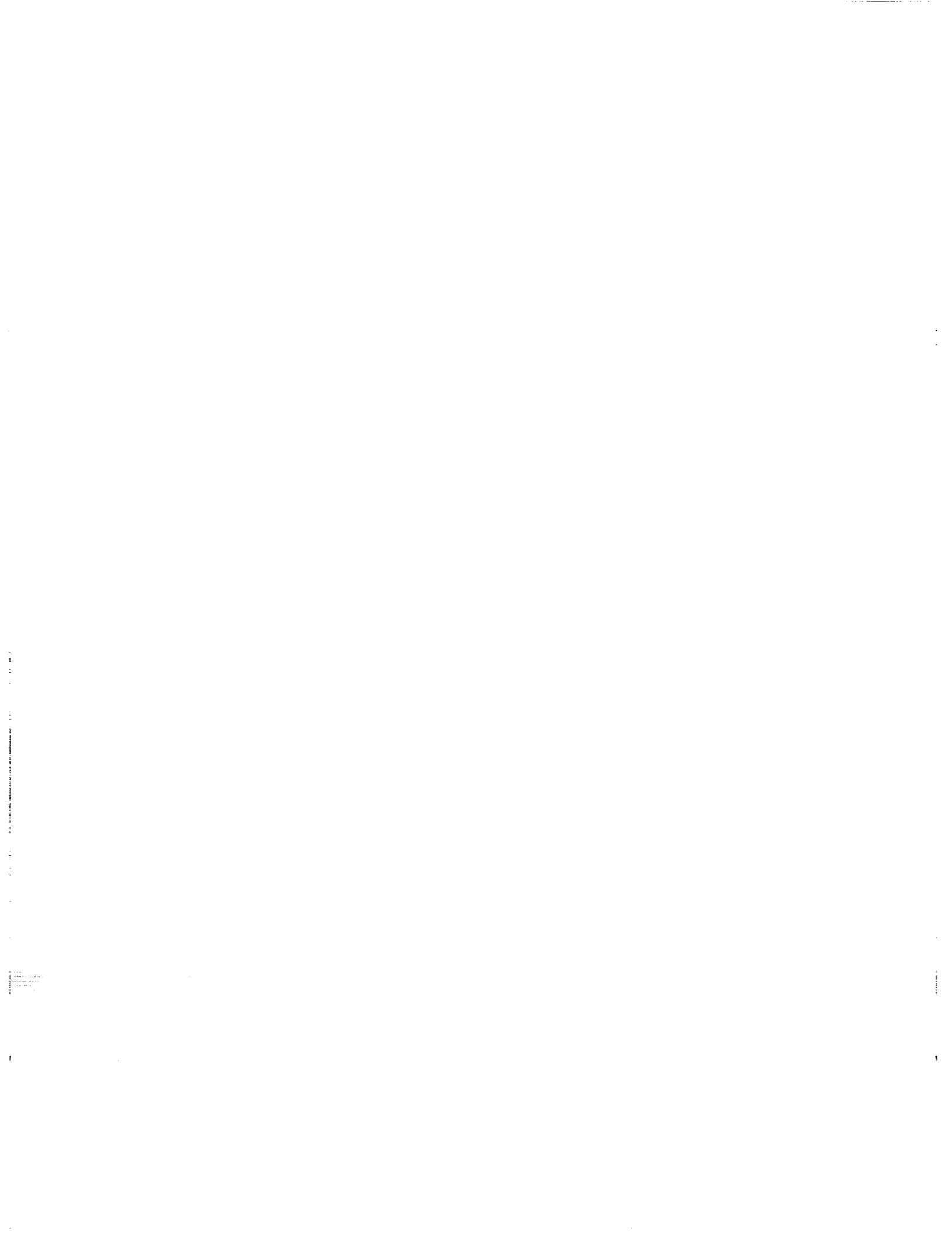
Development of new technologies is the primary purpose of the Office of Aeronautics and Space Technology (OAST). OAST's mission includes the following two goals: (1) to conduct research to provide fundamental understanding, develop advanced technology and promote technology transfer to assure U.S. preeminence in aeronautics and to enhance and/or enable future civil space missions; and (2) to provide unique facilities and technical expertise to support national aerospace needs.

OAST includes both NASA Headquarters operations as well as programmatic and institutional management of the Ames Research Center, the Langley Research Center and the Lewis Research center. In addition, a considerable portion of OAST's Space R&T Program is conducted through the flight and science program field centers of NASA. Within OAST, the Space Technology Directorate is responsible for the planning and implementation of the NASA Space Research and Technology Program.

The Space Technology Directorate's mission is "to assure that OAST shall provide technology for future civil space missions and provide a base of research and technology capabilities to serve all national space goals." Accomplishing this mission entails the following objectives:

- Identify, develop, validate and transfer technology to:
  - Increase mission safety and reliability
  - Reduce flight program development and operations costs
  - Enhance mission performance
  - Enable new missions
- Provide the capability to:
  - Advance technology in critical disciplines
  - Respond to unanticipated mission needs.

In-space experiments are an integral part of OAST's program and provides for experimental studies, development and support for in-space flight research and validation of advanced space technologies. Conducting technology experiments in space is a valuable and cost effective way to introduce advanced technologies into flight programs. These flight experiments support both the R&T base and the focussed programs within OAST.



# SPACE TECHNOLOGY RESEARCH PLANS

## OVERVIEW PLANS

Presented To:  
Space Station Freedom Utilization Conference

Presented by:  
W. Ray Hook  
Director, Space Directorate  
Langley Research Center

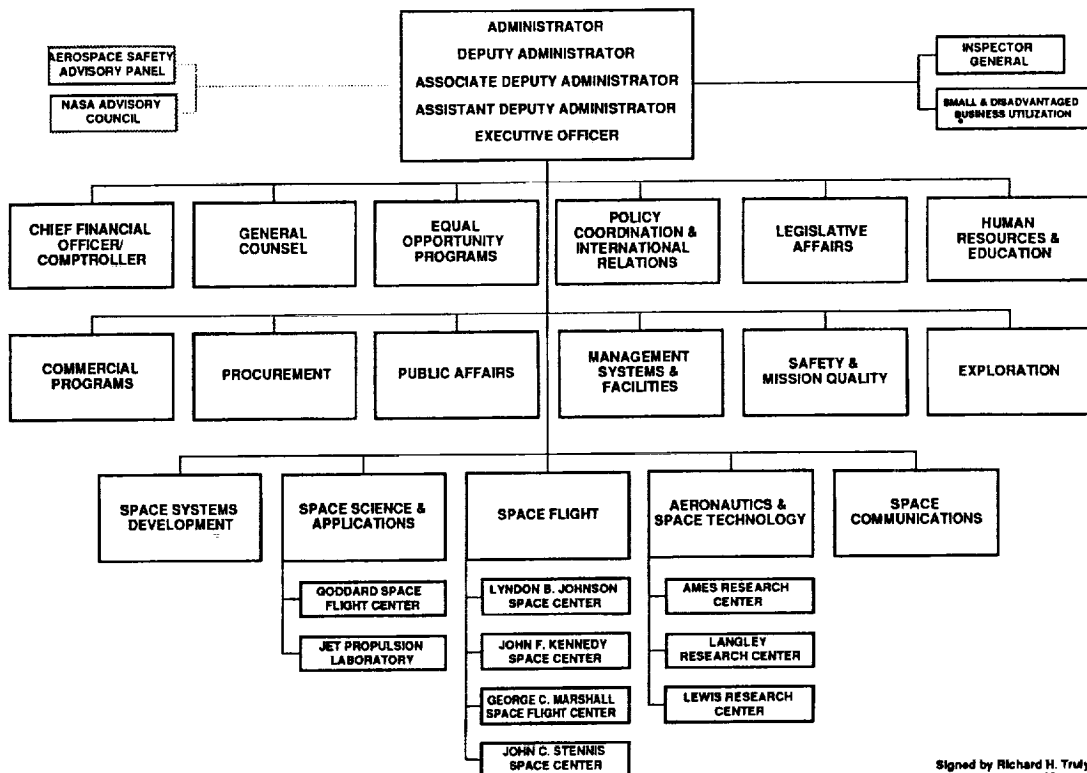
For:  
Office of Aeronautics and Space Technology

August 4, 1992

**OAST**

OFFICE OF AERONAUTICS  
AND SPACE TECHNOLOGY

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

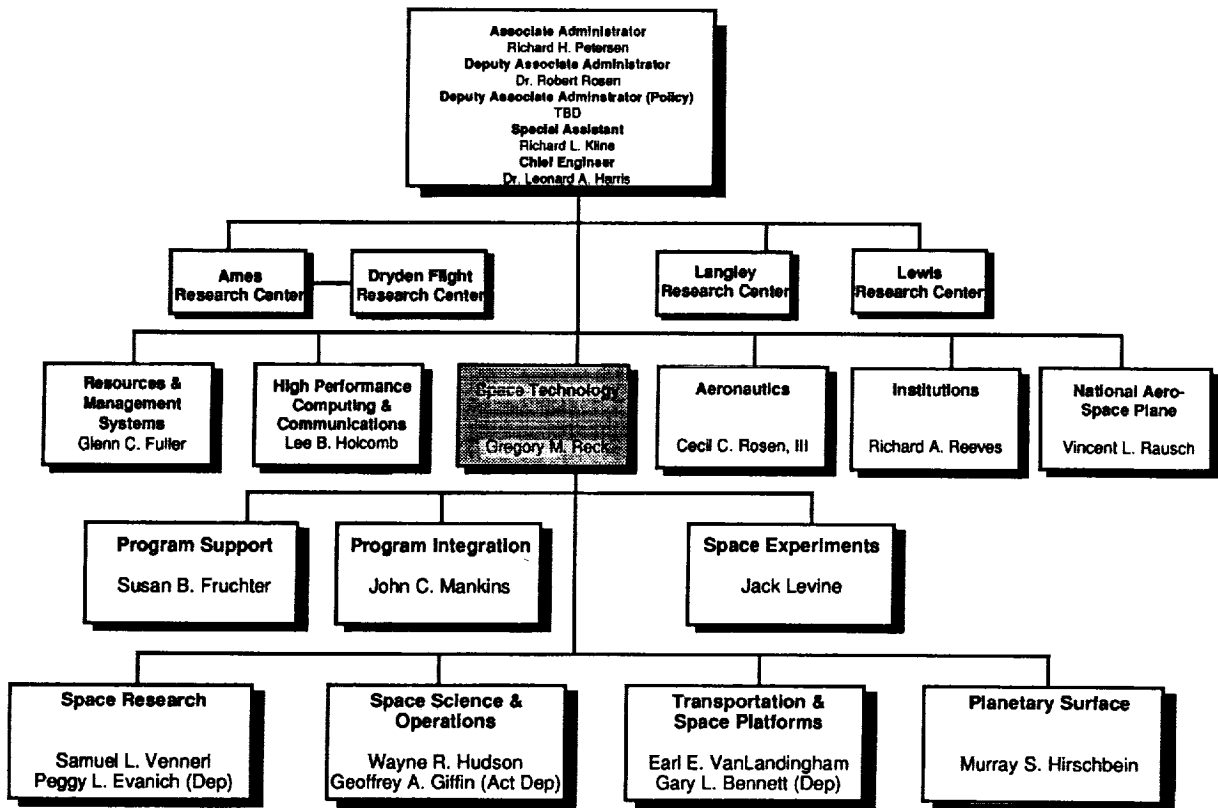


Signed by Richard H. Truly  
October 20, 1991

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**OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY**

OAST



**SPACE R&T VISION & MISSION STATEMENT**

OAST

**VISION**

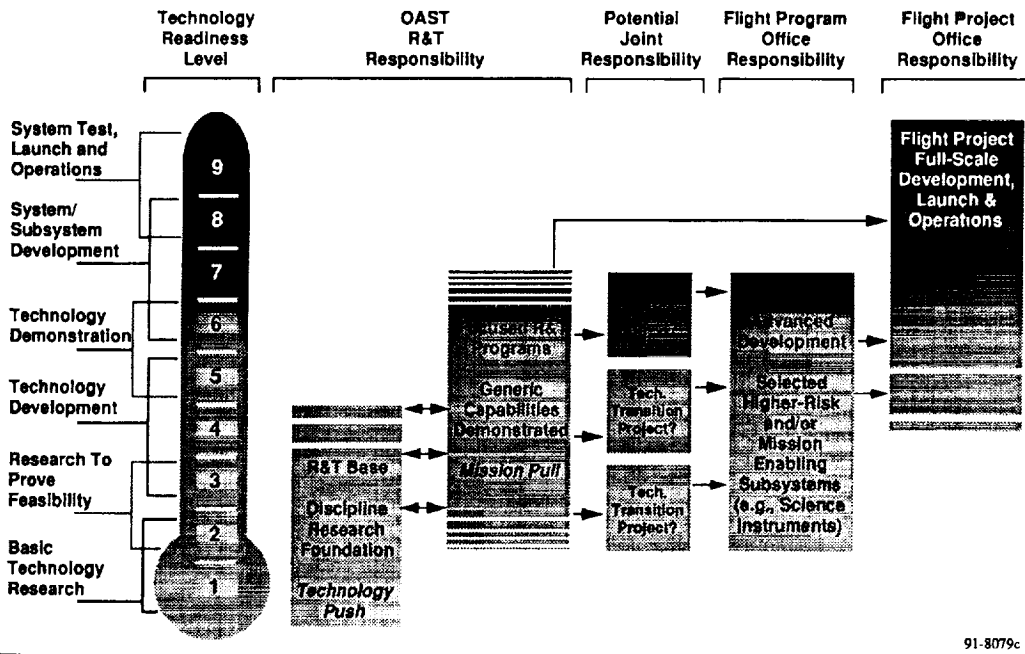
**WORLD LEADERSHIP IN SPACE RESEARCH AND TECHNOLOGY DEVELOPMENT TO MAKE IT POSSIBLE TO LOOK BEYOND THE KNOWN, TO CHALLENGE THE LIMITS OF HUMAN CAPABILITY, TO INSPIRE THE GENERATION OF THE 21ST CENTURY, AND TO SECURE THE BENEFITS OF SPACE FOR LIFE ON EARTH**

**MISSION**

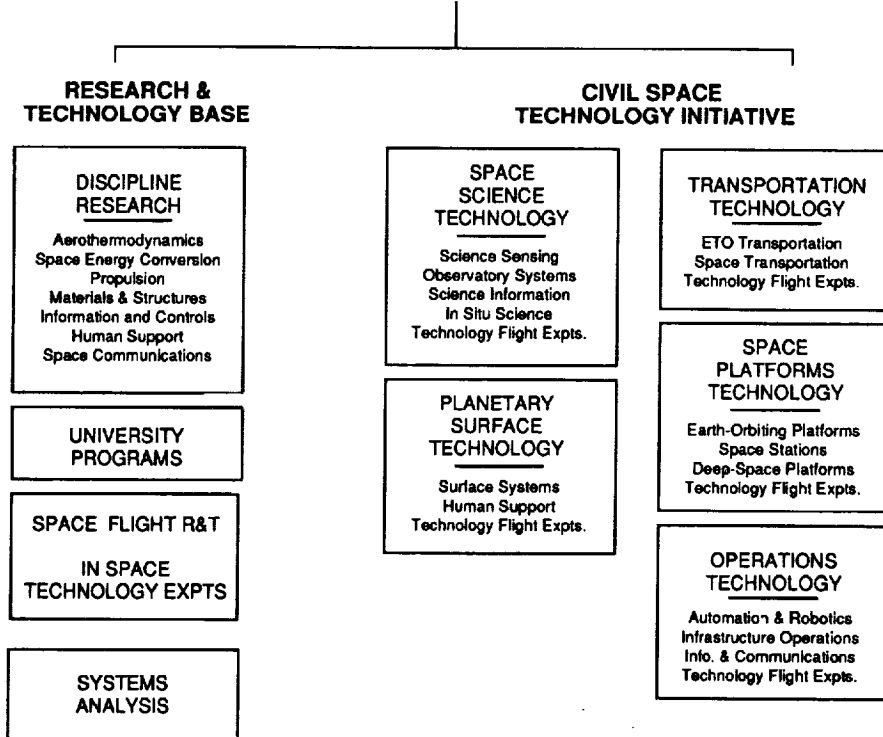
**OAST SHALL PROVIDE TECHNOLOGY FOR FUTURE CIVIL SPACE MISSIONS AND PROVIDE A BASE OF RESEARCH AND TECHNOLOGY CAPABILITIES TO SERVE ALL NATIONAL SPACE GOALS**

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM  
**TECHNOLOGY MATURATION STRATEGY**

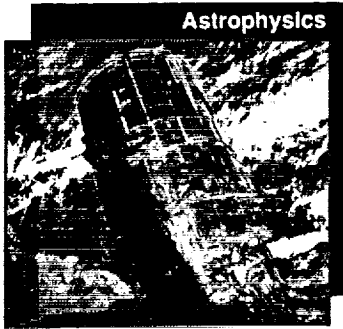
OAST



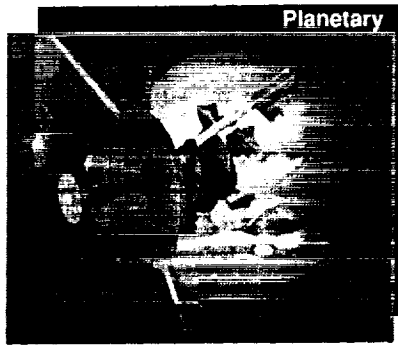
INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM  
**SPACE RESEARCH & TECHNOLOGY**



— TECHNOLOGY CONTRIBUTIONS TO SCIENCE SPACECRAFT —

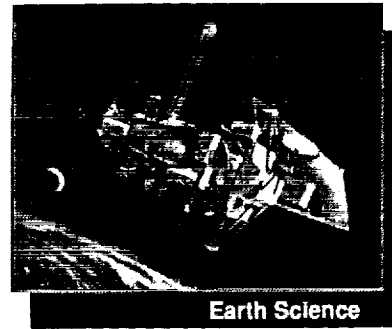


- Hubble - VLSI Data Processing
- Astro - Startracker
- Hubble - Battery Technology
- Hubble - Image Restoration



- Galileo (& Hubble) - CCD Array
- Voyager - Spacecraft Health Monitoring
- Magellan - Radar Ground Processor

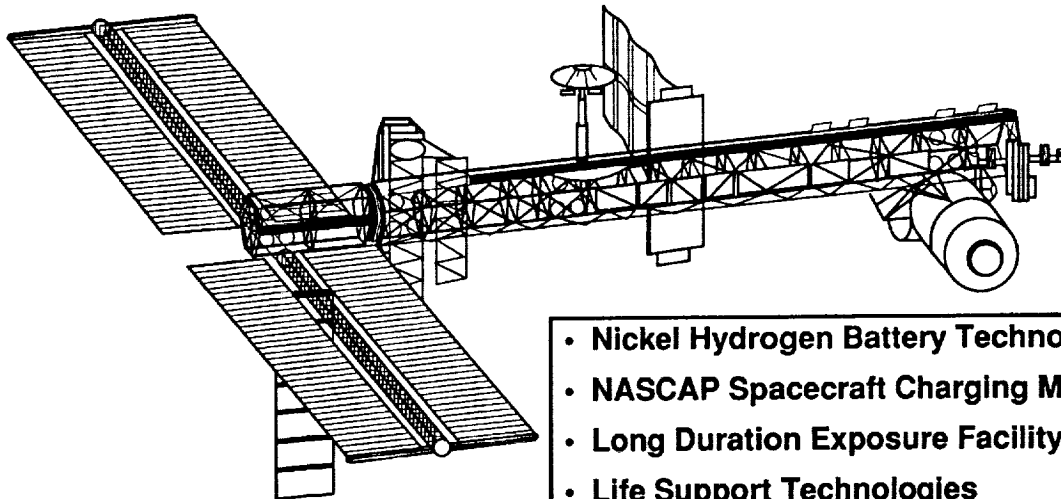
- UARS - 205 GHz Limb Sounder Technology
- Shuttle Imaging Radar - SAR Technologies
- TOPEX - Millimeter Accuracy Laser Ranging



92-8013

*Office of Aeronautics and Space Technology*

— TECHNOLOGY CONTRIBUTIONS TO SPACE PLATFORMS —



- Nickel Hydrogen Battery Technology
- NASCAP Spacecraft Charging Model
- Long Duration Exposure Facility
- Life Support Technologies
- Multipropellant Resistojet
- Large Area Solar Cells
- Arcjet Thruster

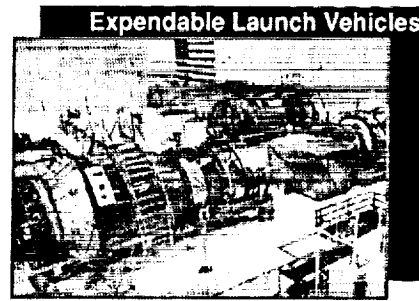
*Office of Aeronautics and Space Technology*





Space Shuttle

- Structural Analysis for Solid Rocket Motor (SRM) Redesign
- Vacuum Plasma Spray Coatings & Chambers
- Health Monitoring (Test Facilities)
- Thermal Protection System
- Bearing Cooling Analysis
- Real Time Data System
- Orbiter Experiments
- Damping Seals
- Modified Tires



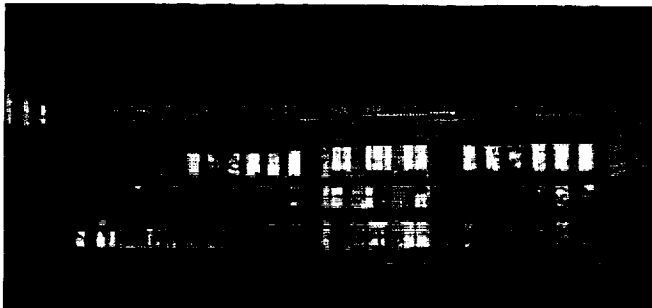
Expendable Launch Vehicles

- Advanced Primary Battery

92-8023a

Office of Aeronautics and Space Technology

## UNIVERSITY SPACE ENGINEERING RESEARCH PROGRAM



### UNIVERSITY-BASED CENTERS

- ATTRACT AND RETAIN STUDENT AND INDUSTRY SUPPORT
- SUPPORT AND EXPAND THE NATION'S ENGINEERING TALENT BASE
- FOSTER INNOVATIVE, MULTI-DISCIPLINARY RESEARCH

- UNIVERSITY OF ARIZONA
  - Planetary Resources
- UNIVERSITY OF CINCINNATI
  - Propulsion Monitoring Systems
- UNIVERSITY OF COLORADO, BOULDER
  - Space Construction
- UNIVERSITY OF IDAHO
  - VLSI hardware
- MASSACHUSETTS INSTITUTE OF TECHNOLOGY
  - Controlled Structures Technology
- UNIVERSITY OF MICHIGAN
  - Space TeraHertz Sensing Technologies
- NORTH CAROLINA STATE AT RALEIGH & NORTH CAROLINA AGRICULTURAL & TECHNICAL STATE UNIVERSITIES
  - Mars Mission Technologies
- PENNSYLVANIA STATE UNIVERSITY
  - Propulsion
- RENSSELAER POLYTECHNIC INSTITUTE
  - Robotics

91-2118

# SPACE R&T PROGRAM 20-YEAR STRATEGIC VISIONS

---

## Space Science

- Technologies Will Be Ready To Enable Low Mass, Facility Class Single Aperture And Interferometric Space-Based Observatories Across The EM Spectrum; To Conduct Cost-Effective, Long Term Remote Sensing; To Make Complex, But Frequent *In Situ* Scientific Studies In Space Laboratories, On The Moon & At The Planets; And, To Enhance Human Understanding Of Extremely Large Science Data Sets

## Planetary Surface

- The Technology Will be Completed To Emplace Safe and Permanent, Largely Self-Sufficient Human Outposts On The Moon Or Mars, With Capabilities For Extensive Surface Exploration & Science, And Resource Exploitation Operations

## Transportation

- Capabilities Will be In Hand To Enable Safe, Highly Operable Reusable Piloted Vehicles For ETO Transport; Low Cost, Reliable Expendable ETO Vehicles For Small, Medium & Large Payloads (Including Internationally Competitive ELVs); And Long Life, High Performance Space Transfer Systems That Enable Human Exploration Of The Moon and Mars, And Ambitious Deep Space Robotic Missions

## Space Platforms

- Technologies Will Be Ready For Long Lived, Earth Orbiting Platforms With Significantly Reduced Masses and Costs, But Increased Payload Capabilities (Manned & Unmanned); And, For Reduced Mass, High Reliability Spacecraft For Long-Duration Deep Space Science & Exploration Mission Applications

## Operations

- New Technology Will Make Possible Largely Autonomous Ground, Flight & In-Space Systems That Reduce The Costs Of Civil Space Mission Operations And Infrastructure, While Improving Their Safety & Reliability, Enabling More Complex Capabilities, And Massively Increasing Mission Data Returns

## Innovative Discipline Research

- Innovative, High-Leverage Concepts Will Be Validated Analytically & In Laboratory Research That Make Possible "Next Generation" Earth & Space Science, Exploration, Commercial, And Infrastructure Missions

thrust visions — JUNE 22, 1992

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## SPACE FLIGHT RESEARCH & TECHNOLOGY

---

PROVIDE FOR EXPERIMENT STUDIES, DEVELOPMENT AND SUPPORT  
FOR IN-SPACE FLIGHT RESEARCH AND VALIDATION OF ADVANCED  
SPACE TECHNOLOGIES



- IN-SPACE TECHNOLOGY EXPERIMENT PROGRAM (IN-STEP)
  - DESIGN, DEVELOP AND FLIGHT TEST INDUSTRY, UNIVERSITY AND NASA TECHNOLOGY FLIGHT EXPERIMENTS
- FLIGHT OPPORTUNITIES VIA
  - SPACE SHUTTLE
  - EXPENDABLE LAUNCH VEHICLES
  - SPACE STATION FREEDOM

Past Flight Experiments

Experiment Name	Launch Date	Carrier	Experiment Name	Launch Date	Carrier
Capillary Loop Pump	1/86	STS-61C	Vapor Growth in II-VI Compounds	7/73	Skylab 3
Assembly Concept for Construction of Erectable Space Structure	11/85	STS-41D	Whisker Reinforced Composites	7/73	Skylab 3
Superfluid Helium	7/85	STS-51F	Astronaut Maneuvering Equip.	4/73	Skylab 1/2
Drop Dynamics	4/85	STS-51B	Coronagraph Contamination Measurement	4/73	Skylab 1/2
Feature Ident. & Location Exp	10/84	STS-41G	ATM Contamination Experiment	4/73	Skylab 1/2
Dynamics Augmentation Exp/ Photogrammetry	8/84	STS-41D	Exothermic Brazing Experiment	4/73	Skylab 1/2
Solar Array Flight Exp	8/84	STS-41D	Foot Control Maneuvering Unit	4/73	Skylab 1/2
Solar Cell Calibration Exp	8/84	STS-41D	Gallium Arsenide Crystal Growth	4/73	Skylab 1/2
Long Duration Exposure Facility	4/84	STS-41C	Inflight Aerosol Analysis	4/73	Skylab 1/2
Tribology Experiment	11/83	STS-41A	Materials Processing Facility	4/73	Skylab 1/2
Thermal Control Exp	8/83	STS-31D	Metals Melting Experiment	4/73	Skylab 1/2
Thermal Canister	11/81	STS-2	Radiation in Spacecraft Exp.	4/73	Skylab 1/2
Multi-Purpose Furnace System	11/73	Skylab 4	Spacecraft Surfaces Exp.	4/73	Skylab 1/2
Zero-O Flammability	11/73	Skylab 4	Sphere Forming Experiment	4/73	Skylab 1/2
Copper Aluminum Eutectic Exp.	7/73	Skylab 3	Thermal Control Coating Exp.	4/73	Skylab 1/2
Growth of Spherical Crystals	7/73	Skylab 3	Planetary Atmosphere Exps. Test	6/71	Scout
Immiscible Alloy Compounds	7/73	Skylab 3	Orbiting Frog Ortolith Experiment	11/70	Scout
Indium Antimonide Crystal Exp	7/73	Skylab 3	Space Electric Rocket Test	2/70	Thorad-Agena
Metal Halide Eutectics Exp.	7/73	Skylab 3	Horizon Definition Research Project	8/66	Scout
Mixed III-V Crystal Growth	7/73	Skylab 3	Pegasus	2/65	Saturn I
Microsegregation in Germanium	7/73	Skylab 3	Flight Investigation Reentry Environment	4/64	Atlas-Antares
Radioactive Tracer Diffusion	7/73	Skylab 3	Scout Reentry Heating Project	3/62	Scout
Silver Grids Melted in Space	7/73	Skylab 3	Radio Attenuation Measurement	8/61	Hybrid RAM

## SPACE EXPERIMENTS PROGRAM

**OAST**

**SCOPE**

- **IN-SPACE EXPERIMENTS ARE AN INTEGRAL PART OF OAST'S PROGRAM**

- TO OBTAIN DATA THAT CAN NOT BE ACQUIRED ON THE GROUND
- TO VALIDATE/DEMONSTRATE CERTAIN ADVANCED TECHNOLOGIES

FEASIBILITY/PROOF OF CONCEPT

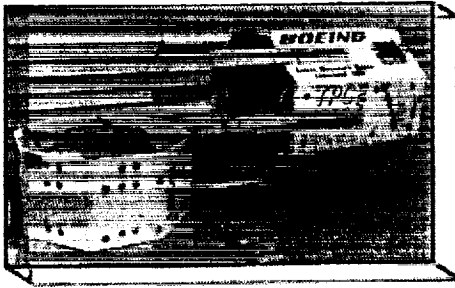
SENSOR/COMPONENT QUALIFICATION

- **FLIGHT EXPERIMENTS SUPPORT BOTH THE R&T BASE AND THE FOCUSED PROGRAMS**

**CONDUCTING TECHNOLOGY EXPERIMENTS IN SPACE IS A VALUABLE AND COST EFFECTIVE WAY TO INTRODUCE ADVANCED TECHNOLOGIES INTO FLIGHT PROGRAMS**

# IN-SPACE TECHNOLOGY EXPERIMENTS

## Tank Pressure Control



## MODE



	Inflatable Antenna Liquid Motion	95
OAST-Flyer	Return Flux Experiment	
OAST-3	Two Phase Flow Sodium Sulfur Battery Vented Tank Resupply Jitter Suppression	94
	Middeck Active Control Experiment Permeable Membrane Electrolysis	
OAST-2	Solar Array Module Plasma Interaction Thermal Energy Storage Emulsion Chamber Technology Cryo System Environmental Investigation of Spacecraft Glow	93
	Middeck 0-G Dynamics/Reflight	
	Environmental Verification Experiment on the Explorer Platform	92
	Heat Pipe Performance	
	Tank Pressure Control / Thermal Phenomena	91
	Tank Pressure Control Middeck 0-G Dynamics	

92-1124

OAST

IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

## MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE) MASSACHUSETTS INSTITUTE OF TECHNOLOGY / LaRC

### OBJECTIVE:

- TO MEASURE MECHANICAL DYNAMICS OF A JOINTED TRUSS STRUCTURE AND THE SLOSH DYNAMICS OF FLUIDS IN LOW GRAVITY

### ACCOMPLISHMENTS:

- COMPLETED STRUCTURAL AND FLUID DYNAMICS TEST OBTAINING 300 MILLION DATA POINTS
  - FOUND NEW MODAL RESONANCES THAT HAD NOT BEEN PREDICTED FROM MODELS DERIVED FROM GROUND BASED DATA
  - FOUND GREATER VISCOSITY EFFECTS THAN MODELS PREDICTED

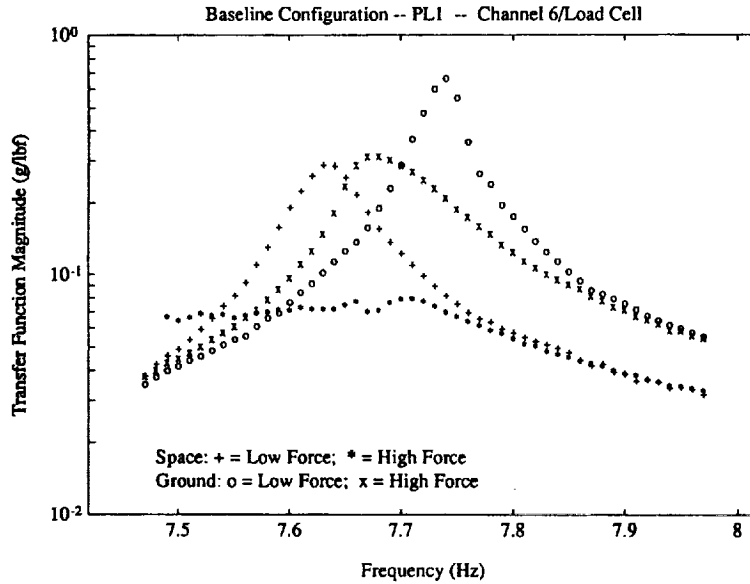
### BENEFITS:

- ADVANCES DESIGN CAPABILITIES FOR:
  - PRECISION CONTROLLED LARGE SPACE STRUCTURES
  - LARGE FLUID MASS FRACTION SPACECRAFT



FIRST FLIGHT STS-48 (MIDDECK)  
SEPTEMBER 1991  
TOTAL COST: \$2.1M  
TOTAL WEIGHT: 135 LBS.

# GROUND VS. FLIGHT RESULTS FOR STA TORSION MODE



Space Engineering Research Center

## TANK PRESSURE CONTROL EXPERIMENT (TPCE) BOEING AEROSPACE CO. AND LeRC

### OBJECTIVES

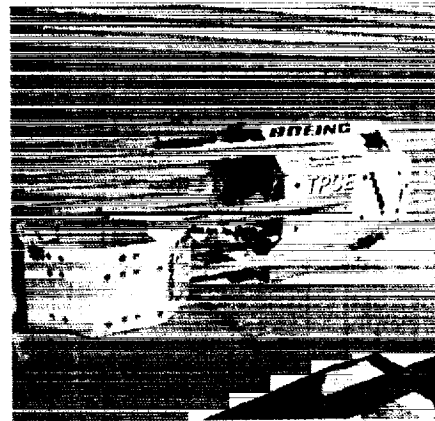
- INVESTIGATE JET MIXING AS A MEANS OF PRESSURE CONTROL OF CRYOGENIC FLUIDS

### ACCOMPLISHMENTS:

- VERIFIED THAT JET-INDUCED FLUID MIXING TECHNOLOGY IS AN EFFECTIVE PRESSURE CONTROL TECHNIQUE FOR CRYOGENIC TANKS IN LOW GRAVITY
- OBTAINED EXCELLENT VIDEO DATA ON THE FLUID DYNAMICS OF JET MIXING FOR COMPARISON WITH DROP TOWER RESULTS AND NUMERICAL PREDICTIONS
- OBTAINED EXTENSIVE LOW-GRAVITY TEMPERATURE/PRESSURE DATA FOR DETERMINATION OF FLUID MIXING TIMES

### BENEFITS:

- CONTINUOUS OR PERIODIC MIXING
  - MAKES FLUID STATE MORE PREDICTABLE
  - REDUCES POTENTIAL FOR SUDDEN PRESSURE CHANGES (WEIGHT & SAFETY IMPACT)
- DATA BASE INCREASES CONFIDENCE IN SIZING MIXERS FOR CRYOGENIC APPLICATIONS

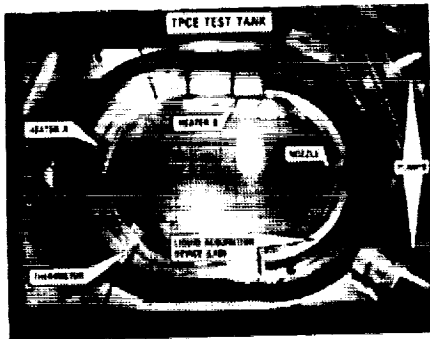


FIRST IN-STEP EXPERIMENT  
FLOWN IN A G.A.S. CANISTER ON STS. 43  
AUGUST, 1991  
TOTAL COST: \$1.7M  
TOTAL WEIGHT: 186 LB

## TANK PRESSURE CONTROL EXPERIMENT (TPCE) STS-43 AUGUST 1991

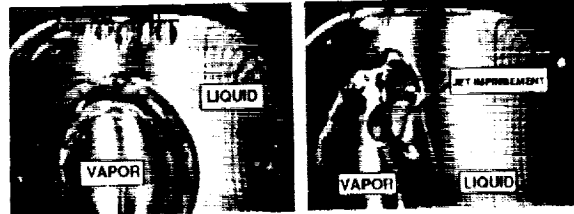
### DESCRIPTION

- LOW-G FLUID MIXING EXPERIMENT ON STS
- FREON IN A PLEXIGLASS TANK IS THERMALLY STRATIFIED BY HEATERS CAUSING THE PRESSURE TO RISE
- THEN MIXED BY AN AXIAL JET MIXER TO EQUILIBRATE
- TEMPERATURE, PRESSURE, AND VIDEO DATA



### RESULTS

38 TEST RUNS WITH 4 HOURS OF EXCELLENT VIDEO



LOW G HEATING

LOW-FLOW JET MIXING

### PRELIMINARY CONCLUSIONS

- FLOW PATTERN WITH CLOSED GEYSER, SHOWN ABOVE, PROVIDES EFFECTIVE PRESSURE CONTROL AND IS MOST EFFICIENT
- THERMAL EQUILIBRATION TIMES AND PRESSURE REDUCTION TIMES IN GENERAL AGREEMENT WITH CERTAIN MODELS
- LOW ENERGY JETS PROVIDE EFFECTIVE AND EFFICIENT PRESSURE CONTROL

OAST

IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

## ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

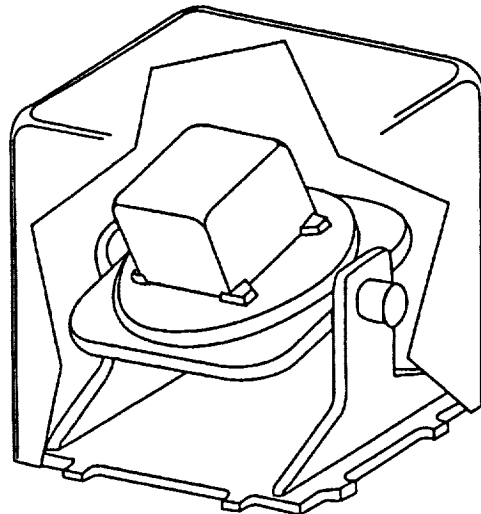
LANGLEY RESEARCH CENTER

### OBJECTIVE:

- ACCURATE MEASUREMENT OF AERODYNAMIC ACCELERATION ALONG THE ORBITER'S PRINCIPAL AXES IN THE FREE MOLECULAR FLOW REGIME AND THROUGH THE TRANSITIONAL FLOW REGIME DURING REENTRY

### APPROACH:

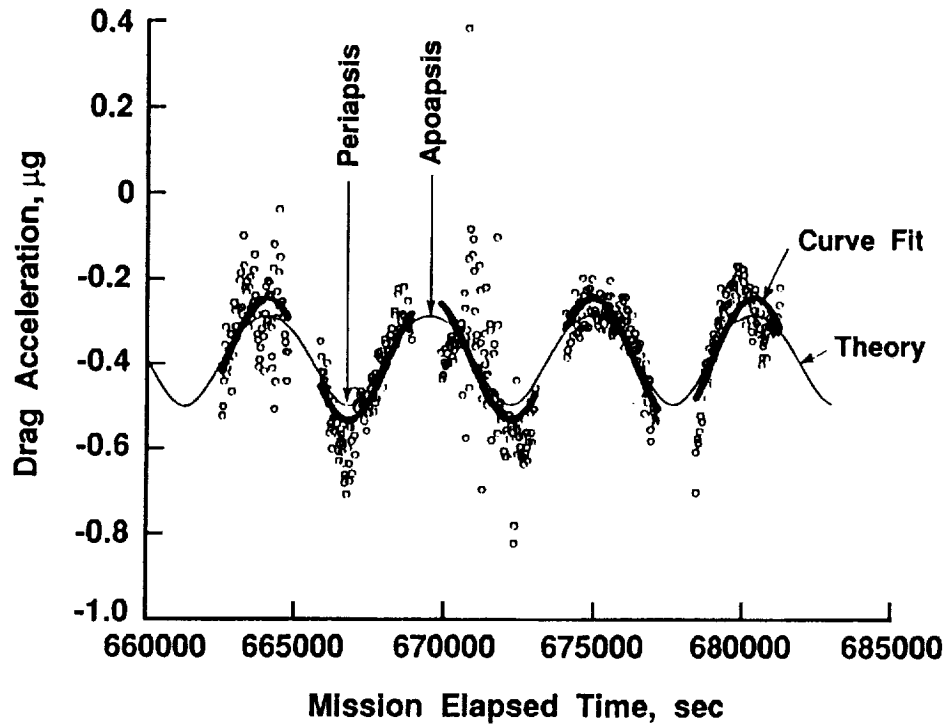
- MEASURES LINEAR ACCELERATIONS (10-9g) IN THE PRESENCE OF ORBITER STRUCTURAL VIBRATION NOISE
- UTILIZES THREE AXIS ELECTROSTATIC ACCELEROMETERS WITH ON-ORBIT CALIBRATION CAPABILITY
- INSTALLED ON THE KEEL BRIDGE FITTING IN THE PAYLOAD BAY
- OPERATIONAL ON OV-102 FLIGHTS 6/92 (STS-50), 6/93 (STS-58)



### APPLICATION:

- DETERMINATION OF ORBITAL DRAG WHICH PROVIDES DESIGN SPECIFICATIONS FOR ORBIT MANAGEMENT AND MAINTENANCE SYSTEM FOR THE SSF
- PROVIDES AERODYNAMIC DESIGN DATA FOR ADVANCED AEROMANEUVERING SPACE TRANSFER VEHICLES
- EXPAND KNOWLEDGE OF MICROGRAVITY ENVIRONMENT NEEDED FOR THE CONDUCT OF MICROGRAVITY EXPERIMENTS

## OARE SENSES PERIODIC ORBITAL DRAG VARIATION



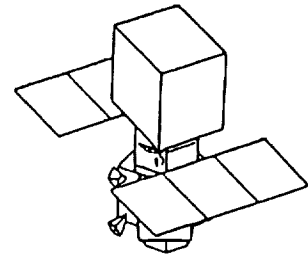
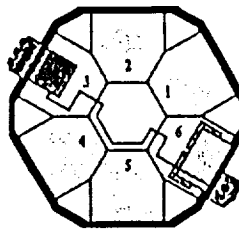
## ENVIRONMENTAL VERIFICATION EXPERIMENT FOR THE EXPLORER PLATFORM (EVEEP) GODDARD SPACE FLIGHT CENTER

### OBJECTIVE:

- VERIFY ACCURACY OF CONTAMINATION MODELING PROGRAMS

### APPROACH:

- FLY TQCM'S ON SPACECRAFT FOR WHICH DETAILED CONTAMINATION MODELS EXIST (EUVE/EXPLORER PLATFORM)
- FLY BOTH TEFLON-COATED AND UNCOATED TQCM'S IN SUN AND SHADE ORIENTATIONS
- FLIGHT DATE: 6/92 DELTA II (EXPLORER PLATFORM)



### APPLICATION:

- FLIGHT RESULTS WILL BE USED TO IMPROVE UNDERSTANDING OF SYNERGISTIC EFFECTS OF UV RADIATION AND ATOMIC OXYGEN ON MATERIALS (TEFLON) AND THE UNDERSTANDING OF VOLATILE MATERIAL DEPLETION MECHANISMS

## LDEF IN ORBIT



### MAJOR RESULTS OF LDEF FLIGHT EXPERIMENTS

- Meteoroid and debris impacts are not random but affected by meteor showers and space operations
- LDEF data being used to upgrade Meteoroid Model SP-8013 for distribution, velocity, directionality, and surface degradation
- LDEF ionizing radiation studies show induced radioactivity not a significant hazard for Space Station Freedom
- LDEF ionizing radiation data being used to establish crew shielding requirements for Space Station Freedom
- No LDEF systems-level failures attributed to natural LEO environment
- LDEF data established long-term degradation rates for polymeric materials, coatings, composites, and reactive metals in the LEO environment
- LDEF verified that some coatings and materials are resistant to atomic oxygen and UV in the LEO environment



# SPACE EXPERIMENTS PROGRAM

**OAST**

OFFICE OF AERONAUTICS  
AND SPACE TECHNOLOGY

## SSF PLANNING

- **PURPOSE**
  - TO ENSURE THAT ADEQUATE SSF RESOURCES WILL BE AVAILABLE FOR OAST USE
- **APPROACH**
  - DEVELOP TRAFFIC MODEL BASED ON PROJECTED USE
  - DEVELOP REQUIREMENTS FOR DESIGN AND DEVELOPMENT
  - SUPPORT SSF UTILIZATION ACTIVITIES AS REQUIRED
  - SUPPORT BY LaRC, SPACE STATION FREEDOM OFFICE
- **STATUS**
  - OAST HAS BEEN ALLOCATED 12% OF THE U.S. SHARE OF ALLOCATABLE RESOURCES ON SSF
  - COMPLETED FIRST ANNUAL INPUT TO THE SSF "PARTNER UTILIZATION PLAN" BASED ON TRAFFIC MODEL
- **MAJOR NEAR TERM ACTIVITY**
  - USE RESULTS OF NEXT A.O. TO PREPARE NEXT YEAR'S INPUT TO "PARTNER UTILIZATION PLAN"

~~OAST~~

~~IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM~~

## MODAL IDENTIFICATION EXPERIMENT LANGLEY RESEARCH CENTER

### OBJECTIVE:

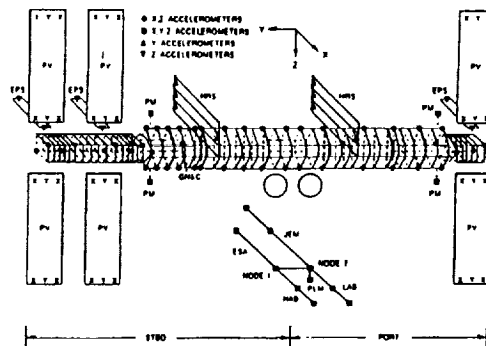
- CHARACTERIZE THE STRUCTURAL DYNAMICS OF SPACE STATION FREEDOM AND REFINE MODELING TECHNIQUES FOR FUTURE LARGE SPACE STRUCTURES

### APPROACH:

- UTILIZING SPACE STATION FREEDOM HARDWARE TO THE LARGEST EXTENT POSSIBLE WITH THE ADDITION OF OAST SUPPLIED INSTRUMENTATION TO FIT RESEARCH NEEDS, MEASURE SYSTEM MODES IN RESPONSE TO EXCITATION

### APPLICATION:

- ON-ORBIT VERIFICATION OF FUTURE LARGE, FLEXIBLE SPACE STRUCTURES FOR SCIENCE AND EXPLORATION



# OAST ANNOUNCEMENT OF OPPORTUNITY

## SPACE EXPERIMENTS PROGRAM

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- **PURPOSE**
  - TO SOLICIT PROPOSALS FOR EXPERIMENTS IN THE TECHNOLOGY CATEGORIES**
  - SPACE MATERIALS, COATINGS, AND ENVIRONMENTAL EFFECTS
  - CRYOGENIC FLUID HANDLING
  - HUMAN SUPPORT
  - SPACE POWER
  - IN-SPACE CONSTRUCTION, REPAIR, AND MAINTENANCE
  - SCIENCE SENSORS AND SENSOR COOLING
  - VIBRATION ISOLATION
  - SPACE COMMUNICATION
  
- **APPROACH**
  - APPROXIMATELY FIFTY PROPOSALS SELECTED BY RIGOROUS REVIEW PROCESS FOR PHASE A
  - DOWN-SELECTION TO PHASE B, LEADING TO NON-ADVOCATE REVIEW
  - NEW EXPERIMENTS READY FOR FLIGHT STARTING 1997
  - ANY SUITABLE CARRIER UTILIZED, INCLUDING SSF, SHUTTLE, ELV
  
- **STATUS**
  - EXPECTED RELEASE IN AUGUST

**OSSA SPACE STATION FREEDOM SCIENCE  
UTILIZATION PLANS**

Presented by Dr. Philip J. Cressy  
Office of Space Science and Applications  
NASA Headquarters

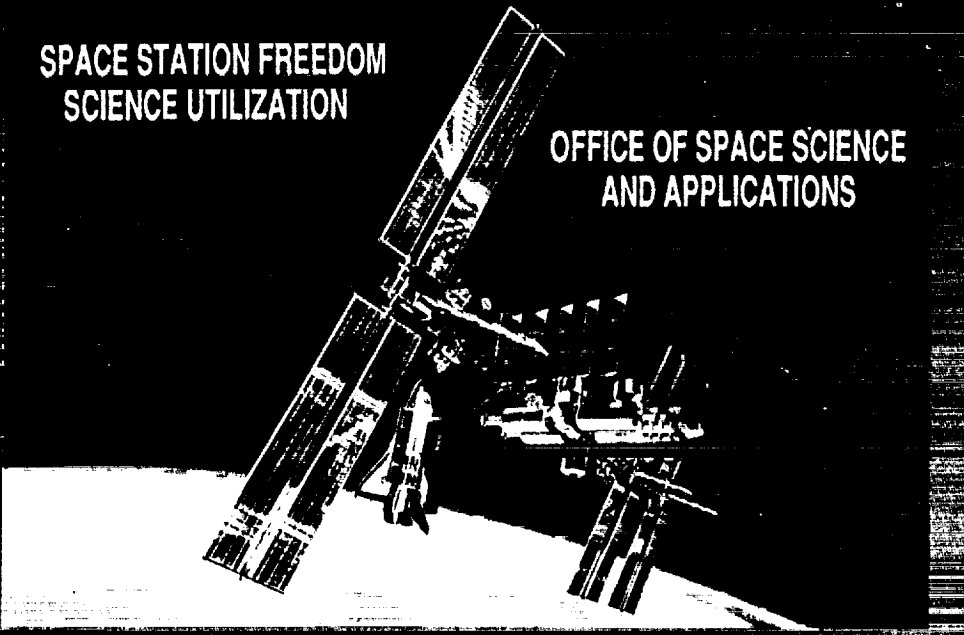
**ABSTRACT**

Long duration exposure to an essentially zero-gravity environment is a phenomenon exclusive to the Space Station Freedom that cannot be duplicated on Earth. The Freedom Station will offer periods of time on orbit extending to weeks and months rather than hours or days, allowing for in-depth space-based research and analysis to a degree never before achieved. OSSA remains committed to exploiting the unique capabilities provided by the Space Station as well as other space-based facilities to study the nature of physical, chemical, and biological processes in a low-gravity environment and to apply these studies to advance science and applications in such fields as biomedical research, plant and animal physiology, exobiology, biotechnology, materials science, fluid physics, and combustion science. The OSSA focus is on progressive science investigations, many requiring hands-on scientist involvement using sophisticated experiment hardware. OSSA science utilization planning for the Freedom Station is firmly established. For this presentation, this planning is discussed in three general areas: OSSA goals and overall approach, the current and on-going program, and plans for space station utilization. In the first area, OSSA addresses its overall approach to space science research, its commitment to transition to Space Station Freedom, and its top-level strategy for the utilization of Freedom. The current and on-going program is next discussed, focusing on the various Spacelab series of missions which are providing the stepping-stones to Space Station Freedom. Selected science results from SLS-1 and USML-1 are cited which underline the value of properly outfitted laboratories in space in which crew-intensive experiment interactions are possible. The presentation is concluded with a discussion of top-level goals and strategies for utilizing the Freedom Station by OSSA's Life Sciences Division and its Microgravity Science and Applications Division.



**SPACE STATION FREEDOM  
SCIENCE UTILIZATION**

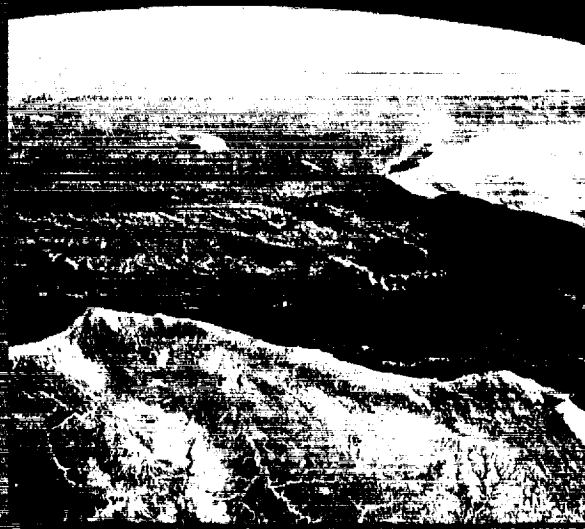
**OFFICE OF SPACE SCIENCE  
AND APPLICATIONS**



91 1-4484 01

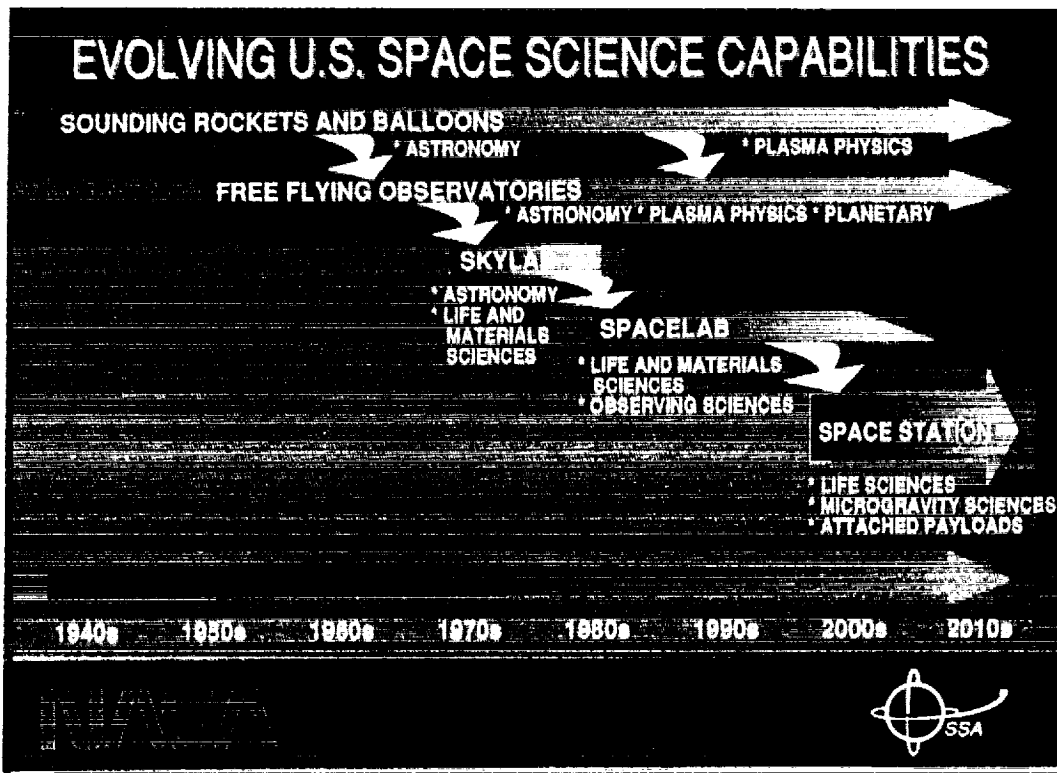
**OFFICE OF SPACE SCIENCE AND APPLICATIONS GOALS**

- TO ADVANCE SCIENTIFIC KNOWLEDGE OF THE PLANET EARTH, THE SOLAR SYSTEM AND THE UNIVERSE
- TO USE THE UNIQUE VANTAGE POINT AND ENVIRONMENT OF SPACE TO STUDY THE UNIVERSE, TO UNDERSTAND THE FACTORS THAT INFLUENCE OUR PLANET'S ENVIRONMENT, AND TO SOLVE PRACTICAL PROBLEMS ON EARTH
- TO EXPAND THE HUMAN PRESENCE BEYOND THE EARTH INTO THE SOLAR SYSTEM




91 1-565202 SSA

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91 1-4464 02

## TRANSITION TO SPACE STATION



BEGINNING WITH SPACELAB AND OTHER IN-SPACE FACILITIES, WE ARE MOVING AGGRESSIVELY, BUT SENSIBLY, TO DEVELOP THE PRINCIPAL AREAS OF SPACE SCIENCE AND APPLICATIONS THAT WILL TAKE ADVANTAGE OF UNIQUE FREEDOM STATION OPPORTUNITIES, FOR MICROGRAVITY SCIENCE AND LIFE SCIENCES RESEARCH IN PRESSURIZED LABORATORIES

OSSA STRATEGIC PLAN 1991

SSA

## OSSA STRATEGY

- PLAN UTILIZATION TO SUPPORT PREPARATION FOR HUMAN EXPLORATION
- EMPHASIZE PRESSURIZED VOLUME UTILIZATION
  - Life Sciences
  - Microgravity Science and Applications
- TRANSITION SENSIBLY FROM SPACELAB TO SPACE STATION
- ENSURE A RANGE OF UTILIZATION OPTIONS
  - Facility-Class Payloads
  - Middeck and Drawer-Class Payloads
  - Small and Rapid Response Payloads
  - Attached (Observational) Payloads
- SOLICIT FIRST-CLASS SCIENCE
  - Planned AOs and NRAs
  - International Collaborations
- INTEGRATE THE INTERESTS OF THE U.S. SCIENCE COMMUNITY



92 1-5003-02

## THE CURRENT PROGRAM

OSSA IS LAYING THE FOUNDATION FOR SPACE STATION FREEDOM WITH ITS SPACELAB SERIES OF MISSIONS

SLS - Spacelab Life Sciences missions dedicated to human, animal, plant, and cell research

USML - US Microgravity Laboratory missions dedicated to materials, fluids, and combustion research

IML - International Microgravity Laboratory missions which emphasize international cooperation in microgravity research



92 1-5003-03

# SOME RECENT SCIENCE RESULTS

## SLS-1

- RAPID TRANSITION IN MUSCLE ACTIVITY AWAY FROM MUSCLES THAT CONTROL WALKING AND POSTURE
- SHIFTS IN MUSCLE NUTRIENT USAGE TO MORE CARBOHYDRATES AND LESS FAT
- IMPAIRMENT OF BLOOD PRESSURE REGULATORY MECHANISMS
- UNEXPLAINED RETENTION OF 1-g LUNG CHARACTERISTICS IN 0-g
- UNEXPECTED INCREASED BLOOD FLOW TO THE KIDNEYS

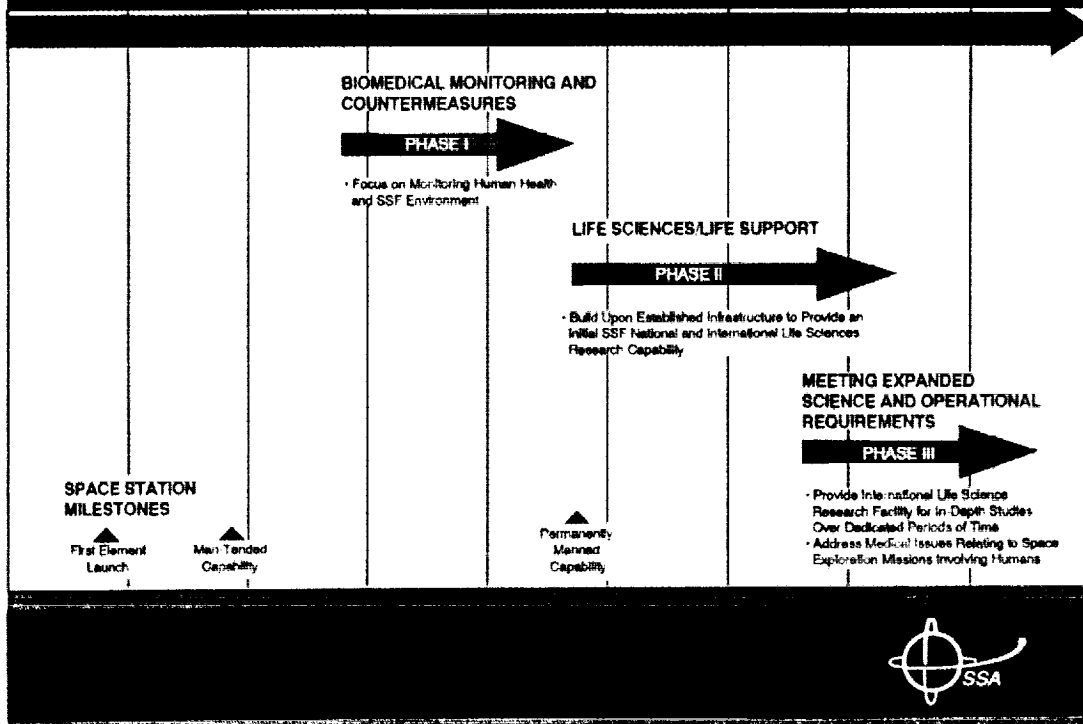
## USML-1

- SEVERAL INORGANIC CRYSTALS APPEAR TO BE LARGEST AND HIGHEST QUALITY GROWN TO DATE
- OVER 700 CREW MANIPULATIONS OF PROTEIN CRYSTAL SAMPLES INCREASED QUALITY AND YIELD
- MANY CRYSTALS WERE OBSERVED TO BEGIN GROWING ONLY LATE IN THE FLIGHT
- MANY UNPLANNED/UNEXPECTED RESULTS WERE OBTAINED



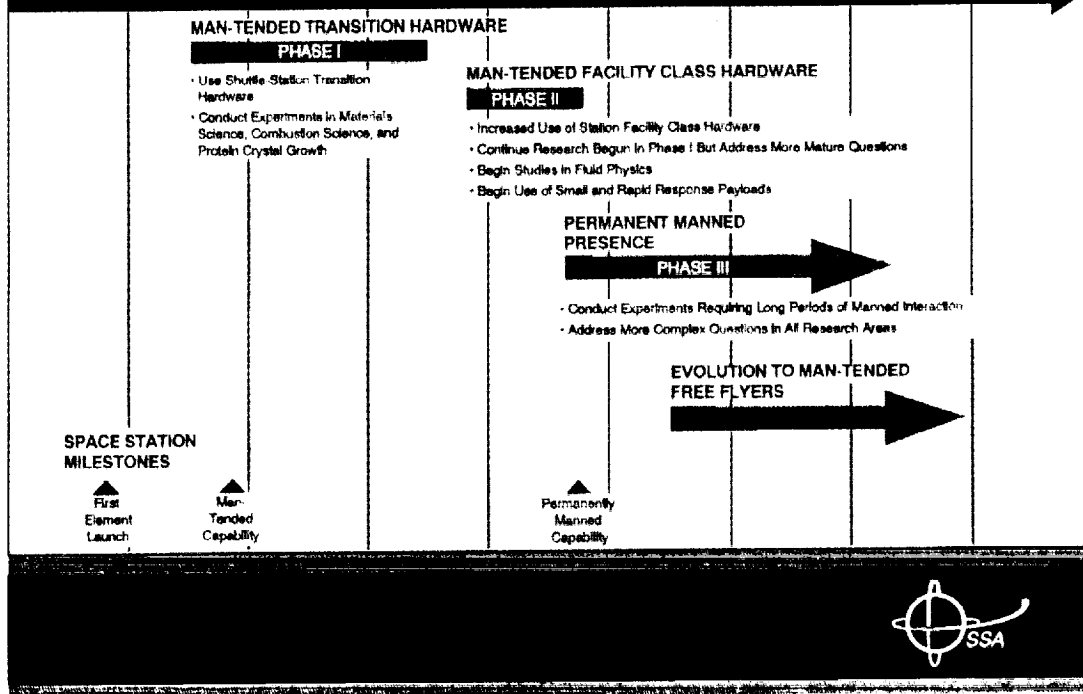
92 1-5003-07

# LIFE SCIENCES STRATEGY





# MICROGRAVITY SCIENCE AND APPLICATIONS STRATEGY



92 1-5003-04



**COMMERCIAL RESEARCHER PERSPECTIVE**

Presented by Dr. Larry DeLucas  
Center for Macromolecular Crystallography  
University of Alabama at Birmingham

**ABSTRACT**

Protein crystallography — a research tool used to study the structure of the complex building blocks of living systems — has a lot to gain from space-based research. In order to know how a protein works in the human body, researchers must understand its molecular structure. Researchers have identified 150,000 different proteins in the body, but they now know the structure of less than a third of them.

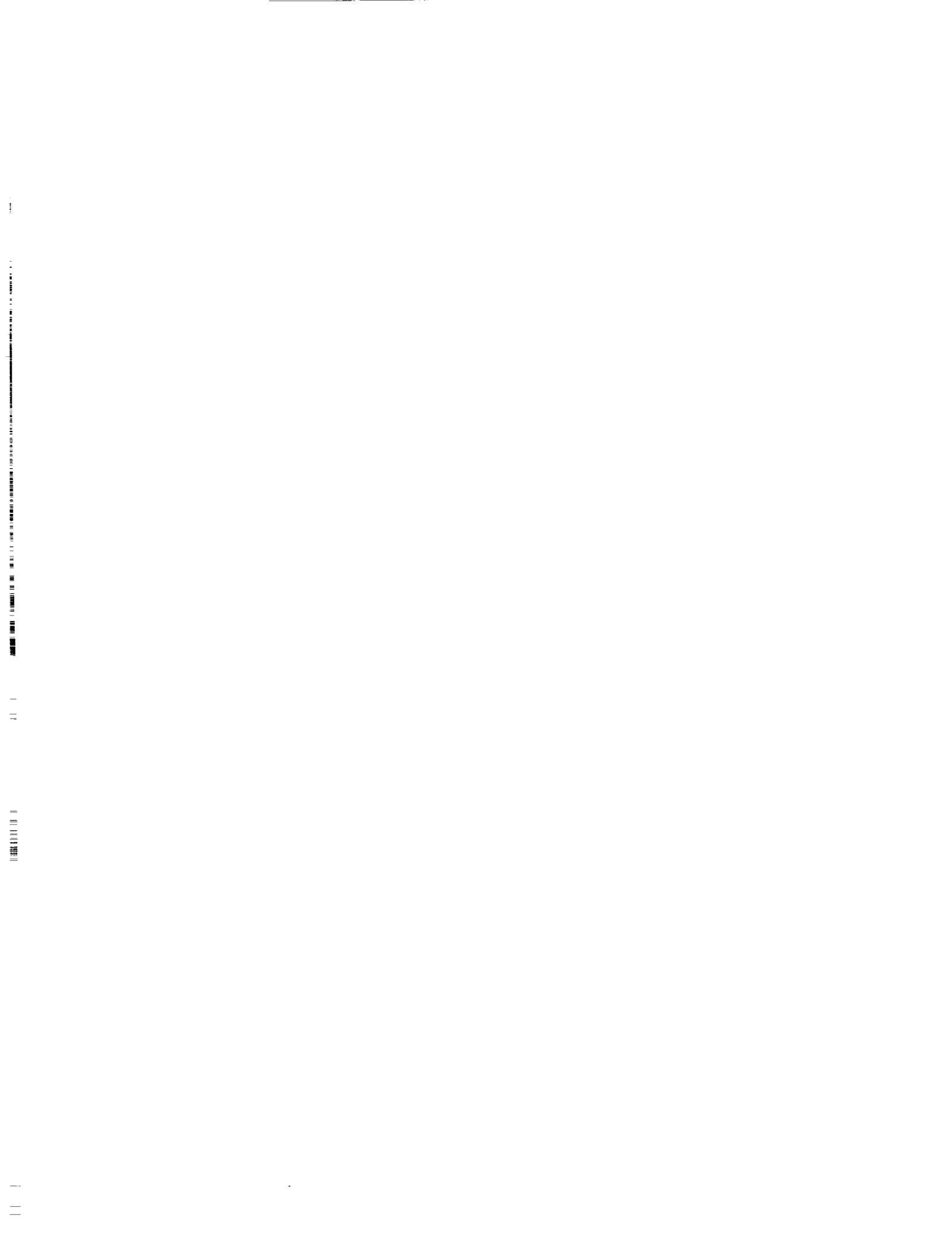
The only viable technique for analyzing the structure of these proteins is x-ray diffraction of the proteins in their crystal form. The better the quality of a protein crystal, the more useful it is to researchers who are trying to delineate its structure. The microgravity environment of space allows protein crystals to grow nearly undisturbed by convection and other gravity-driven forces that cause flaws to form in them on the ground. In space, lack of convection enables protein crystals to grow more slowly than they do on Earth, and the slower a protein crystal grows, the fewer flaws it will have.

Protein crystal growth experiments have already flown on 14 Space Shuttle missions. This year's USML-1 Spacelab mission included protein crystal growth experiments conducted for commercial researchers. The results of protein crystal experiments flown thus far have been larger crystals with more uniform morphologies.

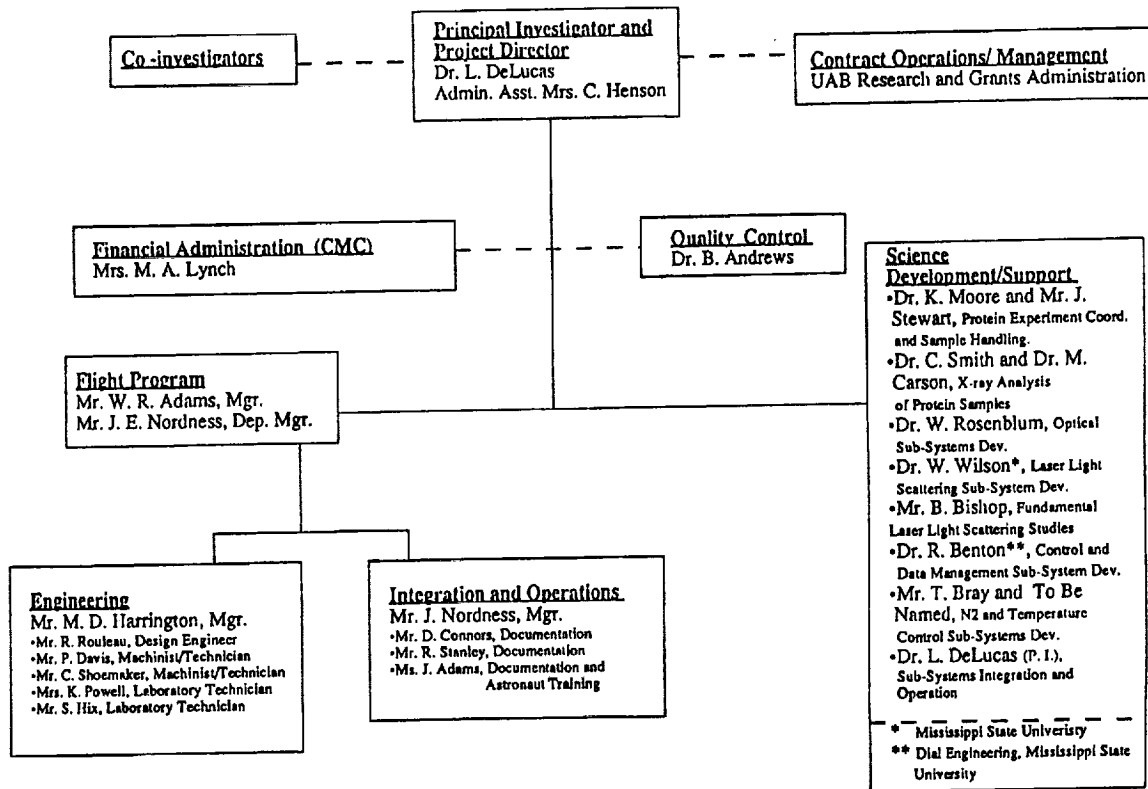
The Center for Macromolecular Crystallography (A NASA-cosponsored CCDS) currently builds flight hardware to meet researchers' needs and handles sample loading and retrieval for flight experiments.

Protein crystallography enables "rational drug design": the development of drugs that bind only with the target protein and, hence, do not cause side effects. For example, pharmaceutical companies presently are interested in developing drugs that can inhibit purine nucleoside phosphorylase (PNP), a protein that plays a role in auto-immune diseases. To continue these kinds of investigations, researchers need a constant supply of protein crystals that are as free of flaws as possible.

Space Station Freedom will provide the kind of research environment that will enable the production of such supplies. In addition, Freedom will provide the kind of long-duration facility required by protein crystal researchers: 40 percent of proteins require more than two weeks to crystallize.



Project Organization  
for  
**Protein Crystal Growth In Microgravity**  
University of Alabama at Birmingham / Center for Macromolecular Crystallography



**Need for Microgravity Environment**

- 450 protein structures completed
- Molecular biology
- Rational drug design
- Large co-investigator group from universities and industries
- No other technique

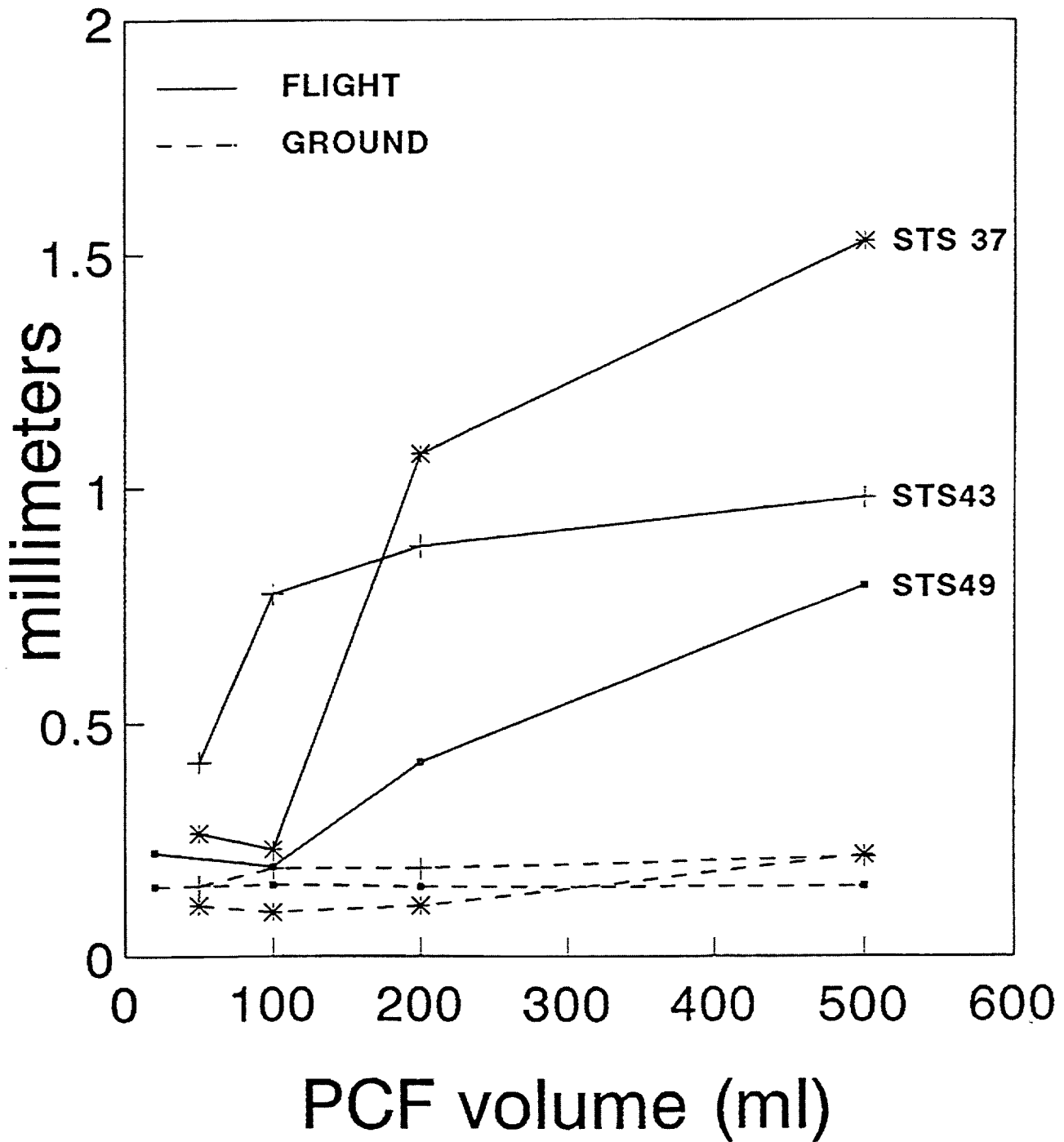
**Morphometry**  
Number of Crystals Sampled, PCF  
STS 37, 43, 49

SHUTTLE FLIGHT	GROUND SINGLE	GROUND ROSETTE	FLIGHT SINGLE	FLIGHT ROSETTE
STS 37	700	600	405	550
STS 43	458	na	1155	na
STS 49	1220	1232	328	530
TOTAL	7178			

# Morphometry

## Length of Single Crystals

### STS 37, 43, 49

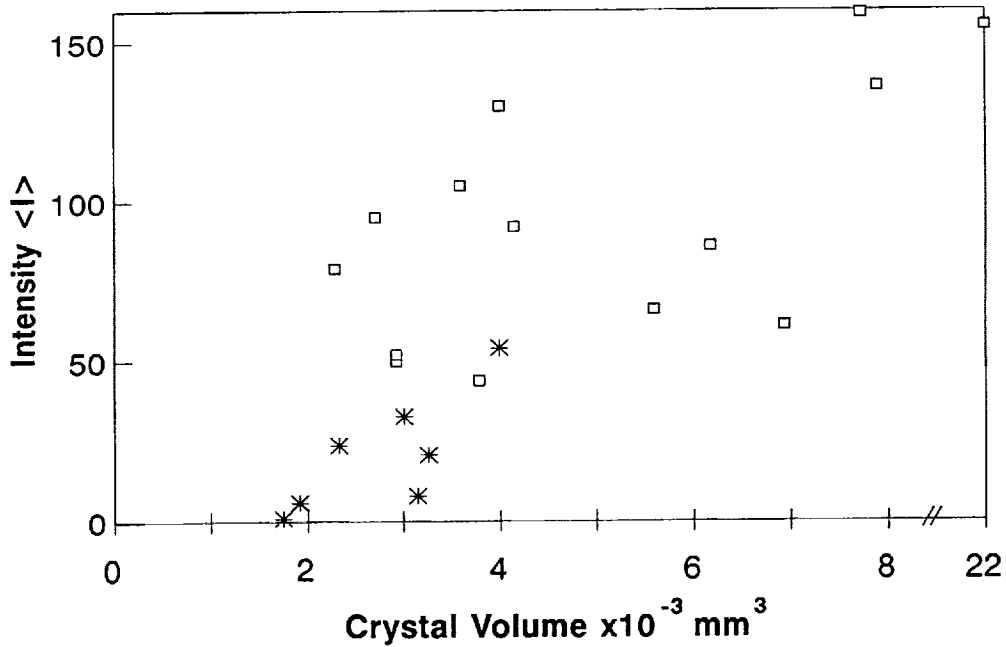


# X-Ray Diffraction

Intensity as Function of Crystal Volume

STS-49: 500ml PCF

\* GROUND □ FLIGHT



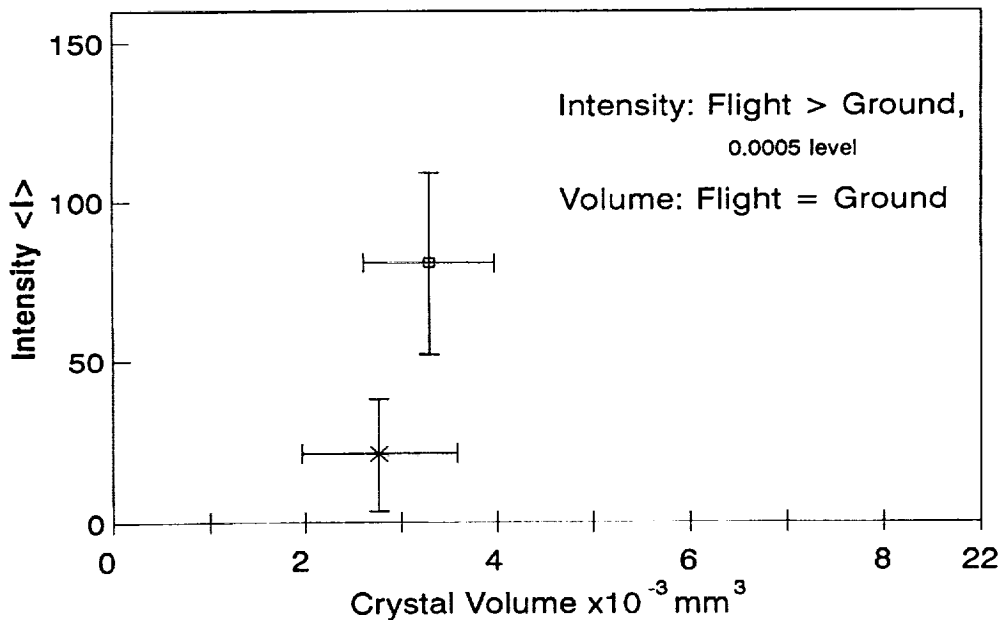
# X-Ray Diffraction

Intensity as Function of Crystal Volume

STS-49: 500ml PCF

Means for 8 Flight and 7 Ground Crystals

\* GROUND □ FLIGHT





# X-Ray Diffraction

Number of Crystals Sampled, PCF  
STS 37, 43, 49

SHUTTLE FLIGHT	GROUND	FLIGHT
STS 37	7	5
STS 43	10	10
STS 49	9	12
TOTAL	53	

### Easy Access

- We build hardware to meet science group's needs
- We handle loading and sample retrieval
- Sample approval process is rapid and can be accomplished late in flow

### Constant Access/Rapid Turnaround

- Need laboratory around the clock
- Need constant supply of crystals
- Crystals must be harvested frequently
- New protein batches transferred via frequent and consistent shuttle schedule

### Dynamic and Flexible Hardware Program

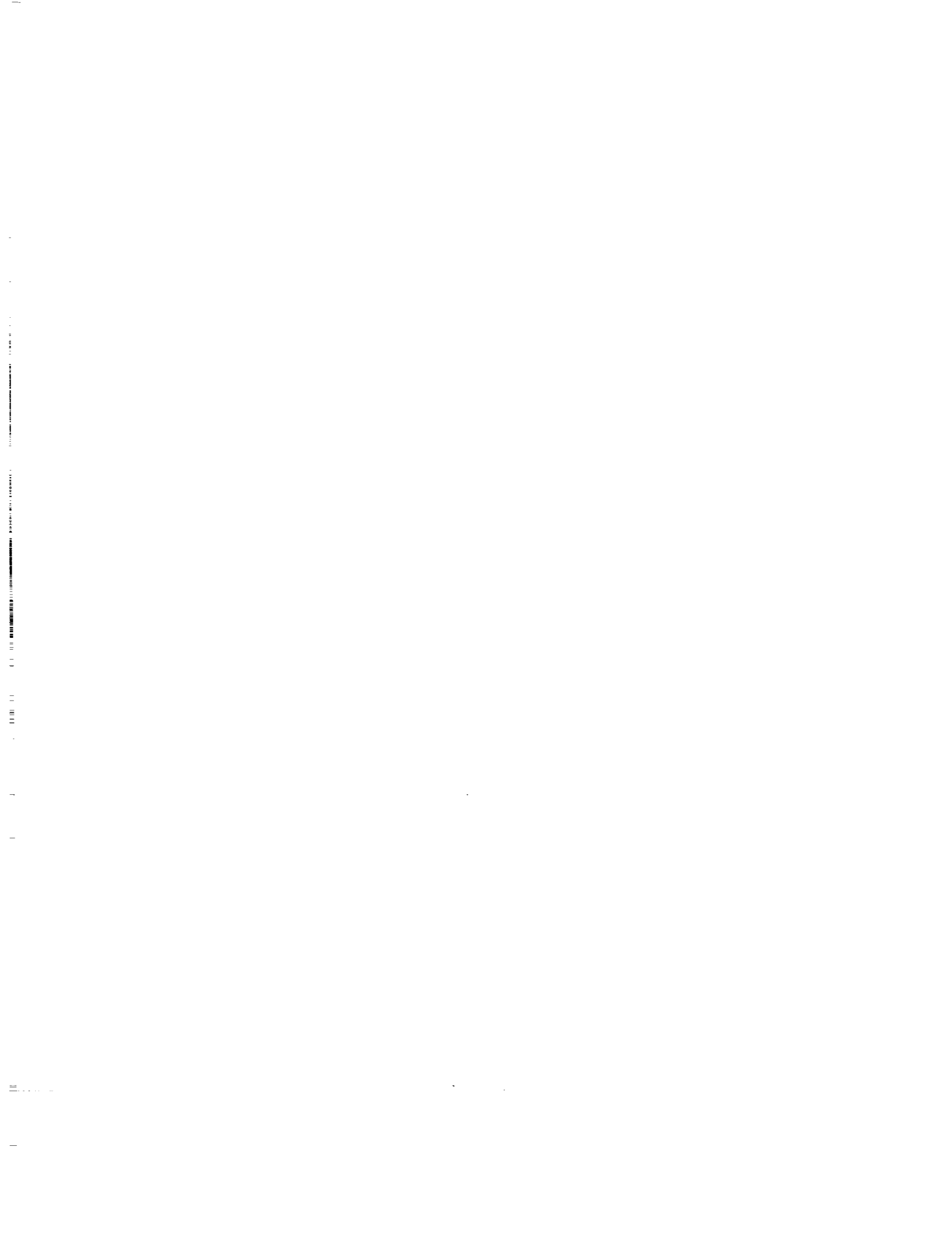
- Facility capable of rapidly meeting needs of each corporate partner
- Thermal Enclosure System (TES)
- Protein crystal growth organizational chart
- Hardware development
  - Science objectives
  - Design/analysis
  - Manufacturing
  - Qualification testing (for flight)
  - Functional testing (to meet science objectives)
  - Verification

### Consistency/Predictable Schedule

- Corporate/Academic Planning
- Reliability

### Real Time Monitoring and Control

- Scientists on board full time
- Observation/Crystal Optimization



**JAPANESE PLAN FOR SSF UTILIZATION**

Toshio Mizuno  
National Space Development Agency of Japan

**ABSTRACT**

The JEM program has made significant progress. The JEM PDR was completed in July 1992; construction of JEM operation facilities has begun; and the micro-G airplane, drop shaft, and micro-G experiment rocket are all operational. The national policy for JEM utilization was also established. The Space Experiment Laboratory (SEL) opened in June '92 and will function as a user support center. Eight JEM multiuser facilities are in phase B, and scientific requirements are being defined for 17 candidate multiuser facilities. The National Joint Research Program is about to start. Precursor missions and early Space Station utilization activities are being defined.



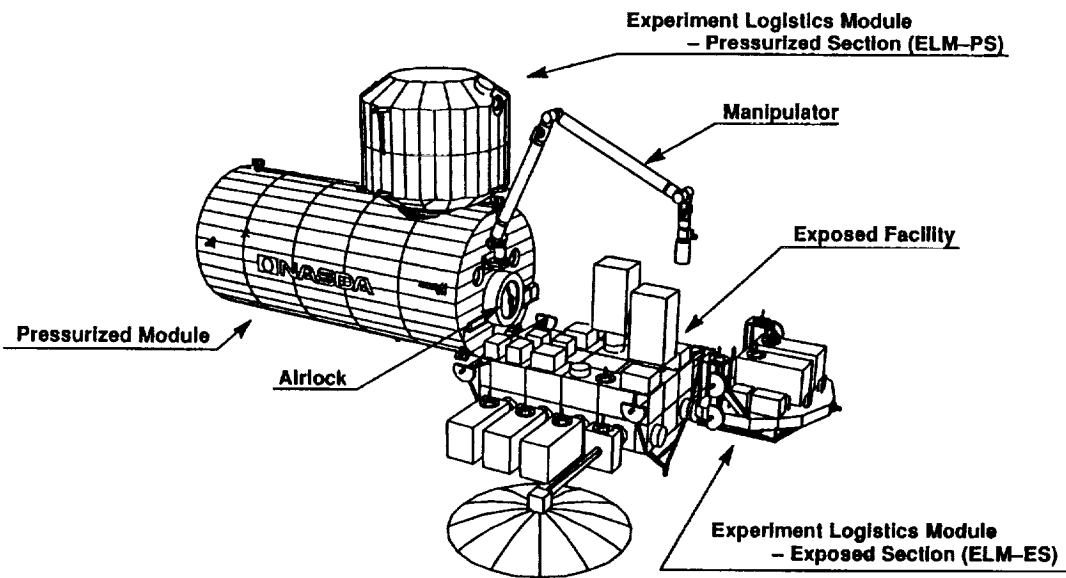


## Japanese Plan for SSF Utilization

T. Mizuno

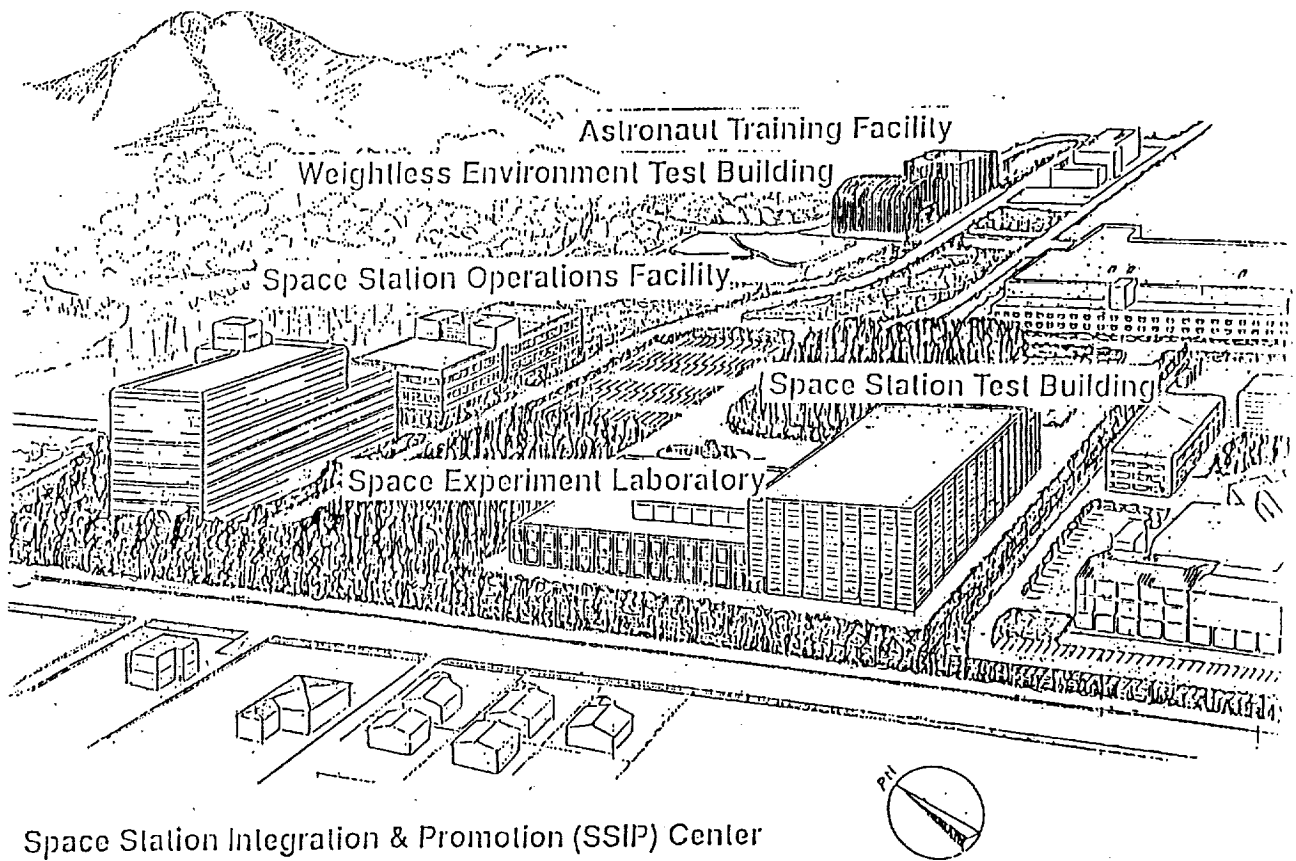
August 4, 1992

Huntsville Alabama



JEM Configuration





## CONTENTS

1. JEM Program Budget Status
2. JEM Utilization Policy Status
3. JEM Development Status
4. JEM Operations Capability Development Status
5. Status of Ground Research to Develop Generic Experiment Support Technology
6. Status of User Support Center Construction
7. Multiuser Facility Development Status
8. Organization National Joint Research Using Space Environments
9. Status of Precursor Mission and JEM Early Utilization Definition
10. Other Topics





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## 1. JEM Program Budget Status (JFY1992)

1.1. JEM Development	¥33.7B(~262M\$)*
(JEM EM, JEM multiuser experiment facility, TR-1A, etc.)	¥24.6B(~190M\$)
1.2. JEM Operations Preparation	¥4.2B(~32M\$)*
(JEM Operations facility, Crew training facility,etc)	¥3.0B(~23M\$)

@1Dollar=129yen

\* multiyear government guarantee for appropriation



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## 2. JEM Utilization Policy

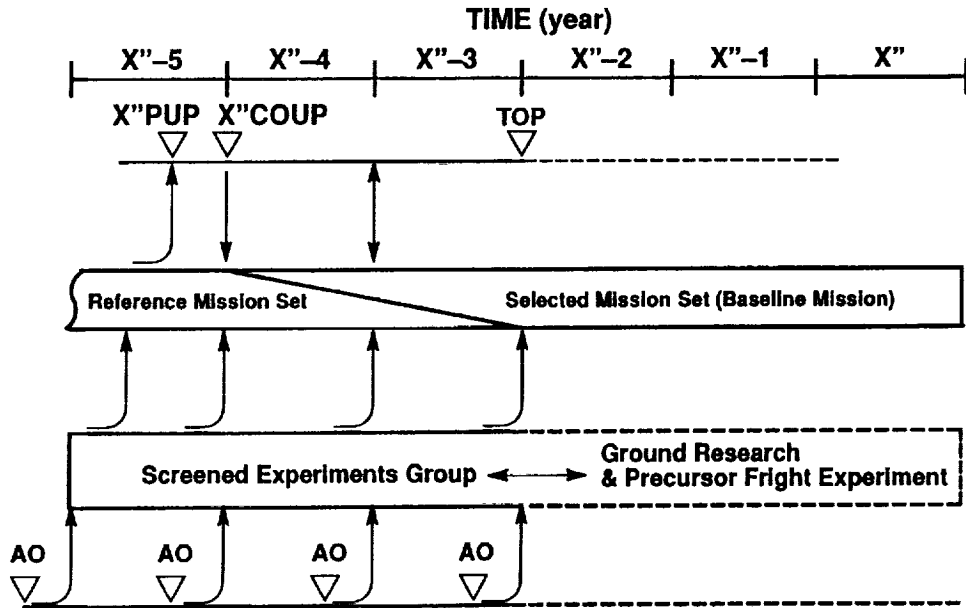
2.1. Report by SAC SS panel was issued in April 1992.

2.2. Report addresses the following:

- (1) Need of national research program for promoting JEM Utilization.
- (2) Importance of developing multiuser facilities  
Identification of facility list and development policy.
- (3) Cost sharing by users consistent with JEM and multiuser facility  
verification/operation phase.
- (4) Identification of AO issues and experiment selection timing and  
frequency.
- (5) Importance of precursor missions.



**AO, Experiment Selection, PUP/ COUP/ TOP**



**3. JEM Development Status**

**3.1. JEM PDR**

Contractor PDR                      January to March 1992

System PDR                              June to July 1992

**3.2. Technology Development Test**

JEM Maintenance and Repair simulation using MSFC WETF in Nov. 1991

**3.3. Engineering Model (EM) and Proto-Flight Model (PFM)**

EM Contracts started in March 1991

PFM budget request is being prepared

**3.4. Construction of JEM Test Facility at TKSC**

Construction starts in summer 1992



## JEM Development Schedule

J. Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Month	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12	4 8 12
Milestone			NASA PDR ▽		JEM PDR ▽	NASA MTC CDR ▽	JEM CDR ▽	FEL △			JEM Launch #1 △ JEM Launch #2 △
Activity Phase	Phase B		Phase C/D								
JEM Development		Development Testing			EM Integration and Testing			PFM Integration and Testing			
JEM Operation System		System Design			Detailed Design & Development				Integration & Training		Operation
	PDR Preliminary Design Review			EM Engineering Model							
	CDR Critical Design Review (#1, Interface; #2, JEM)			PFM Proto Flight Model							

**NASDA**



### 4. JEM Operations Capability Development Status

#### 4.1. Design of JEM Operations System

PRR                      March 1991

System Review      Oct. 1993

#### 4.2. Crew Recruiting

- MS candidate was selected in April 1992
- SS/SO will be recruited every two years

#### 4.3. Construction of JEM Operations Facility

- Weightless Environment Test Facility construction started in March 1992
- Astronaut Training Facility Construction will start in summer 1993
- Construction of SS Operations Facility (Regional Operation Center for JEM) will start in summer 1993



#### **4.4. Development of JEM Operations Planning system**

- Strategic/Tactical planning software and database are being defined

#### **4.5. JFD (JEM Flight Demonstration)**

- JEM Manipulator servicing capability demonstration test will be held in 1996 using STS



#### **5. Status of Ground Research to Develop Generic Experiment Support Technology (GEST)**

##### **5.1. Drop Shaft/Drop Tube**

- JAMIC Facility (10 sec.  $\mu$ -G) has been operational since 1991
- MGLAB Facility (4.5 sec.  $\mu$ -G) will be operational in 1993

##### **5.2. GEST Development using $\mu$ -G Airplane (MU-300 Business Jet)**

- Routine 6 month/year parabolic flight since Sep. 1990

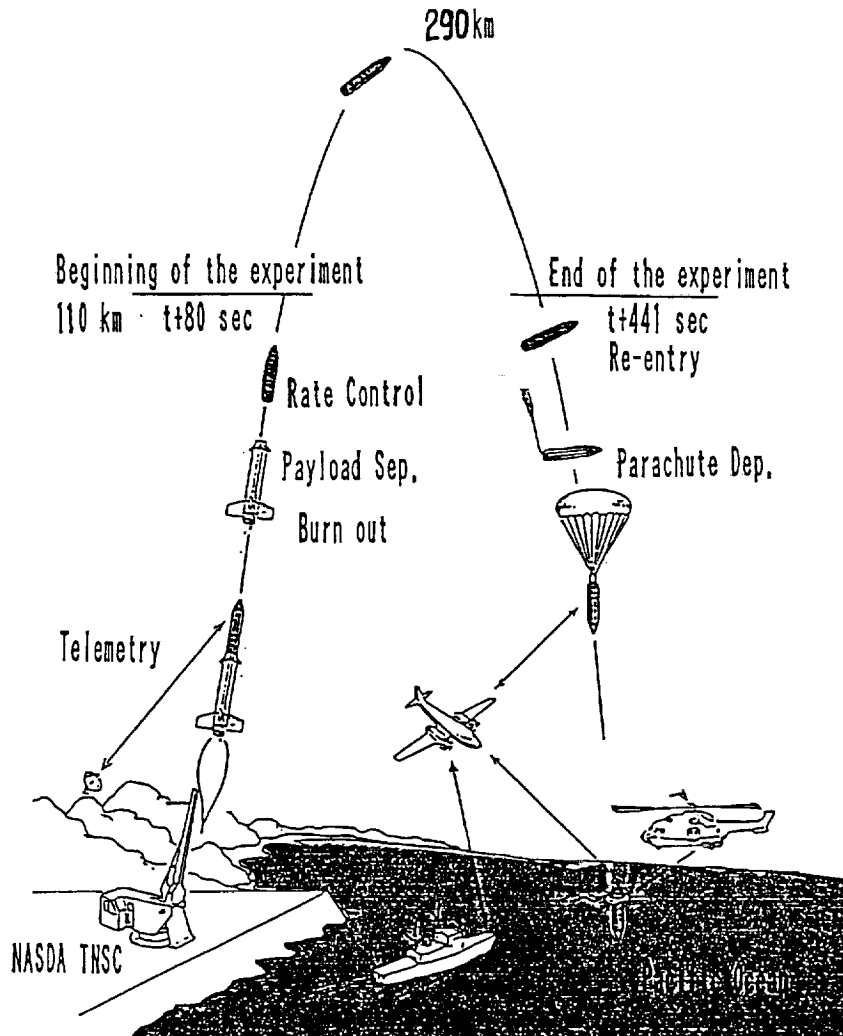
##### **5.3. GEST Development using TR-1A Rocket**

- Successful first flight in Sep. 1991
- Next flight in Aug. 1992

Themes and Co-Investigators of TR-IA Rocket Microgravity Experiments Program

Experiment Module	TR-IA No.1 September 16, 1991	TR-IA No.2 August-September, 1992	TR-IA No.3 August-September, 1993
Module for Experiment Observation Technologies	Field observation of boundary and environment phase in crystal growth Katsuo Tsukamoto (Tohoku U), Kazuhiko Kuribayashi (ISAS), Tsutomu Sawada(NIRIM)		
Module for Measuring Basic Physical Properties of Fluids(FTX)	Marangoni convection generation and control Hisao Azuma (NAL), Akira Hirata (Waseda U), Keiichi Kuwahara(IHI)		
Module for Experimenting Environment Maintaining Technologies(BDH)	Bubble generation, growth and movement Yoshiyuki Abe(Electrotechnical Lab), Masamichi Ishikawa(MRI), Shinya Ishii(MHI)		
General-purpose Furnace (ITF)	Melting and solidification of particle-dispersed alloy Yuji Muramatsu (NRIM)	(Not applicable)	Ceramic material composition Osamu Odawara(TIT)
Temperature-gradient Furnace(TGF)	(Not applicable)	Semiconductor liquid growth Tatau Nishinaga (Tokyo U)	Effects of microgravity on the shape of solid-liquid boundary Kyoichi Kinoshita(NTT)
High-temperature Furnace(HTF)	Melting and solidification of high-temperature oxide superconductor Kazumasa Togano(NRIM)	Melting and solidification of vitreous material Junji Hayakawa(GIRIO)	(Not applicable)

TR-IA MISSION PROFILE





## **6. Status of Japanese User Support Center (USC) Construction**

### **6.1. NASDA Space Experiment Laboratory (SEL) at TKSC**

- SEL plays an integral role for Japanese USCs
- SEL became operational in June 1992

### **6.2. Discipline USCs Concept**

- Major National Institutes are expected to function as discipline-oriented User Support Center

**E.G. NAL for Fluid physics**

**NIRIM for Inorganic Materials**

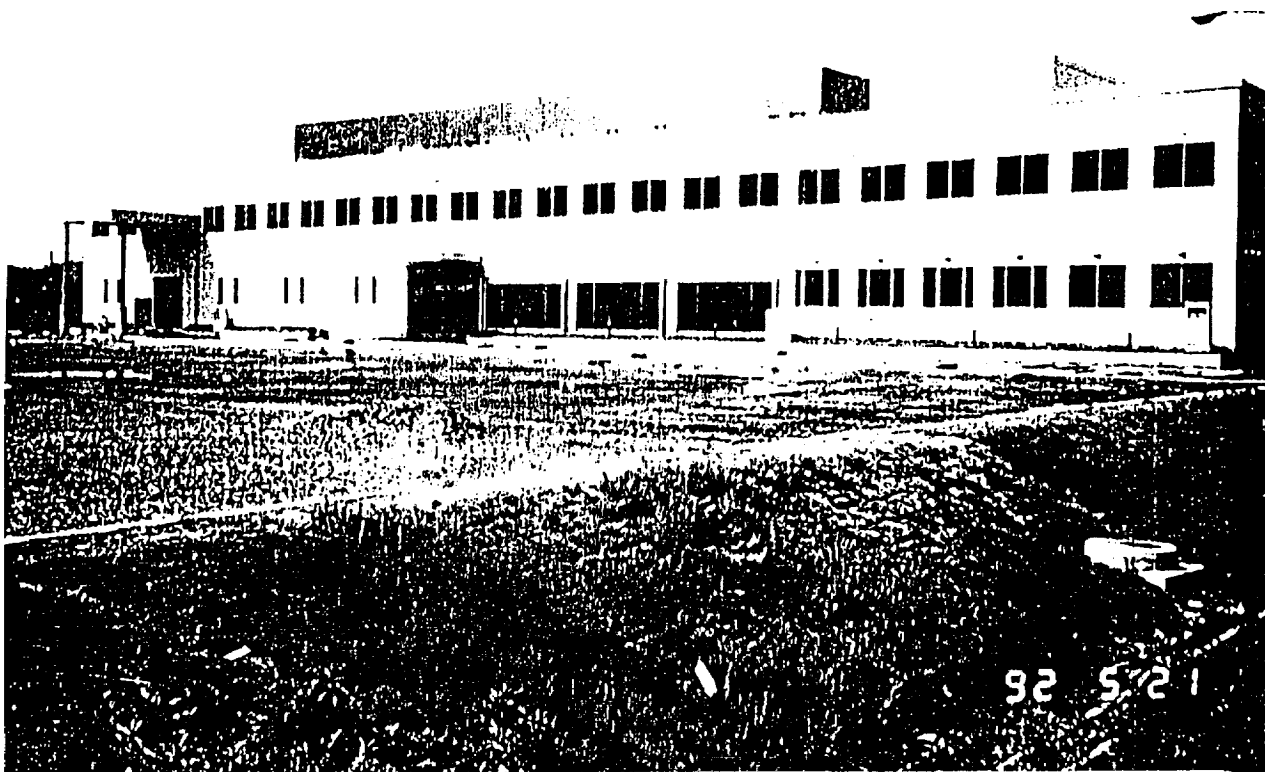
**NRIM for Metals**

**ISAS for Astronomical Observations**



### **6.3. Telescience Technology Application**

- Telescience technology will be applied to link NASDA SEL and Discipline Centers



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## **7. Onboard Multi-User Facility (MUF) Development Status**

### **7.1. Selection of MUF**

- **MUF Candidate List was completed by Pre-AO survey  
List includes three categories, a definitive one, one which needs to be coordinated among international partners, and one which needs to reflect each year's AO**
- **JEM EM system/MUF verification test**
- **JEM traffic model study identifies early stage of MUF**



## **7.2. Technology Development Status**

- 5 MUF technology development will continue until early 1993

## **7.3. Requirements Update by User Advisory G**

- 9 Advisory groups were established
- Requirement update will be completed by summer 1992

## **7.4. Coordination among International Partner**

- Multilateral (MUWG)
- Bilateral



## **8. Organized National Joint Research using Space Environments**

### **8.1. Significance of the Joint Research**

- Enhance research by coordinating/complementing research among national institutes, universities, private sectors
- Easy to accommodate experiments in SS

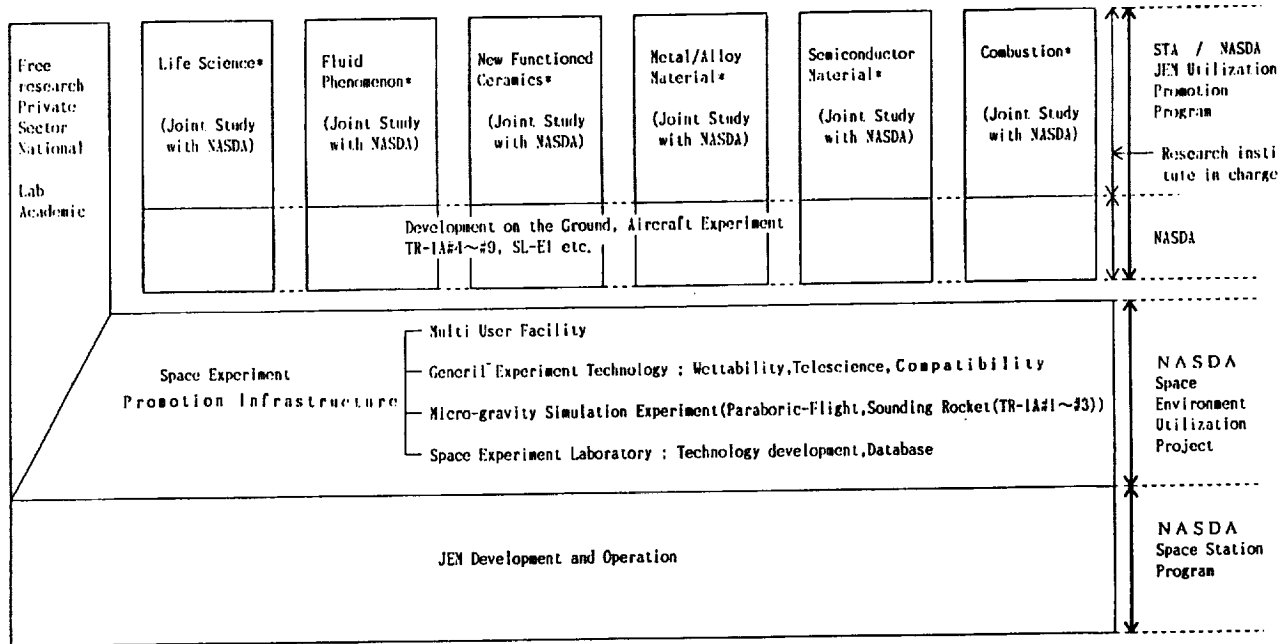
### **8.2. Joint Research Plan**

- STA authorizes the Joint Research (Core Research)
- NASDA develops experiment technology and offers space flight chance
- Assigned Institute for Core Research conducts the research management  
E.G. NAL, NIRIM, NRIM
- JSUP supports general management of the Joint Research
- The plan will be implemented in mid 1992 and will evolve step-by-step





JEM Utilization Preparation



\*: Research Core Name



## 9. Status of Precursor Mission and JEM Early Utilization of Definition

### 9.1. Space Experiment Status

- (1) TR-1A sounding rocket  
#1 Sep. 1991, #2 Aug. 1992, #3 Summer 1993  
follow-on flights are under study
- (2) IML-1  
Jan. 22, 1992, 2 NASDA Experiments
- (3) FUWATT '92 (SL-J/FMPT)  
Sep. 1992, 34 Japanese Experiments
- (4) SFU            Feb.-June 1994
- (5) IML-2        July 1994, 12 Japanese Experiments



### 9.2. Definition of follow-on Precursor Mission

- (1) Preliminary study of Follow-on TR-1A flight, E1 participation, Spacehab Utilization
- (2) Dialogue with international partners for potential cooperation

### 9.3. Definition of Early Utilization of the Space Station

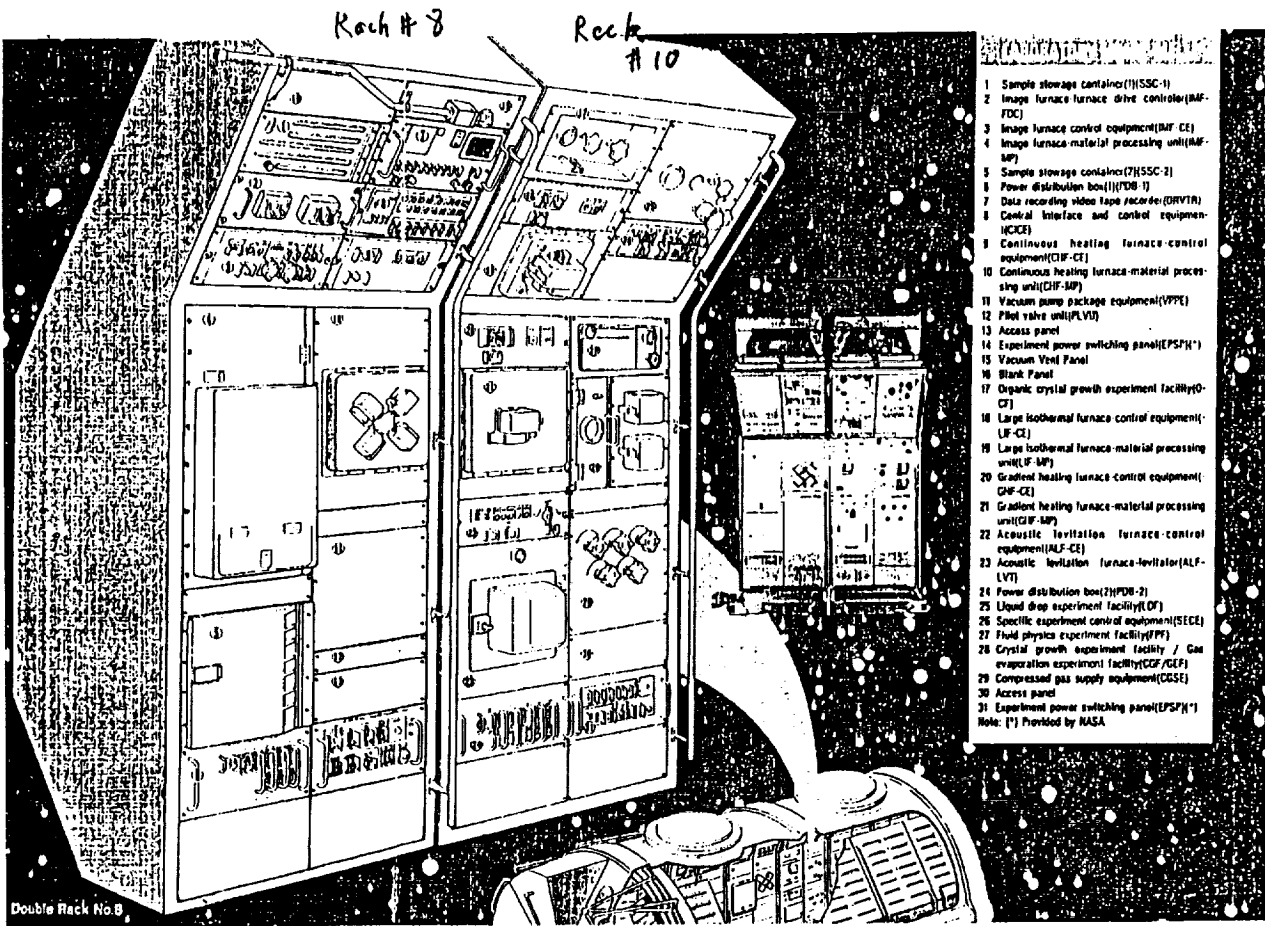
- (1) Traffic model study of JEM early utilization
- (2) Dialogue with international partners for potential cooperation



JEM Utilization Preparation Schedule

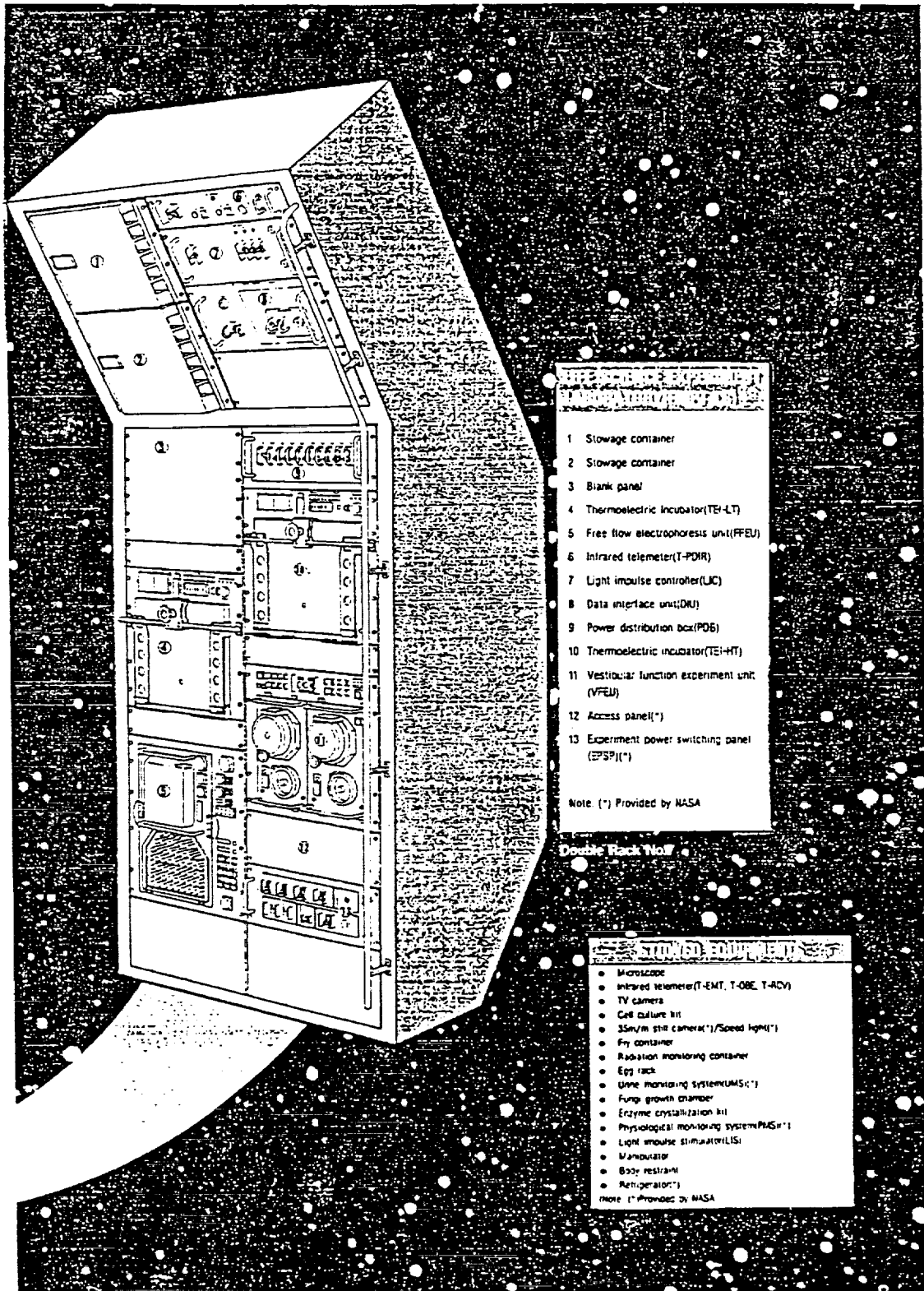
▼ Defined  
▼ Planning

JFY	S63/88	H1/89	H2/90	H3/91	H4/92	H5/93	H6/94	H7/95	H8/96	H9/97	H10/98
Space Station					▼ '88 AO	▼ '98 COUP			TOP		▼ JEM #1 ▼ JEM #2
SIS / SL Free Flyer				▼ INL-1 92/1	▼ FNPT 92/9		▼ INL-2 94/T ▼ SFU 94/2-6				
User Support	Work shop ▼ #8 ▼ #9	▼ #10 ▼ #11	Prelo ▼ #12	▼ #13 ▼ #14	▼ #15	▼ ▼	▼ ▼	▼ ▼	▼ ▼	▼ ▼	
Airplane MU-300	Development ▼		▼▼▼ 90/7~	▼▼▼	▼▼▼	▼▼▼	▼▼▼	▼▼▼	▼▼▼		
Sounding Rocket TR-1A		Development		▼ #1 91/8	▼ #2 92/8	▼ #3 93/9	▼	▼	▼	▼	
Data Base			Development				Operation				
Multuser Facility				Phase B		EM		PFR			
Space Experiment Lab.		Development						Operation			



Double Rack No. 8

- 1 Sample storage container (HSSC-1)
  - 2 Inage furnace furnace drive controller (IMF-FC)
  - 3 Inage furnace control equipment (IMF-CE)
  - 4 Inage furnace material processing unit (IMF-MP)
  - 5 Sample storage container (HSSC-2)
  - 6 Power distribution box (PDB-1)
  - 7 Data recording video tape recorder (DRVTM)
  - 8 Central interface and control equipment (CICE)
  - 9 Continuous heating furnace control equipment (CHF-CE)
  - 10 Continuous heating furnace material processing unit (CHF-MP)
  - 11 Vacuum pump package equipment (VPE)
  - 12 Pinel valve unit (PLVU)
  - 13 Access panel
  - 14 Experiment power switching panel (EPSFH\*)
  - 15 Vacuum Vent Panel
  - 16 Blank Panel
  - 17 Organic crystal growth experiment facility (OCG)
  - 18 Large isothermal furnace control equipment (LIF-CE)
  - 19 Large isothermal furnace material processing unit (LIF-MP)
  - 20 Gradient heating furnace control equipment (GHF-CE)
  - 21 Gradient heating furnace material processing unit (GHF-MP)
  - 22 Acoustic levitation furnace control equipment (ALF-CE)
  - 23 Acoustic levitation furnace levitator (ALF-LV)
  - 24 Power distribution box (PDB-2)
  - 25 Liquid drop experiment facility (LDF)
  - 26 Specific experiment control equipment (SECE)
  - 27 Fluid physics experiment facility (FPF)
  - 28 Crystal growth experiment facility / Gas evaporation experiment facility (CGF/GEF)
  - 29 Compressed gas supply equipment (CGSE)
  - 30 Access panel
  - 31 Experiment power switching panel (EPSFH\*)
- Note: (\*) Provided by NASA



**SCIENCE EXPERIMENT**

- 1 Stowage container
- 2 Stowage container
- 3 Blank panel
- 4 Thermoelectric Incubator(TEI-LT)
- 5 Free flow electrophoresis unit(FFEU)
- 6 Infrared telemeter(T-POIR)
- 7 Light impulse controller(LIC)
- 8 Data interface unit(DIU)
- 9 Power distribution box(PDB)
- 10 Thermoelectric incubator(TEI-HT)
- 11 Vestibular function experiment unit (VFEU)
- 12 Access panel(\*)
- 13 Experiment power switching panel (EPS\*) (\*)

Note: (\*) Provided by NASA

**Double Rack No. 7**

**STOWED EQUIPMENT**

- Microscope
- Infrared telemeter(T-EMT, T-OB, T-ADV)
- TV camera
- Cell culture kit
- 35mm still camera(\*)/Speed light(\*)
- Fry container
- Radiation monitoring container
- Egg rack
- Urine monitoring system(UMS) (\*)
- Fungus growth chamber
- Enzyme crystallization kit
- Physiological monitoring system(PMS) (\*)
- Light impulse stimulator(LIS)
- Manipulator
- Body restraint
- Refrigerator(\*)

Note: (\*) Provided by NASA

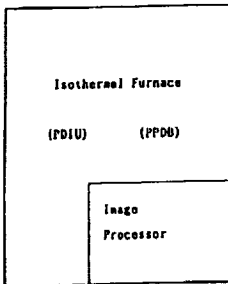
## JEM Early Utilization Traffic Model(as is June. 1992)

	1998			1999		
	MB12(JEM#1)	UF5	UF6	MB15(JEM#2)	UF7	UF8
Experiment Equip.	IF ↑ GHF ↑ ZMF ↑ PCF ↑	Clean bench ↑ CCF ↑	FPEF (norm. Temp) ↑ PSAS ↑	ISCS ↑ SEMS ↑	SGF ↑ LF ↑	EPF ↑ SAHF ↑ TES ↑ SPSS ↑ FPEF ↑ (High Temp) VGF ↑
LSE	Image processor			Refrigerator ↑ Freezer ↑		SCF ↑
UP mass (Except Specimen)	~2.5DRE	~0.75DRE	~0.5DRE	~1DRE ~2EEU	~0.75DRE	~0.625DRE ~3EEU

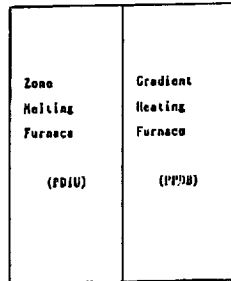
IF : Isothermal Furnace  
 SGF : Solution Growth Facility  
 PCEF: Physics and Chemistry Experiment Facility  
 CCF : Cell Culture Facility  
 GHF : Gradient Heating Furnace  
 ISCS : Intersatellite Communication System  
 TES : Teleoperation Experiment System  
 EOT : Earth Observation TEST  
 SAHF: Small Animal Holding Facility  
 ZMF : Zone Melting Furnace

PCF : Protein Crystallization Facility  
 FPEF: Fluid Physics Experiment Facility  
 LF : Levitation Furnace  
 PSAS: Physiological Signal Acquisition System  
 SEMS: Space Environment Measurement System  
 SPSS: Small Payload Support System  
 SCF : Separation Centrifuge Facility  
 EPF : Electrophoresis Facility  
 VGF : Vapor Growth Facility

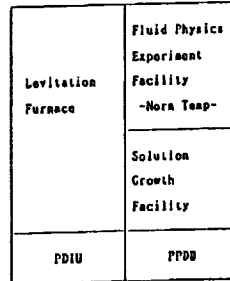
### JEM PM Experiment Rack Installation Model



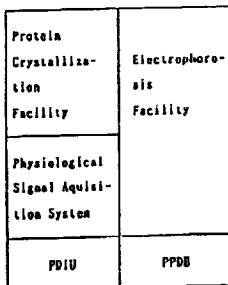
Ground Installation Type  
Experiment Rack



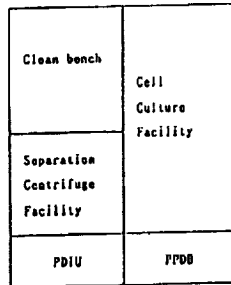
Ground Installation Type  
Experiment Rack



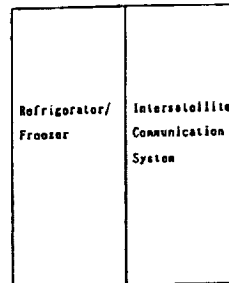
Drawer Type Experiment Rack



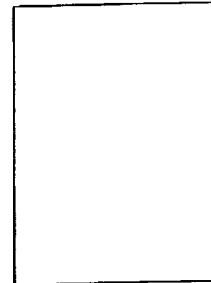
Drawer Type Experiment Rack



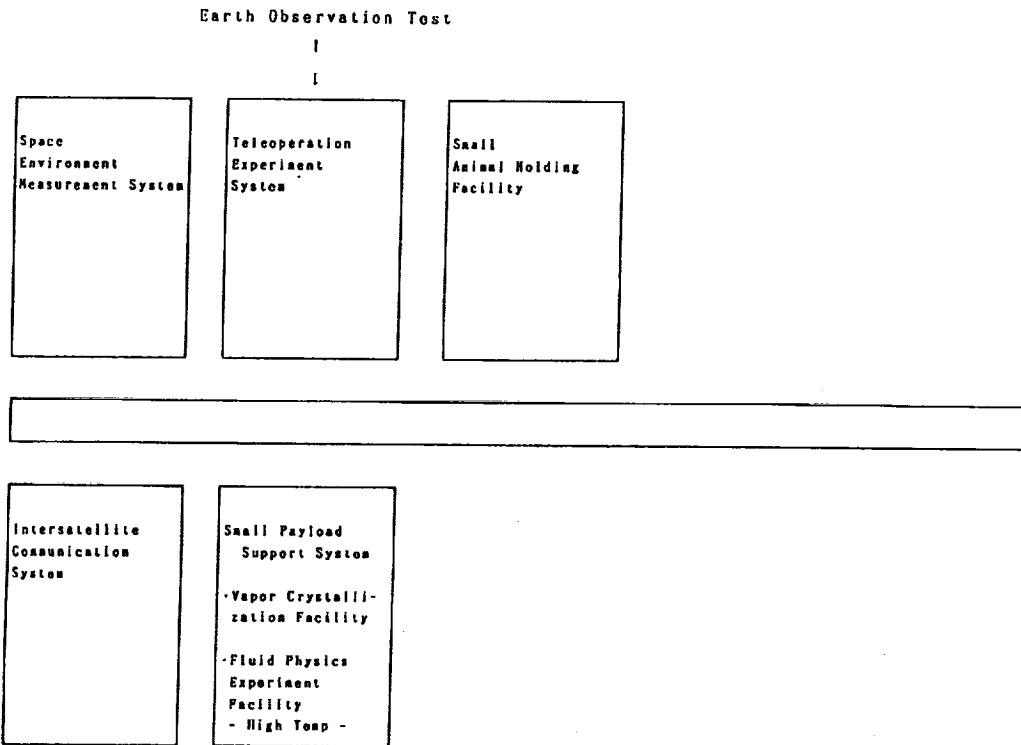
Drawer Type Experiment Rack



User Storage Rack  
(PH ceiling)



User Storage Rack  
(ELS-PS)



## 10. Other Topics

### (1) Space Experiment Data Base Development Status

- Data Base In Japanese became operational in June 1992
- Data Base In English will be operational in mid 1993

### (2) Telescience Test Bed

- Telescience Test Bed was installed in NASDA SEL In June 1992
- Telescience Demonstration Test for JEM MTC operation will be in Nov. 1992

## CANADIAN SPACE AGENCY SPACE STATION FREEDOM UTILIZATION PLANS

Presented by James Faulkner and Ron Wilkinson  
Canadian Space Agency

### ABSTRACT

Under the terms of the NASA/CSA Memorandum of Understanding, Canada will contribute the Mobile Servicing System and be entitled to use 3% of all Space Station utilization resources and user accommodations over the 30 year life of the Station. Equally importantly Canada, like NASA, can begin to exploit these benefits as soon as the Man-Tended Capability (MTC) phase begins, in early 1997.

Canada has been preparing its scientific community to fully utilize the Space Station for the past five years; most specifically by encouraging, and providing funding, in the area of Materials Science and Applications, and in the area of Space Life Sciences. The goal has been to develop potential applications and an experienced and proficient Canadian community able to effectively utilize microgravity environment facilities such as Space Station Freedom. In addition, CSA is currently supporting four facilities; a Laser Test System, a Large Motion Isolation Mount, a Canadian Float Zone Furnace, and a Canadian Protein Crystallization Apparatus.

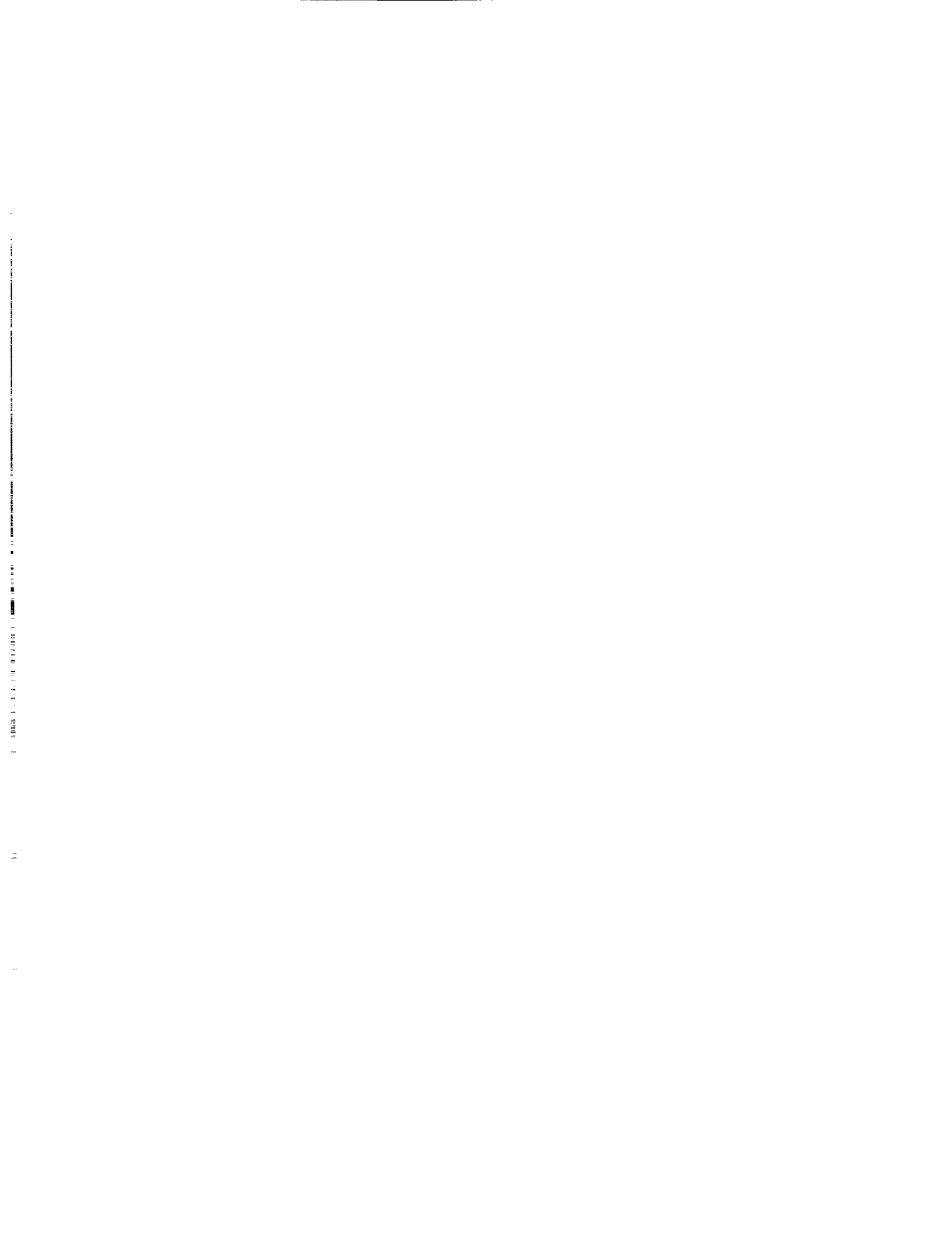
In late April of this year CSA sent out a Solicitation of Interest (SOI) to potential Canadian user from universities, industry, and government. The intent of the SOI was to determine who was interested, and the type of payloads which the community at large intended to propose.

The SOI will be followed by the release of an Announcement of Opportunity (AO) following governmental approval of the Long Term Space plan later this year, or early next year. Responses to the AO will be evaluated and prioritized in a fair and impartial payload selection process, within the guidelines set by our international partners and the Canadian Government.

Payload selection is relatively simple compared to the development and qualification process. An end-to-end user support program is therefore also being defined. Much of this support will be provided at the new headquarters currently being built in St. Hubert, Quebec.

It is recognized that utilizing the Space Station could be expensive for users; costing in many cases millions of dollars to get a payload from conception to retrieval. It is also recognized that some of the potential users cannot or will not invest a lot of money or effort into Space Station utilization, unless there is a perceived significant commercial potential. How best to fund Space Station payloads is under study.

Space Station Freedom will provide the first opportunity for Canada to conduct experiments in a long-duration microgravity environment. CSA have been developing and funding potential users for some time, and considerable interest has been shown by the response to our SOI earlier this year. Canada can be one of the two earliest users for the Space Station, along with NASA. We hope to take full advantage of this opportunity.

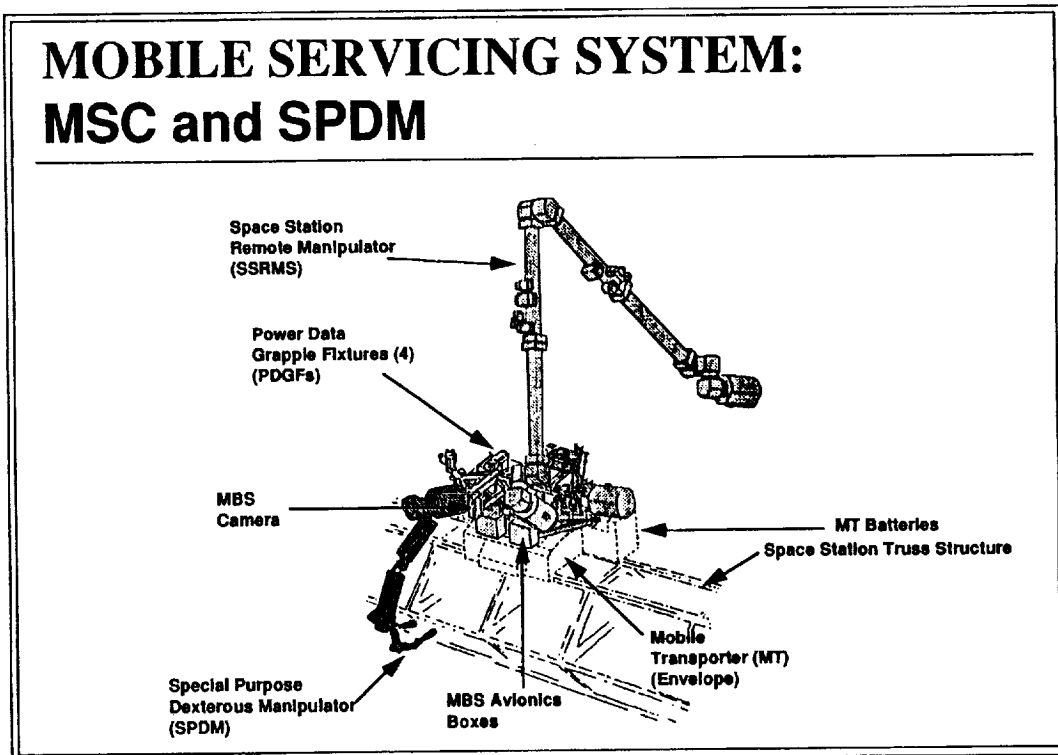






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## SPACE STATION ALLOCATIONS

	CSA	ESA	Japan	NASA
1. Utilization Resources (power, crew time, etc)	3%	12.8%	12.8%	71.4%
2. User Accommodations				
a. NASA Lab Module	3%			97%
b. NASA Truss Attach Points	3%			97%
c. ESA Attached Pressurized Module	3%	51%		46%
d. Japanese Experimental Module	3%		51%	46%
e. NASA Polar Platform	3%			97%
f. ESA Polar Platform	3%	97%		
3. Supporting Services				
a. Space Shuttle launch and return services	3%	12.8%	12.8%	71.4%
b. TDRSS data transmission capacity	3%	12.8%	12.8%	71.4%



Canadian Space Agency  
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SSPO-92MaJF2

## CANADIAN SHARE OF RESOURCES AND ACCOMMODATIONS

	<u>1997</u>	<u>1998</u>	<u>1999 (1)</u>
Pressurized Upmass (kg)	385	334	210
Up-Volume (racks)	0.8	0.6	0.5
On-board Racks	0.5	0.8	1.5
Unpressurized Upmass (kg)	372	372	248
External Attachment Points	0.1	0.1	0.4
Average Power (Kw)	0.26	0.46	0.72
Total Crew Time (hrs)	39	39	26
On-board Data Storage (MB)	8	8	8
Average Down Link (Mbps)	0.93	0.93	0.93

(1) The 1999 figures include allocations up to Sep 1999 (i.e. PMC)



## **USER DEVELOPMENT PROGRAM**

---

- MATERIALS SCIENCES AND APPLICATIONS
- SPACE LIFE SCIENCES
- GOAL: TO DEVELOP A CANADIAN COMMUNITY  
ABLE TO EFFECTIVELY UTILIZE  
MICROGRAVITY ENVIRONMENT  
FACILITIES SUCH AS SPACE STATION



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canadienne

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## **MATERIALS SCIENCES AND APPLICATIONS**

---

- EXPLORATION
  - UNIQUE PHENOMENA
- FUNDAMENTAL SCIENCES
  - FLUID PHYSICS
  - TRANSPORT PHENOMENA
  - CONDENSED MATTER PHYSICS
  - COMBUSTION SCIENCE
  - NUCLEATION
  - CRYSTAL GROWTH
- APPLIED SCIENCE
  - MATERIAL SCIENCE
  - PROTEIN CRYSTALLIZATION
  - LASER MATERIAL PROCESSING
- TECHNOLOGY
  - DEMONSTRATE HARDWARE



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## **SPACE LIFE SCIENCE**

---

- HUMAN PHYSIOLOGY
- GRAVITATIONAL BIOLOGY
- BIOTECHNOLOGY
- THREE COMPONENTS:
  - INVESTIGATOR DEVELOPMENT
  - SPACE STATION PREPARATORY SCIENCE
  - SPACE STATION



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## **USER DEVELOPMENT PROGRAM FACILITIES**

---

- LASER TEST SYSTEM
- LARGE MOTION ISOLATION MOUNT
- CANADIAN FLOAT ZONE FURNACE
- CANADIAN PROTEIN CRYSTALLIZATION APPARATUS



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## SOLICITATION OF INTEREST

---

- |  |     |
|--|-----|
| • MATERIALS RESEARCH                         | 52% |
| • BIOLOGY, LIFE SCIENCES,<br>BIOTECHNOLOGY   | 17% |
| • ROBOTICS, SPACE STRUCTURES,<br>DEVICES     | 12% |
| • EARTH OBSERVATION,<br>ATMOSPHERIC RESEARCH | 8%  |
| • HARDWARE DEVELOPMENT                       | 7%  |
| • COMMUNICATIONS, ENERGY                     | 4%  |



## REVIEW PANELS

---

- REPRESENTATIVES FROM UNIVERSITY, INDUSTRY, GOVERNMENT
- FOUR PANELS TO START:
  - SCIENCE (including related technology);
  - SPACE TECHNOLOGY (e.g. structures, devices, robotics);
  - EARTH OBSERVATION; and
  - COMMUNICATIONS.



## **REVIEW PANEL EVALUATION CRITERIA**

---

- SCIENTIFIC MERIT
- ORIGINALITY
- VALUE TO CANADA
- STATION RESOURCES REQUIRED
- COMMERCIAL POTENTIAL
- COST

## **CANADIAN SPACE STATION PROGRAM ALLOCATION BOARD (CSSPAB)**

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- CSA VICE PRESIDENT OPERATIONS (Chairman)
  - CSA VICE PRESIDENT RESEARCH & APPLICATIONS
  - DIRECTOR GENERAL  
CANADIAN SPACE STATION PROGRAM
  - DIRECTOR GENERAL SPACE SCIENCE
  - CSA USER OPERATIONS PANEL MEMBER
- plus
- CHAIRMEN OF REVIEW PANELS (to relevant meetings)

## **USER SUPPORT PROGRAM**

---

- ASSISTANCE TO PI'S
- TECHNICAL SUPPORT CENTERS
- SPECIALIZED EQUIPMENT
- ARRANGE LAUNCH AND COMMUNICATIONS SERVICES
- PAYLOAD INTEGRATION CENTER
- PAYLOAD OPERATIONS CENTER
- PAYLOAD SUPPORT CENTER



## **FUNDING POLICIES**

---

- TO BE DETERMINED
- INITIAL THOUGHTS:
  - CSA would subsidize the costs associated with integrating, qualifying, launching, controlling, and recovering payloads;
  - PI's absorb some of the payload development costs by contributing in-kind support, or by obtaining funding from other sources; and
  - where there are future commercial returns, the federal government would apply user fees to recover some portion of the costs.







## EUROPEAN RESEARCH PLANS

Presented by Jean-Jacques Dordain  
Head of Microgravity and Columbus Utilisation Department  
European Space Agency

### SPEECH

It is difficult to say in 30 minutes what we shall do in the next 30 years, since the Space Station will be used up to the year 2025, which means that the majority of users are still in school and even some of them are not yet born.

It is also difficult to speak after almost ten speakers about the same subject. As a matter of fact, the European plans on Space Station utilisation are very similar to the plans of the other partners - we have the same hopes and we have the same problems - but we are trying to contribute significantly in the following challenge: How to make the Space Station not only beautiful, but also useful?

Finally, I would like to recall that the European part of the Space Station Freedom is called Columbus, which means a lot!

- Christopher Columbus was truly a European, born in Italy and sponsored by Spain.
- Christopher Columbus established the first link between Europe and America.
- Christopher Columbus opened a new era even though he did not know that he was doing so.

The success for the Space Station would be that future historians could distinguish the pre-Freedom period as they did for the pre-Columbian period.

I shall limit my presentation today to the three following aspects:

1. Why Columbus and, more generally, the Space Station Freedom is a unique tool for Science?
2. What are the capabilities offered by Columbus to the users, in terms of accommodation capabilities and environment?
3. Columbus utilisation has already started, through Precursor Flights: IML-1, ATLAS, EURECA-1 in 1992, Spacelab D-2 next year, later on EURECA-2 and -3, IML-2, SPACELAB E-1 and we are also looking for using the MIR Station and Spacehab, which means any opportunity to prepare the Space Station utilisation and also through ground testbeds. Columbus utilisation is very active on ground. I shall show you pictures of the real stuff and not only artists' concepts and plans. You can visit the Space Station mock-up here in Huntsville; you are all welcome to visit and use the Columbus facilities at ESTEC in the Netherlands.

First Aspect, the Columbus elements will be used as laboratories, which means a place where we are providing capabilities for doing experiments, i.e. power, computers, . . . and as space laboratories, which means a place where we are taking benefit of the space environment, i.e. altitude, vacuum and microgravity. It must be pointed out that scientific utilisation is not the only driver for developing the Columbus elements. To make man live and work in space is also a key objective.

As a matter of fact, most of the science we plan to do onboard the Space Station could be done without the Space Station, except for Life Sciences, which are obviously linked to the presence of man in space. We can do Astronomy, Earth Observation, Technology Experiments, Material Sciences, Fluid Sciences, without the Space Station and **WE DO**.

However, we shall use, and extensively use, the Space Station because, first, it is there, but not only because it is there. Compared to other means to do science in space, and especially regular satellites, the Space Station has key features that make it a unique tool for science.

1. The Station permits us to avoid the transport through the atmosphere of all resources necessary to make an experiment, each time you wish to make an experiment. The resources stay in orbit and you can limit the transport to just instruments, which is a big advantage when you know that, for example, Spacelab is 13 tons for 3 tons of instruments. The key is to carry less through the atmosphere.
2. The Station has large utilisation resources, at least one order of magnitude above those of a regular satellite - 30 kw, tenth of square metres, hundreds of cubic metres.
3. The Station is permanently available with an access every two to three months, which means that you can change, you can repair, and you can introduce new technology as soon as they are available.
4. The Station is manned, which can be very useful, even if not mandatory. Therefore, the Space Station is a unique tool for scientific utilisation.

The Second Aspect I would like to address is the capabilities which are offered by the Columbus elements. These capabilities are twofold:

- Accommodation capabilities, which mean the number and type of instruments you can accommodate and operate.
- Environmental capabilities, i.e. the microgravity environment for instance, which must satisfy the requirements of experimenters and which could be improved by the development of Microgravity Isolation Mounts.

As for the accommodation capabilities, I would like to comment on two key words:

- multidiscipline, which means that we have to satisfy the requirements of a wide range of users;
- cooperation, which means that we have to take the best benefit of the overall capabilities and resources which are available, i.e. avoiding duplication between the partners.

About the multidiscipline aspect, we consider that it would be a mistake to limit the users to a few categories, considering the 30 years of utilisation in front of us. Five years ago, the favourite users were among the Material Sciences type of users; today the favourite users are with Human Physiology because of space exploration; perhaps five years from now they will be recruited in the biology field, and I trust the scientists to have dynamism enough for proposing completely new ideas on how to use space environment 20 years from now. We have to, therefore, be prepared to face this evolution, and our plans are balancing the utilisation of Columbus among all present user communities.

I shall come back to cooperation later on and let me show you now some material on existing ground facilities, available to prepare the utilisation of Columbus. The Columbus Attached Laboratory full size mock-up includes:

- the real interfaces between the Laboratory system and the payload racks;
- breadboards of typical payload and of the General Purpose Workbench;
- a Telescience testbed simulating the interactive payload operations;

- a Crew Work Station testbed evaluating all technologies able to enhance the role of the astronauts;
- an Automation and Robotics testbed evaluating the capabilities of a multi-purpose robot.

In addition to these ground facilities, extensive utilisation of underwater tests and parabolic flights complete the preparation of Columbus utilisation on ground.

I would like to conclude my presentation with the international aspect: The Space Station is an international venture; we are partners with rights and duties. These rights and duties are clearly defined in the Space Station agreements, the IGA and MOUs. But we have to go beyond these papers and to practise this cooperation, and this is the reason why the preparation of the utilisation of the Space Station must be truly international at both levels, user and agency levels, utilisation and operational levels.

To practise cooperation is the best way to realise that cooperation does not exclude competition and that the combination of cooperation and competition is very fruitful. We know that in Europe, where 13 countries are cooperating through the European Space Agency.

This cooperation is already under way:

1. With NASA, thanks to the IML flights and a cooperative agreement on the EURECA reflights.
2. With all the Space Station partners in order to ensure common interfaces for the users and, in order to share the common equipment on board.

This cooperation does not exclude any partner and, therefore, I am confident that the Space Station will offer a new era of space activities, and just to show you what is true cooperation, let me show you the first advertisement I have discovered for Columbus in a US newspaper . . .

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## SPACE LIFE SCIENCES PERSPECTIVES FOR SPACE STATION FREEDOM

Presented by Laurence R. Young, Sc.D.  
Massachusetts Institute of Technology and  
NASA Johnson Space Center

### ABSTRACT

It is now generally acknowledged that the life science discipline will be the primary beneficiary of Space Station Freedom. The unique facility will permit advances in understanding the consequences of long duration exposure to weightlessness and evaluation of the effectiveness of countermeasures. It will also provide an unprecedented opportunity for basic gravitational biology, on plants and animals as well as human subjects. The major advantages of SSF are the long duration exposure and the availability of sufficient crew to serve as subjects and operators.

In order to fully benefit from the SSF, life sciences will need both sufficient crew time and communication abilities. Unlike many physical science experiments, the life science investigations are largely exploratory, and frequently bring unexpected results and opportunities for study of newly discovered phenomena. They are typically crew-time intensive, and require a high degree of specialized training to be able to react in real time to various unexpected problems or potentially exciting findings. Because of the long duration tours and the large number of experiments, it will be more difficult than with Spacelab to maintain astronaut proficiency on all experiments. This places more of a burden on adequate communication and data links to the ground, and suggests the use of AI expert system technology to assist in astronaut management of the experiment. Typical life science experiments, including those flown on Spacelab Life Sciences I, will be described from the point of view of the demands on the astronaut. A new expert system, "PI in a Box," will be introduced for SLS-2, and its applicability to other SSF experiments discussed.



# **SPACE LIFE SCIENCES: EXPERIENCE AND PLANS**

**PROF. LAURENCE R. YOUNG**

**MIT, DEPT OF AERONAUTICS & ASTRONAUTICS**

**PAYLOAD SPECIALIST CANDIDATE, SLS-2**

**HUNTSVILLE, ALABAMA  
AUGUST 4, 1992**

U.S. Gov't



**Man Vehicle  
Laboratory**

# **WHY IS SSF VITAL TO SPACE LIFE SCIENCES?**

**LONG DURATION EXPOSURES**

**COMPARABLE TO MARS EXPLORATION**

**ANIMALS AND PLANTS AS WELL AS HUMANS**

**MULTIPLE GENERATIONS OF PLANTS AND ANIMALS**

U.S. Gov't



**Man Vehicle  
Laboratory**

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## WHAT DOES SSF OFFER FOR LIFE SCIENCES?

### CREW TIME:

SUFFICIENT NUMBER OF SUBJECTS

SPECIALIZED EXPERIMENTERS

FLEXIBILITY TO REPLAN STUDIES

U.S. Gov't

MIT

Man Vehicle  
Laboratory

## FACILITY REQUIREMENTS FROM LIFE SCIENCES

TWO WAY COMMUNICATION AND DATA LINKS  
EVENTUAL USE OF UPLINK VIDEO

SAMPLE RETURN CAPABILITY

ON BOARD ANALYSIS

BIOISOLATION

NORMAL ATMOSPHERIC CONDITIONS

MIT

Man Vehicle  
Laboratory



## MAJOR ON-BOARD EQUIPMENT

### BIOISOLATION:

GLOVE BOX TO PROTECT CREW AND SAMPLES

ANIMAL AND PLANT HOLDING FACILITIES

### CENTRIFUGE:

PROVIDE 1-G CONTROLS

MAINTAIN 1-G SAMPLES UNTIL NEEDED

PERMIT STUDIES IN THE 0-1 G RANGE

HEALTH MAINTENANCE FACILITY



Man Vehicle  
Laboratory

## SPECIALIZED ON-BOARD EQUIPMENT

LINEAR AND ANGULAR ACCELERATORS

IMAGING DEVICE

LOWER BODY NEGATIVE PRESSURE DEVICE



Man Vehicle  
Laboratory

## HUMAN-ORIENTED RESEARCH

### ISSUES RELATED TO ADAPTATION TO 0-G

CARDIOVASCULAR DECONDITIONING  
PULMONARY FUNCTION ALTERATION  
MUSCLE LOSS AND CHANGE OF FIBER TYPES  
BONE LOSS AND CHANGE IN CALCIUM BALANCE  
PLASMA AND RED BLOOD CELL LOSS  
RENAL/ENDOCRINE SYSTEM  
IMMUNE SYSTEM  
SPACE MOTION SICKNESS AND NEUROVESTIBULAR  
ADAPTATION



Man Vehicle  
Laboratory

## PLANT AND ANIMAL EXPERIMENTS

COVER ALL BRANCHES OF PHYSIOLOGY  
CURRENT ANIMAL SPECIES: RATS, MONKEYS, FISH  
REQUIRE SOME SPECIALIZED CREW SKILLS



Man Vehicle  
Laboratory

## RECENT LIFE SCIENCES EXPERIENCE

**SPACELAB LIFE SCIENCES 1 (JUNE '92)**

**FIRST ALL LIFE SCIENCES MISSION**

**TWENTY INVESTIGATIONS/ SIX BODY SYSTEMS**

**HUMANS, RATS AND JELLYFISH STUDIED**

**SUCCESS DEPENDED ON CREW SKILLS**

**SPACELAB LIFE SCIENCES 2 SCHEDULED FOR 1993**

**MIT**

**Man Vehicle  
Laboratory**

U.S. Gov't

## SPECIAL PROBLEM RAISED BY SSF FOR LIFE SCIENCE STUDIES

**LONG DURATION TOURS  
MULTIPLE DISCIPLINES AND EXPERIMENTS  
FLEXIBILITY TO ADJUST PROTOCOLS AND TIMES**

***BUT***

***THE CREW NEEDS TIMELY REMOTE COACHING, AND  
GUIDANCE DURING CONDUCT OF THE EXPERIMENTS***

**HIGH B/W COMMUNICATION TO PI'S IS AN APPROACH  
ON-BOARD EXPERTS SYSTEMS ARE ALTERNATIVES**

**MIT**

**Man Vehicle  
Laboratory**

U.S. Gov't

The following table shows the results of the experiment. The first column is the number of trials, the second column is the number of correct responses, and the third column is the percentage of correct responses.

Number of trials	Number of correct responses	Percentage of correct responses
10	7	70%
20	14	70%
30	21	70%
40	28	70%
50	35	70%
60	42	70%
70	49	70%
80	56	70%
90	63	70%
100	70	70%

As can be seen from the table, the percentage of correct responses is constant at 70% for all numbers of trials. This suggests that the subject is performing at a level of 70% accuracy.

## RESEARCH EXPERIENCES ON MATERIALS SCIENCE IN SPACE ABOARD SALYUT AND MIR

Presented by Liya L. Regel  
International Center for Gravity Materials Science and Applications  
Clarkson University

### ABSTRACT

From 1980 through 1991 approximately 500 materials processing experiments were performed aboard the space stations Salyut 6, Salyut 7 and Mir. This includes work on catalysts, polymers, metals and alloys, optical materials, superconductors, electronic crystals, thin film semiconductors, superionic crystals, ceramics, and protein crystals. Often the resulting materials were surprisingly superior to those prepared on earth. The Soviets were the first to fabricate a laser (CdS) from a crystal grown in space, the first to grow a heterostructure in space, the first superionic crystal in space, the first crystals of CdTe and its alloys, the first zeolite crystals, the first protein crystals, the first chromium disilicide glass, etc. The results were used to optimize terrestrial materials processing operations in Soviet industry.

The characteristics of these three space stations are reviewed, along with the advantages of a space station for materials research, and the problems encountered by the materials scientists who used them. For example, the stations and the materials processing equipment were designed without significant input from the scientific community that would be using them.

It is pointed out that successful results have been achieved also by materials processing at high gravity in large centrifuges. This research is also continuing around the world, including at Clarkson University. It is recommended that experiments be conducted in centrifuges in space, in order to investigate the acceleration regime between earth's gravity and the microgravity achieved in orbiting space stations. One cannot expect to understand the influence of gravity on materials processing from only two data points, earth's gravity and microgravity. One must also understand the influence of fluctuations in acceleration on board space stations, the so-called "g-jitter."

International workshops on high gravity materials processing and jitter are being held at Clarkson in June 1993.



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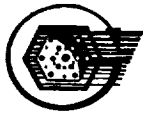


**Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

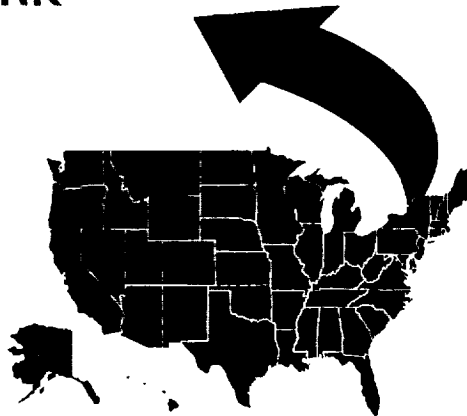
*Research Experiences on Materials Science  
in Space aboard Salyut and Mir*

Liya Regel



International Center for Gravity Materials Science & Applications  
Clarkson University

**INTERNATIONAL CENTER FOR GRAVITY  
MATERIALS SCIENCE AND APPLICATIONS  
CLARKSON UNIVERSITY  
POTSDAM, NEW YORK**





## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

“We have labelled civilizations by the main materials which they have used:

The Stone Age,

The Bronze Age,

The Iron Age...

a civilization is both developed and limited by the materials at its disposal. Today, man lives on the boundary between

**the Iron Age and the New Material Age.”**

- Dr. George P. Thomson,

Nobel Laureate in Physics



## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### **Materials Processing Areas**

- Catalysts
- Polymers
- Metals and Alloys
- Non-Linear Optical Materials
- Superconductors
- Electronic Crystals
- Thin Film Semiconductors
- Ceramics
- Protein crystals





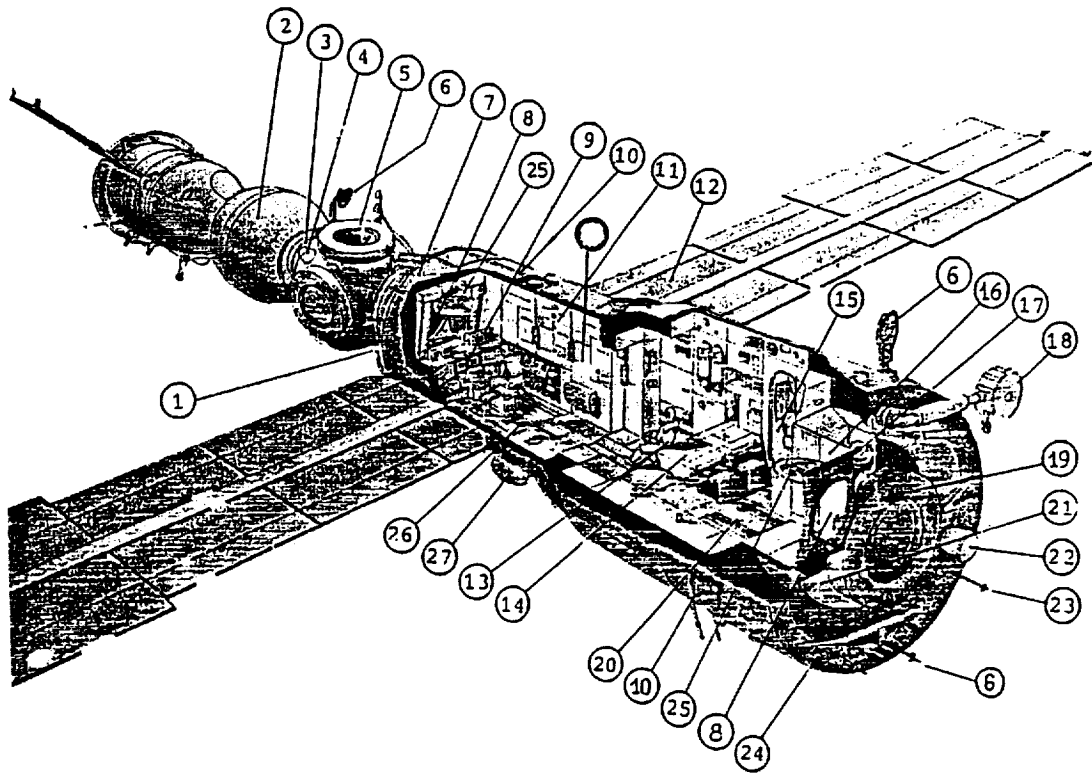
**Some Consequences of "Microgravity" Environment**

- **Greatly reduced buoyancy-driven convection.**
- **Greatly reduced sedimentation of second phase.**
- **Greatly reduced hydrostatic pressure.**
- **Easier containerless processing.**
- **Surface phenomena more important.**



**Why Research on Materials Processing in Space?**

- **Learn more about influence of these phenomena.**
- **Improve processing on earth.**
- **Perhaps learn consequence of improved materials.**
- **Helpful in assembling space stations.**
- **Maybe manufacturing in space, someday.**



## CHARACTERISTICS OF MIR

Inclination of orbit :  $51.6^{\circ}$

Height of orbit : 300-400 km

Accuracy of orientation:

Usual -  $< 1.5$

Precise -  $< 15$  minutes

Total mass of complex :  $> 130,000$  kg

Volume pressurized : 400 m

Length of basic block :

Kvant + 2 spacecraft : 32.9 m

Maximum number of modules : 5

Number of Soyuz that can dock : 0,1,2

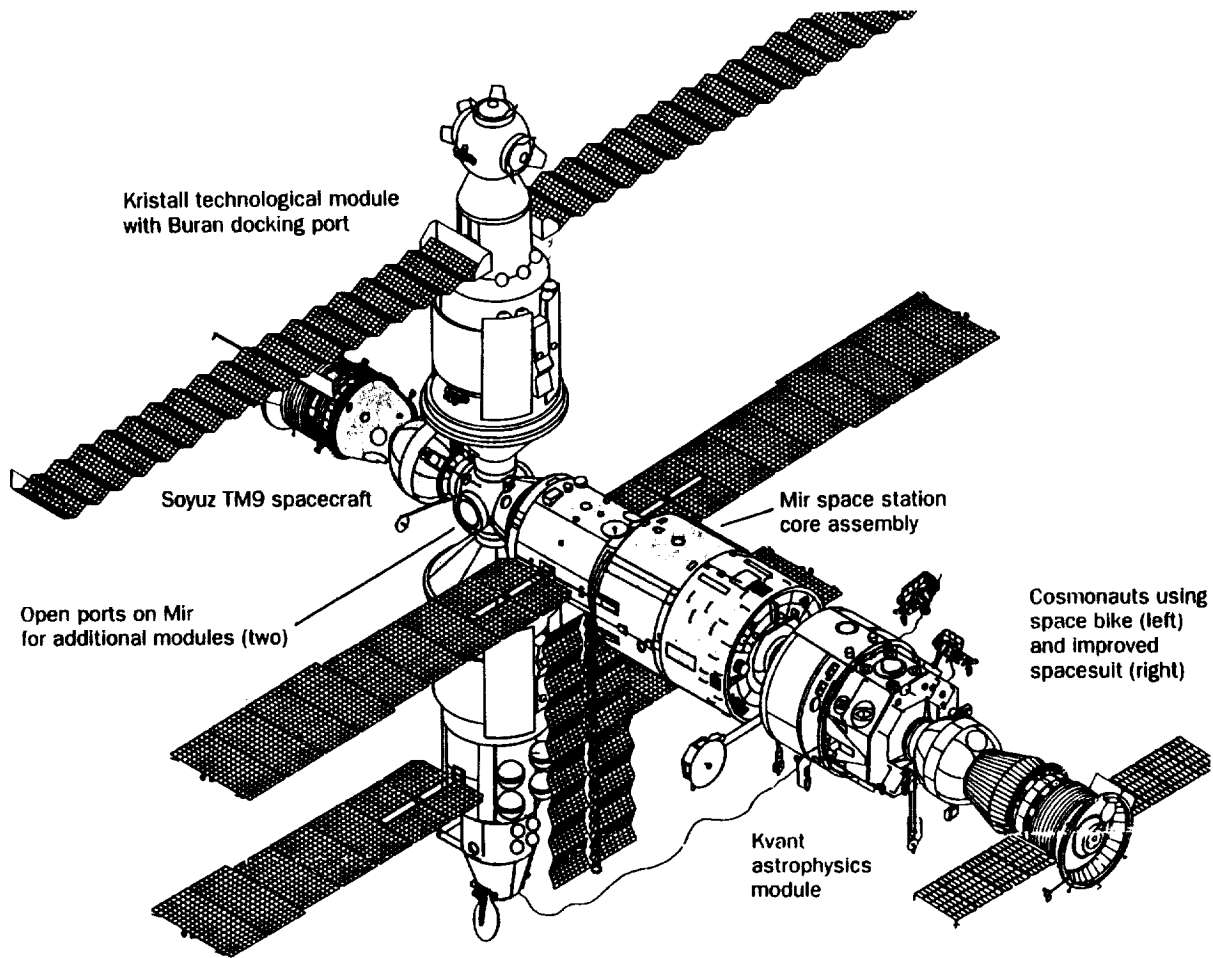
Number of Progress that can dock : 0,1

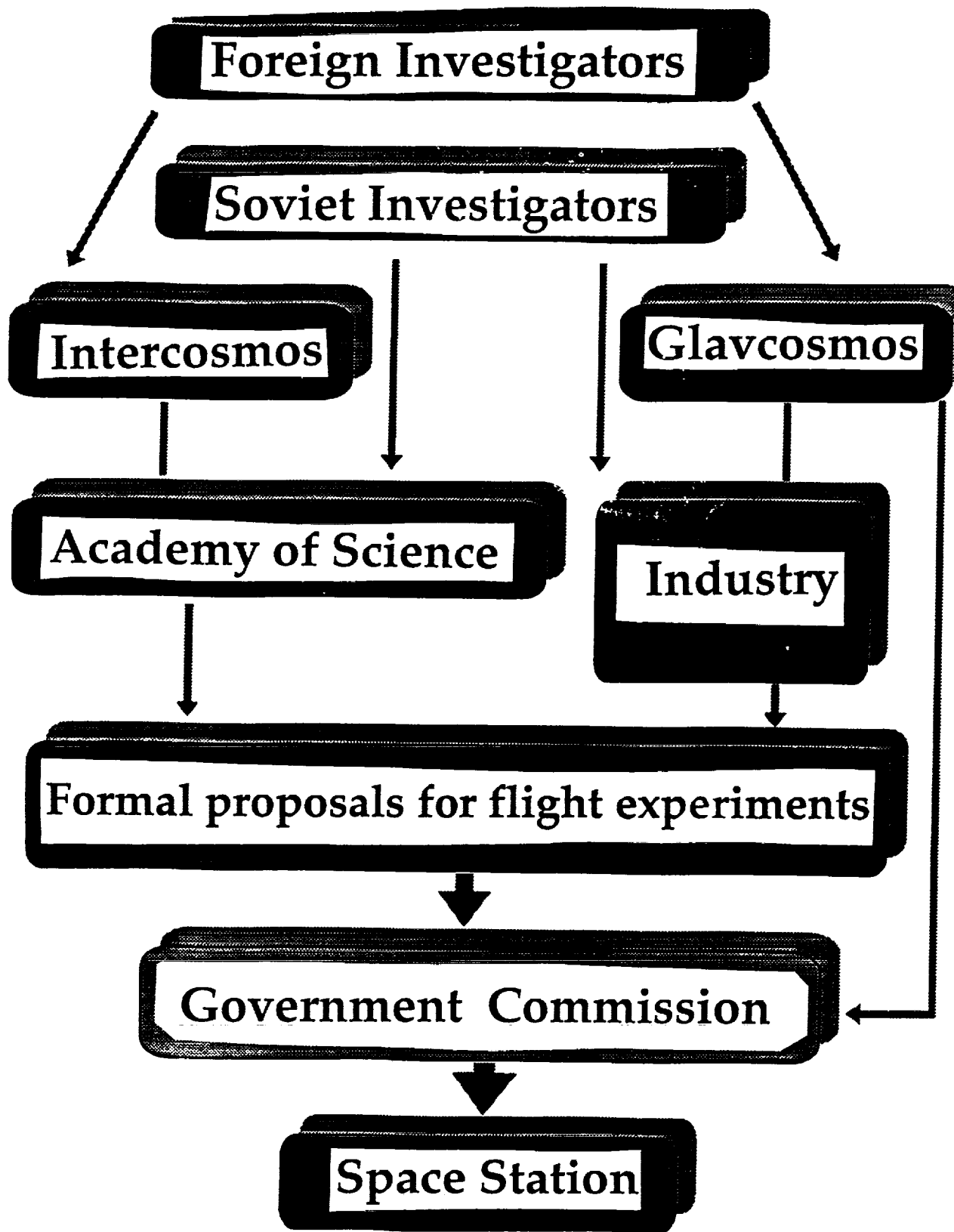
Number of occupants:

Long term - 2,3

Short term - 2,3









**Examples of Hardware in Krystal Module**

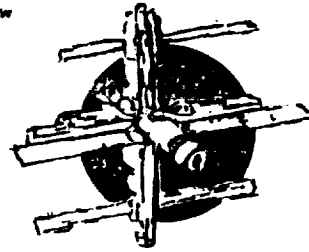
- **Gallar** Tube furnace for 33 mm diameter ampoules, maximum temperature 1300 °C, 1 kw.
- **Crater** Tube furnace for 56 mm diameter ampoules, maximum temperature 1250 °C, 2 kw.
- **Splav** Gradient furnace 20 mm diameter ampoules, 500 to 1050°C, maximum gradient 130K/cm.
- **Optizone** Mirror furnace for floating zone melting of 10 mm diameter silicon up to 150 mm long, 300 to 2100 °C, up to 1.6 kw.



**Characteristics of Typical Scientific Module: Kristall**

- **Mass of Module** 20,600 kg
- **Length of module** 12.5 m
- **Mass of payload** 5,000 kg
- **Transport vehicle** Proton or Energy

Apparatus and samples delivered to Moscow



2

Baikonur

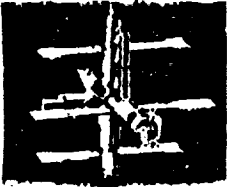
2\*

7\*

25\*

Soyuz Modul Progress

MIR



Experiments performed in MIR

Results of experiments returned



2\*

Baikonur

2\*

Schedule for transportation of experimental apparatus from Moscow to MIR and return.



Space Station Freedom Utilization Conference

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Advantages of Crystal Growth in Mir and Salyut

- Could perform long duration experiments.
- Cosmonauts available to repair equipment and modify experiments.
- A lot of space for equipment, including materials characterization equipment and general purpose apparatus.



**Some Crystal Growth Results from Mir and Salyut**

- **First to fabricate laser from crystal (CdS) grown in space.**
- **First semiconductor heterostructure grown in space.**
- **First crystals of CdTe, HgCdTe, ZnCdTe, and MnCdTe.**
- **First superionic crystal grown in space.**
- **Large monodispersed polymer latex spheres.**
- **First zeolite crystals, several times larger than on earth.**



- **First protein crystals; insulin, pro-insulin, glucogen, tymozine, antitrypsinn, interferon.**
- **First chromium disilicide glass.**
- **First crystallization by rapid mixing of two solutions, to grow hydroxyapatite and calcium sulfate (gypsum).**
- **Results helped to optimize terrestrial crystal growth...**
- . . .
- . . .



## **Space Station Freedom Utilization Conference**

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### **Problems Encountered in Mir and Salyut**

- **Designed without input from user community, resulting in:**
  - Limited power for experimental equipment.
  - Limited periods when power available for experiments.
  - Mass restrictions for equipment.
  - Limited time for experiments.
  - Equipment located far from center of mass of station.
  - Limited air-to-ground communications and data transmission.
- **No accelerometer data to investigators.**
- **Lengthy delays in return of samples and data to investigators**

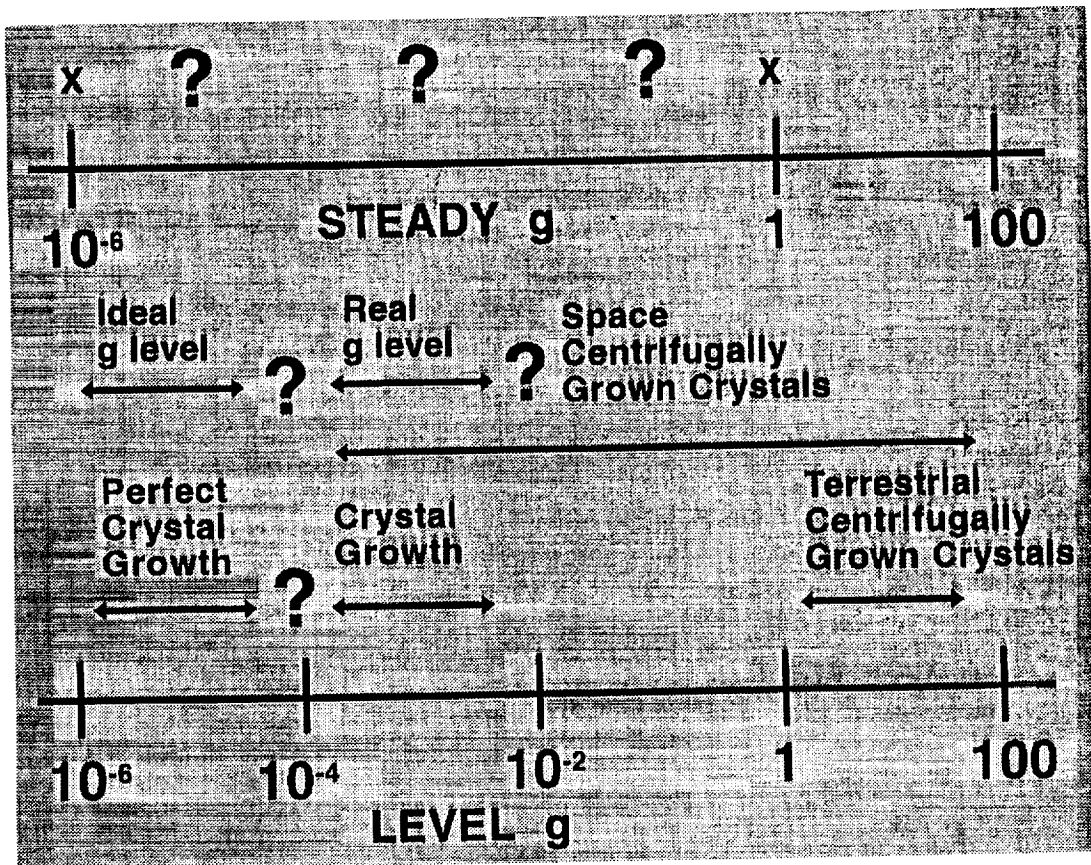


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- **Too many scientific disciplines for cosmonauts to master.**
- **Insufficient training on flight apparatus before launch.**
- **Excessive paperwork for investigators.**
- **Replication of experiments rarely possible.**
- **No support for thorough analysis of flight samples and results.**
- **Criteria for selection of flight experiments never revealed.**





Space Station Freedom Utilization Conference

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### Phenomena in a centrifuge

- Sedimentation
- Increased pressure
- Increased buoyancy convection
- Coriolis forces
- Acceleration gradients



## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### **Materials Processing Results**

- **Very high g:**
  - **Solution growth**
  - **Eutectic solidification**
  - **Movement of solvent inclusions**
- **Moderate g with unstable gradient**
- **Moderate g with "stable" gradient**
  - **Single phase solidification**
  - **Eutectic solidification**
- **Vapor transport at moderate g**



## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### **Implications of Fluid Flow Experiment to Crystal Growth**

- **Space Centrifuge Fluid Flow Experiment will increase the understanding of the controlling forces influencing crystal growth of any material in a wide range of g levels.**
- **Crystal growth in a centrifuge offers a unique environment in which the fluid flow magnitude and flow pattern are controllable, which in turn effects the concentration field.**



## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### **Why Materials Processing Experiments in a Centrifuge in Space Station Freedom?**

- To obtain data points between  $10^{-6}$  g and 1 g; necessary to understand influence of g.
- To explain ground based results from centrifuge without complications of earth's gravity.



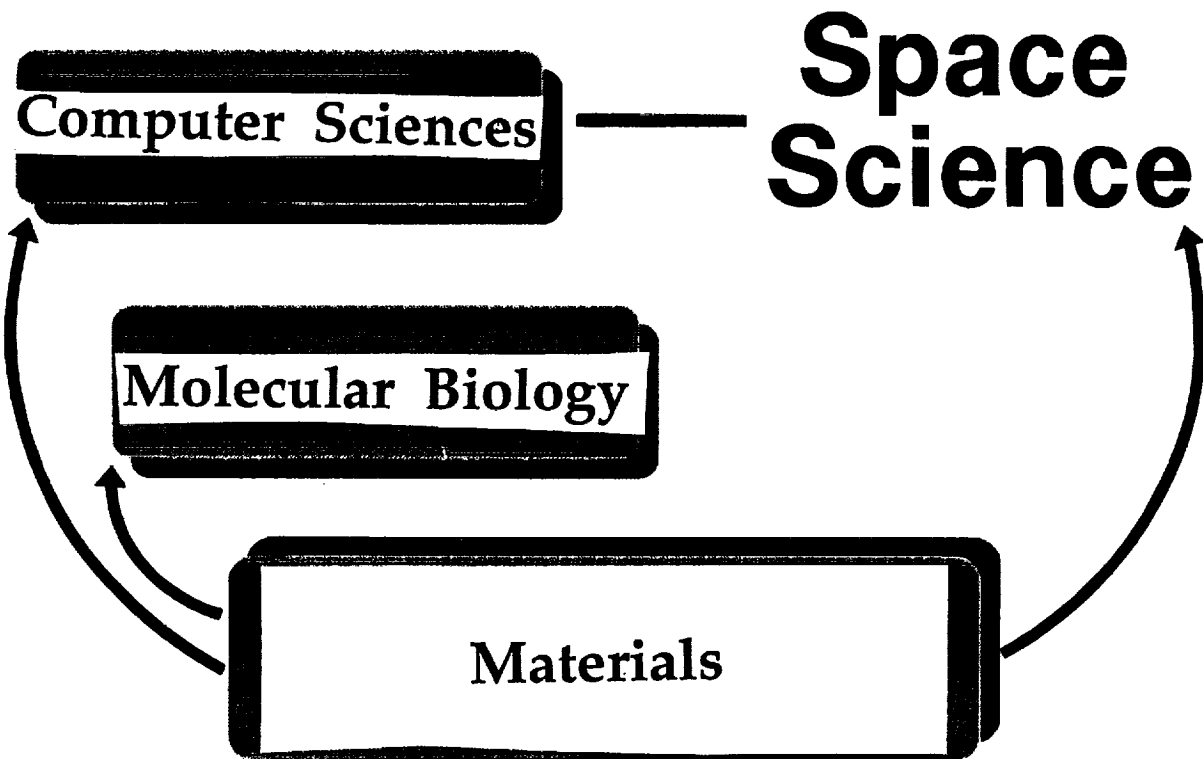
## **Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

### **First International Workshop on g-jitter**

Clarkson University, June 13-18, 1993

- What is g-jitter and how does it arise?
- How can it be predicted?
- How can it be measured?
- How can it be reduced and controlled?
- What does it do to fluids?
- How does it influence materials processing?
- How does it influence combustion?
- How does it influence biological processes?
- What R&D needs to be done?



## "IT'S A MATERIAL WORLD"



**Space Station Freedom Utilization Conference**

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

One of the most pervasive myths of space materials science is that "nothing is known for sure." This adage projects a disarming modesty. Even scientists have been known to fall into the arms of this myth in order to avoid the appearance of dogmatism and arrogance.



## ***Space Station Freedom Utilization Conference***

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

Space, Space, **Space Science** . . . what a wonderful, powerful sounding word! It instantly induces an atmosphere of pure rationality. It rings loudly a symphony of universal knowledge and understanding. It forcefully projects an aura of all encompassing order and of control.



## ***Space Station Freedom Utilization Conference***

Von Braun Civic Center Huntsville, Alabama August 3-6, 1992

In terms of quantity and in terms of analytic inference, it seems to me that space science and sports are very much parallel at the level of public concern. A lot of complexity, a lot of tactics, a lot of numbers, and a lot of perhaps poorly understood probabilistic judgements are present.



ALL ABOARD !

**REMARKS BY  
NASA ADMINISTRATOR DANIEL S. GOLDIN  
SPACE STATION UTILIZATION CONFERENCE  
HUNTSVILLE, ALABAMA  
AUGUST 4, 1992**

First, I want to thank John Bartoe, Jack Lee, Jed Pearson, Arnie Aldrich, and the rest of the NASA team for sponsoring this conference, and all of you for attending, including our international partners from ESA, Canada, and Japan. The more you learn about the possibilities for Space Station Freedom, the more excited you get.

One of the challenges we face as a society — certainly in this period of slow economic growth — is to focus not on the present, but on the future. I believe one of the reasons we're having problems with our economy is that we're not investing in our future to the degree we should.

When I was born in 1940, there were about two billion people on Earth. Today, that's more than doubled to 5.5 billion. And when I'm 100 years old, there'll be almost 10 billion. The people alive during my life have consumed more of the world's resources than all those living in prior generations of human history. We've already used more than we deserve, and now we're stealing from the future to buy the creature comforts of today.

We see it in government, where we have big deficits year after year. We see it in the corporate world, where the focus is on short-term profits, not long-term investment. Last year, the aerospace companies that invested the least in research and development saw their stock prices go up the most. While the rest of the world gears up for the economic competition of the post-Cold War era, America is chowing down on its seed corn to feed its belly today.

NASA scientist Rick Chappell, who works at Marshall, recently had an experience that illustrates this quite clearly. As he was jogging through the wildlife refuge that surrounds the launch pads at Cape Canaveral, he noticed an armadillo by the trail. Later, he looked up and saw an eagle.

He wrote later on, "I was struck by the contrast of their different approaches to life. Where the armadillo never looks up — concentrating only on its next meal, and oblivious to the world around it — the eagle soars quietly and majestically. It is not rooting around on the ground, but is striving for the high ground — seeking a vantage point from where to see the horizon and beyond."

America's first spacecraft that landed on the Moon wasn't called the armadillo; it was the Eagle — the symbol of America. This nation didn't become the greatest in the world by keeping its eyes on the ground. We are about broad visions, about looking over the horizon to see the future, and then blazing the trail for others to follow.

Technology is the fuel in our economic furnace. Technology creates growth. It creates whole new industries and new jobs — high paying, high quality jobs that add value to our economy.

NASA's research and development of advanced technology reaches out into the future to bring back opportunities to the world of today. Between 1979 and 1986, the new products generated from NASA science and engineering created over 350,000 new jobs. And believe me, this is a very conservative estimate, because once NASA invents something and makes it available to industry, we lose track of many byproducts that build on our pioneering work.

NASA has been driving technology forward ever since it was created. Apollo brought us untold bounty — especially in medical technology. Pacemakers, CAT scans, magnetic resonance imaging, intensive care monitoring equipment — all got their start because of research NASA needed to go into space. Mission Control's computer networks and software are the great grandfathers of what runs America's telephone system, banking and credit card networks, and airline computer networks.

But we can't keep living off Apollo's bounty. Currently, the hair of a scientist can turn gray waiting to get their first experiment on the shuttle, let alone the necessary follow-up research. A researcher can't make much progress doing one experiment every few years of so. We can't keep attracting good people to do space science if the research they need for their Ph.D. takes decades to complete.

The House of Representatives took a giant leap in the right direction last week when they voted to continue building Space Station Freedom. As I listened to the debate in the House Chamber and watched the vote tally grow, I was proud that in these difficult economic times, Congress saw the wisdom in investing in our future. It was not just a victory for NASA, but a victory for America and its international partners, who desperately needs the research and technology that will come from a permanent facility in space.

Space Station Freedom will revolutionize our way of life in the 21st century the same way the Apollo program did in the 20th century.

A permanent space station will be the place where we become a true space-faring nation — the place where we learn how to live and work in space. And it will be an example of how nations can unite and work together on projects of peace. All of our plans to build an outpost on the Moon and explore Mars depend on using Space Station Freedom to conduct the necessary life science research to protect astronaut's health from the effects of long duration space travel.

While these studies are going on, the space station will have dual use lab equipment where scientists can systematically study how living organisms and other materials behave without gravity. Essentially, the space station should be thought of as an international research center in orbit. Researchers from universities and the private sector, such as pharmaceutical companies, and our international partners will be able to share facilities on Freedom to facilitate basic research in materials processing biotechnology, and life sciences.

Biotechnology, for instance, is expected to be the big business of the 90s, going from \$4 billion a year currently to \$50 billion by the end of the decade — revolutionizing everything from agriculture to pollution control to health care. The commercial possibilities of biotechnology research in microgravity are mind-boggling. Product improvements developed from this research can fuel the furnace of our economy, creating new jobs and saving lives with new drugs and medical knowledge.

The stunning success of the U.S. Microgravity Lab on the last shuttle flight showed the vast potential of Space Station Freedom. On that flight was Astronaut Larry DeLucas of the University of Alabama at Birmingham, who's an expert in growing protein crystals, which are key to developing new drugs. The protein crystals grown on that flight were some of the largest and best-formed ever. Drug companies and other researchers had attempted to grow some of them on Earth to no avail. One drug company said they accomplished in two weeks an experiment that would have taken two years on the ground.

Yet despite this successful shuttle mission, Dr. DeLucas reached two conclusions: 1) that even a 14-day shuttle flight was not enough time for some of the experiments, and 2) a lab is needed in which scientists can interact and manipulate the experiments on a day-to-day basis.



That's why we need Space Station Freedom. The tidal wave of research that's waiting to be flown in space is what can let us live longer lives, in a cleaner environment, with a higher standard of living.

Clearly investing in the future is worth it, but at what cost? Many people don't realize that NASA receives only 1% of the federal budget — literally two cents a day for every American citizen. When you consider the enormous return on investment a space station will yield, Americans will get far more than their two cents' worth. For that small amount, the dividends we pay are enormous.

Life on Earth is better because of the lives we've sent into space. Thank goodness we have a president that understands how important space is to the strength, and competitiveness, and future economic growth of America. George Bush and Dan Quayle support a robust civil space program because they've seen how science and technology drives this nation forward. Our international partners know this as well, which is exactly why they've joined us.

Every time we have gone to the frontier, we've brought back more than we could ever imagine. Space is no longer just an experiment or a symbol. It's no longer a "luxury," the way automobiles and air travel were once viewed. Space is an essential part of our future in medicine, science, and technology.

We have to get bold again. We have to take risks and make investments so our children will have a better future. By reaching for the stars, we bring inspiration, hope, and opportunity back to Earth.

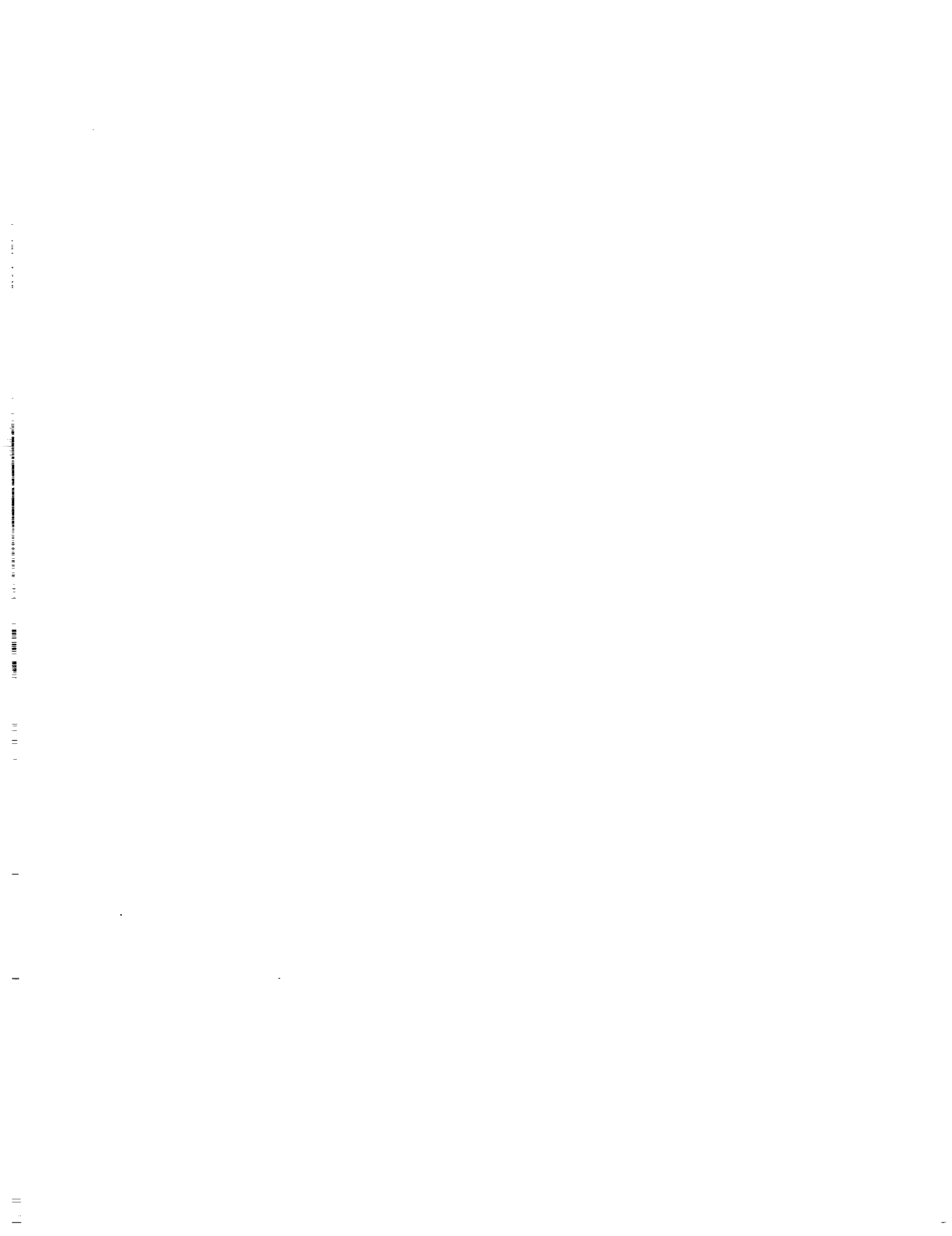
The "armadillos" of the world cannot defeat those of us who choose to be eagles. By flying higher, and seeing farther, we will use our vision to lead the way for the benefit of all humanity.

Let me leave you with a vision of what the space station could mean. It's early in the next century, and a woman in Montgomery, Alabama goes to her doctor to receive a hormone shot to prevent osteoporosis. That night, she sees on TV that a young astronaut at Kennedy Space Center just received the same shot to prevent bone loss before blasting off on the long journey to Mars.

That young astronaut grew up in Huntsville, where decades before, her father was a builder of Space Station Freedom, on which the life science research for long-term space flight uncovered the hormone that prevents osteoporosis. Her father's work on Space Station Freedom had inspired her to study organic chemistry so that when the time came, she'd be qualified to go search for signs of ancient life on Mars.

Space Station Freedom isn't just a job, or a chance to make money. It's a mission to move the human species into breaking the chains of gravity and becoming a multi-planetary society. Pursuing a mission of this monumental importance will lift civilization on Earth to new heights of health, wealth, and knowledge.

The exploration of space is the most inspirational adventure of all time. Our work offers hope that our children's world will be a better place than our own. Join me as we make this vision a reality.



*SESSION 3:  
LIFE SCIENCES RESEARCH*

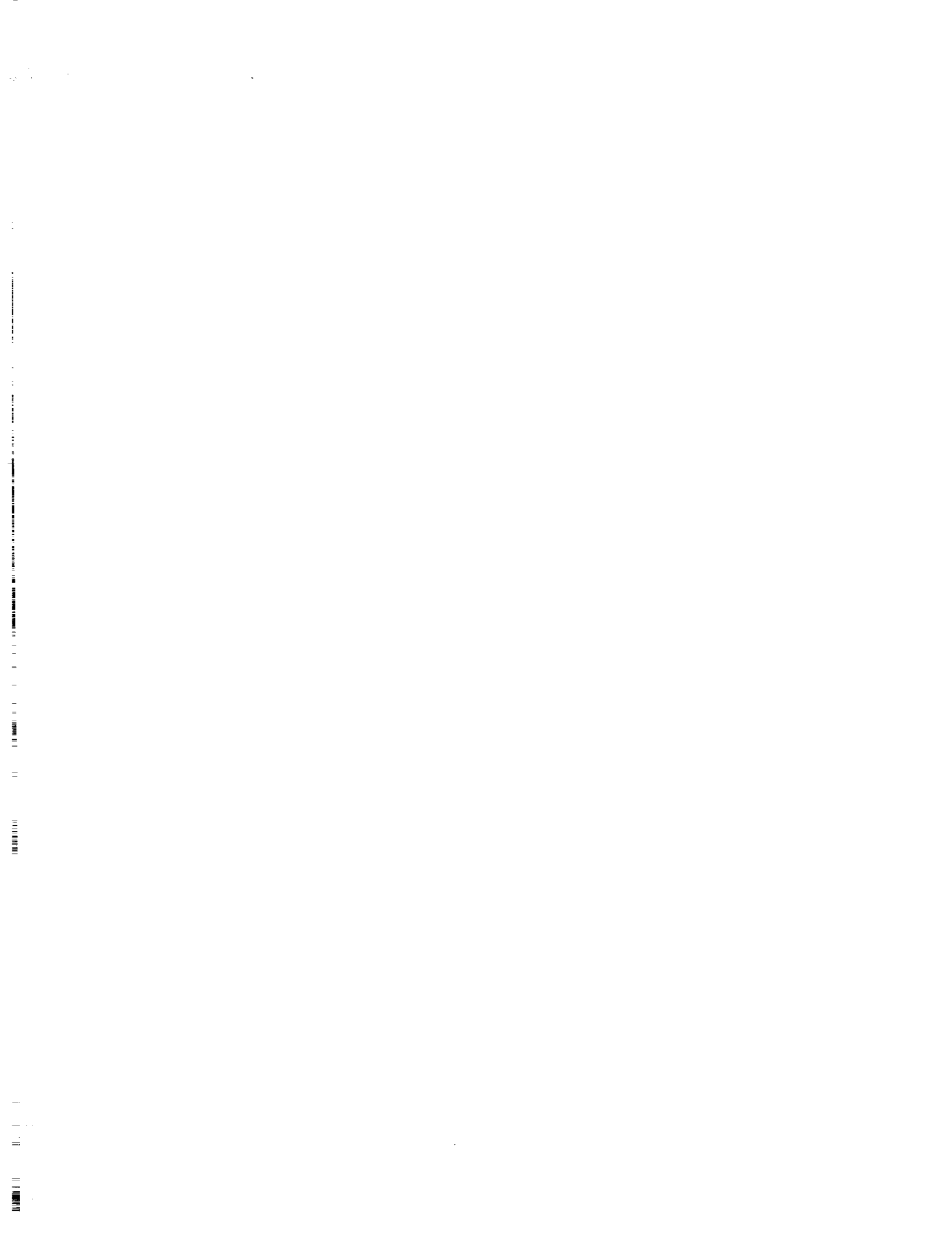
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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 5, 1992*

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**LIFE SCIENCES UTILIZATION OF SPACE STATION FREEDOM**

Presented by Lawrence P. Chambers  
Office of Space Science and Applications  
NASA Headquarters

**ABSTRACT**

Space Station Freedom will provide the United States' first permanently manned laboratory in space. It will allow, for the first time, long term systematic life sciences investigations in microgravity. This presentation provides a top-level overview of the planned utilization of Space Station Freedom by NASA's Life Sciences Division. The historical drivers for conducting life sciences research on a permanently manned laboratory in space as well as the advantages that a space station platform provides for life sciences research are discussed. This background information leads into a description of NASA's strategy for having a fully operational International Life Sciences Research Facility by the year 2000. Achieving this capability requires the development of the five discipline-focused "common core" facilities. Once developed, these facilities will be brought to the space station during the Man-Tended Capability phase, checked out and brought into operation. Their delivery must be integrated with the Space Station Freedom manifest. At the beginning of Permanent Manned Capability, the infrastructure is expected to be completed and the Life Sciences Division's SSF Program will become fully operational. A brief facility description, anticipated launch date and a focused objective is provided for each of the life sciences facilities, including the Biomedical Monitoring and Countermeasures (BMAC) Facility, Gravitational Biology Facility (GBF), Gas-Grain Simulation Facility (GGSF), Centrifuge Facility (CF), and Controlled Ecological Life Support System (CELSS) Test Facility. In addition, hardware developed by other NASA organizations and the SSF International Partners for an International Life Sciences Research Facility is also discussed.



# Life Sciences Utilization of Space Station Freedom



## Space Station Freedom Utilization Conference

August 5, 1992

Lawrence P. Chambers/SBF  
Life Sciences Space Station Freedom  
Program Manager

LP0158/LC-1



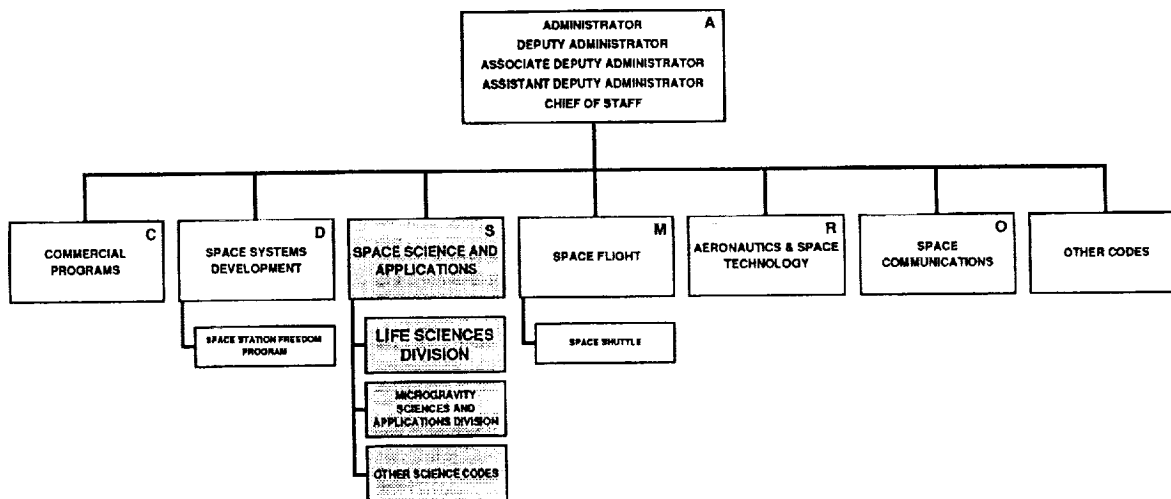
### Space Life Sciences Goals and Objectives

- Ensure the health, safety, and productivity of humans in space
- Acquire fundamental scientific knowledge concerning space biological sciences
- Expand our understanding of life in the Universe
- Develop an understanding of the role of gravity on living systems
- Provide for the health and productivity of humans in space
- Promote the application of life sciences research to improve the quality of life on Earth

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# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



## Historical Drivers for Space Life Sciences Research on Space Station Freedom

- 1958 NASA Charter called for the expansion of human knowledge of phenomena in the atmosphere and space
- 1987 Goldberg Report - Identified a complementary strategy combining basic life sciences and clinical research on Space Shuttle and early SSF
- 1988 Robbins Report - Endorsed the capability of basic research on the Space Station using plants, animals, and humans
- 1990 Augustine Report - Identified life sciences research as a major reason for building the Space Station
- 1992 NASA Advisory Council - Developed list of science questions to be answered by life sciences research on Space Station to enable a mission to the Moon or Mars





## Why Space Station for Biological Research?

- **First permanently manned laboratory in space**
- **Allows long-term, systematic investigations under controlled conditions**
  - Study growth and maturation over time
  - Examine living specimens through multiple generations (seed to seed to seed)
  - Replication based on experimental results
- **Statistical Analysis**
  - Adequate sample size
  - Appropriate control populations
  - Verification through replication



## Life Sciences Space Station Freedom Strategy

- **Life Sciences Space Station Freedom Program will be performed using a suite of discipline-focused “common core” facilities**
  - Five common core facilities being developed by NASA Life Sciences
  - Generic hardware will be used for numerous applications
  - Will be able to support the wide range of life sciences disciplines
  - Integral part of International Life Sciences Research Facility
- **Use Man-Tended Capability (MTC) to develop research infrastructure to establish an International Life Sciences Research Facility. Major objectives during the MTC Phase are:**
  - Bring facilities to orbit and install in pressurized volume
  - Verify and check-out hardware for proper operation
  - Perform science experiments (i.e. Spacelab class) that can be adequately performed in an MTC environment



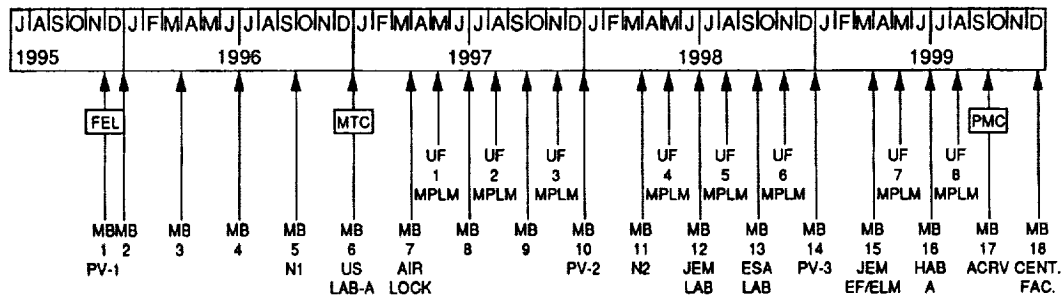
# Life Sciences Space Station Freedom Strategy (Continued)

- Once Permanent Manned Capability achieved (year 2000), life sciences capabilities will be fully operational
  - Can devote in-depth study to each discipline for extended periods of time (nominally 6 months)
  - Hardware items (including Experiment Unique Equipment) can be changed out to match particular discipline focus

LP0158/LC-1



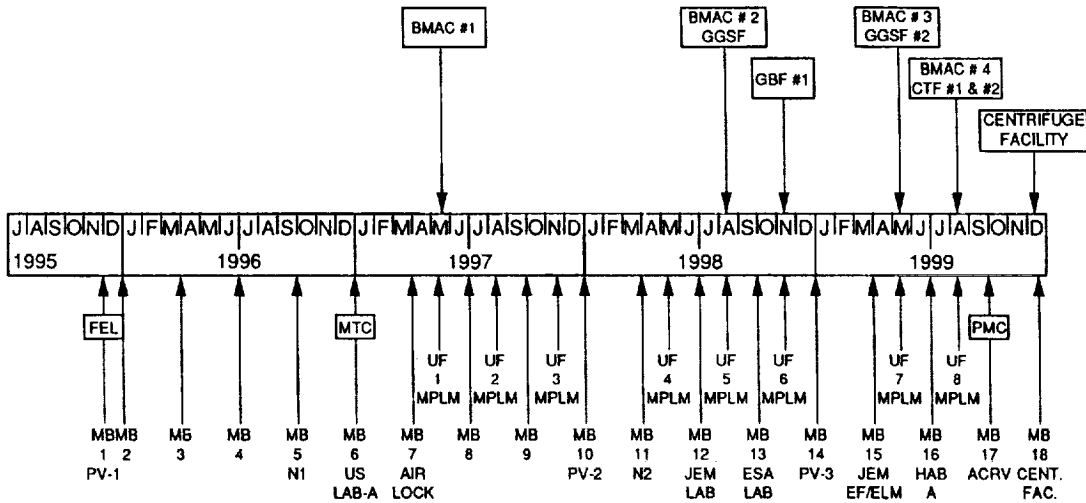
# Space Station Freedom Manifest



LP0158/LC-1



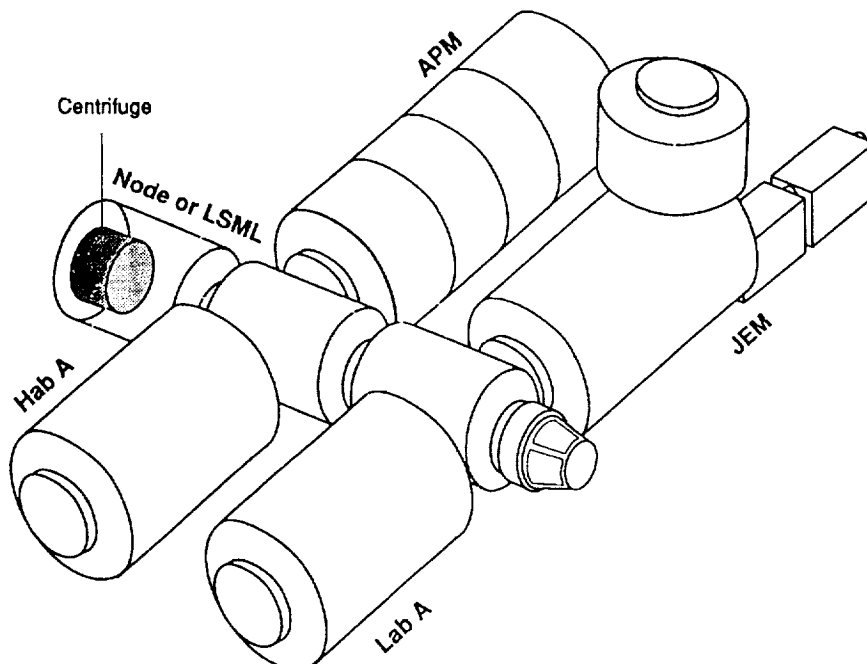
# Space Station Freedom Manifest



LP0158/LC-1

## POTENTIAL CENTRIFUGE LOCATION ON SPACE STATION FREEDOM

### Permanently Manned Capability





## Life Sciences Space Station Freedom Research Facilities

- **Biomedical Monitoring and Countermeasures Facility**
  - 4 rack facility
  - 1st launch—1997
  - Objective is to understand how to maintain crew health and performance for missions of 16 days and longer in a manner that minimally impacts mission operations and resources
- **Gravitational Biology Facility**
  - 2 rack facility
  - 1st launch — 1998
  - Objective is to provide the generic laboratory equipment needed to conduct basic life sciences research in cell biology, developmental biology, and plant biology
- **Centrifuge Facility**
  - 2.5 meter centrifuge plus two habitat racks
  - 1st launch — late 1999
  - Objective is to provide a suite of equipment to allow controlled studies on the influence of gravity on biological systems



## Life Sciences Space Station Freedom Research Facilities (Continued)

- **Gas Grain Simulation Facility**
  - 1 rack facility
  - 1st launch — 1998
  - Objective is to simulate and study fundamental chemical and physical processes of submicron to millimeter sized particles in microgravity to improve understanding of the formative processes of the universe
- **Controlled Ecological Life Support System (CELSS) Test Facility**
  - 2 rack facility
  - Launch — 1999
  - Objective is to study crop growth and productivity in microgravity under a broad range of environmental conditions



## Other Contributions to Life Sciences Research

Other facilities not funded by the Life Sciences Division will be utilized to achieve life sciences research objectives:

- **Laboratory Support Equipment/General Laboratory Support Facilities**
  - **Funded by Office of Space Flight/Office of Space Science and Applications**
  - **Will be shared by all SSF users (life sciences, materials sciences, commercial applications, etc.)**
  
- **International Partner Life Sciences Facilities**
  - **International Partners (ESA, NASDA, CSA) are planning to provide life sciences research hardware for SSF**
  - **NASA Life Sciences will coordinate closely with our International Partners so that an integrated International Life Sciences Research Facility is developed for SSF**
  - **Eliminates duplicate hardware**
  - **Provides most efficient use of limited resources**



## Rack Totals For Life Sciences Facilities

<b>Biomedical Monitoring and Countermeasures</b>	<b>4</b>
<b>Gravitational Biology Facility</b>	<b>2</b>
<b>Gas-Grain Simulation Facility</b>	<b>1</b>
<b>Centrifuge Facility</b>	<b>2 + Centrifuge System</b>
<b>CELSS Test Facility</b>	<b>2</b>
<b>Total Racks:</b>	<b>11 + Centrifuge System</b>



## Summary

- **LIFE SCIENCES LOOKS FORWARD TO SPACE STATION FREEDOM ERA**
- **First permanently manned laboratory in space**
- **Allows systematic, long-term life sciences investigations under controlled conditions**
- **Permits satisfactory statistical analysis of in-flight results**
- **Information obtained from life sciences research on Space Station Freedom will be utilized for lunar and Mars missions**

**LIFE SCIENCES RECRUITMENT OBJECTIVES**

Presented by Dr. J. Richard Keefe  
Office of Space Sciences and Applications  
NASA Headquarters

**ABSTRACT**

The goals of the Life Sciences Division of the Office of Space Sciences and Application are to ensure the health, well being and productivity of humans in space and to acquire fundamental scientific knowledge in space life sciences. With these goals in mind, Space Station Freedom represents substantial opportunities and significant challenges to the Life Sciences Division. For the first time it will be possible to replicate experimental data from a variety of simultaneously exposed species with appropriate controls and real-time analytical capabilities over extended periods of time. At the same time, a system for monitoring and ameliorating the physiological adaptations that occur in humans subjected to extended space flight must be evolved to provide the continuing operational support to the SSF crew. To meet its goals, and take advantage of the opportunities and overcome the challenges presented by Space Station Freedom, the Life Sciences Division is developing a suite of discipline-focused sequence. The research phase of the Life Sciences Space Station Freedom Program will commence with the utilization flights following the deployment of the U.S. laboratory module and achievement of Man Tended Capability. Investigators that want the Life Sciences Division to sponsor their experiment on SSF can do so in one of three ways: submitting a proposal in response to a NASA Research Announcement (NRA), submitting a proposal in response to an Announcement of Opportunity (AO), or submitting an unsolicited proposal. The scientific merit of all proposals will be evaluated by peer review panels. Proposals will also be evaluated based on relevance to NASA's missions and on the results of an Engineering and Cost Analyses. The Life Sciences Division expects that the majority of its funding opportunities will be announced through NRAs. It is anticipated that the first NRA will be released approximately three years before first element launch (currently scheduled for late 1995). Subsequent NRAs will be released on a rotating two year cycle.





# LIFE SCIENCES RECRUITMENT OBJECTIVES



Dr. J. Richard Keefe  
Program Scientist, Life Sciences Division  
Space Station Freedom Program



## SPACE LIFE SCIENCES GOALS AND OBJECTIVES

---

- **Ensure the health, safety, and productivity of humans in space**
  - **Acquire fundamental scientific knowledge concerning biological sciences**
- 
- **Expand our understanding of life in the Universe**
  - **Develop an understanding of the role of gravity on living systems**
  - **Provide for the health and productivity of humans in space**
  - **Promote the application of life sciences research to improve the quality of life on Earth**



# LIFE SCIENCES SPACE RESEARCH STRATEGY

**Phase I**  
**Mercury, Gemini, Apollo (1960's)**

**Objectives**

- Human Survival
- Adequate Human Performance for Lunar Trip

**Methodology**

- Pre-/Post-flight Human Studies
- Highly Limited Inflight Studies

**Phase II**  
**Skylab (1970's)**

**Objectives**

- Human Adaptation for 2-3 Months
- Biomedical Research Focus

**Methodology**

- Extensive Noninvasive Biomedical Studies
- Frequent Inflight Collection of Blood and Urine
- First Provocative Testing in Space

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# LIFE SCIENCES SPACE RESEARCH STRATEGY

**Phase I**

**Phase II**

**Phase III**  
**Spacelab, Middecks, COSMOS (1980's, Early 1990's)**

**Objectives**

- Focused Second Generation Biomedical Studies
- Initial Testing of Animals as Human Surrogates
- Initiation of Research in Basic Biology

**Methodology**

- Limited Invasive Studies on Humans
- Invasive Animal Studies
- Sophisticated Laboratory Equipment
- Plant and Cell Biology Facilities

**Phase IV**



## Phase IV

### Late Spacelab, MIR, Early Space Station Freedom (Mid-Late 1990's)

#### Objectives

- Third Generation Biomedical Studies (Countermeasures Emphasis)
- Development of Animal Models
- Develop Foundations for Exploration
- Fundamental Studies in Basic Biology

#### Methodology

- Integrated International Laboratories
- Comprehensive Laboratory Research Facilities
- Carefully Controlled Human, Animal, and Plant Studies
- Replications as Required

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## IMPETUS FOR SPACE STATION FREEDOM

"...back to the Moon, back to the future. And this time, back to stay. And...a journey into tomorrow...a manned mission to Mars." President George Bush, 1989.

"...the Space Station is deemed essential as a life sciences laboratory, for there is simply no Earth-bound substitute. The Space Station is a critical next step if the U.S. is to have a manned space program in the future." Report of the Advisory Committee on the Future of the U.S. Space Program, 1990.

"[Space Station] Freedom will provide the means to acquire basic knowledge on mechanisms of gravity perception while paving the way for extended-duration exploration missions with humans." Space Life Sciences Strategic Plan, 1992.

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## RECENT RECOMMENDATIONS TO THE LIFE SCIENCES

- Life Beyond the Earth's Environment: The Biology of Living Organisms in Space. NRC Space Science Board. Neal S. Bricker, Chairman. 1979
  - Focused on science priorities for Spacelab missions
- A Strategy for Space Biology and Medical Science: for the 1980s and 1990s. NRC Space Science Board. Jay M. Goldberg, Chairman. 1987
  - Focused on developing priorities for late STS and early space station program
- Exploring the Living Universe: A Strategy for Space Life Sciences. A Report of the NASA Life Sciences Strategic Planning Study Committee. Frederick C. Robbins, Chairman. 1988.
  - Focused programmatic requirements for Space Station Freedom
- Life Sciences Discipline Working Group Science Plans. 1991
  - Focused on discipline specific science
  - Developed prioritized list of critical questions within each discipline
- NASA Advisory Council, Aerospace Medicine Advisory Committee Report. Harry Holloway, Chairman. 1992
  - Focused on meeting requirements for Moon/Mars missions
  - Developed prioritized list of science questions across disciplines

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## SPACE LIFE SCIENCES CUSTOMERS

1. MISSION IMPLEMENTORS
  - Requirement Capability for human exploration of space
  - LSD Product Deliverables identified by AMAC strategy
2. SCIENCE COMMUNITY
  - Requirement Access to space for conduct of scientific research
  - LSD Product Support of science described in discipline plans
3. PUBLIC
  - Enhance the quality of life on Earth
  - Stimulate the imagination
  - Motivate science and engineering education

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## CATEGORIES FOR LIFE SCIENCES DISCIPLINES

### *Human Physiology and Performance*

Behavior, Performance and Human Factors  
Regulatory Physiology  
Cardiopulmonary  
Musculoskeletal  
Neuroscience

### *Life Support*

Environmental Health  
Radiation Health  
Life Support, including CELSS

### *Gravitational Biology*

Cell and Developmental Biology  
Plant Biology

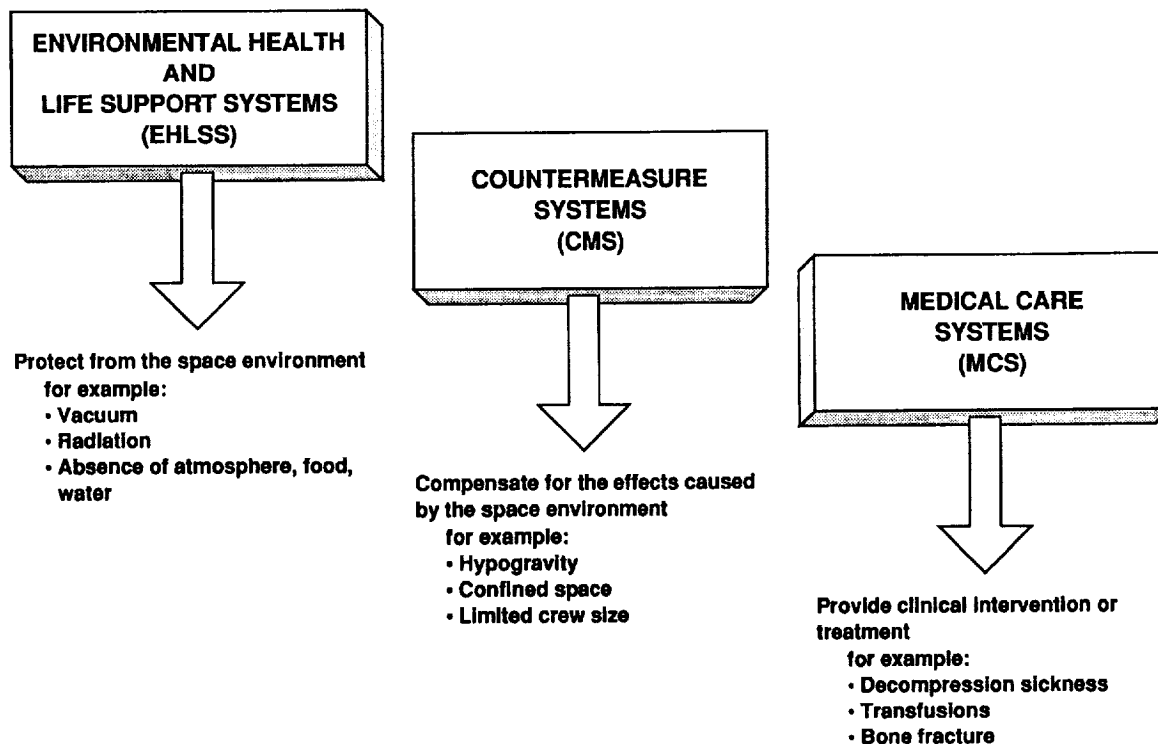
### *Exobiology*

Exobiology  
Planetary Protection

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## ENABLING LIFE SCIENCES RESEARCH THRUSTS FOR HUMAN EXPLORATION MISSIONS





## DEFINITIONS OF CRITICALITY, ROBUST AND CONSTRAINED PROGRAMS

Category	Criticality			
	1	2	3	4
EHLSS	<b>Constrained</b>		<b>Robust</b>	
CMS				
MCS				
Enabled Science	<b>SEI CRITICALITY NOT APPLICABLE</b>			
Basic Science				

**Criticality 1:** Consensus that answer is required for Mars mission (known effect and known problem for mission).\*

**Criticality 2:** Answers might be required, science basis to evaluate risk is not adequate.

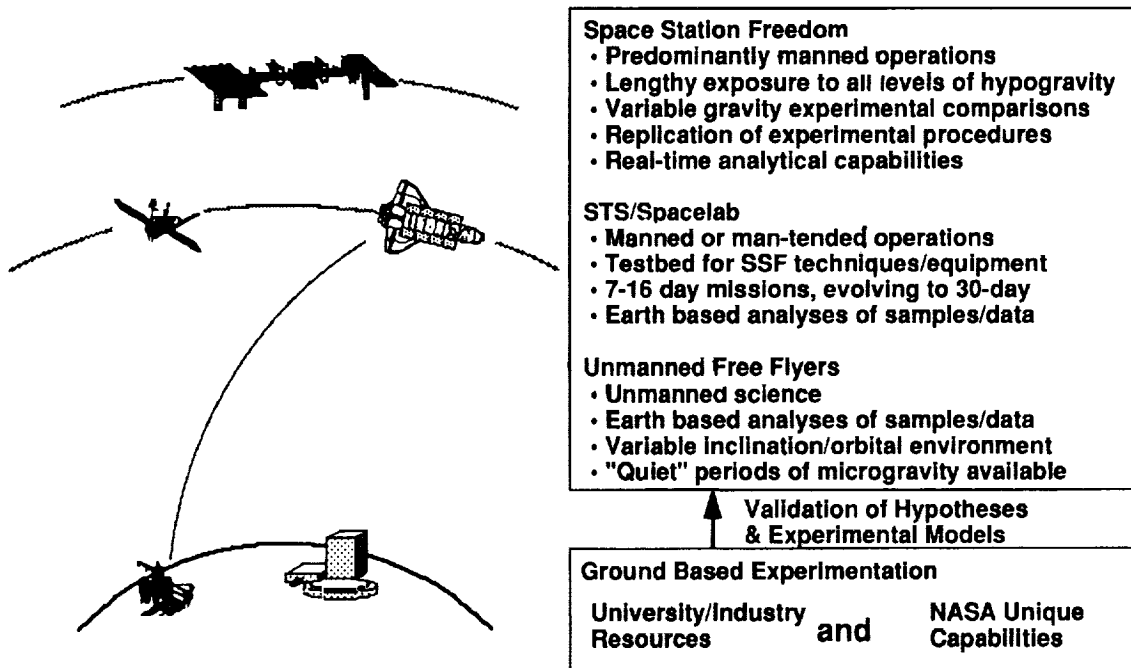
**Criticality 3:** Required for practical optimization of resources (or countermeasure effectiveness) and minimization of risk.

**Criticality 4:** Important science that is relevant to exploration mission.

\* Crewmembers must be able to effectively perform mission tasks in transit vehicles and on planetary surfaces; and must recover, in a reasonable time, upon return to Earth



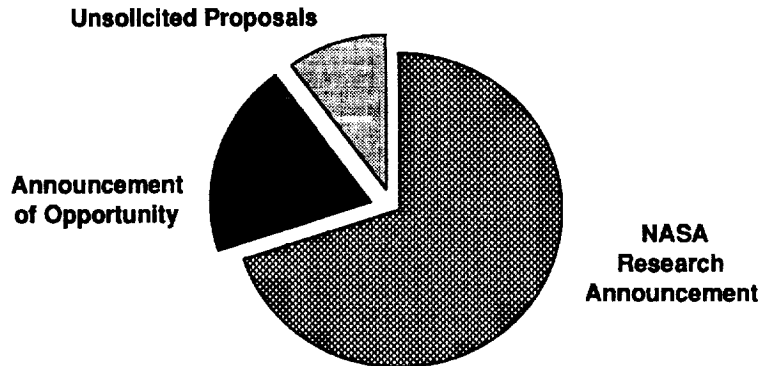
## LIFE SCIENCES RESEARCH RESOURCES




Life Sciences planning matches Science Requirements with the most appropriate Platform



## METHODS OF FUNDING



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 <b>SOLICITED PROPOSALS</b>		
	NASA Research Announcements (NRA)	Announcements of Opportunity (AO)
Types of investigations	<ul style="list-style-type: none"> <li>ground-based research</li> <li>flight experiments not requiring major hardware development</li> </ul>	<ul style="list-style-type: none"> <li>flight hardware development oriented projects</li> </ul>
Funding mechanism	<ul style="list-style-type: none"> <li>usually grants</li> </ul>	<ul style="list-style-type: none"> <li>usually contracts</li> </ul>
Funding level	<ul style="list-style-type: none"> <li>varies, depending on requirements/justification</li> </ul>	<ul style="list-style-type: none"> <li>varies usually larger than NRA due to complex nature of hardware development</li> </ul>
Evaluation process	<ul style="list-style-type: none"> <li>peer reviewed science</li> <li>NASA programmatic evaluation</li> </ul>	<ul style="list-style-type: none"> <li>peer reviewed science</li> <li>NASA programmatic evaluation</li> <li>more involved "CEM" evaluation than NRA</li> </ul>

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## UNSOLICITED PROPOSALS

- Investigator initiated
- Mailed directly to appropriate Program Manager
- Evaluated like NRA/AO
- Appropriate for small, low cost experiments utilizing existing hardware/facilities

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## SOLICITATION OF RESEARCH ON SPACE STATION FREEDOM

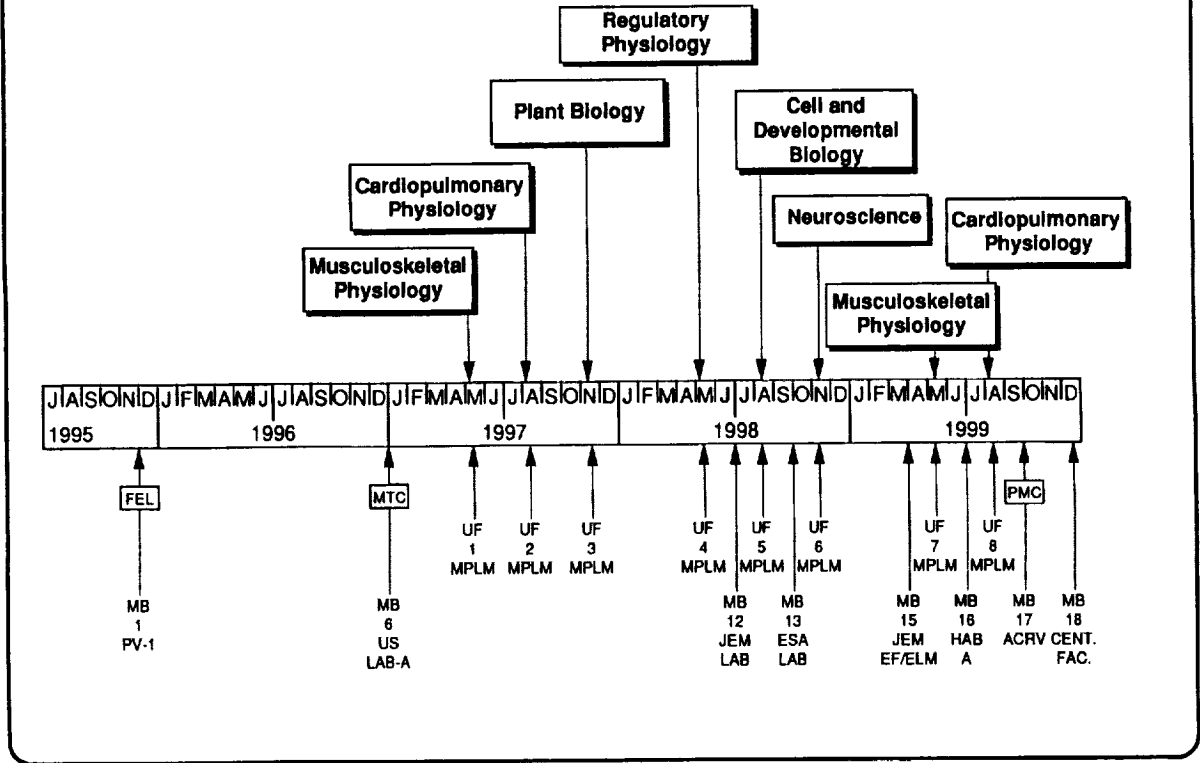
- Primary method of solicitation/funding will be through discipline focused NASA Research Announcements (NRA).
  - Discipline sequence will be determined in consultation with the scientific community and our international partners.
- NRAs will announce submittal dates for established discipline sequences.
- Nominal two year cycle from solicitation to funding.

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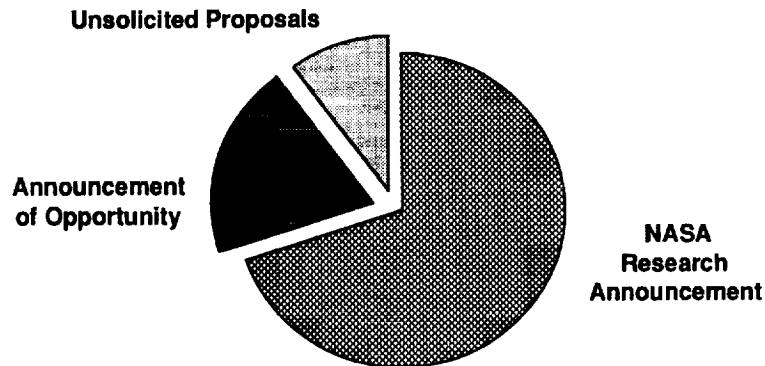
## EXAMPLE DISCIPLINE FOCUSED INCREMENTS



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## METHODS OF FUNDING



**Target Funding Range \$60 - \$100 K per year**



## PROPOSAL EVALUATION CRITERIA

- Scientific merit - determined by an extramural peer review panel
- Relevance to NASA's mission - determined by NASA
- Engineering, Cost, and Management Review - standardized review performed by NASA. Used to assess costs, development risks, hardware availability, potential incompatibilities, and the technical aspects of implementing the proposed investigation.

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## TYPES OF FLIGHT OPPORTUNITIES ON SPACE STATION FREEDOM

### Utilization of common-core facilities

- Nominal use
  - facilities used as provided, no additional hardware built
  - solicitation to integration/flight cycle = 2 years
- Experiment Unique Equipment required
  - additional hardware or significant modifications to facilities required
  - solicitation to integration/flight cycle > 2 years
- Small and Rapid Response Payloads
  - small experiments
  - integrated tissue sharing protocols
  - integration/flight may be accomplished in 6 months

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## SUPPORT PROVIDED BY THE NASA GRANT

- Experiment definition, development, and ground based data collection.
- Development of Experiment Unique Equipment (EUE) - if approved.
- Postflight data analysis

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## OTHER SUPPORT PROVIDED BY NASA

- Experiment Integration
  - Physical
  - Analytical
- Use of common-core facilities and hardware
- Mission operations/ logistics
- Inflight data collection
- Data Archive

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**BIOMEDICAL MONITORING AND COUNTERMEASURES FACILITY**

Presented by Donald F. Stewart, M.D.  
Life Sciences Division  
NASA Headquarters

**ABSTRACT**

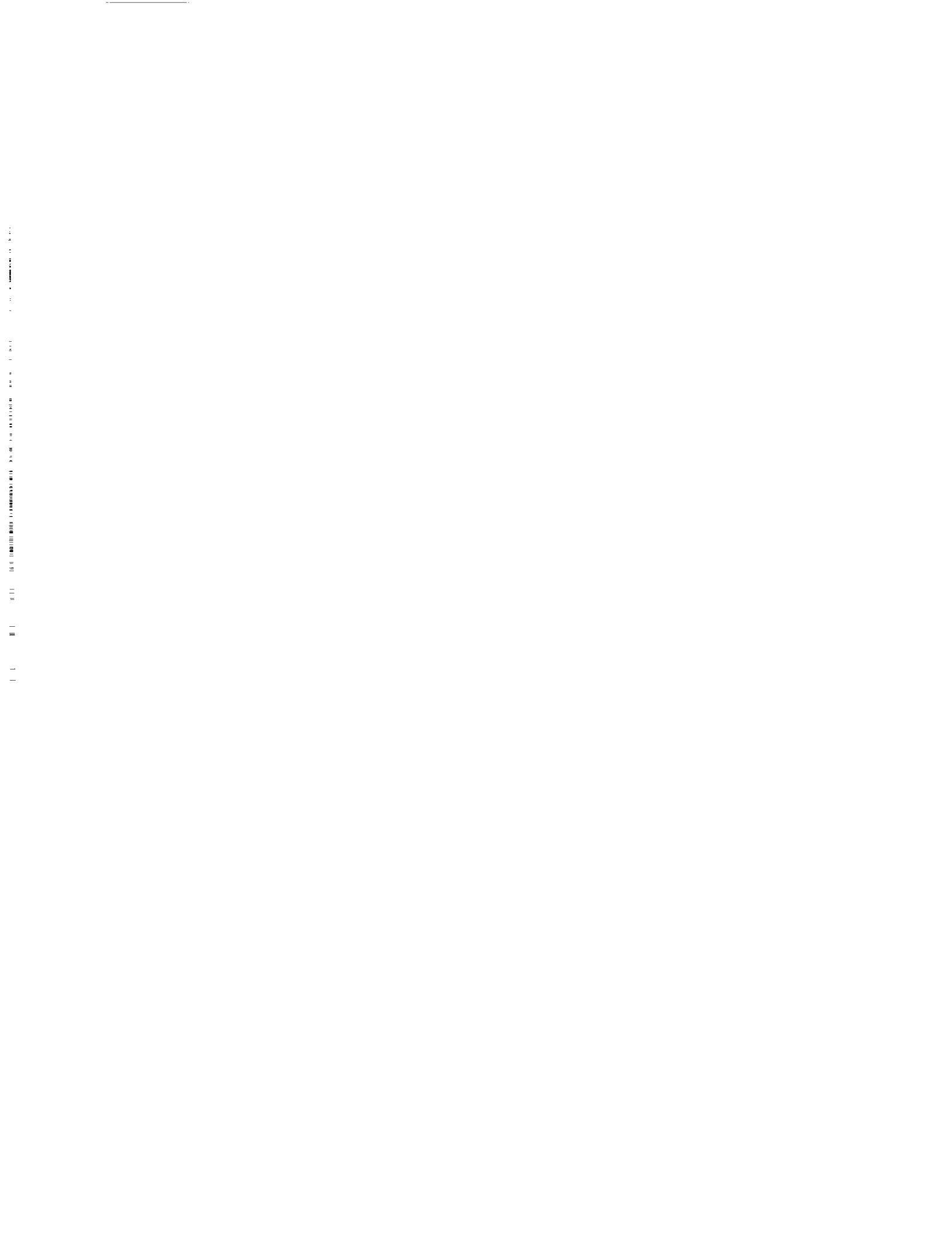
The Space Station Freedom Program (SSFP) represents the transition within the US Space program from the "heroic" era of space flight (characterized most vividly by the Mercury and Apollo programs) to an epoch characterized by routine access to the space environment. In this new era, the unique characteristics of the microgravity environment will enable new types of research activities, primarily in the life sciences, materials science, and biotechnology fields.

In addition to its role as a "microgravity science laboratory," Space Station Freedom (SSF) constitutes the operational platform on which the knowledge and skills needed to continue our exploration of space will be acquired. In the area of spacecraft operations, these skills include the ability to assemble, operate, and maintain large structures in space. In the area of crew operations, the potentially harmful effects of extended exposure to microgravity must be understood in order to keep the crew mission capable. To achieve this goal, the complex process of physiological deconditioning must be monitored, and countermeasures utilized as needed to keep the individual crew members within acceptable physiological limits.

The countermeasures program under development for the SSF Program is titled the Biomedical Monitoring and Countermeasures (BMAC) program. As implied by the name, this activity has two primary products, a biomedical monitoring element and a countermeasures development effort. The program is a critical path element in the overall SSF Program, and should be considered an essential element of operations on board the space station.

It is readily apparent that the capability to both protect and optimize the health and performance of the human operators onboard SSF will be a critical element in the overall success of the SSFP. Previous experience within the Russian space program has demonstrated that the time required for countermeasures on extended missions can become a monumental operational burden. Therefore, one of the primary objectives of the countermeasures development activity will be to design and implement countermeasures which are significantly more effective than the existing generation. Other primary objectives include the following:

- To set health and human performance standards for all mission phases.
- To determine critical issues that affect performance or return to flight status.
- To develop and implement monitoring systems to follow health and performance status.
- To understand risk, and balance the resource costs of countermeasures vs. the benefit gained.



# Program Overview

Don Stewart, M.D.

BMAC Program Manager

## A Fact

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**EITHER SINGLY OR IN COMBINATION, THESE HUMAN RESPONSES ARE DIRECT LIMITATIONS TO MANNED SPACE FLIGHT MISSIONS**

- Bone density is reduced
- Muscle strength and mass are reduced
- Neurological changes affect gait, stability, and cardiovascular function on return to a gravity environment
- Wound healing appears to be impaired
- Body fluid volume and blood volume, including both plasma volume and red blood cells, are reduced
- Orthostatic intolerance and exercise capacity loss is manifested on re-exposure to gravity
- Space motion sickness is experienced during the first week of space flight by about half of the crewmembers
- Cardiac arrhythmias have been seen during extravehicular activity and other mission phases
- Immunity is impaired after prolonged space flight
- Absorption of medications is impaired
- Hormone blood levels and function are altered
- Interpersonal conflicts, irritability and fatigue are increased on long duration space flight missions

# Mission Needs Statement

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- NASA plans to continue to fly humans in space
- First, NASA must be sure in so doing that it does not subject humans to a level of risk that is not understood and acknowledged to be appropriate for NASA's overall mission
- Second, NASA must be sure in so doing that human participants are capable of providing the level of activity and performance required to assure mission success

**NASA has a need to conduct a continuing program of biomedical monitoring and countermeasure development to assure that space flight involving humans does not contain unknown or unmitigated risks at a level that would harm participating crewmembers or cause mission success to be impacted**

*BMAC - Biomedical Monitoring and Countermeasures is that program*

BMAC Program Review 10/2003 11:29 AM

## Background

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- Space Medicine as a speciality is in the early stages of discipline development
  - We (including the Russian experience) do not understand the full extent of human risk associated with space flight or the means to mitigate that risk to acceptable levels (more details later in briefing)
- Increasing mission durations (and complexity) carry progressively higher risk levels
- CHeCS (Crew Health Care System) as a stand-alone capability was not intended to accomplish the goals and objectives of BMAC
- BMAC provides the essential medical data base in support of current and future programs (including SEI)
- If human space flight is to successfully extend beyond 16 days, this is a "must do" and not a "could do" program
  - We assume that there will be a continuous progression of the human presence in space



# Specific Mission of BMAC

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Assure the **health, well-being, and performance** of humans during space operations through a process of diligent monitoring of human adaptation and performance and application of countermeasures

- **Health**
  - Maintain crewmembers below a clinical horizon
  - Provide information to the clinical health care program so that clinical and long-term health issues are integrated
- **Well-being**
  - Assure optimal crew performance by maintaining a positive quality of life
  - Monitoring and countermeasures must be efficiently integrated into the operational environment
- **Performance**
  - Humans must be able to perform in space and on return to earth according to the requirements of each mission

BMAC Program Review 7/19/03 10:54 AM

## BMAC Goals

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- To understand and maintain crew health and performance on missions 16 days and longer
- To provide systems and procedures which minimize the time required to return to flight status

# Agency Goals

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- **It is NASA's policy when humans travel in space**
  - Medical risk is reduced to an acceptable minimum level
  - They are provided medical care and support to enable them to accomplish the goals of the mission
- **Recent Presidential directives have provided a major challenge to that policy**
  - "establishing a permanent human presence in space"
  - This requires a level of effort and priority above that needed for current short duration flights (16 days or less)
- **Advisory groups have been unanimous in their support for a vigorous human life science program**
  - Robbins, Augustine, Stafford, AMAC

BMAC Program Review 7/15/92 2:37 PM

## BMAC Objectives

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- **To set health and human performance standards for all mission phases**
- **To determine critical issues that affect performance or return to flight status**
- **To develop and implement monitoring systems to follow health and performance status**
- **To develop, implement, and validate countermeasures that mitigate the negative biomedical consequences of mission 16 days and longer**
- **To understand risk, and balance the resource costs of countermeasures vs. the benefit gained**

# Typical Programmatic Questions Addressed by BMAC

---

- What are the optimal biomedical monitoring scenarios and schedules?
- Are there physiological, biochemical, or behavioral changes that limit mission duration?
- Do these changes limit the number of missions an individual can fly?
- How can crew productivity be optimized on flights of increasing duration & mission complexity?
- What countermeasures are needed? When?
- Is there an optimum mission length?
- How can the operational impacts from monitoring & countermeasures application be minimized?
- Are there crew selection criteria related to observed changes that need to be implemented?
- What major program/mission design considerations should be considered during early planning and development?

BMAC Program Review 7/9/92 1:08 PM

## Primary Deliverables

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- Risk levels associated with un-mitigated human adaptation to and operation in the space flight environment
- Evaluation of the impact of these human risks on mission performance and success
- A set of operational countermeasures that reduce unacceptable human risks to acceptable levels
- Biomedical monitoring equipment, procedures, data analysis techniques, and selection criteria that provide individualized risk status during all mission phases
- Human-machine interfaces and habitability requirements
- A set of recommendations for mission planning and operations that integrate the knowledge of individual human risk and the resultant impact on mission risk
  - With sufficient advance that the information can “enable” the design of future manned programs and missions

MEDICALLY QUALIFYING THE CREW

# **Level I Requirements/Program Discipline Areas**

---

- **BMAC shall be organized around 5 discipline areas**
  - Neurosensory
  - Cardiovascular/Pulmonary
  - Musculoskeletal
  - Regulatory Physiology
  - Behavior and Performance
- **Critical issues shall be defined within these categories**
- **Monitoring capabilities shall be defined within these categories**
- **Risk assessment studies shall be defined within these categories**
- **Countermeasures shall be defined within these categories**

# **Level I Requirements/Investigative Approaches**

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- **Detailed investigative approaches shall be developed which includes three main functions for understanding risk**
  - **Operational Biomedical Monitoring (during all feasible scheduled operational activities)**
  - **Functional Monitoring - standardized, periodic testing of all body system categories in order to detect and monitor adaptive trends**
  - **Risk Assessment Studies - test protocols designed to evaluate specific risk issues**
- **A robust process shall be established which integrates the information from these three activities and along with any clinical health information provides an overall health status assessment capability**

# Operational Monitoring

---

- **Monitoring during all operational activities in which human responses provides essential information associated with risk assessment - specific monitoring depends on mission design**
  - EVA
  - During utilization of verified countermeasures
  - Launch
  - Landing/recovery
- **Basic physiological and performance measurements**
  - Heart rate
  - EKG/EMG
  - Blood pressure
  - Respiration rate
  - Body temperature/skin temperature
  - Motion
  - Doppler blood flow
  - Performance parameters
- **Specific monitoring tailored to operational activity**
- **Monitoring activities must not increase risk of accomplishing the operational activity**

# Functional Monitoring

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- **Periodic functional tests conducted on each crewmember through the application of standardized stress and other tests**
  - Determine status of all body systems
- **Determine the time course and magnitude of adaptation**
  - Efficacy of applied countermeasures
  - Determine what changes in countermeasure procedures should be implemented
- **Attempt will be made to develop an optimized test set which will not require major changes during the course of the BMAC program**
- **Baseline measurement set**
- **Provides the major input for a long-term standardized data base of human responses to space flight**
- **Monitoring Schedule**
  - Weekly (2 hours per crewman)
  - Bi-weekly (3 hours per crewman)

# Functional Monitoring - Cont'd

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- **Specific test protocol TBD but considerations include**
  - Single level known workload aerobic exercise test
  - Focused muscle strength test
  - Single level LBNP test
  - Selected pulmonary function tests
  - Sleep monitoring
  - Selected blood and urine tests
  - Selected neurosensory tests
  - Selected anthropometric tests
  - Selected behavioral and performance measurements
- **Approach is to look at end-point parameters which indicate overall system status**
- **Contingency measurement/evaluation systems available to “follow-up” on any anomalous responses**

## Risk Assessment Studies

---

- **A basic premise of BMAC is the ability to assess and understand human risk related to adaptation and operations in the space flight environment**
  - These risks are not the same as safety issues being addressed by SR&QA
- **As noted previously, there is not currently a sufficiently complete data base to assign risk levels for the known issues (and new issues that may be uncovered)**
- **It will be necessary to implement specific test protocols or investigations designed to elucidate the necessary risk information**
- **AMAC Report used as a driving function for investigations**
- **Risk assessments are different from operational monitoring or functional testing**
  - Specific investigative protocols with required number of subjects conducted over an identified number of flights
  - As required to identify specific risk parameters and/or levels
  - May or may not involve assessment of specific countermeasures
  - While exact manifesting of these studies is TBD, current experience has demonstrated a need of 1.5 hours/day/crewmember

# Involving the Scientific Community

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- One of NASA's charters is to provide access to space for conducting research
- The operational medical certification of humans and space flight systems is a NASA *responsibility* which cannot be "transferred"
- However, the breadth and challenges of BMAC will require that the expertise and knowledge of the life science community be utilized and included in the program
- BMAC will provide this collaboration within schedule and budgetary resources
- Two recommended approaches will be detailed later that address this issue
  - Resident Discipline Expert (RSE) Program
  - Focused NASA Research Announcements (NRAs)

## Extramural Participation - Flight Opportunities

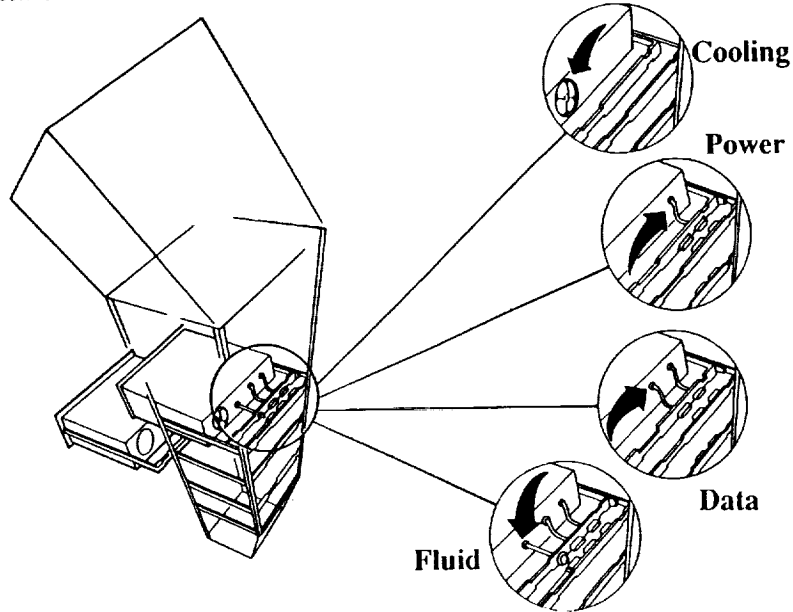
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- BMAC traffic model based on 12/91 OSSA plan:
  - 1 double rack launched in 1997 (Phase 1)
  - 1 double rack launched in 1998 (Phase 1)
  - 2 double racks launched in 1999 (Phase 2)
- SSF traffic model provides 3 "utilization flights" (UF - assumed 13 day durations) in 1997, 3 UFs in 1998, and 2 UF in 1999
- Additional 12 "Mission Build" (MB -assumed 7 day duration) flights projected through the same timeframe

# Standard Interface Rack - Concept

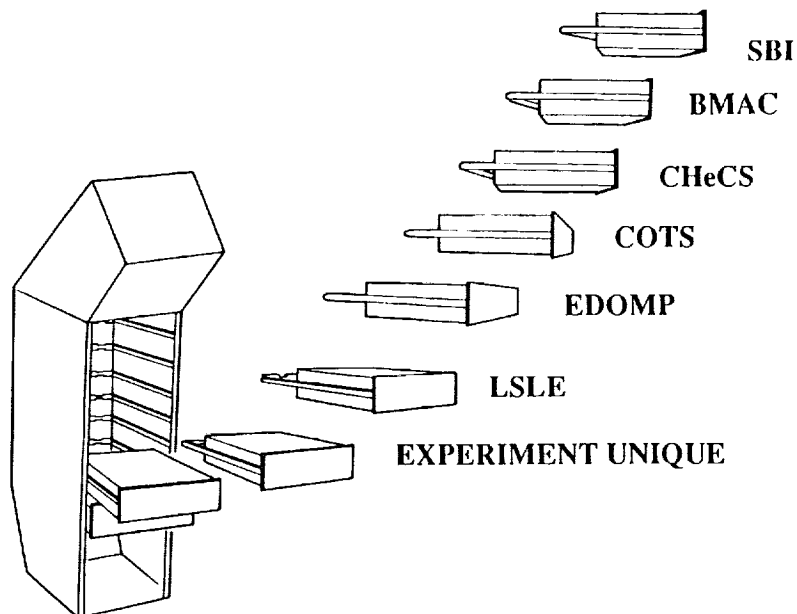
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## Hardware to Rack Standard Interfaces



# Standard Interface Rack - Applications

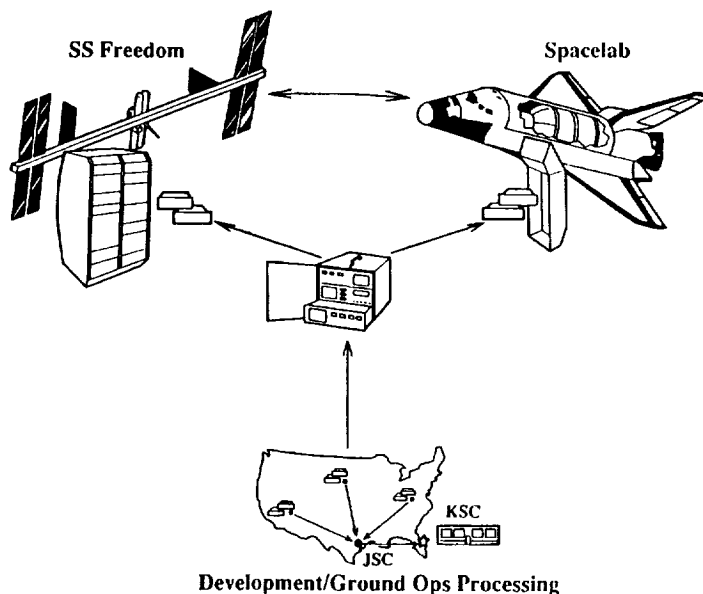
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# Standard Interface Rack - Utilization

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## Deliverables - End-Items/Rack 1

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### Rack Mounted

Activity Monitor (has stowed component)  
Automatic blood pressure system (ABPS)  
Body temperature - core  
Computer system, experiment control  
Data recorder, 12 channel  
Echocardiograph/doppler blood flow  
Gastrointestinal pH capsule system  
Physiological bio-potential recorder-12 lead  
Pulmonary analysis system - mass spec  
Pulse oximeter  
Pulse pressure measurement device  
Refrigerator/freezer  
Specimen labelling device

### Stowed

Ambulatory blood pressure monitor (ABPM)  
Bar code reader  
Biowaste ID tag generator  
Blood centrifuge  
Blood collection systems  
CMI multi-test hypersensitivity system  
pH sensitive strips in fluid handling tools  
Fluid handling tools and system  
Electrode impedance meter  
Hematocrit centrifuge  
Lower body negative pressure (LBNP)  
Physiological monitor (Vitalog)  
Stress and strain devices  
Holter monitor  
Temperature measurement kit  
Urine sample device  
Voice recorder

### Other Location

Dynamometer, isometric-isokinetic  
Ergometer, dual cycle  
In-suit doppler bubble detector

## **Deliverables - End-Items/Rack 2**

---

### **Rack Mounted**

Auditory evaluation system  
Biopotential Acquisition system  
Breath hydrogen analyzer (microlyzer)  
Carotid sinus baroreceptor stimulator  
CO delivery/measurement system  
Glovebox (GFE)

### **Stowed**

Eye & head movement detection system  
Gustatory & olfactory threshold tester  
Physiological monitoring system (PMS)  
Proprioceptive tester  
Pulmonary analysis system - K2  
Saliva collection unit  
Spirometer  
Three-D linear accelerometers (translation)  
Video/data collection system

## **Deliverables - End-Items/Rack 3**

---

### **Rack Mounted**

Anthropometric measurement system  
Body position detection system  
Incentive field recording system S/W  
Mass measurement - whole body  
Microbial analyzer  
Microscope system  
Motion analysis system  
Musculoskeletal overload trainer  
Small mass measurement device  
Visual sensory evaluation  
Visual stimulator

### **Stowed**

Macro-zoom lens  
Middeck posture platform  
Phantom head/torso  
Sample prep device

# Deliverables - End-Items/Rack 4

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## Rack Mounted

Cognitive performance tester

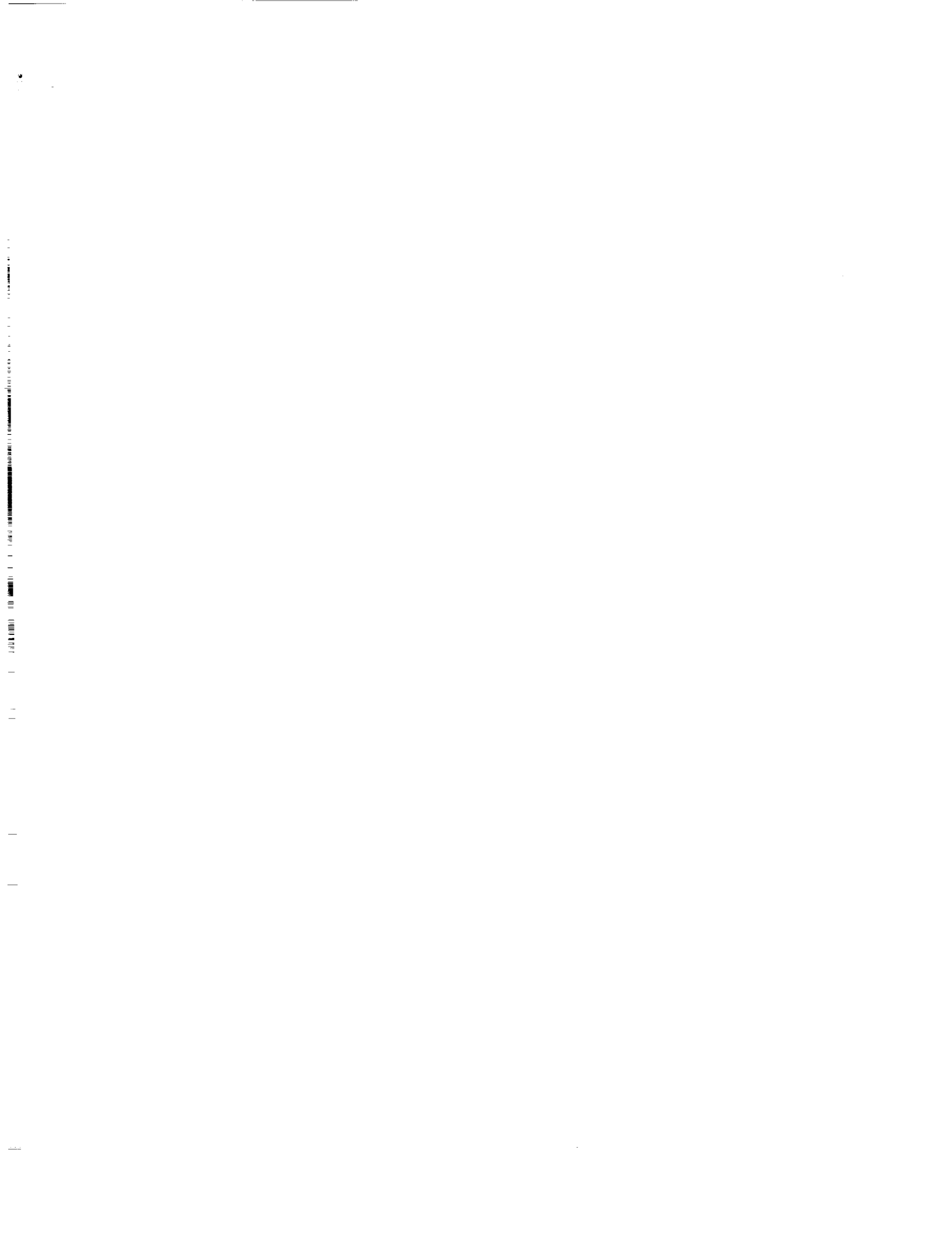
Electromagnetic stimulator

Rotating chair system

Virtual reality system

## Stowed

Muscle biopsy kit



**GRAVITATIONAL BIOLOGY FACILITY ON SPACE STATION:  
MEETING THE NEEDS OF SPACE BIOLOGY**

Prepared by Katherine Allen and Dr. Charles Wade  
GE Government Services  
NASA Ames Research Center

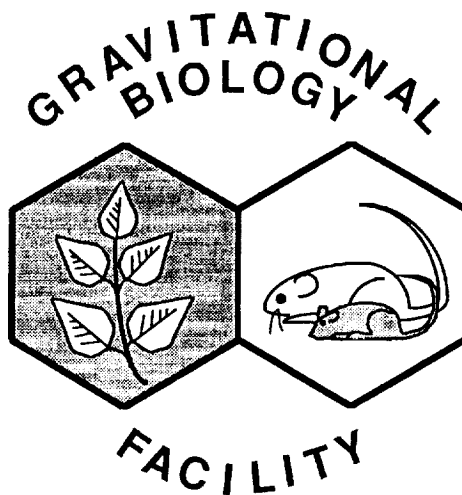
Presented by Katherine Allen

**ABSTRACT**

The Gravitational Biology Facility (GBF) is a set of generic laboratory equipment needed to conduct research on Space Station Freedom (SSF), focusing on Space Biology Program science (Cell and Developmental Biology and Plant Biology). The GBF will be functional from the earliest utilization flights through the permanent manned phase. Gravitational biology research will also make use of other Life Sciences equipment on the space station as well as existing equipment developed for the space shuttle. The facility equipment will be developed based on requirements derived from experiments proposed by the scientific community to address critical questions in the Space Biology Program. This requires that the facility have the ability to house a wide variety of species, various methods of observation, and numerous methods of sample collection, preservation and storage. The selection of the equipment will be done by the members of a scientific working group (5 members representing cell biology, 6 developmental biology and 6 plant biology) who also provide requirements to design engineers to ensure that the equipment will meet scientific needs. All equipment will undergo extensive ground based experimental validation studies by various investigators addressing a variety of experimental questions. Equipment will be designed to be adaptable to other space platforms. The theme of the Gravitational Biology Facility effort is to provide optimal and reliable equipment to answer the critical questions in Space Biology as to the effects of gravity on living systems.



# GRAVITATIONAL BIOLOGY FACILITY: MEETING THE NEEDS OF SPACE BIOLOGY



Katherine Allen, Project Bioengineer  
GE Government Services  
NASA Ames Research Center



## Gravitational Biology Facility Description

- Provides laboratory equipment items to conduct state-of-the-art, critical space life sciences research in:
  - Cell Biology
  - Developmental Biology
  - Plant Biology
- Includes common research equipment
  - Supports a wide range of specimen types
  - Various sample manipulation and preservation methods
- Hardware developed in evolutionary manner
  - Functional from Utilization Flights through PMC



## Cell Biology Critical Questions

- How are cell functions influenced by gravity and or affected by microgravity?
  - Gene activation and function
  - Membrane/Signal transduction
  - Cellular differentiation/Cell division
  - Cellular immunology (immune cell function)
- Do single cells "sense" gravity directly (intracellularly) or indirectly (environmentally-mediated effect)?
  - In vitro macromolecular assembly
  - Oxygen tension and cellular respiration

SSF Utilization Conference, Huntsville, Alabama, August 5, 1992



## Developmental Biology Critical Questions

- Which developmental mechanisms have evolved to be dependent on gravity (1-g)?
  - Oocyte maturation
  - Axis formation, pregastrulation & gastrulation
- How does gravity effect organogenesis and the development of anatomical structures?
  - Vestibular development
  - Skeletal growth and maturity
  - Structural muscle development and morphology
- Does the ontogeny of animals raised through more than one life cycle in microgravity differ from the 1-g classical pattern?
  - Insect, avian, aquatic and mammalian studies





## Plant Biology Critical Questions

- **What are the mechanisms that underlie gravity perception?**
  - Altered gene expression
- **Can plants successfully reproduce through more than one generation in space?**
  - Seed production
  - Anthesis and Fertilization
  - Plant embryogenesis
- **Are anabolic and catabolic pathways and the photosynthetic apparatus and pathway altered in microgravity?**
  - Photosynthetic partitioning
  - Nutrient absorption and up take
  - Alterations in cell wall synthesis

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## GBF Science Working Group

**Program Scientist:**

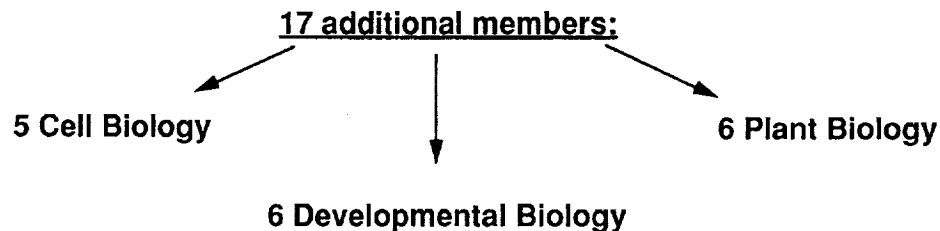
- Dr. Thora Halstead, NASA HQ

**Project Scientist and SWG chair:**

- Dr. Charles Wade, ARC

**Deputy Project Scientist:**

- Dr. William Knott, KSC



**Responsible for:**

- Developing and reviewing GBF Reference Experiments
- Developing GBF Science Requirements for equipment items
- Providing science review and guidance in GBF equipment development effort



## Equipment Development Process

- Develop and Solicit Experiments for GBF
- Identify equipment items from GBF Reference Experiments
- Develop prioritized list of GBF hardware
- Science Working Group provides science requirements to engineers
- Studies to evaluate different hardware designs
- Develop approach for the design and development of GBF hardware
- Prototype hardware testing (ground-based, parabolic flights, shuttle experiments)

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## Reference Experiment Development

- Solicitation for reference experiments from the science community.
- Provided guidelines for:
  - areas of research
  - flight opportunities and time frames
  - justification for space flight
- SWG review, critique, and revision of experiments
- Solicitation for additional experiments for research areas not fully covered



## Reference Experiment Set

- More than 125 experiments received (> 75 authors).
- Distribution between early flights (MTC) and PMC.
- Distribution over discipline specific research areas and critical questions.
- High degree of similarity of equipment required among the experiments and among the disciplines.

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## GBF Specimen Habitats

<ul style="list-style-type: none"><li>√ Cell culture apparatus</li><li>• Small Plant</li><li>• Medium Plant</li><li>• Insect</li><li>• Egg Incubator</li><li>• Small Aquatic (salt and fresh water)</li><li>• Medium Aquatic</li><li>• Rodent Birthing</li></ul>	<ul style="list-style-type: none"><li>• Large Plant</li><li>• Rodent Breeding</li><li>• Avian Hatchling</li><li>• Rodent Rearing</li><li>• Rodent Weanling to Adult</li><li>• Avian Adult</li><li>• Large Aquatic</li></ul>
--	---

### Habitat characteristics:

- 1-g control
- Environmental control
- Video monitoring

√ = Multi-Discipline Equipment Item



## GBF Preservation & Storage Equipment

- √ Freezers (-196°C, -70°C, -20°C)
- √ Fixation capability
- √ Refrigerator
- √ Freeze Drier
- √ Snap Freezer
- √ Ambient Storage
- √ Refrigerator/Incubator

### Purpose:

- Preserve and store samples on orbit
- Preserve samples during return to Earth for analysis

√ = Multi-Discipline Equipment Item

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## GBF Manipulation & Analysis Equipment

- √ Fluid handling tools
- √ Compound Microscope (CCD)
- √ Work Area
- √ Dissection Equipment
- √ Dissecting Microscope
- √ Temperature Controlled Laboratory Centrifuge
- √ Data Storage
- √ Radioisotope Handling Equipment

- Digital Multimeter
- Ion Selective Electrodes
- Spectrophotometer
- √ Mass Measurement Device
- Electrophysiology Measuring Equipment
- √ Micromanipulation Device
- Luminometer

### Purpose:

- Preparation of samples for ground-based analysis
- On orbit measurements and analysis



## Summary

**Gravitational Biology Facility supports:**

- **Earliest life sciences experiments on Space Station Freedom**
- **Diverse specimen types and areas of research in Cell, Developmental, and Plant Biology**
- **Common laboratory equipment for life sciences research**

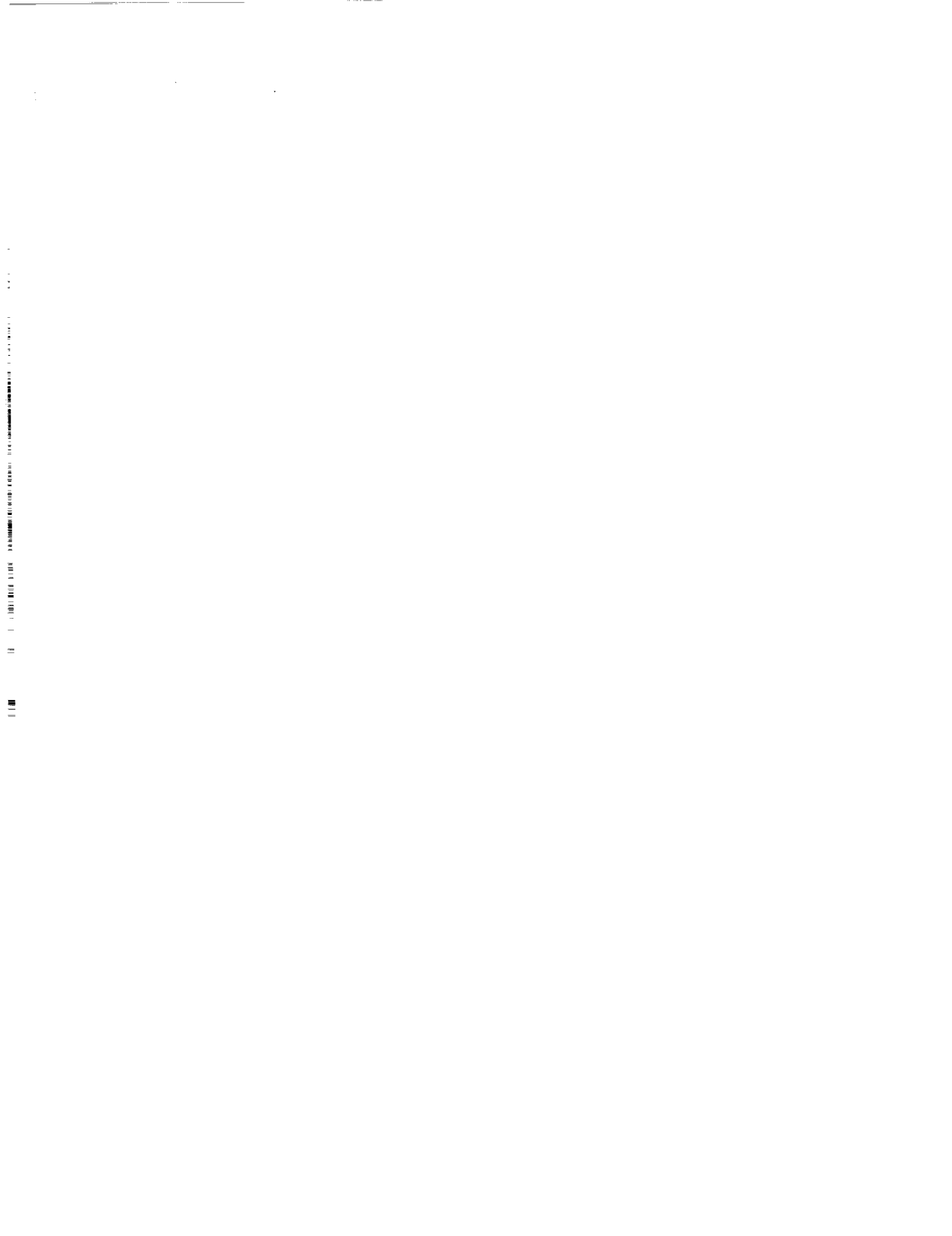
- **For more information, contact:**

**Kellie McKeown  
GBF Project Manager  
MS 244-14  
NASA Ames Research Center  
Moffett Field, CA 94035-1000  
(415) 604-4862**

**Dr. Charles Wade  
GBF Project Scientist  
MS 239-11  
NASA Ames Research Center  
Moffett Field, CA 94035-1000  
(415) 604-3943**

SSF Utilization Conference, Huntsville, Alabama, August 5, 1992





**GAS-GRAIN SIMULATION FACILITY (GGSF)**

Presented by Ken Greenwald  
Space Science Division, Solar Systems Exploration Branch  
NASA Ames Research Center

**ABSTRACT**

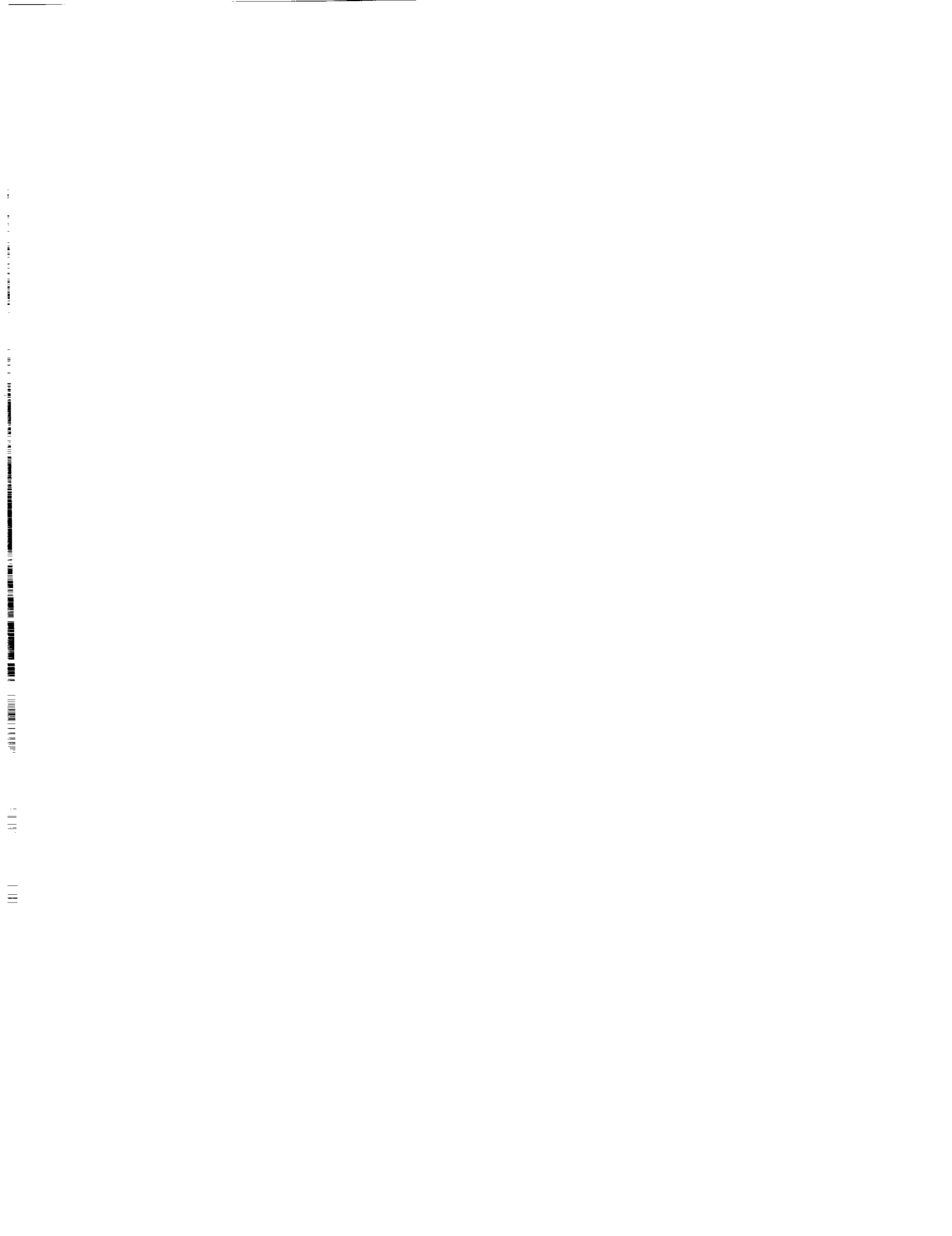
The goal of the Gas-Grain Simulation Facility project is to provide a microgravity laboratory to facilitate research relevant to exobiology (the study of the origin and evolution of life in the universe). Such a facility will also be useful in other areas of study important to NASA including planetary science, biology, atmospheric science, astrophysics, chemistry, and physics. To achieve this goal, the project will develop and support the GGSF, a modular facility-class payload planned for inclusion on Space Station Freedom. The GGSF will consist of an experiment chamber(s) supported by subsystems that provide chamber environment regulation and monitoring capabilities; sample generation, injection, positioning, and retrieval capabilities; and computer control, data acquisition and housekeeping capabilities. The facility will also provide analytical tools such as light-scattering measurement systems, aerosol size-spectrum measurement devices, and optical imaging systems.

As much as possible, facility components will be designed to be modular, allowing evolutionary growth of the facility capabilities. A modular design will also allow flexibility in facility configuration; provide for on-orbit integration of experiment unique equipment into the facility; and allow GGSF subsystems to be added, removed or exchanged with minimal crew interaction. To further minimize crew interaction requirements, the GGSF and each experiment to be performed on the GGSF are expected to make use of automation, telescience and artificial intelligence, allowing nearly autonomous operation.

Laboratory research enabled by the GGSF involves simulating and studying fundamental chemical and physical processes such as formation, growth, nucleation, condensation, evaporation, aggregation, coagulation, collision and mutual interaction of small (sub-micron to millimeter size) particles (e.g., crystals, powders, liquid droplets and dust grains). Twenty-two potential GGSF experiments involving such processes have been defined to date. Benefits of microgravity and specific potential experiments representative of the various disciplines will be discussed.

Currently, TRW is conducting a Phase A engineering reference design study for the GGSF. This design will be outlined and sketches of the concept shown. The GGSF science community met to discuss science requirements and this reference design at the third GGSF science workshop held in May of 1992 at the Desert Research Institute in Las Vegas, Nevada. The project is currently working toward launch of the GGSF to Space Station Freedom in 1998. GGSF science and hardware concept validation tests both ground and space-based are being planned with precursor experiments scheduled for launch on Shuttle in 1996.

Other work related to GGSF development includes four experiment concept studies for the Aerosol Physics Module, a precursor to the GGSF. These explore potential GGSF experiments dealing with smoke agglomerates, fractal particles, Titan atmosphere aerosols, and organic compound synthesis on growing particles. Another related study involves numerical modeling of coagulation and diffusion effects in the GGSF as a tool for experiment design and data analysis. Also related to GGSF development is an experiment just successfully completed in July on the Space Shuttle mission USML- 1, which studied a method of dispersing solid particles in a microgravity environment.





# Gas-Grain Simulation Facility (GGSF)

Space Station Freedom Utilization Conference

Huntsville, Alabama

August 3 - 6, 1992

Ken Greenwald

NASA Ames Research Center

**NASA**

Ames Research Center

**GGSF**  
GAS-GRAIN  
SIMULATION  
FACILITY

## Project Goals

- Support exobiology's goal to understand how cosmic, solar system, and planetary evolution have influenced the origin, evolution, and distribution of life and life-related molecules in the universe
- Provide a microgravity laboratory to facilitate research relevant to exobiology, biology, planetary science, astrophysics, atmospheric science, chemistry, and physics

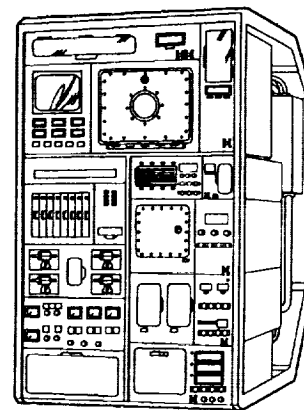
## Project History

- 1984-85:** Workshops propose and develop concept
- 1987:** Physics feasibility study by Martin Marietta  
Workshop identifies science community, establishes experiment concept data base
- 1991:** Science Working Group convenes  
Phase A concept analysis/definition study begins for GGSF and precursor experiment  
4 Aerosol Physics Module/GGSF concept studies funded
- 1992:** Science Workshop - GGSF community examines Phase A design concept  
USML-1 Glovebox Expt. tests particle dispersion method

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## Payload Data

- **Readiness**
  - Core Facility (MTC): 1998
  - Mature Facility (PMC): 2001
- **Lifetime:** > 10 years
- **Mass (total):** 700 Kg
- **Size:** 80"H x 42"W x 39"D (1 ISPR)
- **Volume:** ~ 1 m<sup>3</sup>
- **Power:** < 3 KW peak
- **Location:** Pressurized Laboratory



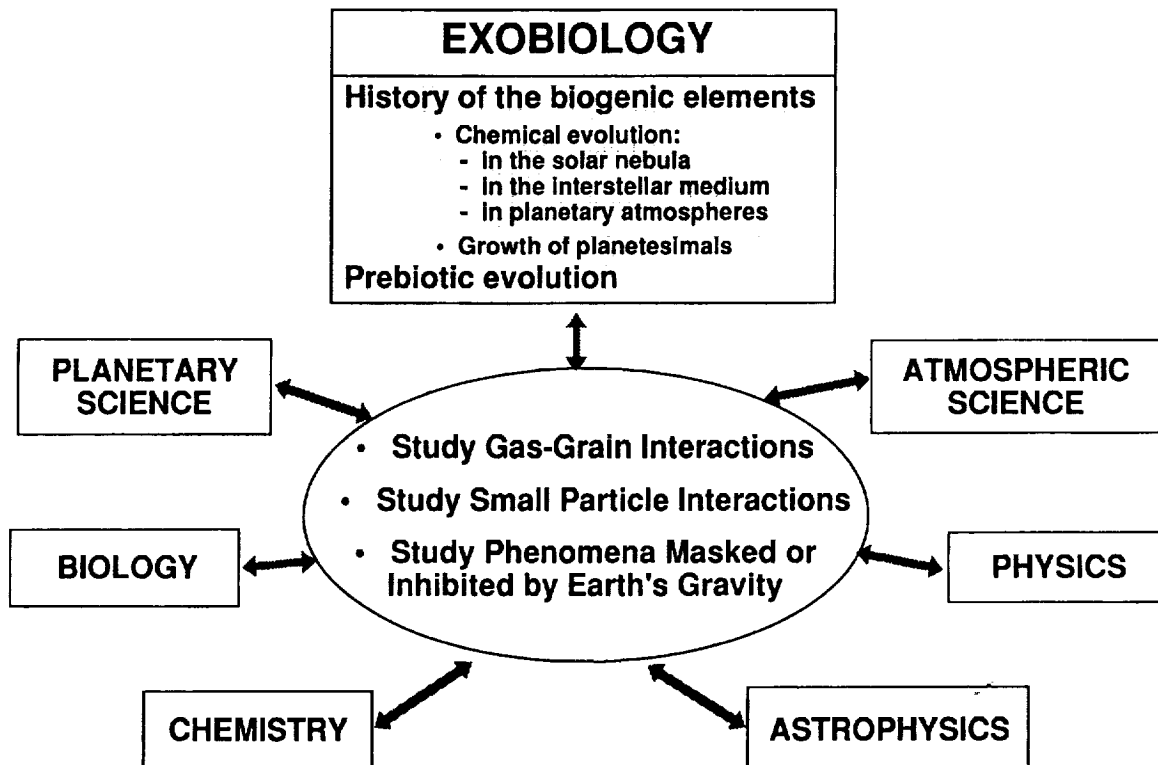
## Science Objectives

To investigate fundamental chemical & physical processes involving suspended particles mainly in the sub-micron to millimeter size range (e.g., dust grains, crystals, combustion products, droplets, ...):

- Nucleation
- Condensation
- Evaporation
- Particle/Droplet Formation
- Particle/Droplet Growth
- Aggregation
- Coagulation
- Collisions
- Mutual Interactions

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## GGSF Science



## Exobiology

### Question

What can planetary scale atmospheric chemistry reveal about the conditions on early Earth which led to the origin of life?

### Potential GGSF Experiment

#### Titan's Atmospheric Aerosol Simulation

- Simulate formation and growth of organic haze
- Measure optical properties
- Determine chemical composition

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## Biology/Aerobiology

### Question

What is the fate of airborne microbes, and how does microgravity affect aerosol disease spread in a confined space such as Space Station?

### Potential GGSF Experiment

#### Airborne Bacteria in Microgravity

- Examine metabolism and growth, if any, of aerosolized microbes
- Determine the interrelationship between atmospheric trace gases (e.g., NO<sub>x</sub>) and airborne microbes
- Determine how being airborne affects microbial pathogenicity

## Astrophysics

### Question

What are the properties of fractal materials? Do fractals play an important role in circumstellar and interstellar environments as well as in the early solar nebula?

### Potential GGSF Experiment

#### Study of Fractal Particles

- Measure coagulation coefficients of silicates & metal grains
- Measure scattering & extinction efficiencies of aggregates
- Measure cohesive strength
- Study fractal structure
- Look for signatures to distinguish fractal aggregates from a distribution of particles

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## Planetary Science

### Question

How do low energy collisions influence the behavior of ring structures such as those of Jupiter, Saturn, Uranus, and Neptune?

### Potential GGSF Experiment

#### Planetary Ring Dynamics

- Study collision dynamics
- Measure energy loss in low velocity collisions
- Determine coefficients of restitution
- Analyze the transfer of linear to angular momentum

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## Atmospheric Science

### Question

What are the properties of cirrus cloud crystals and what role do they play in the the balance of the Earth's atmospheric radiation budget? What is their effect on global warming?

### Potential GGSF Experiment

**Ice Scavenging and Aggregation: Optical and Thermal IR Absorption and Scattering Properties**

- Study crystal growth
- Study aggregation
- Measure optical and thermal IR scattering and absorption properties
- Study scavenging of aerosols by ice crystals

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## **GGSF Strawman Investigations**

- 1 Low-Velocity Collisions Between Fragile Aggregates**
- 2 Low-Energy Grain Interaction/Solid Surface Tension**
- 3 Cloud Forming Experiment**
- 4 Planetary Ring Particle Dynamics**
- 5 Aggregation of Fine Geological Particulates in Planetary Atmospheres**
- 6 Optical Properties of Low-Temperature Cloud Crystals**
- 7 Ice Scavenging and Aggregation**
- 8 Synthesis of Tholin and Measurement of its Optical Properties**
- 9 Metallic Behavior of Aggregates**
- 10 Organic Compound Synthesis on Surfaces of Growing Particles**
- 11 Crystallization of Protein Crystal-Growth Inhibitors**
- 12 Dipolar Grain Coagulation and Orientation**
- 13 Titan Atmospheric Aerosol Simulation**
- 14 Surface Condensation and Annealing of Chondritic Dust**
- 15 Studies of Fractal Particles**
- 16 Emission Properties of Particles and Clusters**
- 17 Effect of Convection on Particle Deposition and Coagulation**
- 18 Study of Smoke Agglomerates**
- 19 Airborne Bacteria in Microgravity**
- 20 Infrared Emissivity of Extraterrestrial Particles**
- 21 Radiation-Induced Rotation of Interplanetary Dust**
- 22 Dynamics and Evaporation of Clusters of Drops in Vortical Flows**

## GGSF Strawman Experiment Investigators

- 1 Weidenschilling, *Planetary Science Institute*
- 2 Sievers and Thompson, *Cornell University*
- 3 Hudson, *Desert Research Institute*
- 4 Bridges, *U.C. Santa Cruz*
- 5 Marshall, *Arizona State University*
- 6 Pope, *ARC* and Tomasko, *U. of Arizona*
- 7 Hallett, *Desert Research Institute*
- 8 Khare, *Cornell University*
- 9 Traver, *Johns Hopkins University*
- 10 Oberbeck, *Ames Research Center*
- 11 Raymond, *U. of South Alabama*
- 12 Freund, *SETI Institute*
- 13 Scattergood, *S.U.N.Y.* and McKay, *ARC*
- 14 Rietmeijer and McKinnon, *U. of New Mexico*
- 15 Nuth, *Goddard* and Stephens, *Los Alamos Lab.*
- 16 Allamandola, *Ames Research Center*
- 17 Rhim, *Jet Propulsion Laboratory*
- 18 Mulholland, *NIST*
- 19 Mancinelli, *SETI Institute*
- 20 Goebel, *Ames Research Center*
- 21 Misconi, *Space Research Institute*
- 22 Bellan, *Jet Propulsion Laboratory*



## Benefits of Microgravity to GGSF

- Suspension times increased
  - Permits long duration aerosol studies
  - Enables low-velocity collision experiments
- Buoyancy-driven convection reduced ( $\Delta T_{cr} \propto 1/g$ )
- Allows low energy interactions that are masked by gravitational forces on Earth
- Fractals and other gravitationally unstable ( at 1 g) objects may be studied

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## Modular Design Concept (Phase A)

- Interchangeability of subsystems accommodates a broad range of experiments
- Allows for new experiments and technology upgrades
- Four interchangeable chambers

Function	Temperature (K)	Pressure (bar)	Volume (Liters)
Core	150 to 400	$10^{-6}$ to 1	67
Low Temp.	40 to 400	$10^{-6}$ to 3	4.2
High Temp	300 to 1200	$10^{-6}$ to 1	8.2
High Vacuum	60 to 300	$10^{-10}$ to 1	4.2

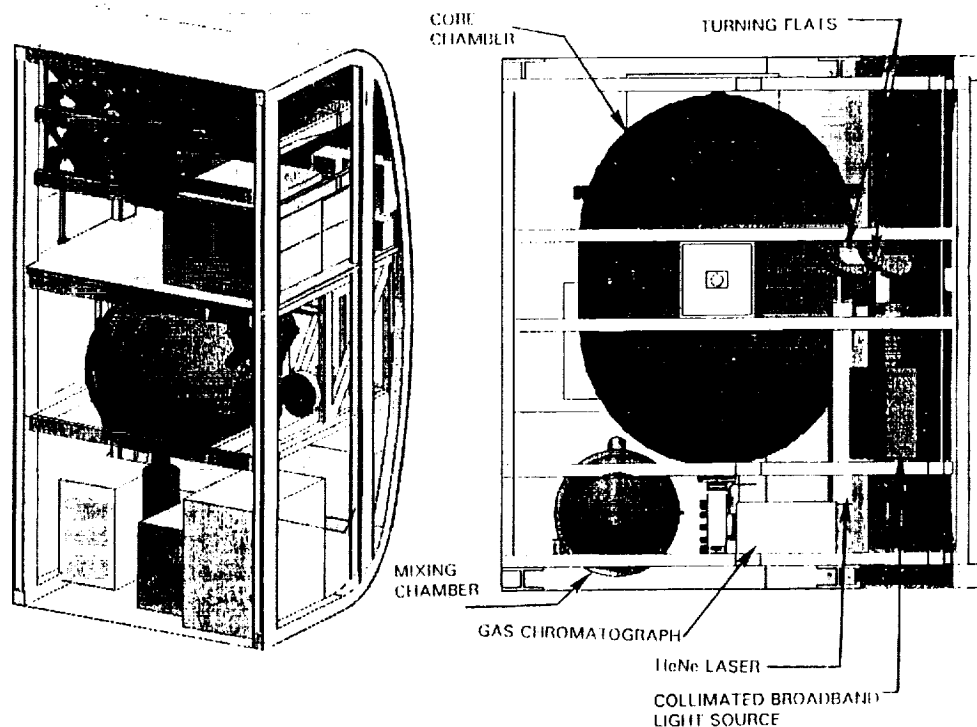
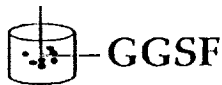
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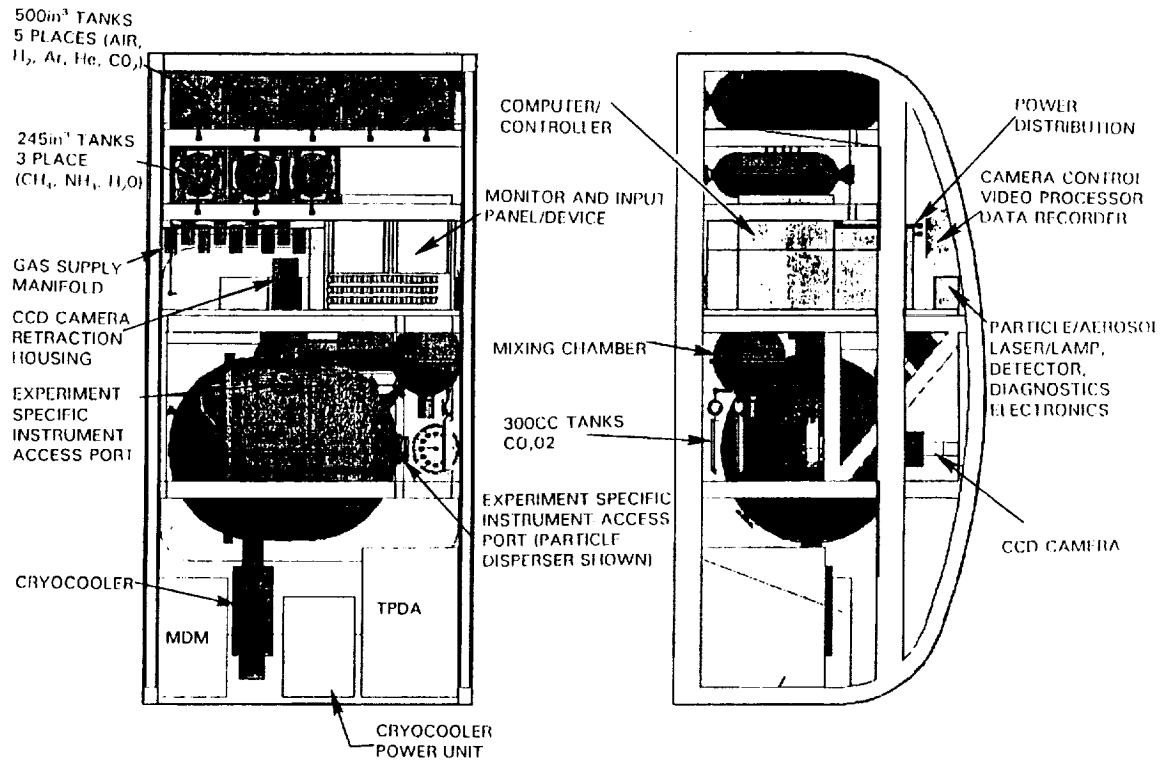
The 4 Chambers Accommodate the Following:

Physical Objectives
Aggregation
Biological
Condensation/Nucleation
Crystal Formation
Particle Dynamics/Collisions
Spectral/Optical Properties
Synthesis of Compounds

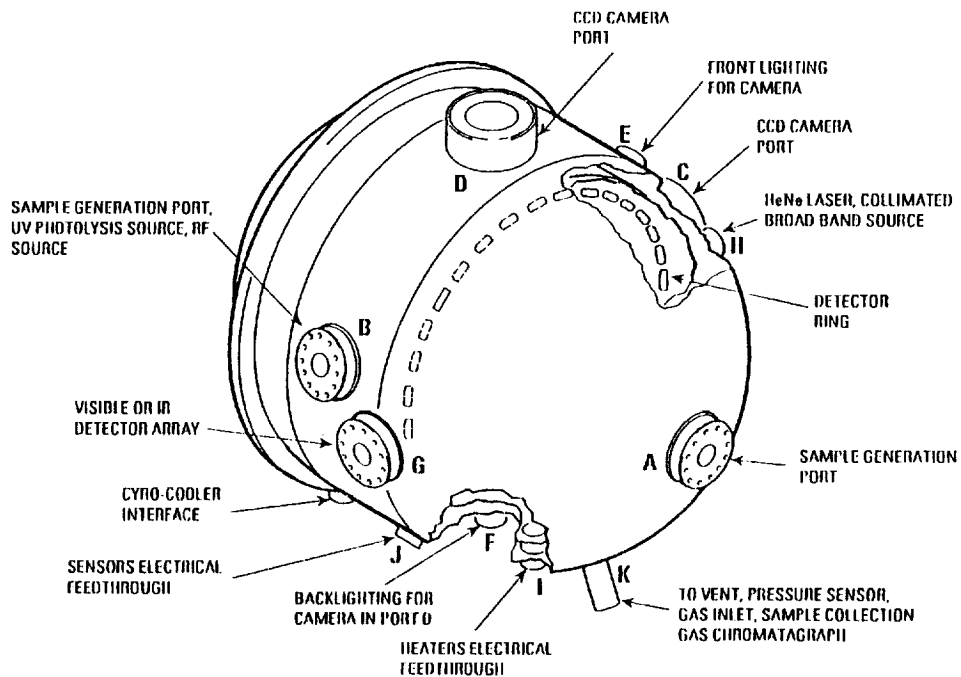
Generation Methods
Low Temp. Nuc./Condensation
High Temp. Vapor Formation
Solid Particle Dispersion
• Single/Small Number
Combustion (Smoke/Soot)
Liquid Aerosol Dispersion
• Single/Small # of Drops
Radiation-Induced Synthesis

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### Core Chamber



## Future Plans

- **Science and Hardware Concept Validation**
  - **Ground-based KC-135, drop tower; space-based Shuttle middeck and Spacelab opportunities**
  - **Reduces hardware development risks**
  - **Provides early science return**
  
- **GGSF Technology Workshop**
  
- **GGSF Science Workshop**

## RESEARCH OPPORTUNITIES WITH THE CENTRIFUGE FACILITY

Presented by Glenn A. Funk, Ph.D.  
GE Government Services  
NASA Ames Research Center

### ABSTRACT

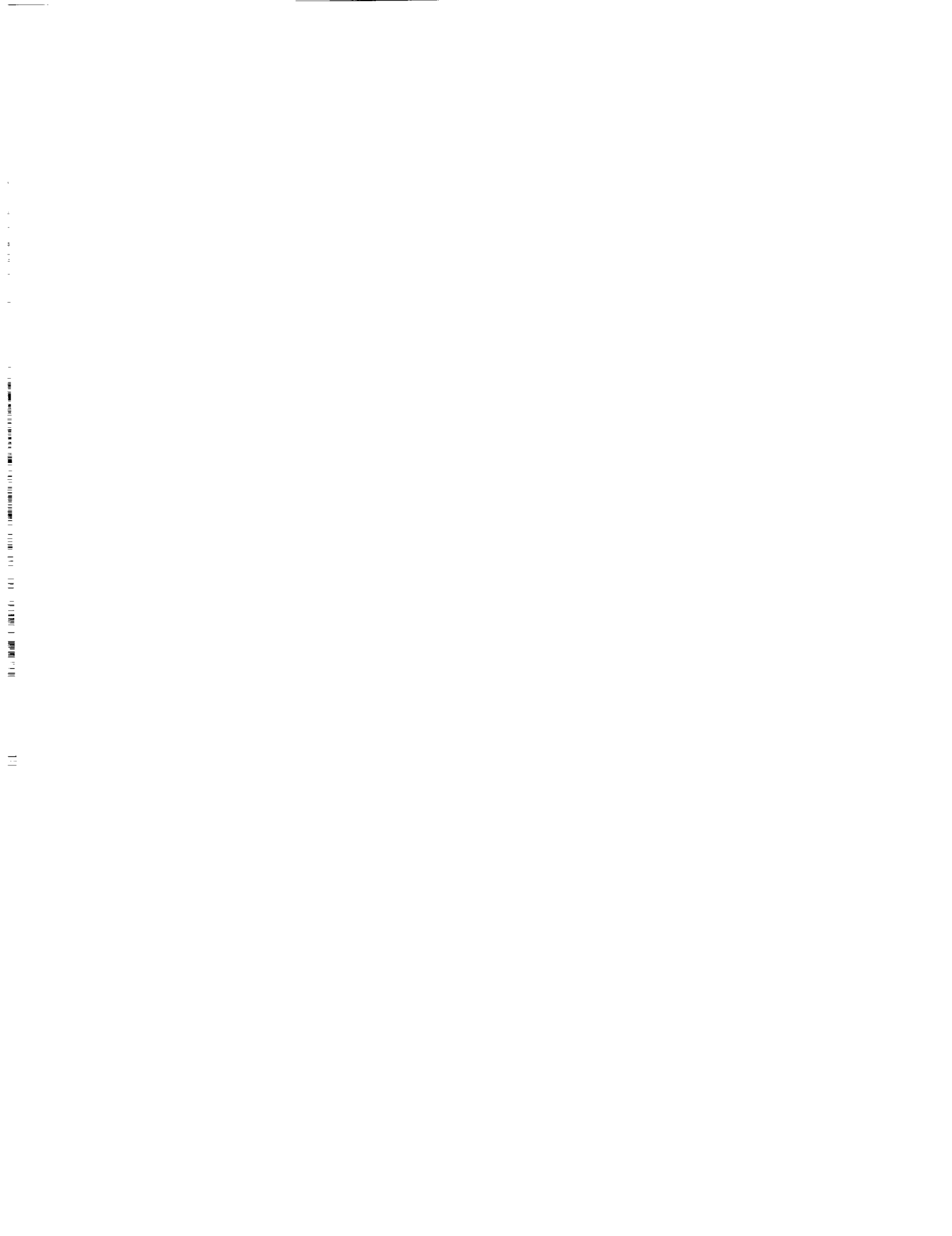
The Centrifuge Facility on Space Station Freedom will consist of a 2.5-meter diameter Centrifuge accommodating two concentric rings of Habitats and providing variable g forces between 0.01g and 2.0g; Modular Habitats providing housing and life support for rats, mice, and plants; a Habitat Holding System providing power, water, airflow and other utilities to several Modular Habitats; and a Life Sciences Glovebox, an isolated work volume accommodating simultaneous operations by at least two scientists and providing lighting, airflow, video and data access, and other experiment support functions.

The Centrifuge Facility will enable long-duration animal and plant microgravity research not previously possible in the NASA flight research program. It will offer unprecedented opportunities for use of on-board 1-g control populations and statistically significant numbers of specimens. On-orbit 1-g controls will allow separation of the effects of microgravity from other environmental factors. Its selectable-g and simultaneous multiple-g capabilities will enable studies of gravitational thresholds, the use of artificial gravity as a countermeasure to the effects of microgravity, and ready simulation of Lunar and Martian gravities.

Many exciting research opportunities stem from the permanent presence of the Centrifuge Facility on-orbit. Long-duration exposure to microgravity will permit extended studies directly relevant to the health and welfare of crew members on long space mission. It will also allow studies that encompass both significant portions of a subject's life span and, of special interest, studies that examine microgravity effects over several generations of both plants and animals. In the process of supporting multigeneration studies, the Facility will simultaneously support the derivation of spaceadapted colonies of subjects for future use. The permanent presence of scientist-astronauts will enable real-time experiment manipulation, alteration, and replication. To capitalize on this capability, many Facility elements are being designed for maximum flexibility and on-orbit reconfigurability.

The Centrifuge Facility will accommodate studies in all life sciences disciplines, from behavioral experiments to detailed investigations of physiologic systems, e.g., cardiovascular, musculoskeletal, and neurovestibular. It will support the collection of on board samples and fixation of samples for return to Earth for sophisticated analyses which cannot be performed on-orbit. However, there will be a wide variety of on board laboratory equipment and analytical instruments. While initially designed for use with rodents and plants, it will ultimately accommodate a wide range of biospecimens, including small primates, fish, amphibians, arthropods, and microbial and cell cultures. The Facility will provide variable housing configurations, well-controlled environmental parameters, water and nutrient delivery, waste management, video, and access to biotelemetry and other data. It will also accommodate a variety of add-on experiment-unique equipment such as special video cameras, unique specimen chambers, and custom sensors.

For the first time, the Centrifuge Facility and Space Station Freedom will permit systematic research to understand the physiological and biochemical changes in living organisms that take place in the space environment.





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## RESEARCH OPPORTUNITIES WITH THE CENTRIFUGE FACILITY

Glenn A. Funk, Ph.D.  
GE Government Services  
NASA Ames Research Center  
Moffett Field, CA

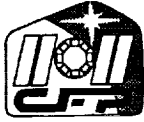


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## THE CENTRIFUGE FACILITY

- **CENTRIFUGE**
  - 2.5-meter diameter; provides variable-g capability (0.01-2.0 g)
- **MODULAR HABITATS**
  - Interchangeable between Centrifuge, Holding System and Glovebox
  - Provide housing and life support for plants and rodents
- **HABITAT HOLDING SYSTEM**
  - Provides utilities and services to Modular Habitats
- **LIFE SCIENCES GLOVEBOX**
  - Provides bioisolated work volume for experiment and maintenance procedures
- **RODENT TRANSPORTER**
  - Provides housing for rodents during transport to orbit



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## ACCOMMODATIONS

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- **THE CENTRIFUGE FACILITY WILL SUPPORT ALL OF NASA'S LIFE SCIENCES RESEARCH DISCIPLINES:**
  - Cardiopulmonary
  - Cell & Developmental Biology
  - Musculoskeletal
  - Regulatory Physiology
  - Neuroscience
  - Environmental Health & Radiation
  - Plant Biology
  - Behavior and Performance
  
- **THE CENTRIFUGE FACILITY WILL ACCOMMODATE A VARIETY OF DIFFERENT BIOSPECIMEN TYPES:**
  - Initially: Rats, mice, and plants
  - Post-2000: Squirrel monkeys
  - Ultimately: Fish, birds, amphibians, arthropods, microbial and tissue cultures, etc.



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## WHAT DOES THE CF OFFER?

---

- **ON-BOARD CONTROL POPULATIONS**
- **STATISTICALLY SIGNIFICANT NUMBERS OF SPECIMENS**
- **FRACTIONAL GRAVITY CAPABILITIES**
  - Hypo-g studies: Gravitational thresholds  
Lunar, Mars and other g simulations  
Countermeasures
  - Hyper-g studies: Extension of ground-based centrifuge studies  
Countermeasures
- **LONG-DURATION MICROGRAVITY EXPOSURE**
  - Significant fraction of normal life span
  - Multigeneration studies
  - Space-adapted colonies





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## ASSOCIATED FEATURES

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- **ON-BOARD ADJUNCT CAPABILITIES**
  - ***Gravitational Biology Facility:*** a suite of generic laboratory equipment and biospecimen habitats to support the Cell & Developmental and Plant Biology disciplines
  - ***Laboratory Support Equipment:*** a suite of generic laboratory instruments to support life sciences microgravity research, e.g., refrigerators, freezers, mass measurement devices, etc.
  - ***Biomedical Monitoring and Countermeasures:*** common equipment items
  - ***Crew Health Care System:*** common equipment items
  - **Scientist/Astronaut crew**
  - **Telescience/Remote coaching (eventually)**
- **ACCOMMODATION OF EXPERIMENT-UNIQUE EQUIPMENT (EUE)**
  - **Unique specimen chambers (e.g., mating, birthing/rearing)**
  - **Specialized video cameras (e.g., lenses, spectral qualities)**
  - **Custom sensors**



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## FLIGHT VERIFICATION SCIENCE

---

- **THREE SEQUENTIAL 90-DAY FLIGHT INCREMENTS ONLY**
- **PLANNED FOR YEAR 2000**
- **GOAL IS TO VERIFY THE PROPER PERFORMANCE OF THE CENTRIFUGE FACILITY ON-ORBIT**
  - **Engineering**
  - **Science**
- **INVESTIGATORS WILL BE SOLICITED**
  - **Normal Headquarters-directed solicitation process**
  - **Research plans must meet verification goals first**
  - **Research plans must minimize need for EUE**

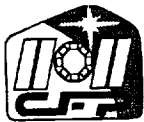


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## ONGOING SCIENCE

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- **ONGOING SCIENCE PROGRAM TO BEGIN FOLLOWING SUCCESSFUL COMPLETION OF FLIGHT VERIFICATION**
- **ANTICIPATED START IN YEAR 2001**
- **NORMAL HEADQUARTERS-DIRECTED SOLICITATION PROCESS**
- **90-DAY INCREMENTS WILL BE DISCIPLINE-ORIENTED**
- **WILL PROVIDE:**
  - **On-orbit sampling and storage, some processing and analysis**
  - **Data acquisition, processing, storage and downlink**



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## STATUS AND PLANS

---

- **CENTRIFUGE FACILITY HARDWARE**
  - **Phase A and B studies complete**
  - **Phase C/D RFP released July 7, 1992**
  - **Phase C/D start 1993**
- **CENTRIFUGE FACILITY SCIENCE**
  - **Verification increment science NRAs - 1994**
    - Investigators to be on-board by CDR (early 1995)**
    - Verification experiment development 1995-2000**
  - **Ongoing science NRAs ~1997**
    - Experiment development ~1998 on**

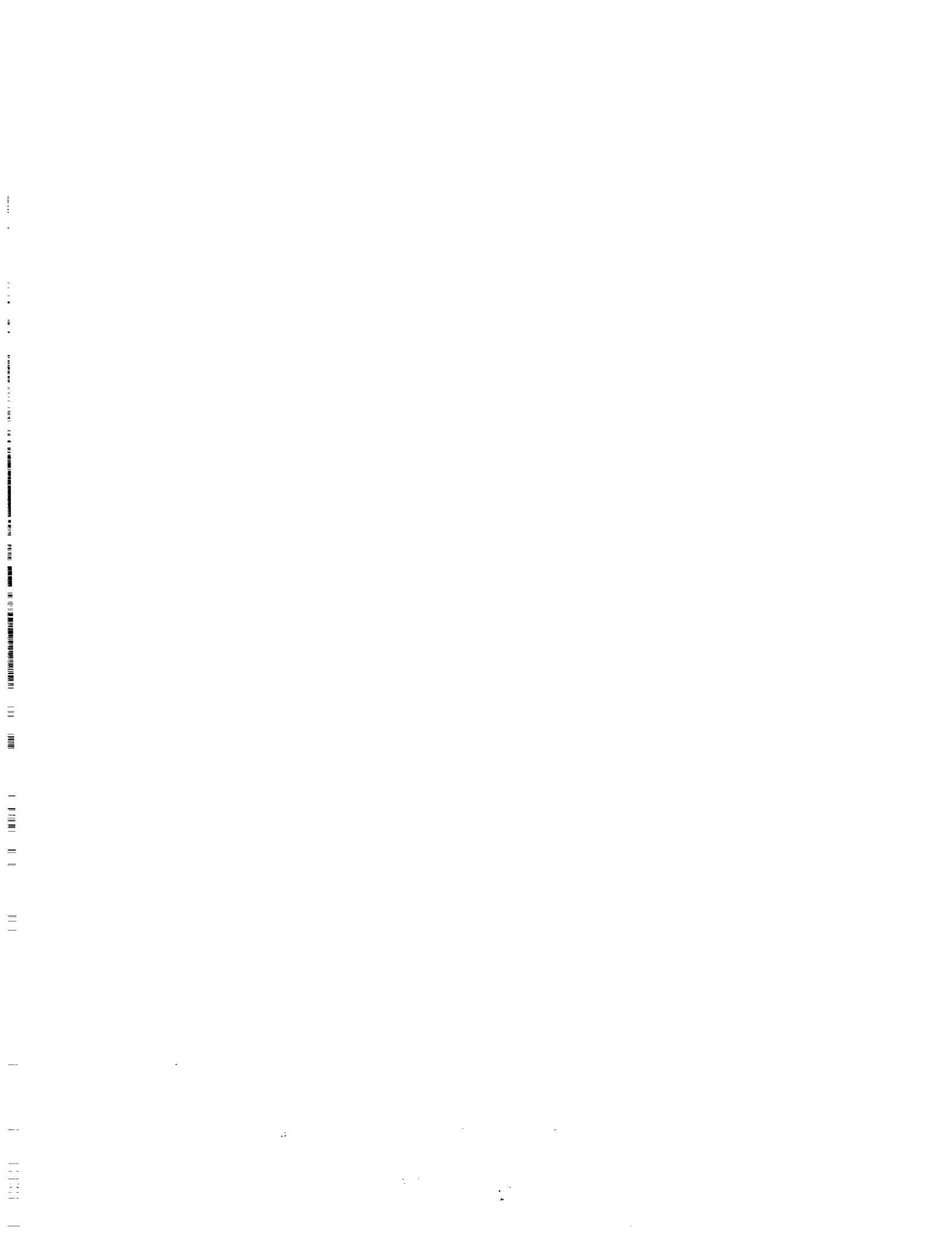


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## CONCLUSION

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**THE CENTRIFUGE FACILITY WILL MAKE POSSIBLE THE  
SYSTEMATIC RESEARCH NECESSARY TO UNDERSTAND  
THE PHYSIOLOGICAL, BIOCHEMICAL AND GENETIC  
CHANGES IN LIVING ORGANISMS THAT TAKE PLACE IN  
THE SPACE ENVIRONMENT**



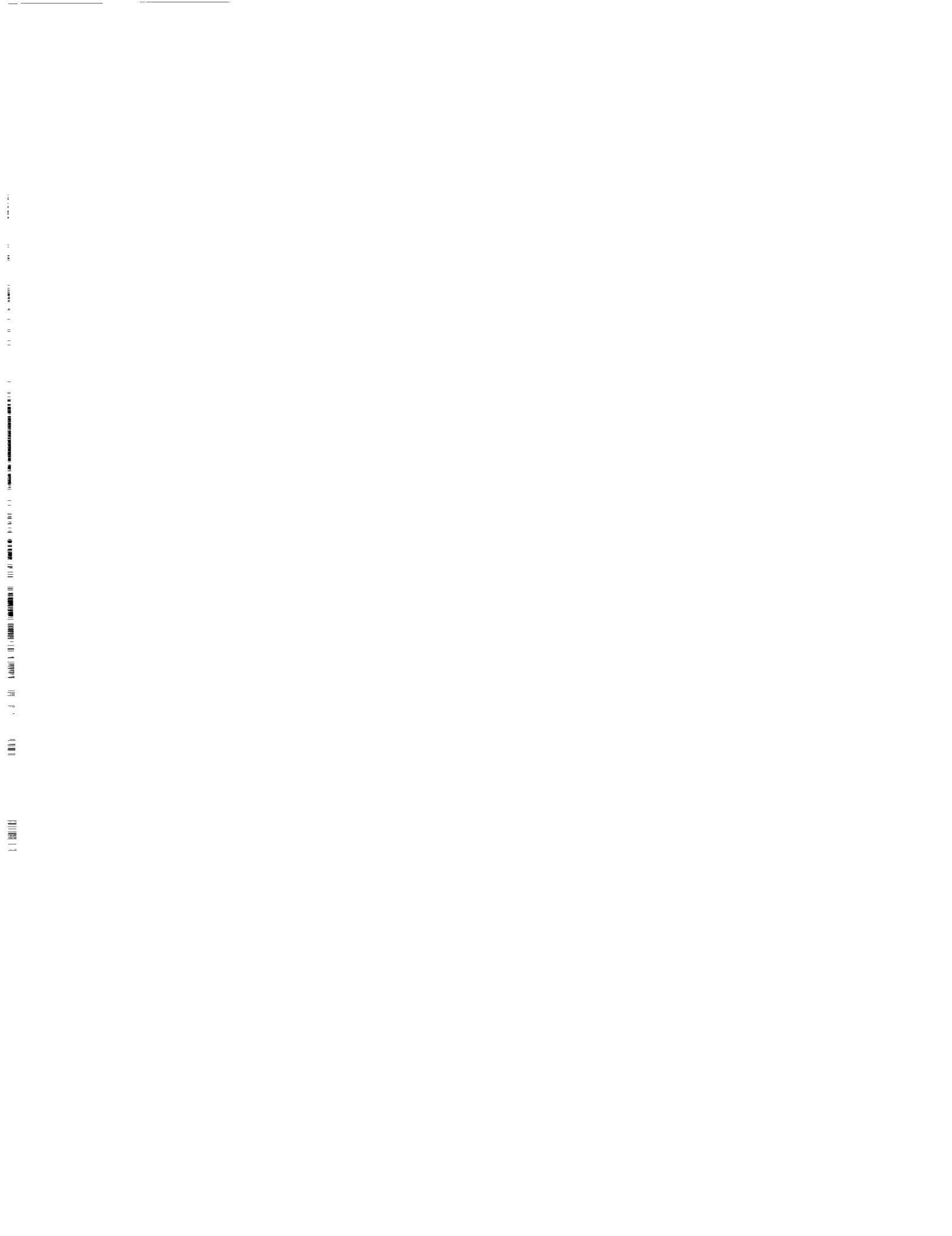
**CLOSED ECOLOGICAL LIFE SUPPORT SYSTEMS  
(CELSS)  
TEST FACILITY**

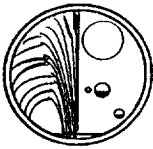
Presented by Dr. John Tremor

Prepared by Dr. Robert D. MacElroy  
Project Manager  
NASA Ames Research Center

**ABSTRACT**

The CELSS Test Facility (CTF) is being developed for installation on Space Station Freedom (SSF) in August 1999. It is designed to conduct experiments that will determine the effects of microgravity on the productivity of higher (crop) plants. The CTF will occupy two standard SSF racks and will accommodate approximately one square meter of growing area and a canopy height of 80 cms. The growth volume will be isolated from the external environment, allowing stringent control of environmental conditions. Temperature, humidity, oxygen, carbon dioxide, and light levels will all be closely controlled to prescribed setpoints and monitored. This level of environmental control is needed to prevent stress and allow accurate assessment of microgravity effect ( $10^{-3}$  to  $10^{-6}$  x g). Photosynthetic rates and respiration rates, calculated through continuous recording of gas concentrations, transpiration and total and edible biomass produced will be measured. Toxic byproducts will be monitored and scrubbed. Transpiration water will be collected within the chamber and recycled into the nutrient solution. A wide variety of crop plants, e.g., wheat, soy beans, lettuce, potatoes, can be accommodated and various nutrient delivery systems and light delivery systems will be available. In the course of its development, the CTF will exploit fully, and contribute importantly, to the state-of-art in closed system technology and plant physiology - Controlled Environmental Agriculture, sensors and instrumentation, plant growth environment modeling, atmosphere control and gas concentration maintenance among a few.





## Controlled Ecological Life Support Systems

**NASA**  
National Aeronautics and  
Space Administration

August 5, 1992

**SPACE STATION FREEDOM UTILIZATION CONFERENCE**

**AUGUST 1-6, 1992**

**HUNTSVILLE, AL**

### **CELSS TEST FACILITY**

**PRESENTED BY DR. JOHN TREMOR**

**PREPARED BY DR. ROBERT D. MAC ELROY  
PROJECT MANAGER  
NASA AMES RESEARCH CENTER**

**CELSS TEST FACILITY PROJECT**



## Controlled Ecological Life Support Systems

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National Aeronautics and  
Space Administration

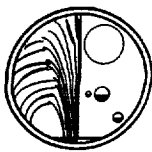
August 5, 1992

**AUGUSTINE REPORT: *OF ALL THE CRITICAL ELEMENTS FOR LONG DURATION SPACE FLIGHT, CLOSED ECOLOGICAL SYSTEMS REMAIN AMONG THE LEAST UNDERSTOOD AND THE MOST CHALLENGING***

- **BIOREGENERATIVE LIFE SUPPORT SYSTEMS WILL OPERATE WITH A COMBINATION OF BIOLOGICAL (e.g., HIGHER PLANTS (WHEAT, )), PHYSICAL AND CHEMICAL COMPONENTS, TO RECYCLE THE WATER, OXYGEN, FOOD AND CARBON DIOXIDE NEEDED BY HUMAN CREWS**
- **THE NASA CELSS PROGRAM IS CHARGED WITH DEVELOPMENT OF THE SCIENCE AND TECHNOLOGIES NECESSARY TO CONSTRUCT BIOREGENERATIVE LIFE SUPPORT SYSTEMS FOR USE IN SPACE**
- **THE CELSS TEST FACILITY IS BEING DESIGNED TO GROW HIGHER PLANT CROPS ON SPACE STATION FREEDOM UNDER STRINGENTLY CONTROLLED ENVIRONMENTAL CONDITIONS FOR THE PURPOSE OF DETERMINING CROP PRODUCTIVITY**

**CELSS TEST FACILITY PROJECT**

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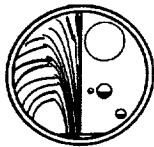
## Controlled Ecological Life Support Systems

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August 5, 1992

- THE CELSS PROGRAM HAS SUPPORTED MAJOR RESEARCH EFFORTS THAT HAVE FOCUSED ON HIGHER PLANT PRODUCTIVITY
  - PRODUCTIVITY IS DEFINED AS THE RATE OF PRODUCTION OF FOOD, WATER OR OXYGEN PER UNIT OF RESOURCE USE (E.G., AREA, VOLUME, KW POWER, ETC.)
- CELSS RESEARCH HAS EXPLORED THE UPPER LIMITS OF HIGHER PLANT PRODUCTIVITY AT  $1 \times g$  BY INVESTIGATING THE EFFECTS OF ENVIRONMENTAL CONDITIONS ON PLANT GROWTH RATES
  - FOR EXAMPLE, WHEAT CROPS GROWN UNDER RIGOROUSLY CONTROLLED ENVIRONMENTAL CONDITIONS EXCEED FIELD PRODUCTIVITY FIVE-FOLD

CELSS TEST FACILITY PROJECT



## Controlled Ecological Life Support Systems

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- A MAJOR UNKNOWN IS THE PRODUCTIVITY OF PLANTS IN SPACE: IN ORBIT AT MICRO-GRAVITY ( $10^{-6}$  TO  $10^{-3} \times g$ ), ON THE MOON'S SURFACE ( $0.16 \times g$ ) AND ON MARS SURFACE ( $0.38 \times g$ )
- WHILE THE INITIAL USE OF THE CELSS TEST FACILITY WILL BE ON SPACE STATION FREEDOM, THE FACILITY CAN BE ADAPTED TO STUDY PLANT GROWTH ON THE MOON'S SURFACE AS A LABORATORY INSTRUMENT IN AN EARLY LUNAR BASE

CELSS TEST FACILITY PROJECT





# Controlled Ecological Life Support Systems

**NASA**  
National Aeronautics and  
Space Administration

August 5, 1992

## Science and Technology Working Group

Robert MacElroy	NASA/AMES Research Center
John Tremor	Bionetics/AMES Research Center
Marcel Andre	Cadarache Research Center (CEA) France
Charles Blackwell	University of Texas/AMES Research Center
Ray Bula	U Wisconsin/WCSAR
Joe Cowles	Virginia Technical University
Joe Gale	Hebrew University of Jerusalem
Arthur Galston	Yale University
Gary Jahns	NASA/AMES Research Center
William Knott	NASA/Kennedy Space Center
Marv Luttges	University of Colorado/Aerospace Engineering Science
Ralph Mitchell	Harvard University/Division of Applied Science
Cary Mitchell	Purdue University/Department of Horticulture
Frank Salisbury	Utah State University/Plants Soils and Biometeorology Department
Tyler Volk	New York University
Richard Wisniewski	NASA/AMES Research Center

CELSS TEST FACILITY PROJECT



# Controlled Ecological Life Support Systems

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## Controllable Environmental Conditions

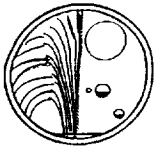
### Chamber Parameters:

Temperature	18-40 deg C	± 1 deg C
Humidity	60-80% RH	± 10%
O <sub>2</sub> Level	5-23.7 kPa	± 5%
CO <sub>2</sub> Level	300-5000 μmols/mol	± 10 μmols/mol
Lights	on/off	
Light Intensity	200-2000 μmols/m <sup>2</sup> /s	± 5%

### Crop:

- Cultivars
- Species
- Genetic Engineering
- Polyculture

CELSS TEST FACILITY PROJECT

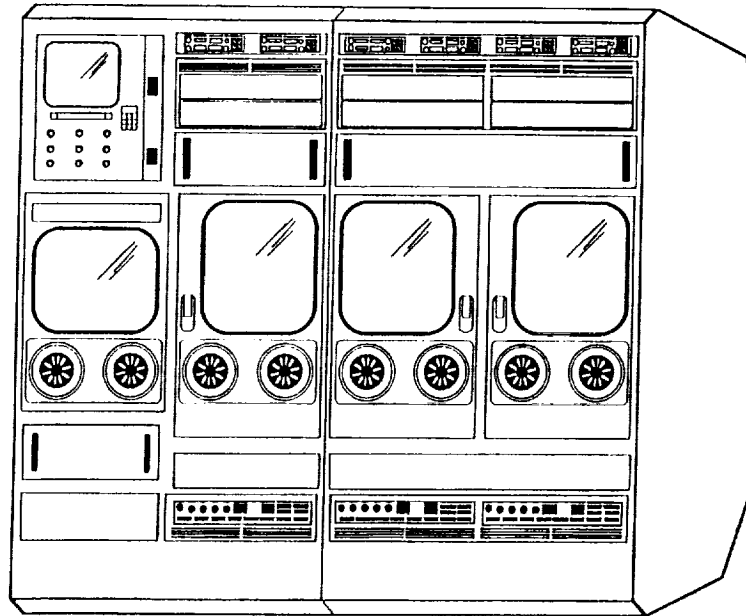


# Controlled Ecological Life Support Systems

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## Early Concept



CELSS TEST FACILITY PROJECT

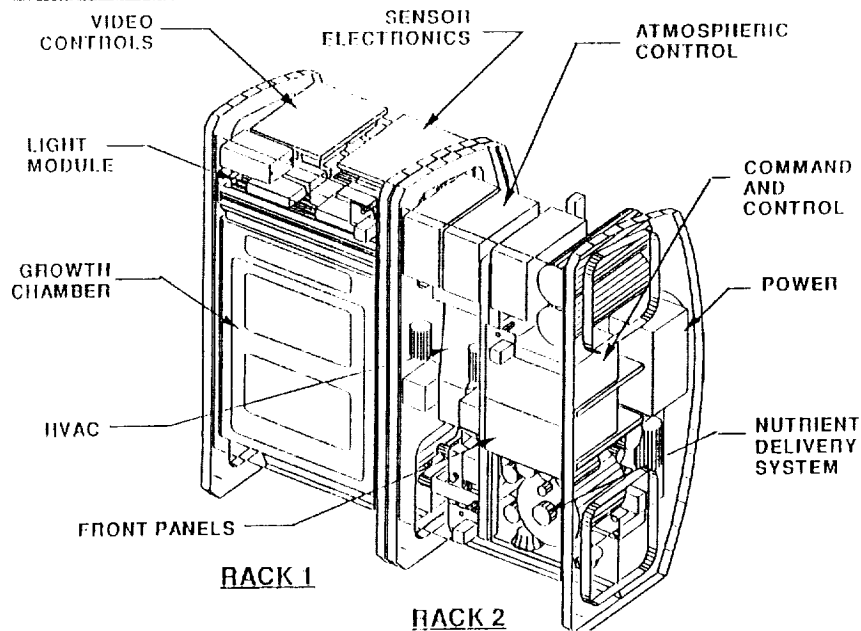


# Controlled Ecological Life Support Systems

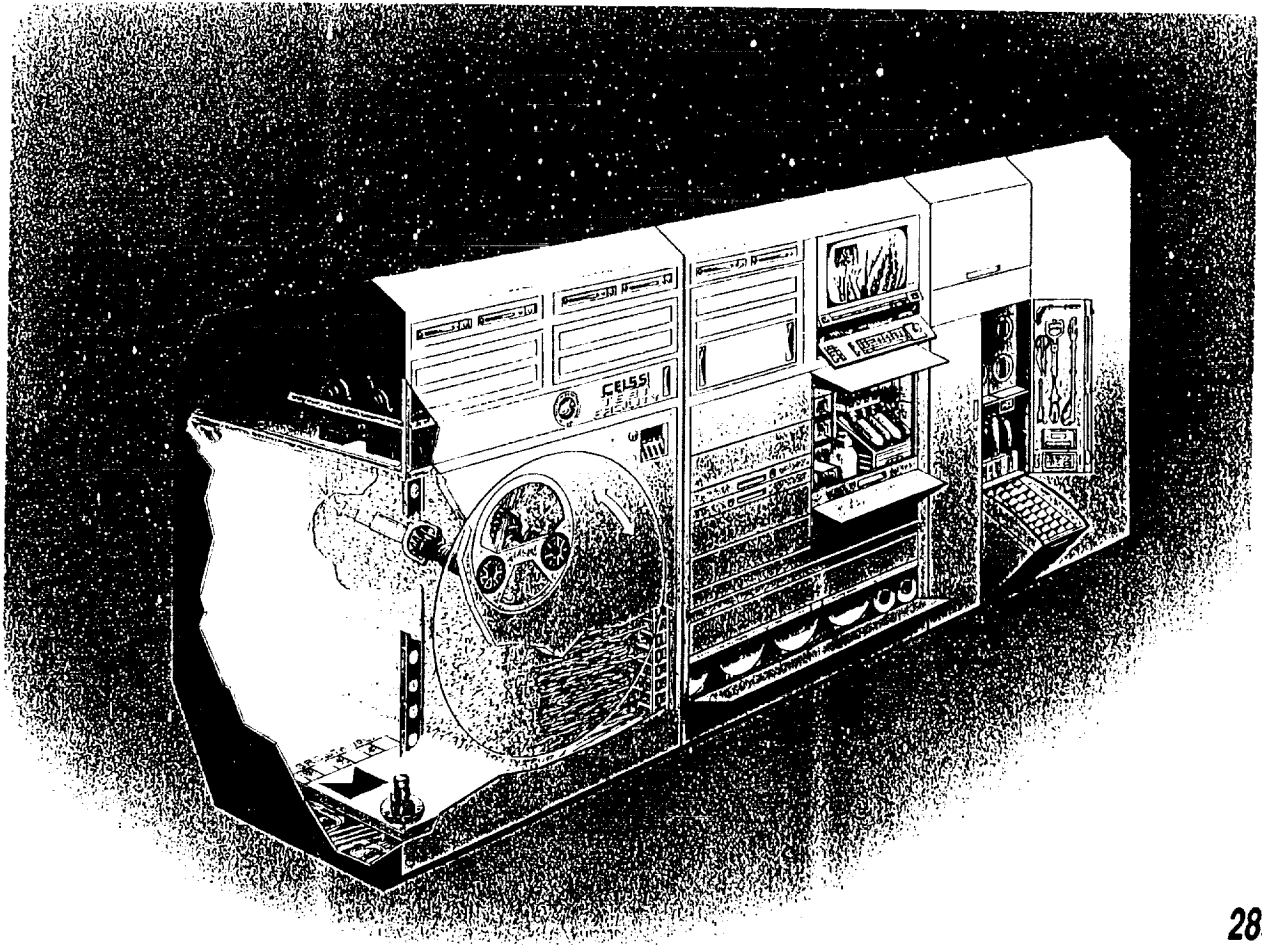
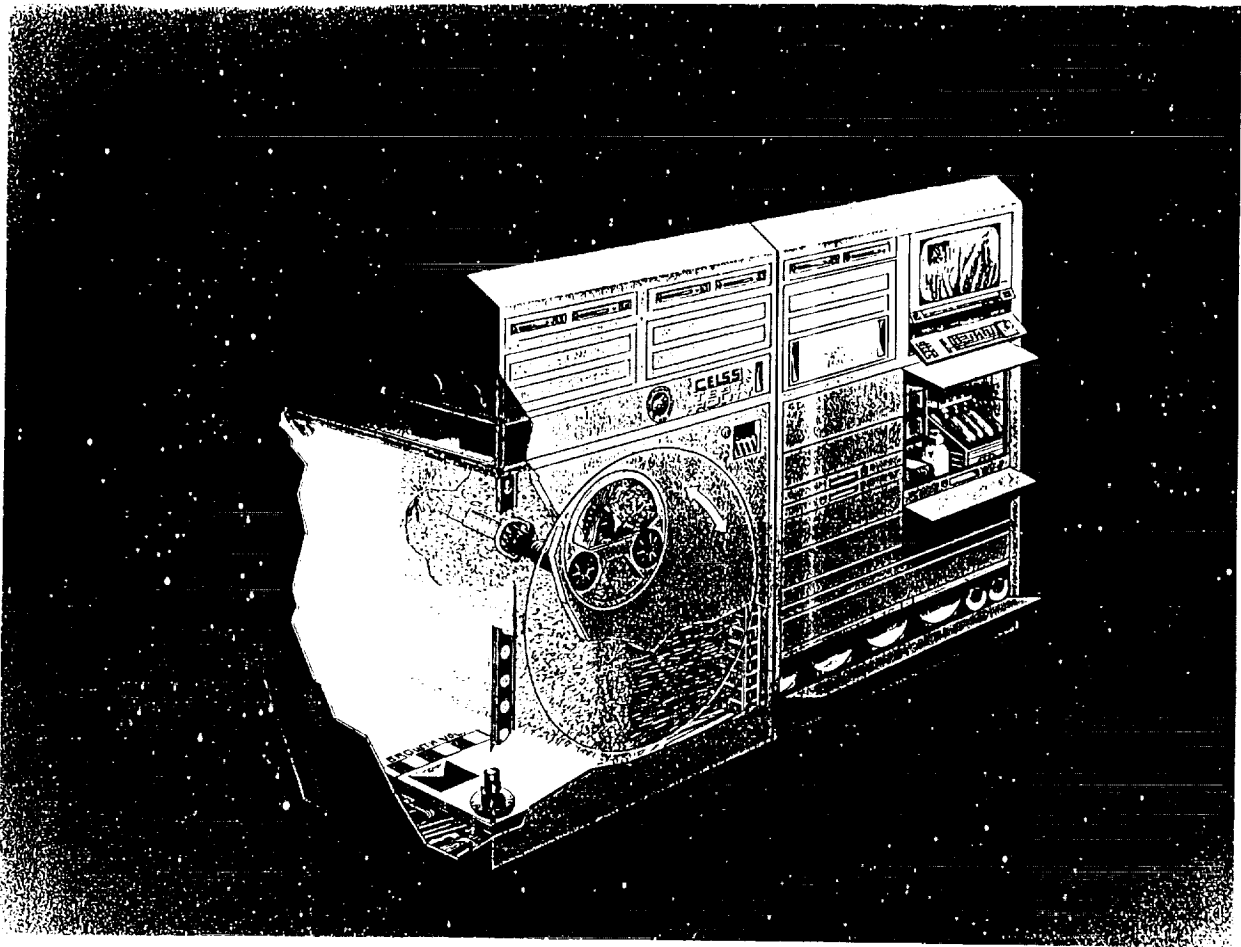
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## Rack Assembly



CELSS TEST FACILITY PROJECT



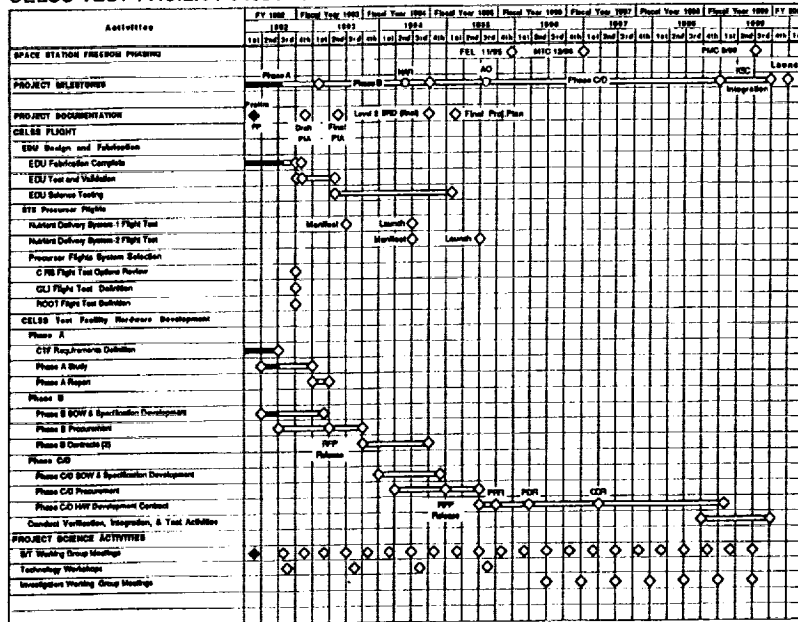


# Controlled Ecological Life Support Systems

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## CELSS TEST FACILITY PROJECT SCHEDULE



CELSS TEST FACILITY PROJECT

## AN ON-ORBIT VIEWPOINT OF LIFE SCIENCES RESEARCH

Presented by Byron K. Lichtenberg  
Omega Aerospace, Inc.  
Consultant- Boeing

### ABSTRACT

As a Payload Specialist who has flown on two space shuttle missions and a life science researcher, I want to present several issues that impact life science research in space. During early space station operations, life science and other experiments will be conducted in a time-critical manner, long-duration human experiments will generally not be done, and there will be the added duties of both space shuttle and space station systems operation (and the concomitant training overhead).

Life sciences research is different from other science research done in space because the crew is involved both as an operator and as a subject. There is a need for pre- and post-flight data collection as well as inflight data collection. It is imperative that the life science researcher incorporate the crewmembers into their team early in the training cycle to fully explain their science and make the crew aware of the importance and sensitivities of their experiment.

During the pre-flight phase, the crew is incredibly busy with a myriad of duties. Therefore, it is difficult to get "pristine" subjects for the baseline data collection. There are also circadian shifts, travel and late nights to confound the data. During this time it is imperative that the researcher develop, along with the crew, a realistic estimate of crew-time required for their experiment.

Inflight issues that affect the researcher are the additional activities of the crew, the stresses inherent in spaceflight, and the difficulty of getting early in-flight data. During SSF activities the first day or two will be taken up with rendezvous and docking. Other issues are the small number of subjects on any given flight, the importance of complete and concise procedures, and the vagaries of on-board data collection.

Postflight, the crew is tired and experiences a "relaxation." This along with circadian shifts, and rapid re-adaptation to 1-g make immediate post-flight data collection difficult.

Finally, the blending of operational medicine and research always results in either competition for resources (crew time, etc) or can influence the physiological state of the crew member by imposing mandated countermeasures. However, the unique opportunity to conduct research in an environment that cannot be duplicated here on Earth outweighs all of the "challenges" that exist for space life researchers!

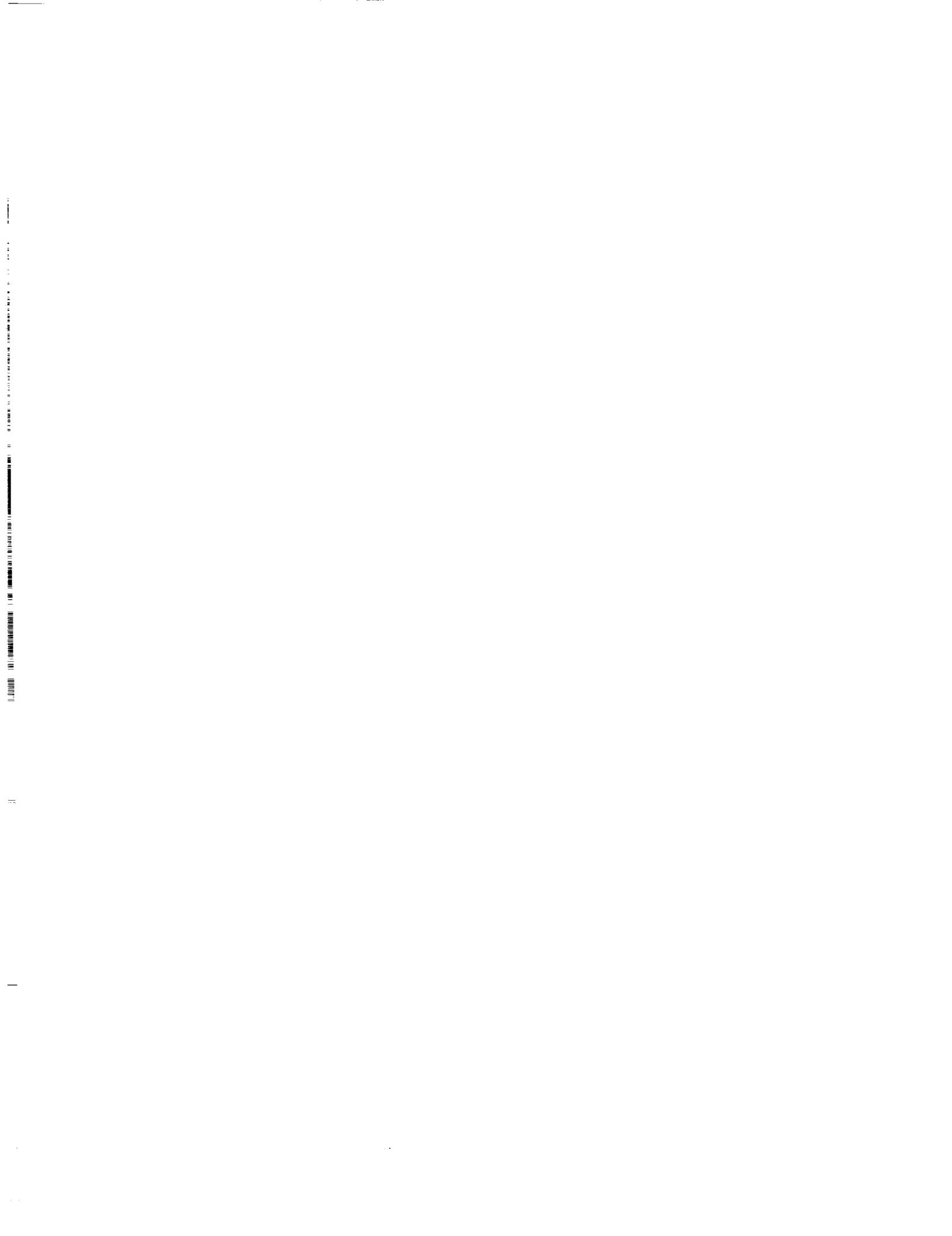


**CREW HEALTH**

Presented by Roger Billica, M.D.  
Medical Operations Branch  
NASA Johnson Space Center

**ABSTRACT**

Crew health concerns for Space Station Freedom are numerous due to medical hazards from isolation and confinement, internal and external environments, zero gravity effects, occupational exposures, and possible endogenous medical events. The operational crew health program will evolve from existing programs and from life sciences investigations aboard Space Station Freedom to include medical monitoring and certification, medical intervention, health maintenance and countermeasures, psychosocial support, and environmental health monitoring. The knowledge and experience gained regarding crew health issues and needs aboard Space Station Freedom will be used not only to verify requirements and programs for long duration space flight but also in planning and preparation for Lunar and Mars exploration and colonization.







# CREW HEALTH

## CREW HEALTH

- o How does SSF utilization depend upon crew health?
- o How does the field of Space Medicine plan to utilize SSF?

## **IMAGINE...**

- **Health (short term, long term)**
- **Well-being**
- **Performance**
- **Mission schedule**
- **Mission goals**
- **Mission success**
- **Program viability**

## **MEDICAL HAZARDS OF SPACE FLIGHT**

1. **Zero - Gravity**
  - a. **Physiological changes (cardiovascular, musculoskeletal, etc)**
  - b. **Illnesses (SMS)**
2. **Isolation / Confinement**
  - a. **Psychosocial stress**
  - b. **Nutritional deficiency**
  - c. **Infectious disease**
3. **Environment**
  - a. **External (radiation, vacuum)**
  - b. **Internal (noise, toxic exposure, vibration)**
4. **Space flight (general)**
  - a. **Trauma**
  - b. **Endogenous illness**
  - c. **G-forces (acceleration, impact)**

# **COMPREHENSIVE HEALTH CARE PROGRAM**

- 1. Medical Assessment and Certification**
- 2. Countermeasures Implementation**
- 3. Medical Intervention**
- 4. Psychosocial Support**
- 5. Environmental Health Monitoring**

**for ALL mission phases:**

**Preflight - Inflight - Postflight**

## **NASA Medical Care Systems for Space Flight**

- o Provide monitoring, diagnosis and treatment for:**
  - first aid and routine simple medical events**
  - emergencies (incl. decompression sickness)**
  - dental**
  - stabilization and transport for more serious illnesses and injuries**
- o Space Shuttle = Shuttle Orbiter Medical System (SOMS)**
- o Space Station = Crew Health Care System (CHeCS)**
  - Health Maintenance Facility**
  - Environmental Health System**
  - Exercise Countermeasures Facility**

## **SPACE MEDICINE UTILIZATION OF SSF**

- 1. Establish baselines and norms for humans in space, isolation and confinement (closed systems.)**
- 2. Develop and verify monitoring and countermeasures.**
- 3. Gain operational experience in remote health care, verify procedures and protocols.**
- 4. Testbed for Lunar and Mars health care systems.**

## **OPERATIONAL RESEARCH AND DEVELOPMENT**

- 1. Medical intervention technologies**
- 2. Remote monitoring and diagnostic technologies (non-invasive)**
- 3. Circadian shifting**
- 4. Telemedicine**
- 5. Decontamination and toxic management strategies**
- 6. Medical computer informatics and expert systems**
- 7. Extended life pharmaceuticals**
- 8. Blood and fluid replacement systems**
- 9. Radiation protection**
- 10. Crew selection and psychosocial support**
- 11. Packaging logistics**

## **GOAL**

**PROVIDE A PROGRAM OF COMPREHENSIVE HEALTH CARE  
NECESSARY TO ENABLE A HEALTHY AND PRODUCTIVE  
CREW THAT IS ABLE TO ACCOMPLISH MISSION GOALS,  
AND TO AVOID LONG TERM NEGATIVE CREW HEALTH  
CONSEQUENCES.**

**QUESTIONS ?**



*SESSION 3:  
TECHNOLOGY RESEARCH*

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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 5, 1992*

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## SPACE STATION FREEDOM AS AN ENGINEERING EXPERIMENT STATION: AN OVERVIEW

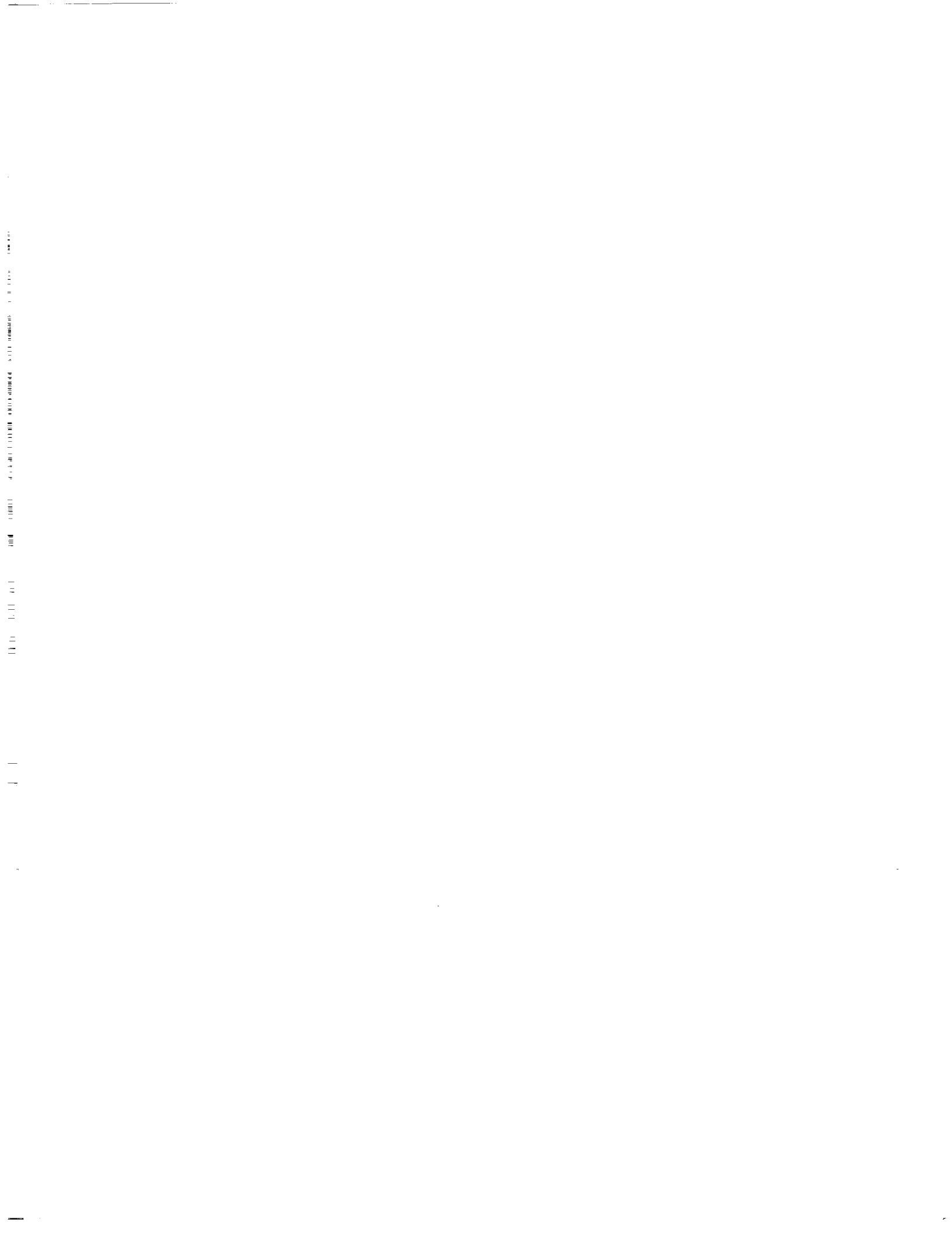
Presented by M. Frank Rose  
Space Power Institute  
Auburn University

### ABSTRACT

It is one of NASA's missions to provide the technological underpinnings for space flight, be it manned or unmanned. As a consequence, the relevant technologies such as power, propulsion, life support and materials technologies are investigated throughout the space community. The results of these investigations quite often produce laboratory prototypes which are sometimes an order of magnitude better than the technology employed in the currently flying spacecraft. Attempts to bring these developments to the point where they will readily be used by spacecraft designers invariably stumbles on the issue of space qualification. The process to do this is long and, while terrestrial simulation can give confidence, nothing suffices for full qualification like time in space.

In this presentation, the premise that Space Station Freedom has great utility as an engineering experiment station will be explored. There are several modes in which it can be used for this purpose. The most obvious are space qualification, process development, in space satellite repair, and materials engineering. The range of engineering experiments which can be done at Space Station Freedom run the gamut from small process oriented experiments to full exploratory development models. A sampling of typical engineering experiments are discussed in this session. First and foremost, Space Station Freedom is an elaborate experiment itself which, if properly instrumented, will provide engineering guidelines for even larger structures which must surely be built if mankind is truly "outward bound". Secondly, there is the test, evaluation and space qualification of advanced electric thruster concepts, advanced power technology and protective coatings which must of necessity be tested in the vacuum of space. The current approach to testing these technologies is to do exhaustive laboratory simulation followed by shuttle or unmanned flights. Third, the advanced development models of life support systems intended for future space stations, manned mars missions, and lunar colonies can be tested for operation in a low gravity environment. Fourth, it will be necessary to develop new protective coatings, establish construction techniques, evaluate new materials to be used in the upgrading and repair of Space Station Freedom. Finally, the industrial sector, if it is ever to build facilities for the production of commercial products must have all the engineering aspects of the process evaluated in space prior to a commitment to such a facility.

The necessity for EVA, an engineering laboratory, and the appropriate compliment of instrumentation will be discussed in terms of what is now planned for Space Station Freedom and what would ideally be needed. The link with transportation will be discussed in terms of cost, lift capability and current state of the art.





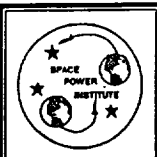
# SPACE STATION FREEDOM UTILIZATION CONFERENCE

## SPACE STATION FREEDOM AS AN ENGINEERING EXPERIMENT STATION AN OVERVIEW

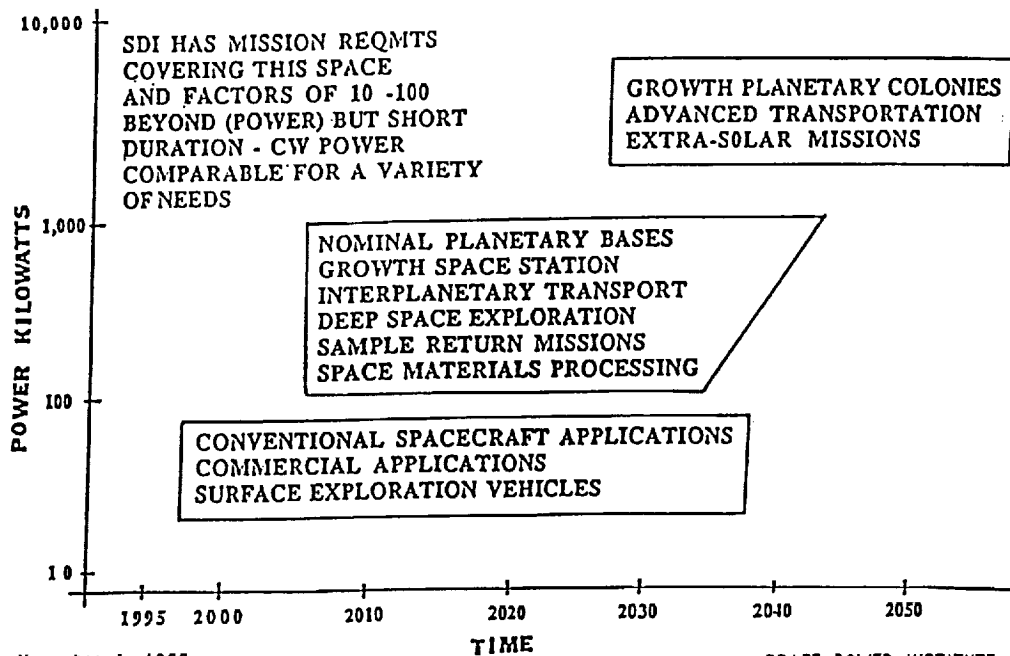
PRESENTED TO  
SPACE STATION FREEDOM UTILIZATION CONFERENCE  
AUGUST 3 - 6, 1992

M. FRANK ROSE  
SPACE POWER INSTITUTE  
231 LEACH CENTER  
AUBURN UNIVERSITY, AL

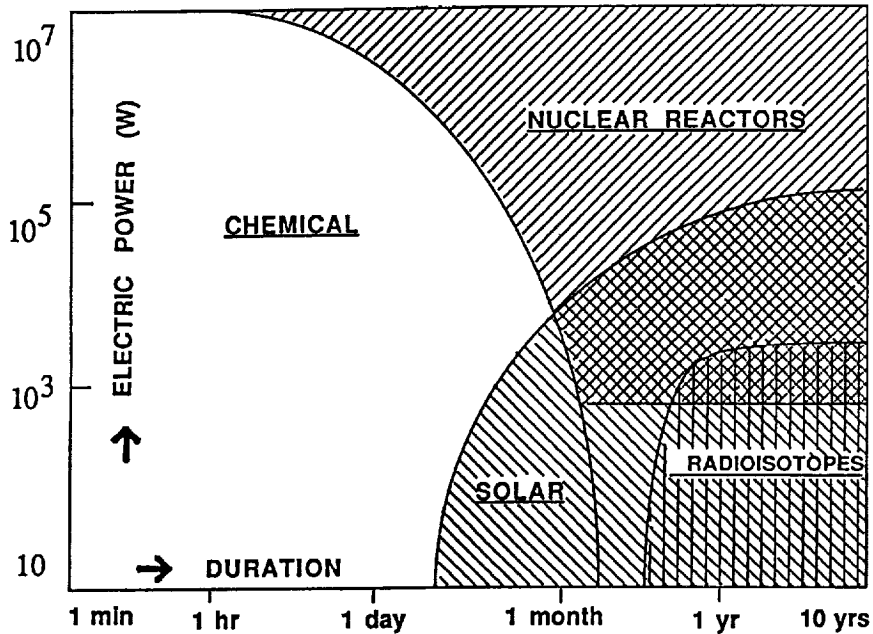
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# POWER LEVEL GROWTH





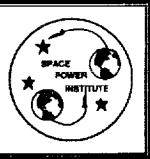


Space power technologies as related to mission duration



## SPACE STRUCTURES TECHNOLOGY

- EFFICIENT RELIABLE POWER - SSF REPRESENTS A MAJOR EXPERIMENT IN POWER FOR FUTURE FACILITIES
- MATERIALS AND THEIR INTERACTION WITH THE SPACE ENVIRONMENT
  - THOSE ON THE STATION
  - NEW MATERIALS FOR NEXT GENERATION
- THERMAL MANAGEMENT FOR LARGE STRUCTURE
- PROPULSION AND STATION KEEPING
- EFFECTS OF OPERATIONS
- DYNAMICS OF THE STRUCTURE

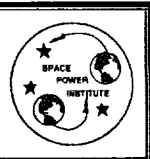


## ENGINEERING EXPERIMENT STATION

- EVALUATE NEW LIFE SUPPORT SYSTEM CONCEPTS, COMPONENTS AND SYSTEMS
- MANS ABILITY TO FUNCTION AND PROSPER IN THE SPACE ENVIRONMENT
  - .. HUMAN FACTORS
  - .. PRODUCTIVITY
  - .. MAN - MACHINE TEAMS
- SPACE QUALIFY
  - .. POWER
  - .. PROPULSION
  - .. ELECTRONICS
  - .. MATERIALS
- ASSEMBLY AND REPAIR OF COMPLEX SPACECRAFT
  - .. NODE IN THE LUNAR AND MARS MISSIONS
  - .. REFURBISH AND REPAIR SATELLITES ALONG THE LINES OF THE SHUTTLE CREW EXPERIENCE

ASSEMBLE, TEST, SPACE QUALIFY COMPONENTS, SYSTEMS, ETC INTENDED FOR COMMERCIAL OPERATIONS

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## AERONAUTICS AND SPACE TECHNOLOGY CODE - R

- RESPONSIBLE FOR DEVELOPING THE TECHNOLOGICAL UNDERPINNINGS OF ANY FUTURE SPACE ENDEAVOUR
- HAS DEVELOPED MANY COMPONENT TECHNOLOGIES WHICH REPRESENT SIGNIFICANT IMPROVEMENTS OVER FLIGHT HARDWARE
- NEEDS TO ADVANCE TO TECHNOLOGY DEMONSTRATORS
  - .. TERRESTRIAL
  - .. SPACE DEMONSTRATOR
- SPACE QUALIFY AND TRANSFER TO THE AEROSPACE COMMUNITY

SPACE STATION FREEDOM SHOULD BE THE LABORATORY FOR  
TRANSITIONING CODE - R TECHNOLOGY TO THE SPACE FLEET

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• **Conclusion:** OAST has an enormous spectrum of science and technology which must form the basis of a permanent space infrastructure. SSF's greatest value to OAST is as an engineering experiment station where advanced technologies can be researched, developed and space qualified, SEI hardware space tested, engineering guidelines for future space hardware determined, and commercial prototyping established.

**Recommendation:** OAST should promote this interpretation of SSF insisting that SSF is much more than a platform for life sciences and microgravity materials R&D. OAST should coordinate with Code C to actively promote a joint constituency. OAST should constantly negotiate with SSF to insure maximum man in the loop experimentation aboard SSF and obtain NASA administrator support for this.

August 3, 1992

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• **Conclusion:** The SSF planning cycle for experimental access is estimated to be greater than 5 years and needs to be streamlined and made user friendly.

**Recommendation:** OAST should insist on standardization of procedures and equipment, reduction of "paperwork", and the establishment of a field center office whose function is to guide and expedite the process of "getting an experiment through the system". In general, it should push for a time line of 1-3 years. Rapid response SARR type payloads should be minimal time response with large complicated experiments taking no more than four years.

August 3, 1992

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*--- OAST SECURE A MANDATE  
FROM THE NASA ADMINISTRATOR TO HEAVILY  
USE SSF TO PURSUE THE RELEVANT SCIENCE,  
ESTABLISH ENGINEERING GUIDELINES,  
SPACE QUALIFY PROMISING TECHNOLOGIES  
AND TEST PROTOTYPE SYSTEMS INTENDED  
FOR COMMERCIAL ENTERPRISES AND MAN'S  
INEVITABLE PERMANENT PRESENCE IN  
SPACE ---*

August 3, 1992

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## **KEY ISSUES ENGINEERING EXPERIMENT STATION**

- WILL THE SSF AS FINALLY BUILT BE ADEQUATE
  - WORK SPACE
  - EQUIPMENT COMPLIMENT
  - PERSONNEL
- CAN PROCEDURES BE STREAMLINED TO MINIMIZE TIME NEEDED TO TAKE AN EXPERIMENT TO THE STATION
- CAN EVA WORKLOAD BE SCHEDULED TO SERVICE STATION AND MAJOR EXTERNAL EXPERIMENTS
- COST OF TIME AT STATION
- COST OF TRANSPORTATION
- SUPPORT OF THE CONGRESS AND THE AMERICAN PEOPLE

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*It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely lukewarm defenders in those who would gain by the new ones.*

**Machiavelli, "The Prince", 1513.**

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## **SPACE STATION FREEDOM UTILIZATION CONFERENCE**

- 8:30 Overview—Dr. M. Frank Rose
- 9:00 Precursor Space Station Experiments—Sherwin M. Beck, Director, Systems Analysis and Engineering, Space Station Freedom Office, NASA LaRC
- Modal Identification Experiment—Dr. Brantley Hanks, Head, Spacecraft Dynamics Office, NASA LaRC
- 9:40 Instrumented Space Station—Dr. Lenwood G. Clark, Acting Deputy Manager, Earth Probes Program, NASA Headquarters
- Middeck Q-g Dynamics Experiment—Professor Edwin F. Crawley, Department of Aeronautics and Astronautics, MIT
- 10:00 Break
- 10:30 Potential Attached Payloads—Don E. Avery, Space Station Utilization Office, NASA LaRC
- Spacecraft Materials & Coatings—Wayne Slomp, Applied Materials Branch, Materials Division, NASA LaRC
- Materials Experiments Opportunities—Robert Schmidt, Center for Materials & Structures, Case Western Reserve University
- 11:30 Potential Pressurized Payloads—Roy McIntosh, Head, Advanced Development & Flight Experiment Section, NASA Goddard Space Flight Center
- Two-Phase Thermal Flow—Roy McIntosh
- Q-g Life Support & Thermal Control for Space Station—Liese A. Dall-Bauman, System Engineering Analysis Office, NASA Johnson Space Center

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**PRECURSOR SPACE STATION FREEDOM EXPERIMENTS**

Presented by Dr. Roger A. Breckenridge

Prepared by Sherwin M. Beck  
Space Station Freedom Office  
NASA Langley Research Center

**ABSTRACT**

The NASA Office of Aeronautics and Space Technology uses the In-Space Technology Experiments Program (IN-STEP) as the primary management vehicle to pursue innovative and potentially high payoff space technology experiments. The purpose of this presentation is to provide an overview of the IN-STEP approach in developing precursor Space Station experiments; identify those experiments now in the program; review the key points of the IN-STEP 1992 Announcement of Opportunity; and describe the OAST in-space technology experiments development process.

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## Space Station Utilization Conference

### Precursor Space Station Experiments

Sherwin M. Beck  
Space Station Freedom Office  
NASA Langley Research Center  
Hampton, Virginia

LaRC SSFO



- OAST In-Space Technology Experiments Program
- Current In-Space Experiments
- OAST 1992 In-STEP Announcement of Opportunity
- OAST In-Space Development Process

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## In-Space Technology Experiments Program (In-STEP)

- Evolved from the NASA In-reach and Out-reach Programs
- Small in size and cost
- Proposals solicited as a group by Announcement of Opportunity from NASA, industry, universities
- Proposals solicited in technical areas of highest priority to OAST
- Selection based on rigorous technical and programmatic review (NASA, industry, and universities evaluators)



## OAST Space Technology - In-space Experiments

### Platforms

- 16 Experiments
- Mid-deck 0-G Dynamics Experiment (MODE) flown on STS-48 Mission (MIT-SERC/LaRC)

### Transportation

- 4 Experiments
- Tank Pressure Control Experiment (TPCE) flown on STS-43 Mission (Boeing/LeRC)

### Science

- 6 Experiments

### Planetary Surface

- 1 Experiment

## In-Space Experiments

### Platforms

Emulsion Chamber Technology (ECT)  
 Middeck Active Control Exp. (MACE)  
 Joint Damping  
 Middeck 0-G Dynamics Exp. (MODE)  
 Middeck 0-G Dynamics Exp. Reflight  
 Jitter Suppression  
 Heat Pipe Performance (HPP)  
 Liquid Motion  
 Two-Phase Flow  
 Risk Based Fire Safety  
 Solar Array Module Plasma Interaction Exp. (SAMPIE)  
 Thermal Energy Storage (TES)  
 Modal Identification Experiment (MIE)  
 Optical Properties Monitor  
 Electrolysis  
 Sodium Sulfur Battery

### Transportation

Tank Pressure Control Exp. (TPCE)  
 Tank Pressure Control/Thermal Phenomenon (TPCE/TP)  
 Vented Tank Resupply  
 Acceleration Measurement

### Science

Investigation of Spacecraft Glow (GLOW)  
 Cryo System Experiment  
 Hydrogen Maser Clock  
 Environmental Verification Exp. for the Explorer Platform (EVEEP)  
 LIDAR In-space Technology Exp. (LITE)  
 Inflatable Antenna  
 Orbital Acceleration Research Exp. (OARE)  
 Cryo-heat Pipe

### Planetary Surface

Permeable Membrane

## In-STEP 1992 Announcement of Opportunity

- Technology Categories of Interest:

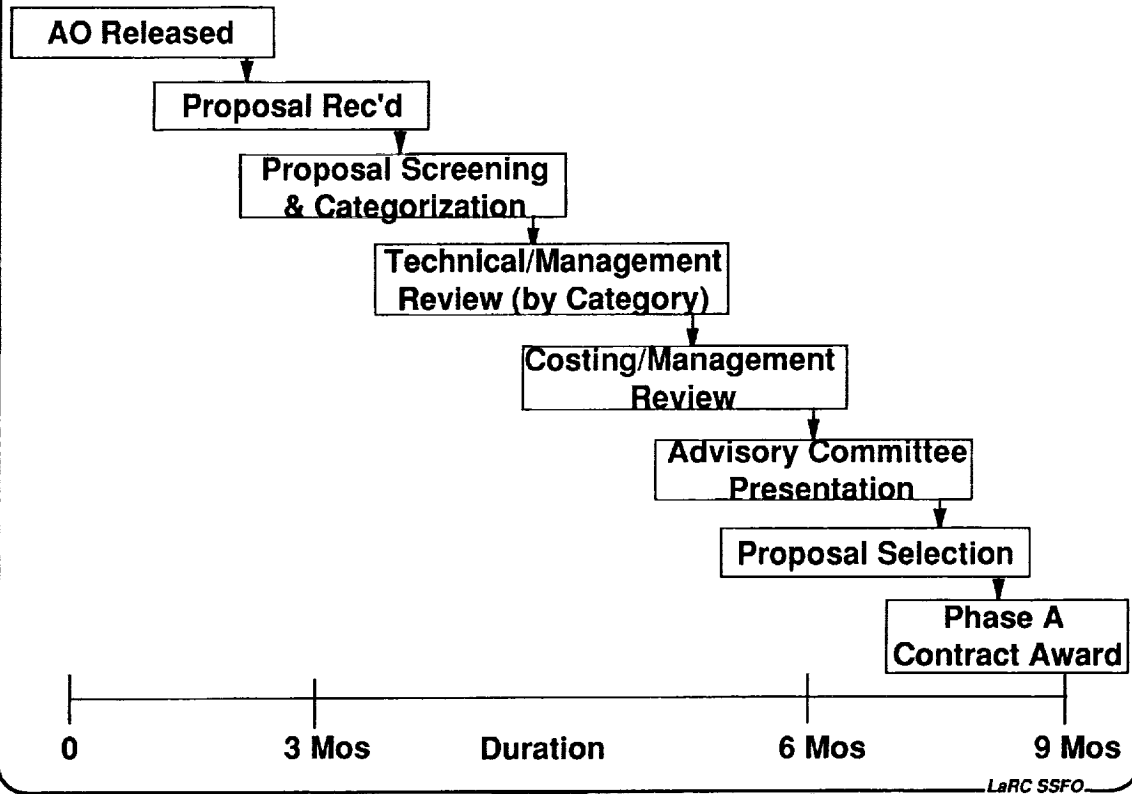
- (1) Space materials, coatings, and environmental effects
- (2) Cryogenic fluid handling
- (3) Human support
- (4) Space power
- (5) In-space construction, repair, and maintenance
- (6) Science sensors and sensor cooling
- (7) Vibration isolation
- (8) Space communications

- Key Points:

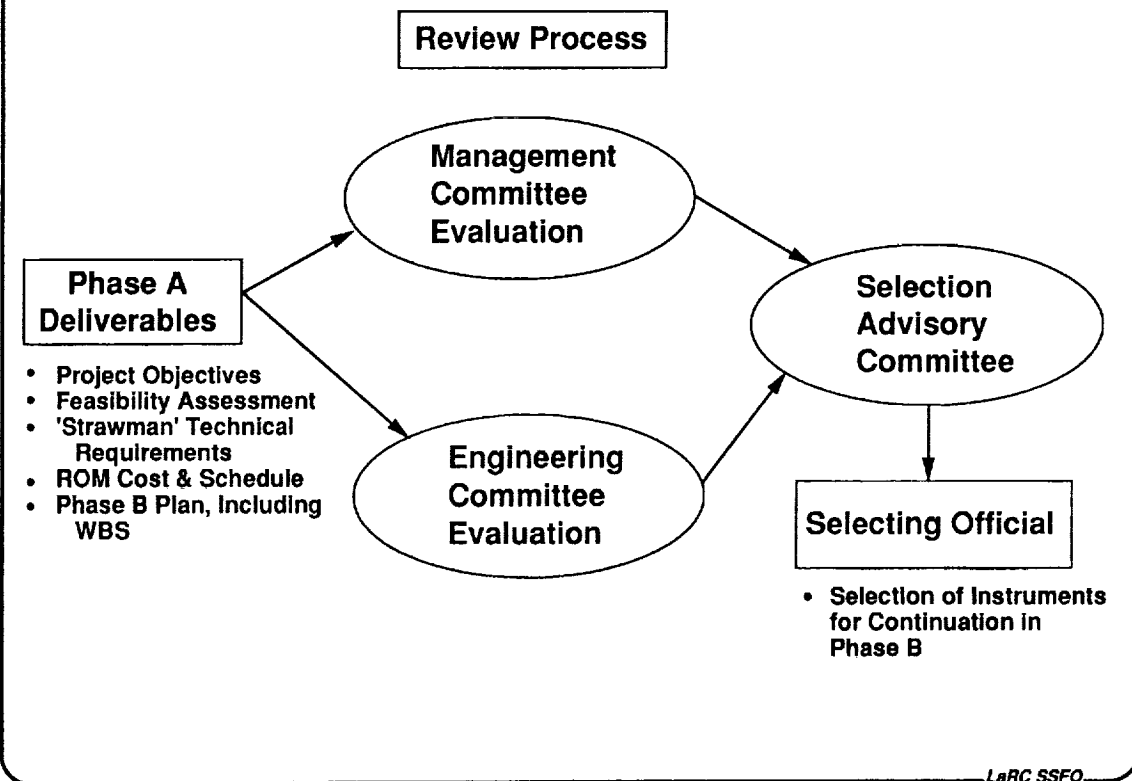
- Approximately fifty Phase A proposals to be selected
- New experiments ready for flight starting 1997
- Use any suitable carrier--including Space Station Freedom



# Experiment Selection Process

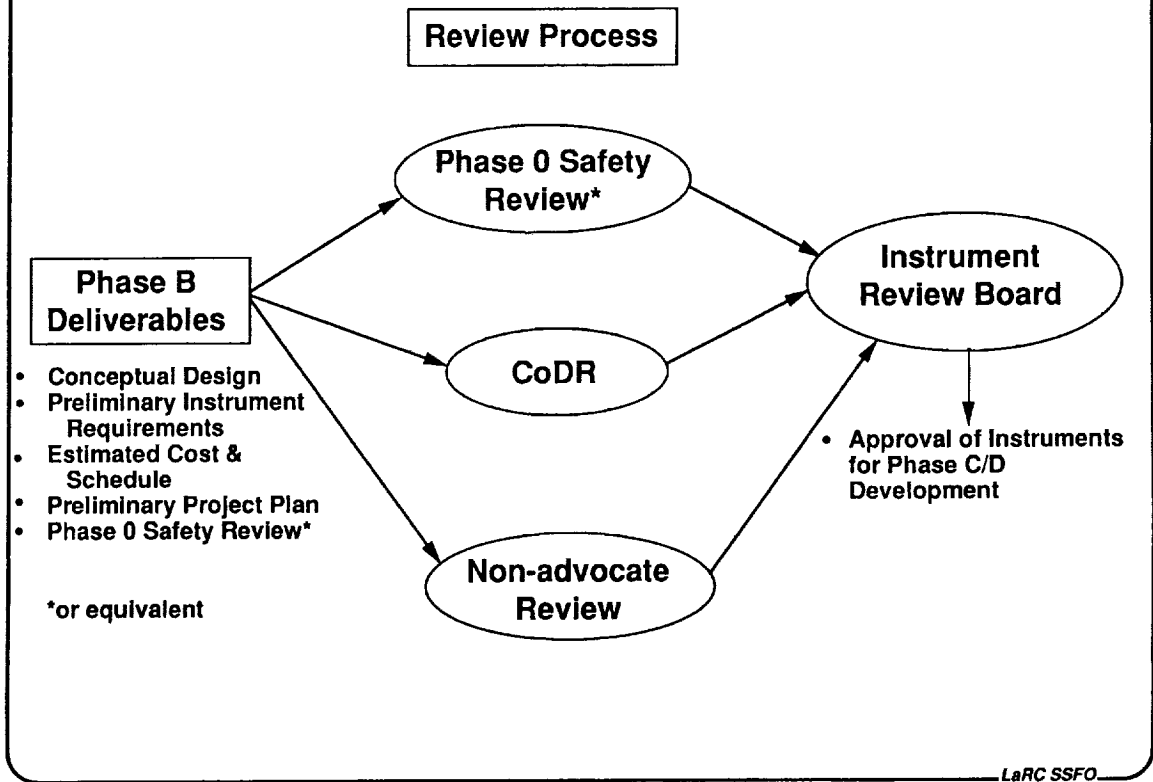


# Phase A: Feasibility

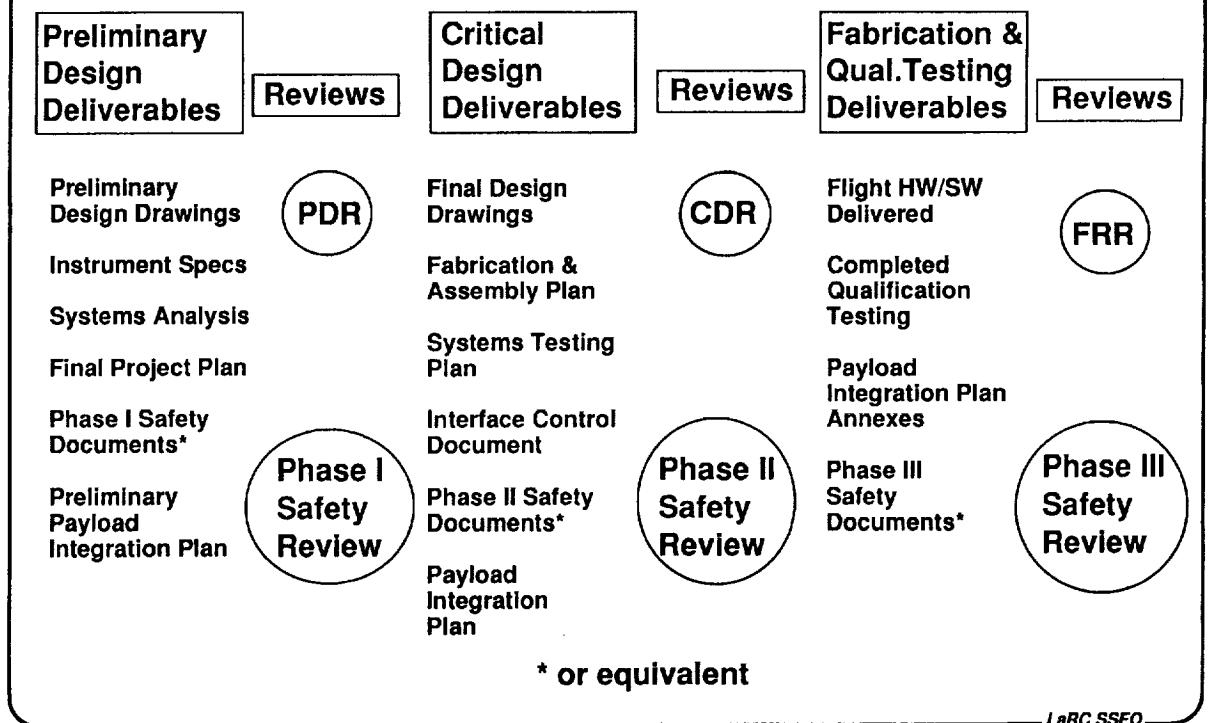




## Phase B: Project Definition



## Phase C/D: Project Implementation



## Phase E - Flight Operations and Technology Transfer

- Flight Operations
- Data Reduction/Analysis
- Conference Presentations
- Publications

**PRECURSOR SSF UTILIZATION: THE MODE EXPERIMENTS**

Presented by Edward Crawley  
Space Engineering Research Center  
Massachusetts Institute of Technology

**ABSTRACT**

The MIT Space Engineering Research Center is the principal investigator for a series of experiments which utilize the Shuttle Middeck as an engineering dynamics laboratory. The first, which flew on STS-48 in September 1991, was the Middeck O-gravity Dynamics Experiment (MODE). This experiment focused on the dynamics of a scaled deployable truss, similar to that of SSF, and of contained liquids in tanks. MODE will be reflown in the fall of 1993. In mid-1994, the Middeck Active Control Experiment (MACE) will examine the issues associated with predicting and verifying the closed loop behavior of a controlled structure in zero gravity. The paper will present experiment background, planning, operational experience, results and lessons learned from these experiments which are pertinent to SSF utilization.





## **PRECURSOR SSF UTILIZATION: THE MODE/MACE EXPERIMENTS**

Edward F. Crawley  
Director, MIT SERC  
August 5, 1992

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*MIT Space Engineering Research Center*

### **APPROACH**

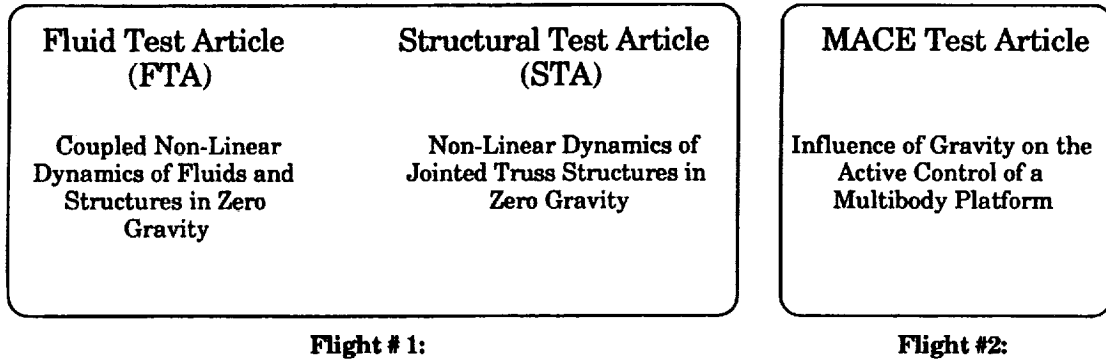
- Experimental background and philosophy
- MODE STA experience
- MODE FTA experience
- MACE planning
- Lessons learned

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*MIT Space Engineering Research Center*

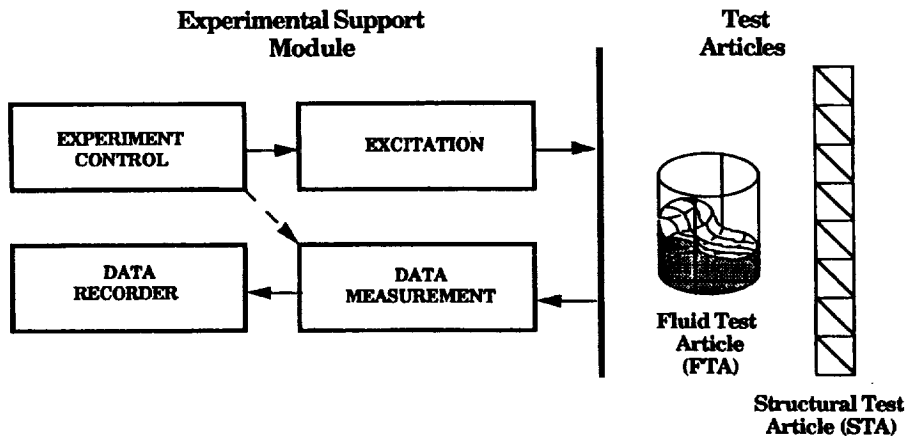
## ***THE MODE FAMILY OF EXPERIMENTS***



## ***EXPERIMENTAL PHILOSOPHY***

- Use the shuttle/station for engineering research (as opposed to demonstration or verification)
- Investigate (dynamics) phenomena which are influenced by gravity
- Use the Middeck Laboratory Module as a shirt sleeve lab environment with heavy reliance on crew interaction
- Use scaling laws to build model which capture the essential physics of the problem and yield results of practical value, at modest size and cost

# ***THE MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)***

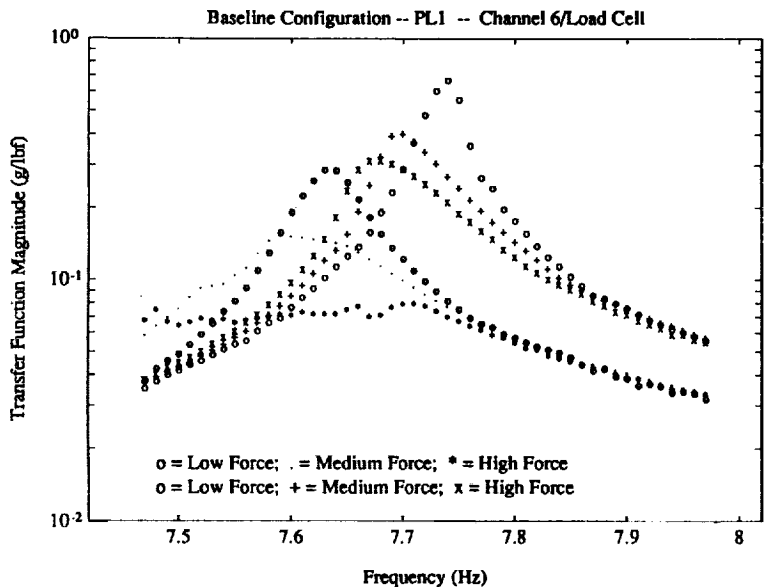


MODE provides a reusable dynamics test facility which will be used on the first flight to test two rather different types of test articles.

## ***STA OBJECTIVES, REQUIREMENTS & APPROACH***

- Engineering science objectives are to characterize the fundamental changes in dynamics in 0-g due to absence of gravity on joints, to quantify the changes due to the absence of suspension and gravity load on members, and to obtain quantitative data for correlation with numerical models.
- Requirements
  - Truss structure containing elements of future space structures.
  - Nonlinear joints with variable pre-load to test nonlinear behavior in several gravity/joint pre-load conditions.
  - Reconfigurable truss with deployable and erectable bays.
- Modelling approach
  - Develop global linear model using FEM and modal test data.
  - Develop Force-State Map of non-linear sub-components.
  - Develop describing functions from Force-State Map.
  - Insert describing functions into global model and solve for forced response using Harmonic Balance Method.
  - Verify predictions with MODE flight and ground test results.

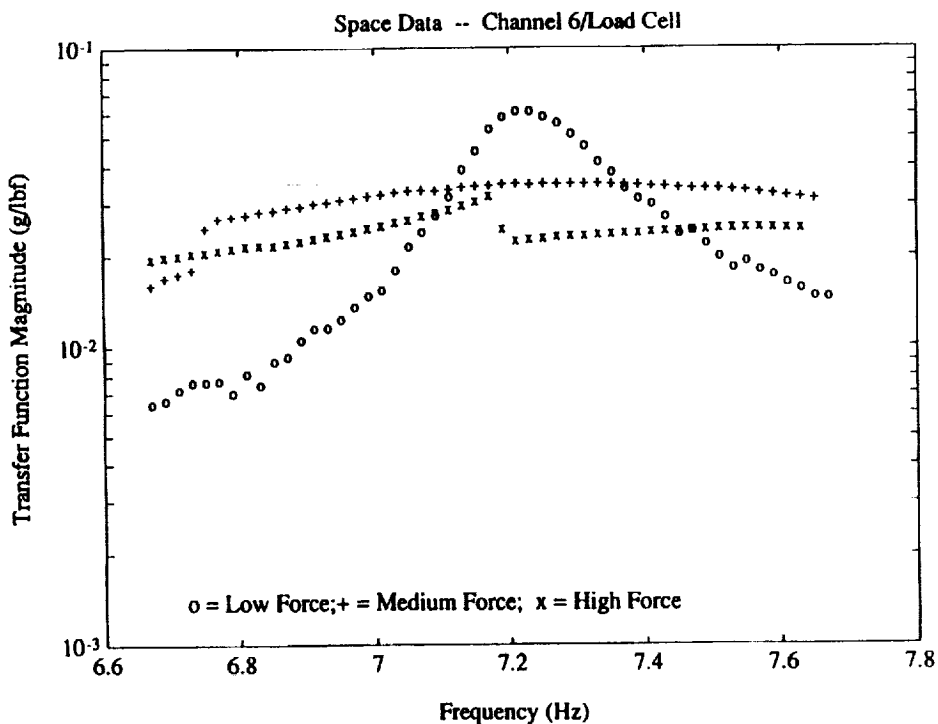
# COMPARISON OF GROUND TO ORBITAL DATA FOR THE BASELINE CONFIGURATION



NOTE: Torsion Mode Only. High Pre-Load.

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## TORSION MODE ALPHA LOOSE





## **CONCLUSIONS OF ORBITAL TESTING**

- Variation measured for erectable, deployable and articulated hardware as a function of force amplitude, joint preload and gravity loading
- Nonlinearities of the STA are more apparent in 0-gravity, especially the alpha loose, which loses resonant behavior
- Modes generally soften with increasing force, but increase in damping is significantly more pronounced
- Changes in frequency between earth and space are generally within the variance of ground testing for the baseline, but outside the variance for the alpha and L configurations.
- Changes in damping are well outside the variance of ground testing

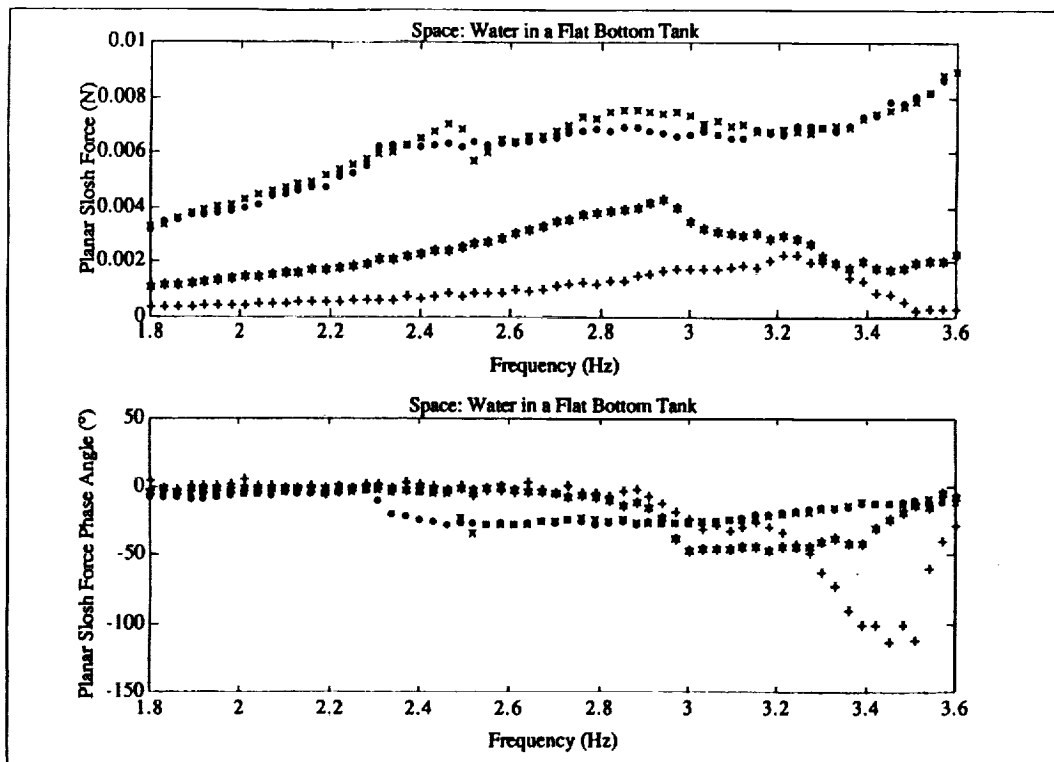
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## **FTA OBJECTIVES, REQUIREMENTS AND APPROACH**

- Engineering science objective is to characterize fundamental 0-g slosh behavior and obtain quantitative data on slosh force and spacecraft response for correlation of numerical model.
- Requirements
  - Scaled tank
  - Properly modelled fluid
  - Simulation of coupled spacecraft mode
  - Harmonic excitation
  - Measurement of slosh force
- Modelling approach
  - Find fluid flow potential and free surface motion solutions.
  - Express kinetic and potential energies in terms of generalized coordinates.
  - Derive governing differential equations by applying Lagrange's Principle.
  - Solve nonlinear equations subject to harmonic excitation.
  - Verify predictions with MODE flight and ground test results.

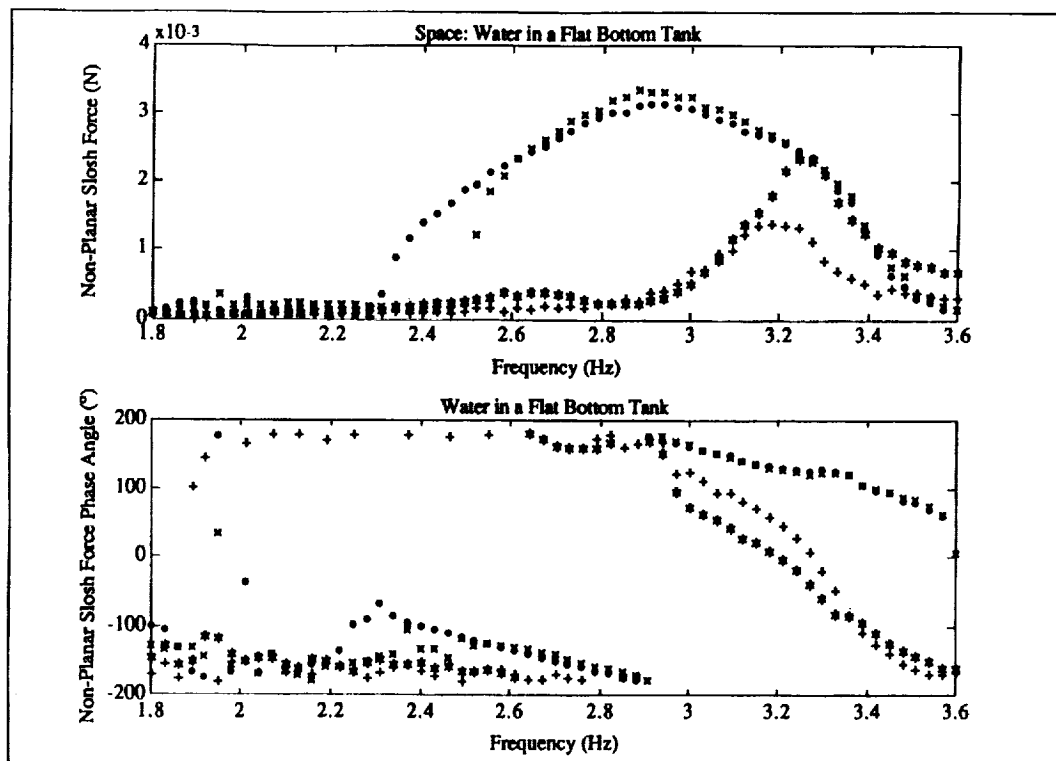
# SPACE RESULTS



Uncoupled Test with Distilled Water as Test Fluid in a 3.1 cm Flat Bottom Cylindrical Tank .  
Planar Slosh Force.

18

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Uncoupled Test with Distilled Water as Test Fluid in a 3.1 cm Flat Bottom Cylindrical Tank .  
Non-planar Slosh Force.

18

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## ***SUMMARY AND CONCLUSIONS***

### **Space Experiments:**

- More benign nonlinear behavior in space than observed on earth
- Modal damping ratios and frequencies significantly different from earth tests
- Demonstrated the ability to investigate fluid slosh in micro-gravity

### **Analytical Model**

- Model more accurate for one-gravity conditions
- Nonlinear solution required that can find "all" the solutions
- Accurate prediction of slosh damping ratios a pre-requisite for an accurate prediction

### **Future**

- Improve nonlinear solution technique
- More space experiments required to investigate effects of contact angle hysteresis, contact angles and dissipation rates.

## ***MODE RESOURCE SUMMARY***

Mode pushed the current Middeck capabilities:

- 115 Watts
- 3 1/2 lockers
- 60 lbs in a single locker
- 16 hours of on orbit testing
- about 25% of Middeck volume during STA testing

## ***MACE SCIENCE OBJECTIVE***

To develop a well verified set of Control Structure Interaction - Controlled Structures Technology (CSI/CST) methods and approaches that will allow designers of future CST spacecraft, which cannot be dynamically tested on the ground in a sufficiently realistic zero-gravity simulation, to have confidence in the eventual orbital performance of such spacecraft.

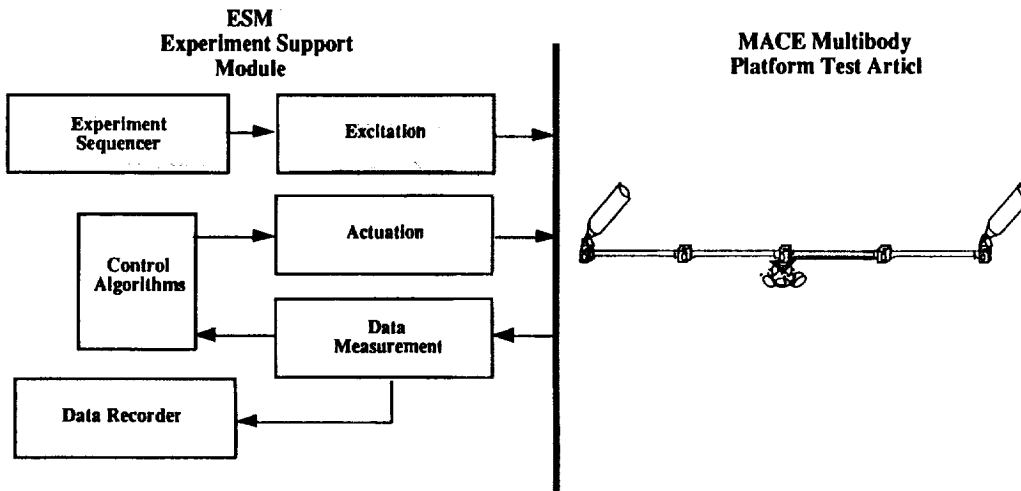
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### ***THE MACE APPROACH***

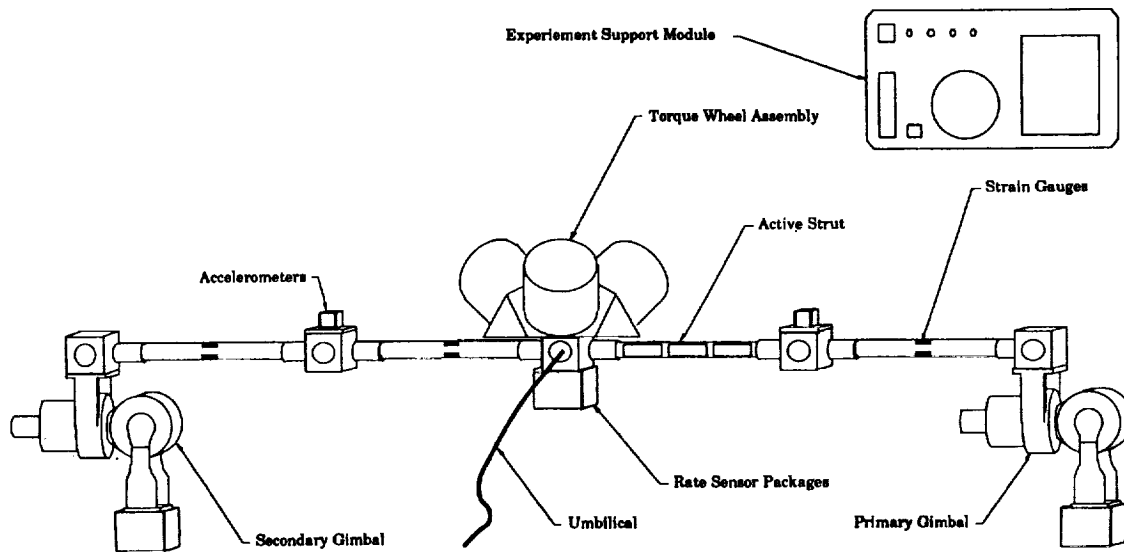
- Select a test article of interest to NASA, which has near-term mission relevancy, is CSI challenging, and is sensitive to gravity perturbations.
- Dynamically scale the test article to fit in middeck in order to integrate at low cost.
- Become a pathfinder for CSI Qualification scenario:
  - Develop analytical models to incorporate the predicted gravity effects. This will lead to development of analytical CSI tools for use by future spacecraft.
  - Perform an extensive ground test program using state-of-the-art suspension systems to identify ground test limitations.
  - Perform a flight test with controllers derived from ground testing/modeling as well as from on-orbit testing.
- Transfer technology to the government/industrial sector
- Educate the next generation of engineers with a challenging, scientifically relevant project.

# THE MIDDECK ACTIVE CONTROL EXPERIMENT (MACE)



- Substantial commonality of ESM hardware/software
- Significant savings in integration/certification process.

## MULTIBODY PLATFORM - CONFIGURATION #1



## ***ON-ORBIT OPERATIONS SUMMARY***

- Operations require one crew member for three eight-hour days.
- First day operations include:
  - test article assembly and electronics check-out;
  - open-loop system identification;
  - implementation of pre-programmed control protocols;
  - system ID data reduction in preparation for downlink;
  - downlink of system identification data;
  - disassembly and storage of hardware.
- Second day operations include:
  - test article assembly and electronics check-out;
  - implementation of pre-programmed control protocols;
  - disassembly and storage of hardware.
- Third day operations include:
  - test article assembly and electronics check-out;
  - uplink of system identification data-based controllers;
  - implementation of uplinked control protocols;
  - disassembly and storage of hardware.

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## ***RESOURCE SUMMARY***

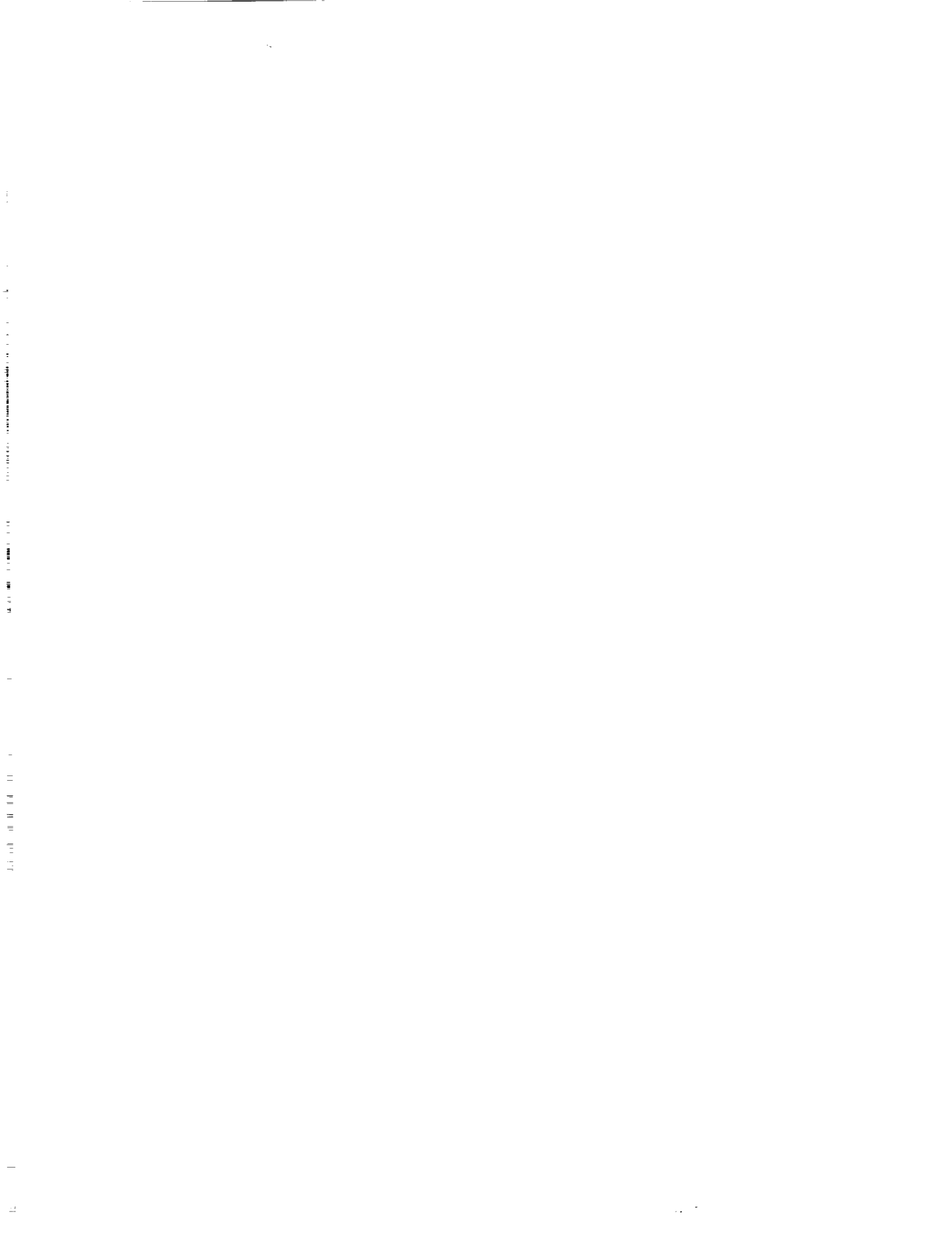
<b>RESOURCE</b>	<b>ACTUAL</b>	<b>TARGET</b>	<b>SSP LIMIT</b>
Power	470 Watts	600 Watts	1000 Watts
Mass			
ESM	57.3 lbs	59.0 lbs	68 lbs
Test Article	86 lbs	100 lbs	162 lbs
Volume			
Stowed	4 lockers	5 lockers	negotiable
Operational	70 ft <sup>3</sup>	70 ft <sup>3</sup>	negotiable
Operations			
Crew Members	1	1	negotiable
Crew Time	3x8 hr days	3x8 hr days	negotiable
Crew Training	?	28 days	negotiable
Uplink (modem)	1 hr.	1 hr.	negotiable
Downlink (Ku band)	4 mins.	8 mins.	negotiable
Downlink (modem)	2 hrs.	2 hrs.	negotiable

## ***MODE/MACE LESSONS LEARNED***

- Low cost experiments happen
- Integration is an art, not a science
- PI should be responsible for payload mission success, ?  
intergrating center
- Crew can be vesitile contributor, if well prepared
- Investigator team must be prepared for mission operations, and  
their limitations
- Hardware shortcuts are penny-wise and pound foolish
- Scaling laws can be exploited to do small/low cost research  
experiments
- Flight experiments are fun, but take a significant fraction of a  
career

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## UTILIZATION OF SPACE STATION FREEDOM FOR TECHNOLOGY RESEARCH

Presented by Don E. Avery  
Space Station Freedom Office  
NASA Langley Research Center

### ABSTRACT

Space Station Freedom presents a unique opportunity for technology developers to conduct research in the space environment. Research can be conducted in the pressurized volume of the Space Station's laboratories or attached to the Space Station truss in the vacuum of space. Technology developers, represented by the Office of Aeronautics and Space Technology (OAST), will have 12% of the available Space Station resources (volume, power, data, crew, etc.) to use for their research.

Most technologies can benefit from research on Space Station Freedom and all these technologies are represented in the OAST proposed traffic model. This traffic model consists of experiments that have been proposed by technology developers but not necessarily selected for flight. Experiments to be flown in space will be selected through an Announcement of Opportunity (A.O.) process. The A.O. is expected to be released in August, 1992. Experiments will generally fall into one of the 3 following categories; (1) Individual technology experiments, (2) Instrumented Space Station, and (3) Guest investigator program. The individual technology experiments are those that do not instrument the Station nor directly relate to the development of technologies for evolution of Space Station or development of advanced space platforms. The Instrumented Space Station category is similar to the Orbiter Experiments Program and allows the technology developer to instrument subsystems on the Station or develop instrumentation packages that measure products or processes of the Station for the advancement of space platform technologies. The guest investigator program allows the user to request data from Space Station or other experiments for independent research.

When developing an experiment, a developer should consider all the resources and infrastructure that Space Station Freedom can provide and take advantage of these to the maximum extent possible. Things like environment, accommodations, carriers and integration should all be taken into account. In developing experiments at Langley Research Center an iterative approach is proving useful. This approach uses Space Station utilization and subsystem experts to advise and critique experiment designs to take advantage of everything Station has to offer. Also, solid object modeling and animation computer tools are used to fully visualize the experiment and its processes. This process is very useful for attached payloads and allows problems to be detected early in the experiment design phase.



# UTILIZATION OF SPACE STATION FREEDOM FOR TECHNOLOGY RESEARCH

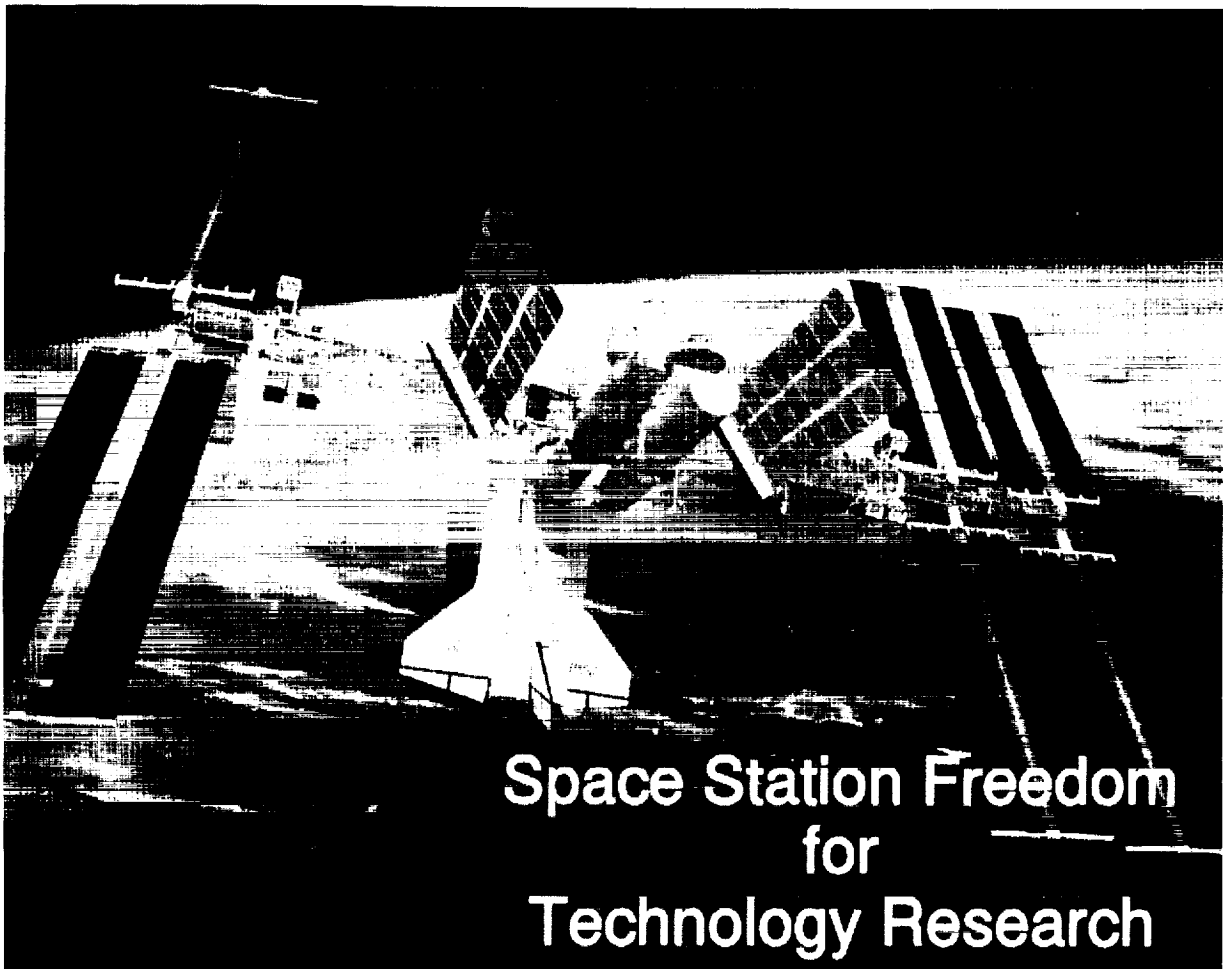
OVERVIEW  
ATTACHED PAYLOADS  
DESIGN CONSIDERATIONS

Presented To:  
Space Station Freedom Utilization Conference

Presented by:  
Don E. Avery  
Manager, Technology Experiments  
Space Station Utilization Office

August 5, 1992

**LaRC**  
LANGLEY RESEARCH CENTER  
HAMPTON, VIRGINIA



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## ALLOCATION OF SSF RESOURCES

### NASA ALLOCATIONS

U.S. LAB	97%	] MTC	] PMC
EXTERNAL TRUSS	97%		
ESA LAB	47%		
JEM LAB & EXPOSURE FAC.	47%		

### OAST SUB-ALLOCATION

12% OF NASA ALLOCATION

UP/DOWN MASS	ONBOARD DATA STORAGE
UP/DOWN VOLUME	PAYLOAD RACKS
DOWN LINK	ATTACHED PAYLOAD SITES
POWER	CREW TIME

## IN-SPACE TECHNOLOGY EXPERIMENT NEEDS

### ENVIRONMENT

PRESSURIZED VOLUME  
UNPRESSURIZED SITES

### RESOURCES

POWER  
CREW  
DATA  
SPACE STATION FREEDOM

SSE CAN SUPPLY ALL TECHNOLOGY EXPERIMENT  
REQUIREMENTS

## TECHNOLOGIES TO BENEFIT FROM SSF

- MATERIAL EXPOSURE RESEARCH
- STRUCTURAL DYNAMICS
- SPACE OPERATIONS
- SPACE CONSTRUCTION
- LIFE SUPPORT SYSTEMS
- ELECTRONICS
- FLUIDS
- ROBOTICS
- POWER
- THERMAL

**TECHNOLOGIES REPRESENTED IN CURRENT  
OAST TRAFFIC MODEL**

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## PROPOSED TRAFFIC MODEL FOR SSF (FOR PLANNING PURPOSES)

	1995	1996	1997
ATTACHED P/Ls*	MODAL IDENTIFICATION EXP		S/C STRAIN & ACOUSTIC SENSORS S/C MATERIALS & COATINGS MICROELECTRONIC DATA SYS EXP
PRESSURIZED P/Ls*		MANNED OBS. TECHN. IN-SITU TRACE CONTAM. ANA. TRANSIENT UPSET PEHNM. VLSIC INFO. SCIENCE EXP. SYS.	ACOUSTIC CONTROL TECH. INTERNAL SARR ADV. SENSOR DEVELOPMENT
LSE		BATTERY CHARGER CAMERA CAMERA LOCKER PASSIVE DOSIMETER FILM LOCKER	DIGITAL OSCILLOSCOPE GEN. PURPOSE HANDTOOLS EM-SHIELDED LOCKER
ATTACHED P/Ls*	1998 EXTERNAL SARR THERMAL INTERFACE TECH FLIGHT DYNAMICS ID POLYMER MATRIX COMP.	1999 CRYO-TANK SERVICING EXP. LDR STRUCTURAL EXP. LIQUID STREAM TECH. TEST BED	2000 ADV. ADAPTIVE CONTROL FTS FORCE REACTION SYS. SPATIAL PERCEP. AUDITORY REFLEX
PRESSURIZED P/Ls*	RISK-BASED FIRE SAFETY FLIGHT CREW HEALTH	MICROBIOLOGICAL MONITOR FOR S/C REGENERATIVE LIFE SUPPORT, T-1	ROBOT FOR LABORATORY QUANTIZED VORTEX STR. He TWO-PHASE FLUID BEHAVIOR
LSE	L.S. ELECTRODE IMPED. MONITOR REFRIGERATOR FREEZER SPECIMEN LABELING DEVICE CLEANING EQUIPMENT FLUID HANDLING TOOLS		

\*UP PAYLOADS ONLY

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## TECHNOLOGY PAYLOAD CATEGORIES

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- **INDIVIDUAL TECHNOLOGY PAYLOADS**
  - SPACECRAFT MATERIALS AND COATINGS
  - ADVANCED SENSOR DEVELOPMENT
  - TRANSIENT UPSET PHENOMENON IN VLSIC
  
- **INSTRUMENTED SPACE STATION**
  - OEX TYPE EXPERIMENTS
  - INSTRUMENT STATION SUBSYSTEM  
STRUCTURES- MIE  
ENVIRONMENTAL  
THERMAL  
DATA
  
- **GUEST INVESTIGATOR PROGRAM**
  - USE DATA FROM EXISTING INSTRUMENTS  
MIE  
STATION SUBSYSTEM INSTRUMENTS

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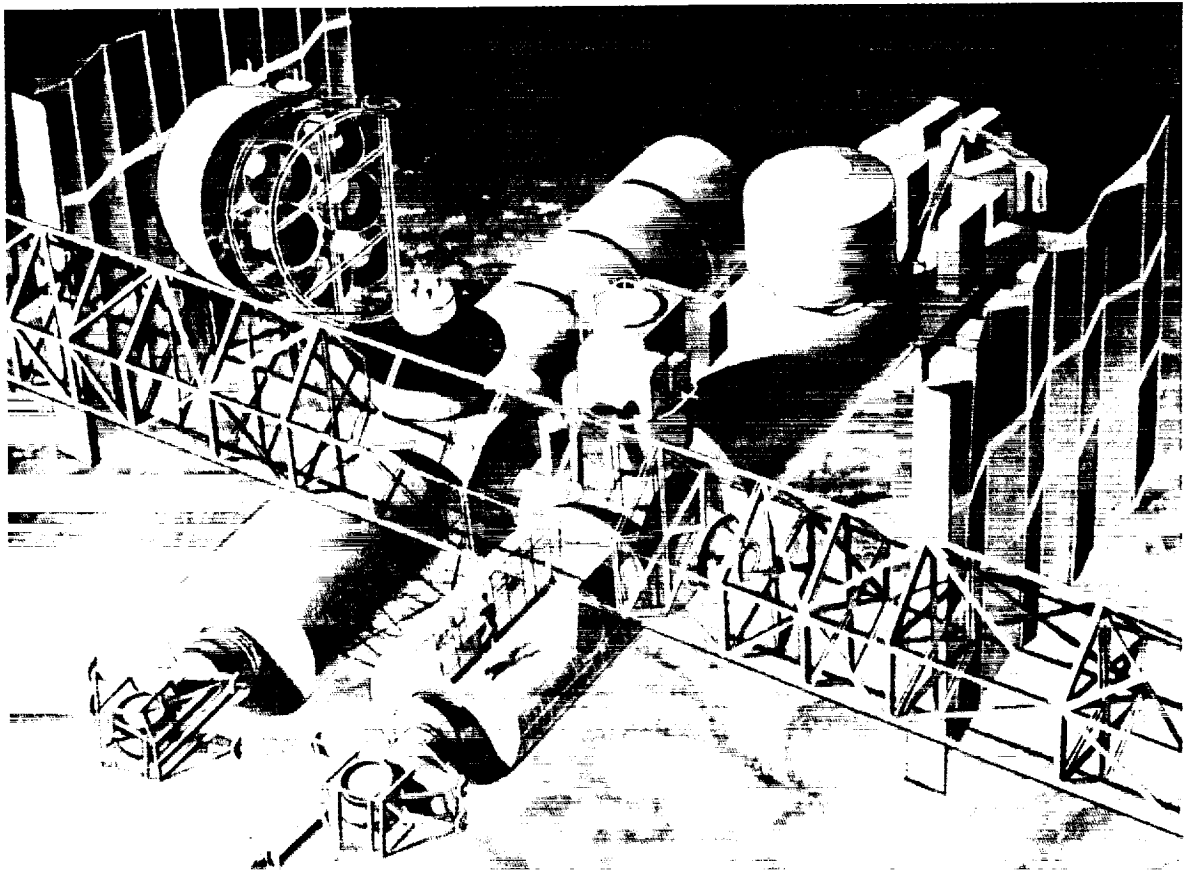
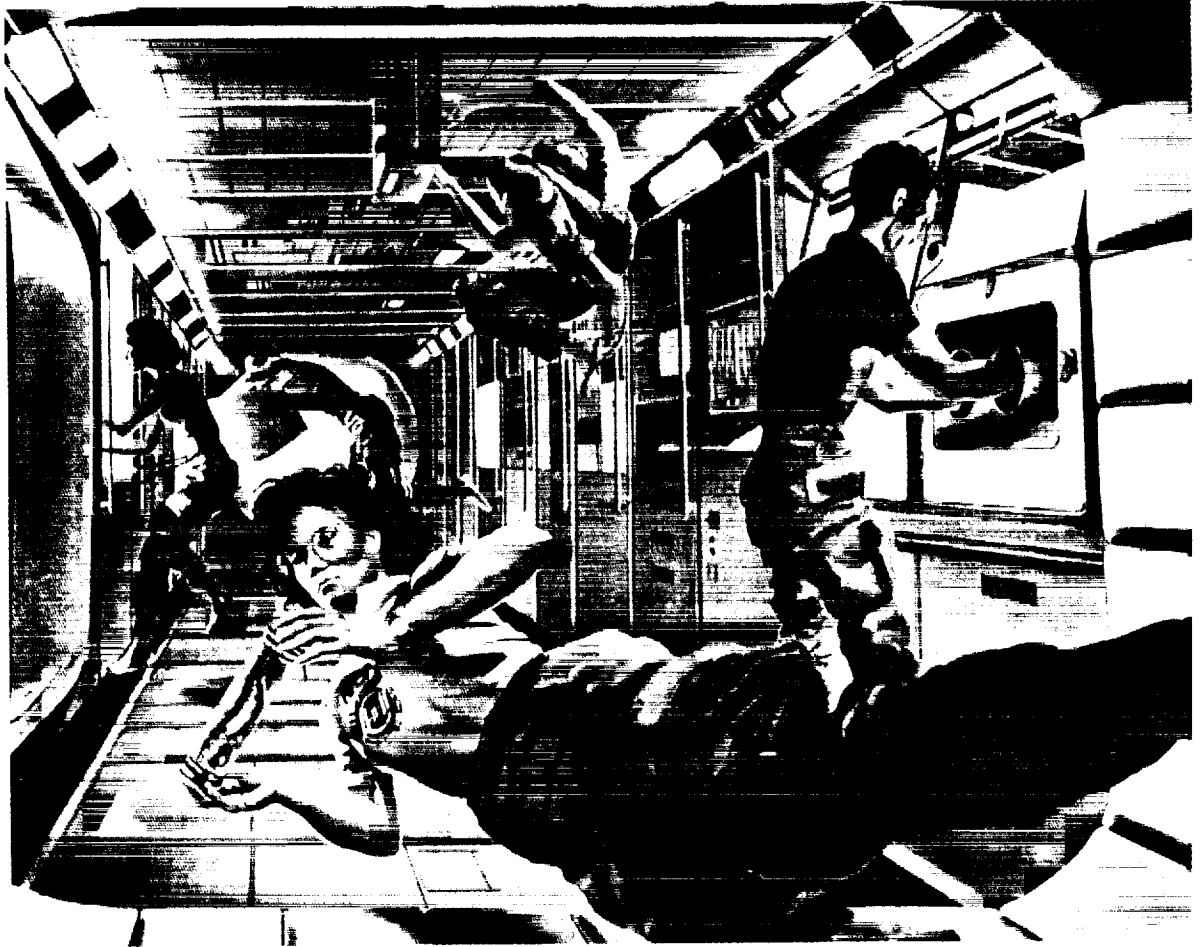
## TECHNOLOGY PAYLOAD DESIGN CONSIDERATIONS

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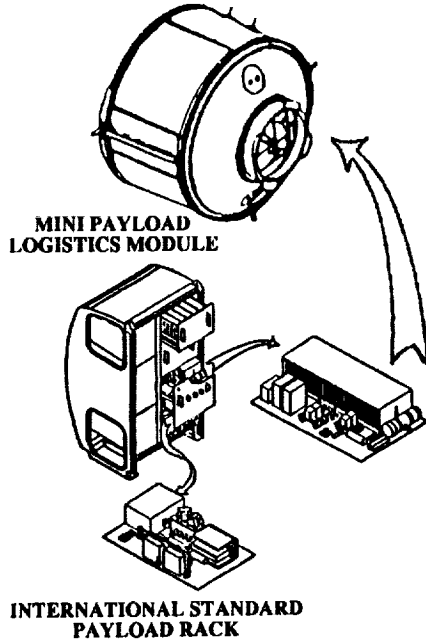
- **ENVIRONMENT**
  - PRESSURIZED PAYLOADS
  - ATTACHED PAYLOADS
  
- **PAYLOAD ACCOMMODATIONS**
  - RESOURCES AVAILABLE  
POWER, DATA, CREW, ETC.
  - REAL ESTATE  
RACKS, ATTACHMENT SITES, PALLETS
  
- **CARRIER**
  - TRANSPORTATION
  - PLM/ULC
  - RACK/DRAWER/ULC
  
- **INTEGRATION**
  - ONTO CARRIERS
  - ONTO STATION

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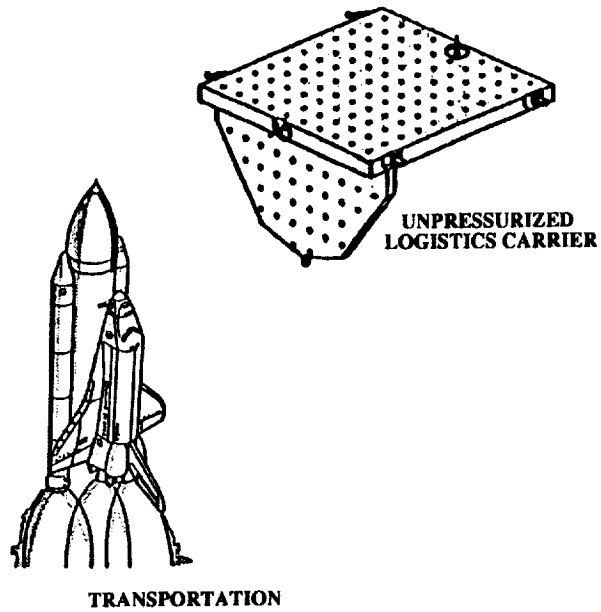


## PAYLOAD CARRIER SYSTEMS

### PRESSURIZED PAYLOADS



### ATTACHED PAYLOADS



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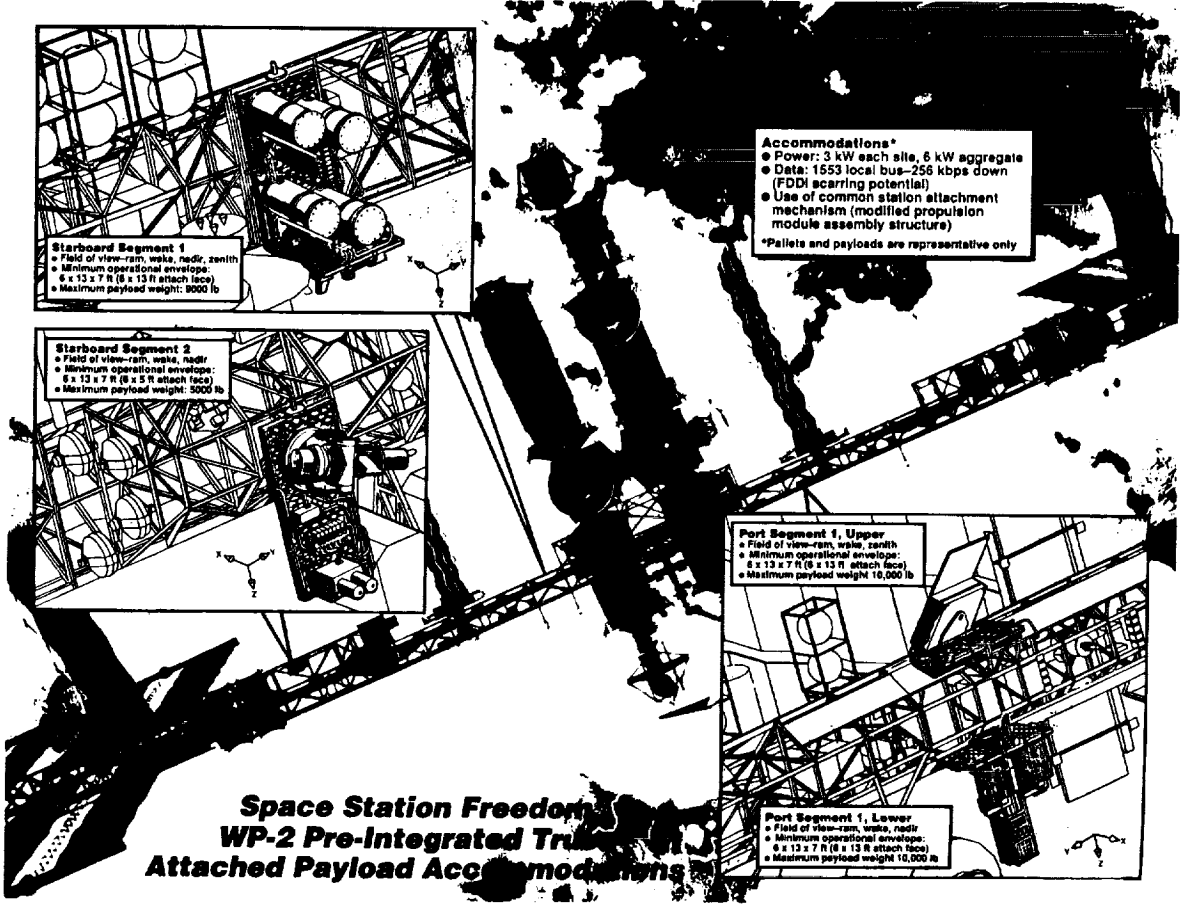
## ATTACHED PAYLOADS

### EXAMPLE

<b>PAYLOAD SITES:</b>	STARBOARD 1 - Available May 1997 STARBOARD 2 - Available May 1997 PORT 1 - Available August 1997 PORT 2 - Available August 1997
<b>PAYLOAD VOL. ENVELOPE:</b>	DIFFERENT AT EACH SITE
<b>DATA:</b>	1553 LOCAL BUS (MAX THROUGHPUT 700 kbps MINUS OVERHEAD)
<b>EVA:</b>	INSTALL PROPULSION MODULE ADAPTOR SYSTEM
<b>THERMAL:</b>	NONE
<b>CARRIER:</b>	UNPRESSURIZED LOGISTIC CARRIER OF SOME DESIGN
<b>STATION INTEGRATION:</b>	PMAS PAYLOAD PALLET ROBOTIC INSTALLATION

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**Starboard Segment 1**

- Field of view-ram, wake, nadir, zenith
- Minimum operational envelope: 6 x 13 x 7 ft (6 x 13 ft attach face)
- Maximum payload weight: 5000 lb

**Starboard Segment 2**

- Field of view-ram, wake, nadir
- Minimum operational envelope: 6 x 13 x 7 ft (6 x 5 ft attach face)
- Maximum payload weight: 5000 lb

**Accommodations\***

- Power: 3 kW each site, 6 kW aggregate
- Data: 1653 local bus-256 kbps down (FDDI scarring potential)
- Use of common station attachment mechanism (modified propulsion module assembly structure)

\*Pallets and payloads are representative only

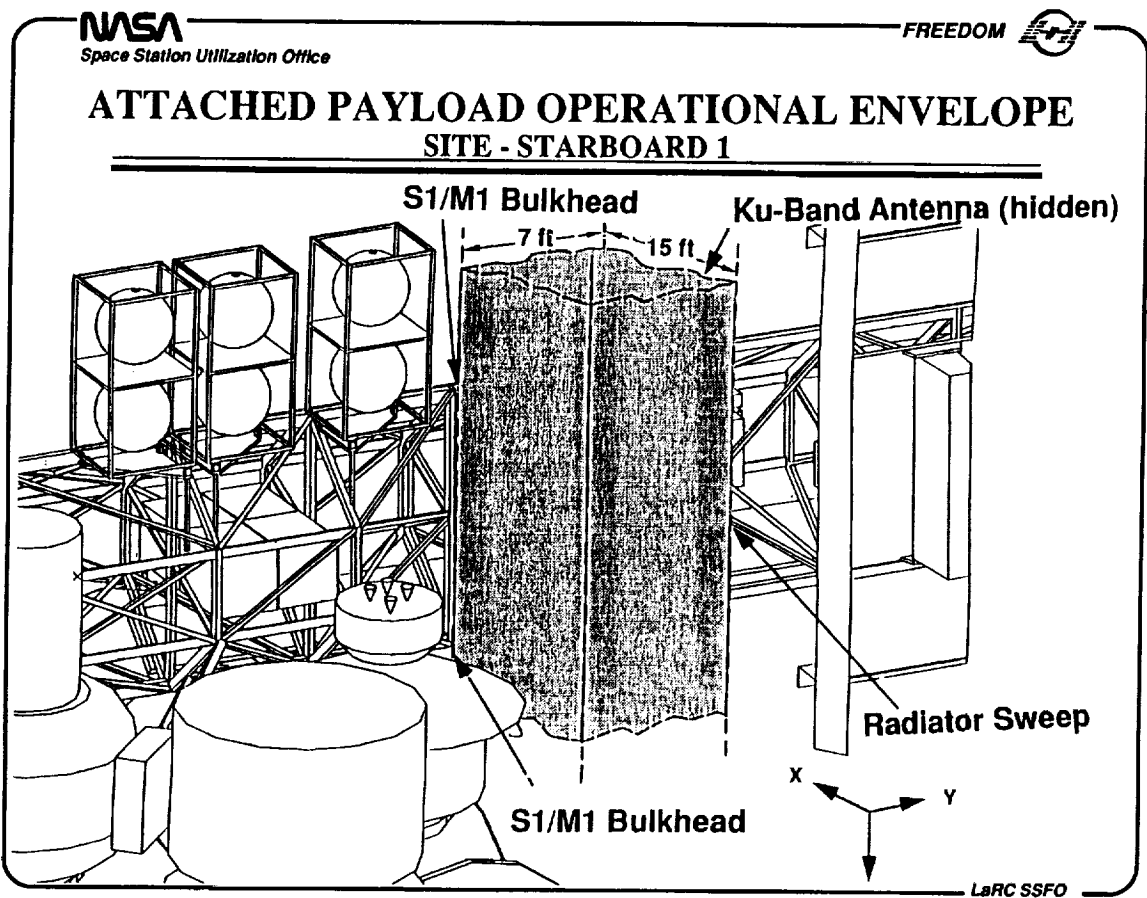
**Port Segment 1, Upper**

- Field of view-ram, wake, zenith
- Minimum operational envelope: 6 x 13 x 7 ft (6 x 13 ft attach face)
- Maximum payload weight 10,000 lb

**Port Segment 1, Lower**

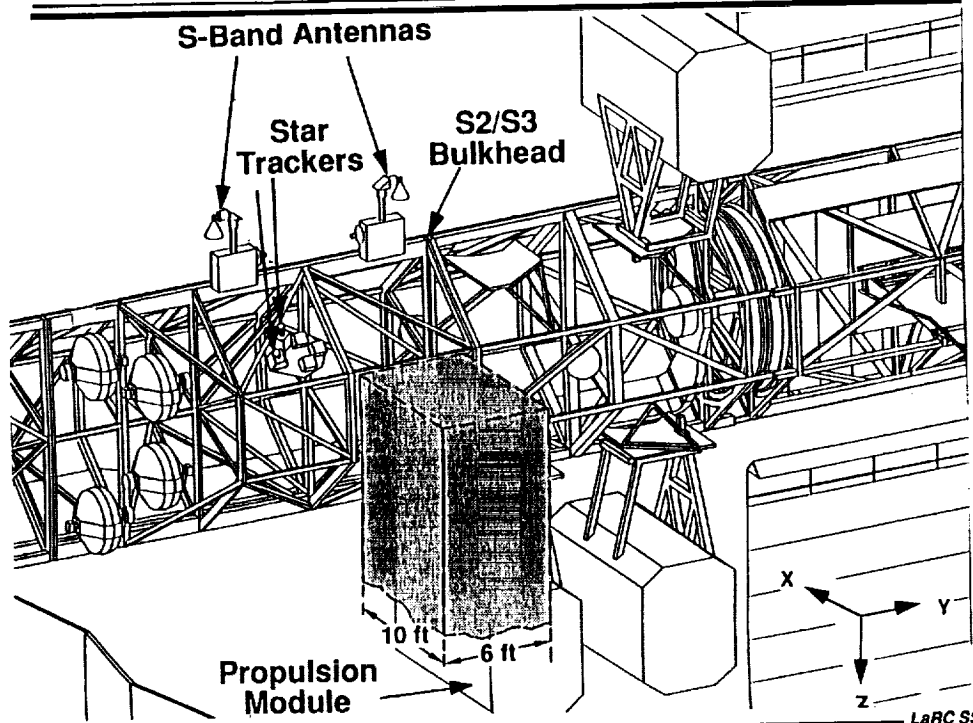
- Field of view-ram, wake, nadir
- Minimum operational envelope: 6 x 13 x 7 ft (6 x 13 ft attach face)
- Maximum payload weight 10,000 lb

**Space Station Freedom  
WP-2 Pre-Integrated Truss  
Attached Payload Accommodations**



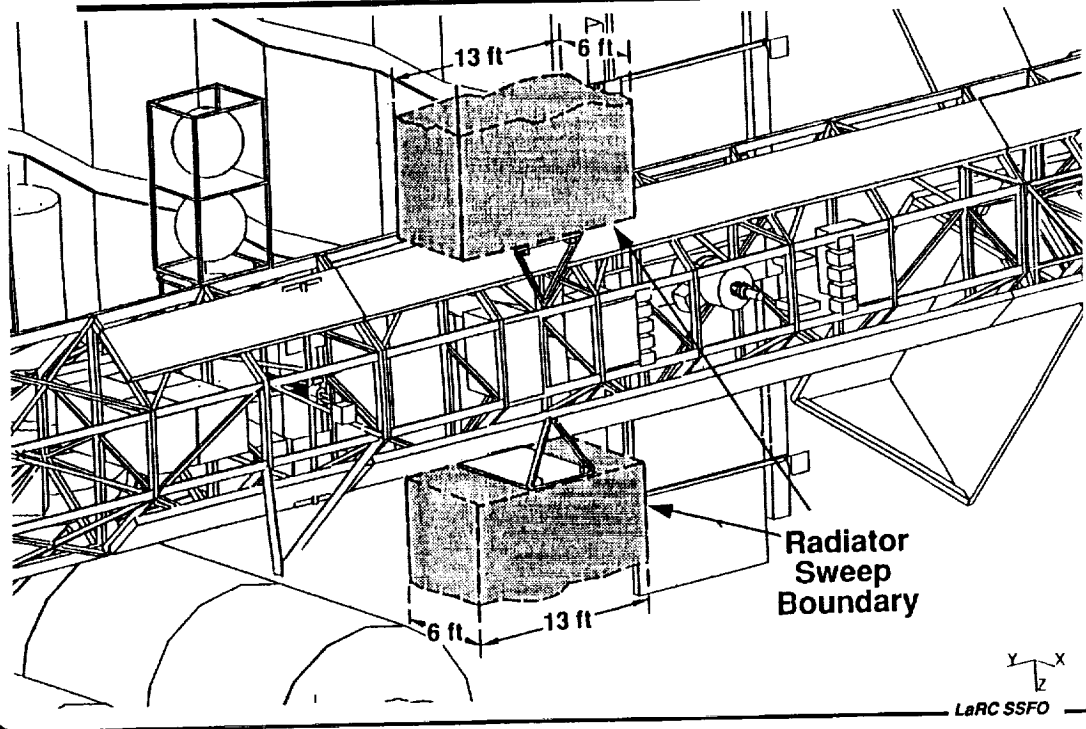
# ATTACHED PAYLOAD OPERATIONAL ENVELOPE

## SITE - STARBOARD 2

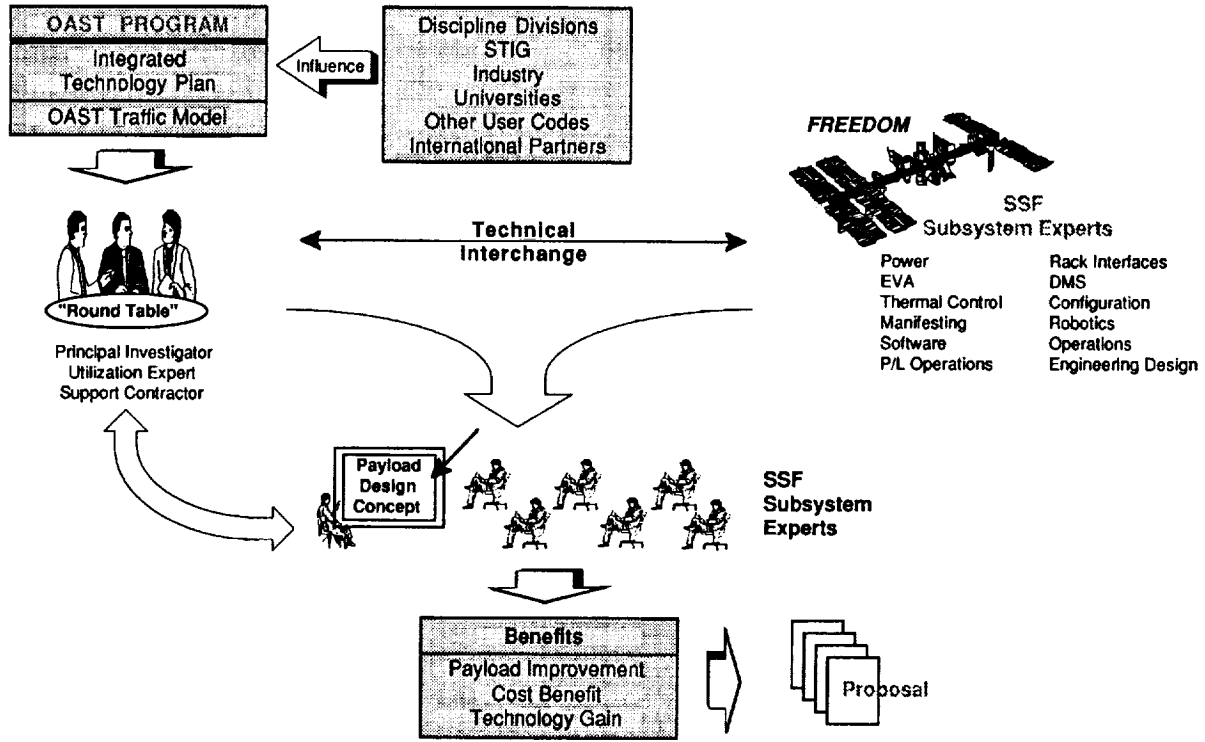


# ATTACHED PAYLOAD OPERATIONAL ENVELOPE

## SITE - PORT 1 AND PORT 2



## A TECHNOLOGY PAYLOAD DESIGN APPROACH

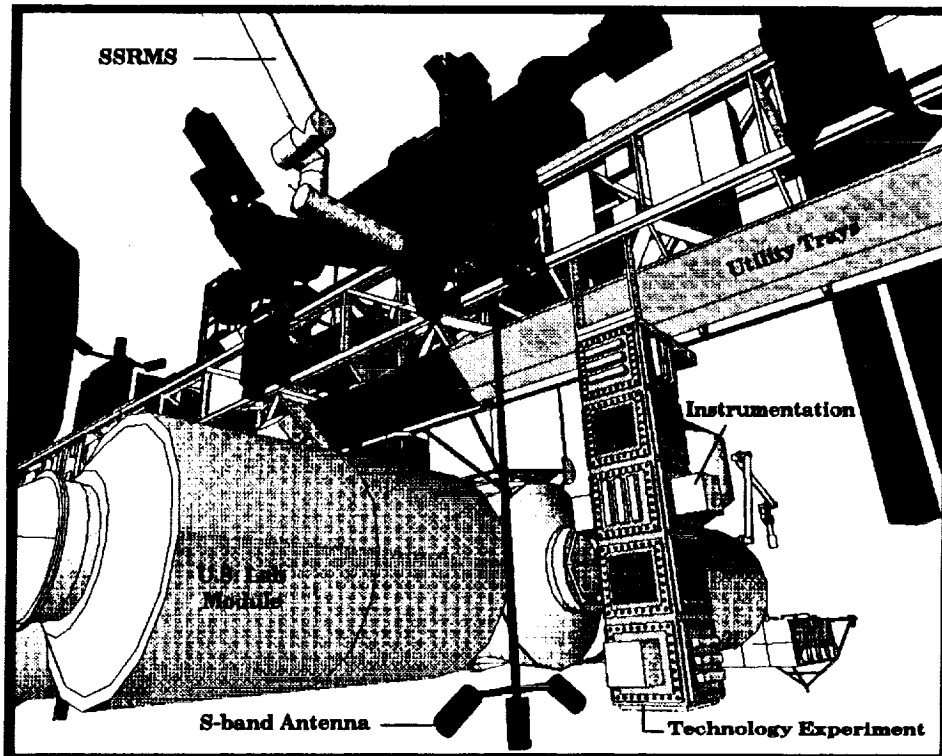


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## SOLID OBJECT MODELING

- GIVES VISUAL PERSPECTIVE OF CARRIER AND EXPERIMENT
- ALLOWS OBSERVATION OF PROBLEMS EARLY IN DESIGN
  - S-BAND ANTENNA CLOSE TO EXPERIMENT
  - U.S. LAB MAY VENT ONTO EXPERIMENT
  - VIEWING
  - SHADOWS
  - ETC.

## Technology Experiment Example



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## ANIMATION

- ANIMATION ALLOWS FULL VISUALIZATION OF SCENE
  - WAVEFRONT USED AS ANIMATION TOOL
  - WAVEFRONT USES 3D OBJECT
  - 2D IMAGES CAN BE RENDERED FROM 3D OBJECTS FOR STILLS OR VIDEO
  
- ALLOWS OBSERVATION OF PROBLEMS EARLY IN DESIGN PROCESS
  - MOTION RESTRICTIONS BECAUSE OF UNKNOWN OBSTACLES
  - KEEP OUT ENVELOPES
  - MOVEMENT RESTRICTIONS OF ROBOTIC ARMS
  - COMPLICATED MOVEMENTS SHOWN VISUALLY INSTEAD OF EXPLAINED

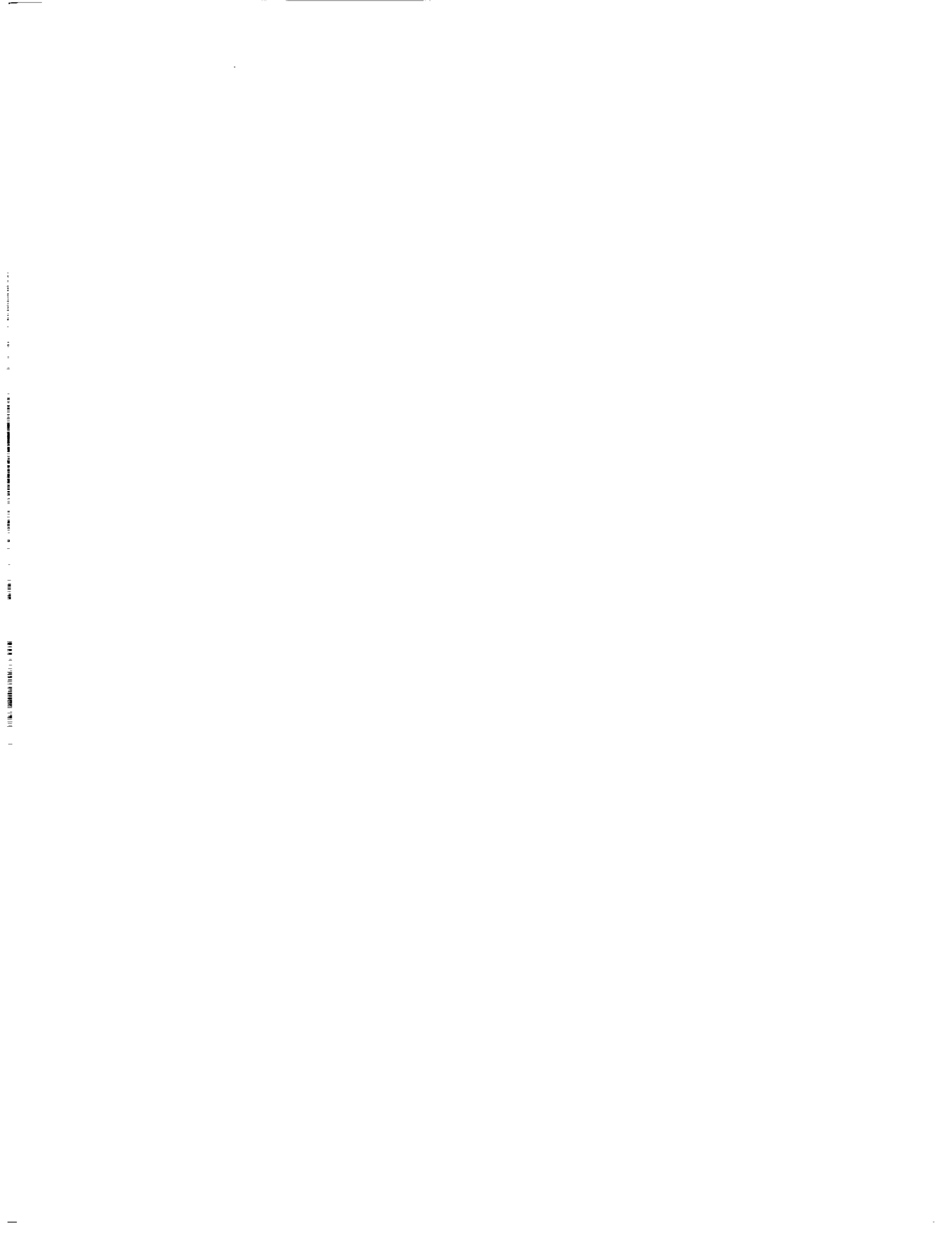
LaRC SSFO

# **OAST ANNOUNCEMENT OF OPPORTUNITY**

## **SPACE EXPERIMENTS PROGRAM**

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- **PURPOSE**
  - TO SOLICIT PROPOSALS FOR EXPERIMENTS IN THE TECHNOLOGY CATEGORIES**
  - **SPACE MATERIALS, COATINGS, AND ENVIRONMENTAL EFFECTS**
  - **CRYOGENIC FLUID HANDLING**
  - **HUMAN SUPPORT**
  - **SPACE POWER**
  - **IN-SPACE CONSTRUCTION, REPAIR, AND MAINTENANCE**
  - **SCIENCE SENSORS AND SENSOR COOLING**
  - **VIBRATION ISOLATION**
  - **SPACE COMMUNICATION**
  
- **APPROACH**
  - **APPROXIMATELY FIFTY PROPOSALS SELECTED BY RIGOROUS REVIEW PROCESS FOR PHASE A**
  - **DOWN-SELECTION TO PHASE B, LEADING TO NON-ADVOCATE REVIEW**
  - **NEW EXPERIMENTS READY FOR FLIGHT STARTING 1997**
  - **ANY SUITABLE CARRIER UTILIZED, INCLUDING SSF, SHUTTLE, ELV**
  
- **STATUS**
  - **EXPECTED RELEASE IN AUGUST**



**MODAL IDENTIFICATION EXPERIMENT**

Presented by Raymond G. Kvaternik  
Spacecraft Dynamics Branch  
NASA Langley Research Center

**ABSTRACT**

The Modal Identification Experiment (MIE) is a proposed on-orbit experiment being developed by NASA's Office of Aeronautics and Space Technology wherein a series of vibration measurements would be made on various configurations of Space Station Freedom (SSF) during its on-orbit assembly phase. The experiment is to be conducted in conjunction with station reboost operations and consists of measuring the dynamic responses of the spacecraft produced by station-based attitude control system and reboost thrusters, recording and transmitting the data, and processing the data on the ground to identify the natural frequencies, damping factors, and shapes of significant vibratory modes. The experiment would likely be a part of the Space Station on-orbit verification.

Basic research objectives of MIE are to evaluate and improve methods for analytically modeling large space structures, to develop techniques for performing in-space modal testing, and to validate candidate techniques for in-space modal identification. From an engineering point of view, MIE will provide the first opportunity to obtain vibration data for the fully-assembled structure because SSF is too large and too flexible to be tested as a single unit on the ground. Such full-system data is essential for validating the analytical model of SSF which would be used in any engineering efforts associated with structural or control system changes that might be made to the station as missions and uses evolve over time.

Extensive analytical simulations of on-orbit tests, as well exploratory laboratory simulations using small-scale models, have been conducted in-house and under contract to develop a measurement plan and evaluate its potential performance. In particular, performance trade and parametric studies conducted as part of these simulations were used to resolve issues related to the number and location of the measurements, the type of excitation, data acquisition and data processing, effects of noise and nonlinearities, selection of target vibration modes, and the appropriate type of data analysis scheme.

The purpose of this talk is to provide an executive-summary-type overview of the modal identification experiment which has emerged from the conceptual design studies conducted to-date. Emphasis throughout is on those aspects of the experiment which should be of interest to those attending the subject utilization conference. The presentation begins with some preparatory remarks to provide background and motivation for the experiment, describe the experiment in general terms, and cite the specific technical objectives. This is followed by a summary of the major results of the conceptual design studies conducted to define the baseline experiment. The baseline experiment which has resulted from the studies is then described.





# **MODAL IDENTIFICATION EXPERIMENT**

**Raymond G. Kvaternik  
NASA Langley Research Center  
Hampton, Virginia**

**Space Station Freedom Utilization Conference  
Huntsville, Alabama  
August 3-6, 1992**

## **OUTLINE**

- **Introductory Remarks**
- **Experiment Definition Studies**
- **Baseline Experiment Design**
- **Summary and Concluding Remarks**

## INTRODUCTORY REMARKS

### MOTIVATION

- **Dynamic characteristics of spacecraft traditionally verified by ground vibration tests**
- **Emerging space structures (such as Space Station Freedom) too large/flexible to test as complete systems on ground**
- **Complete reliance on math models to verify dynamic behavior**
- **Math models must be validated to establish accuracy**
- **Vibration mode shapes for fully-assembled structure essential for validating/updating dynamic models**
- **Required data can only be obtained on-orbit**

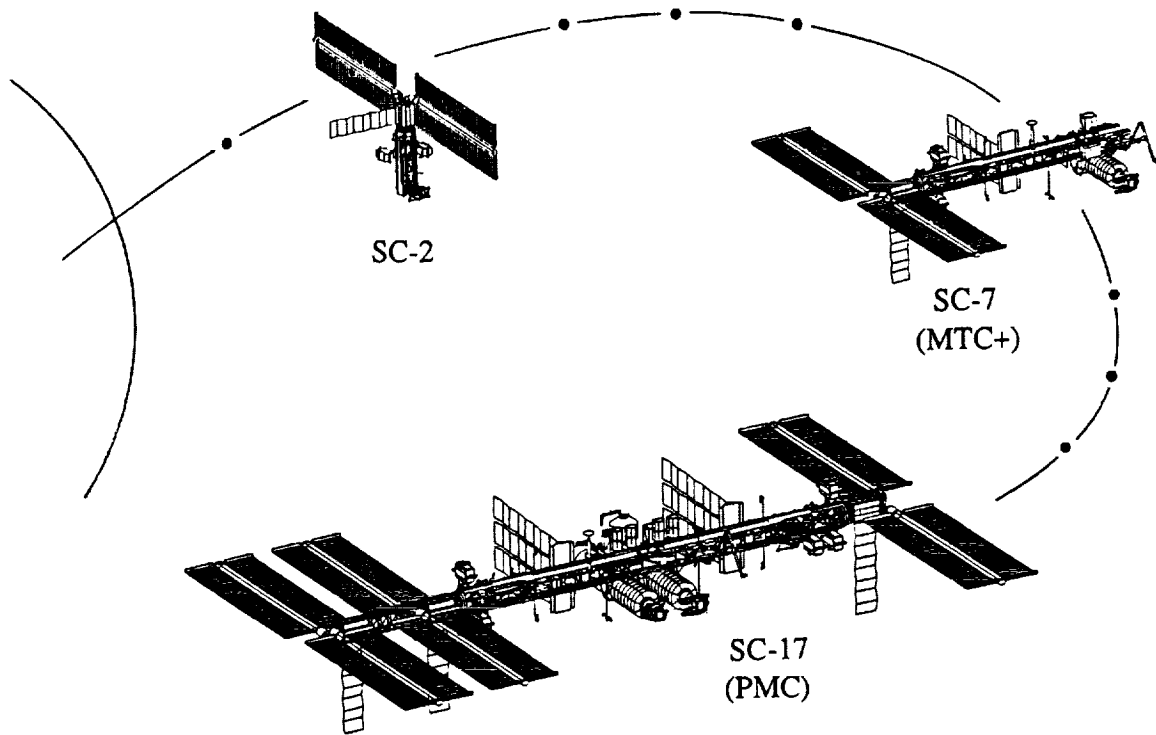
## **BACKGROUND**

- **Modal Identification Experiment (MIE) utilizing Space Station Freedom (SSF) proposed in 1984**
- **Element of NASA's space technology program**
  - **Sponsor is Office of Aeronautics and Space Technology**
  - **Object is in-space research and technology**
- **Not element of Space Station program**

## **ESSENCE OF PROPOSED EXPERIMENT**

- **Collect vibration measurements on various configurations of SSF during its on-orbit assembly phase**
- **Conduct experiment in conjunction with station reboost operations**
- **Key Steps:**
  - **Excite structure**
  - **Measure dynamic responses**
  - **Record and transmit data**
  - **Apply system identification techniques to data**
- **Identify significant vibratory modes**

# ON-ORBIT ASSEMBLY OF SPACE STATION PERMITS UNIQUE RESEARCH OPPORTUNITY



## SPECIFIC TECHNICAL OBJECTIVES

- **Engineering**
  - Data essential for verifying dynamic math models of integrated system
  - Enhanced model for changes/growth studies
- **Research**
  - Technology for predicting dynamics of large space structures
  - Techniques for performing on-orbit modal testing
  - Spacecraft scale model ground vibration test technology
  - Techniques for in-space system identification
  - Improved dynamics modeling techniques

## **EXPERIMENT DEFINITION STUDIES**

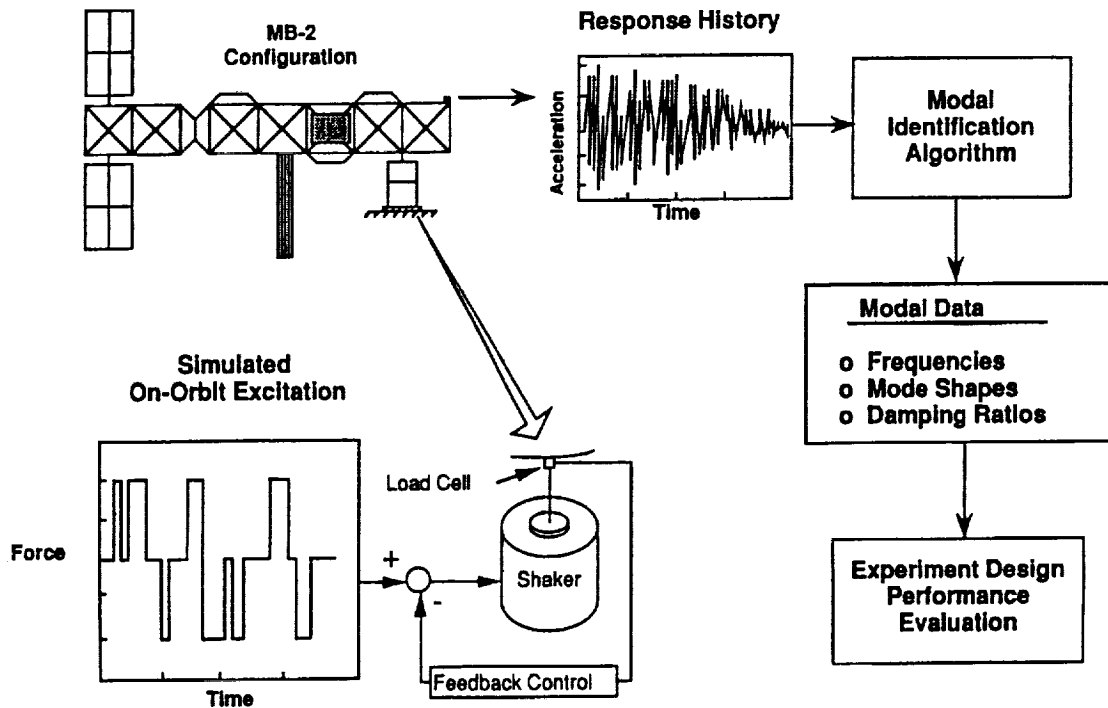
### **MAJOR PARTICIPANTS**

- **McDonnell Douglas Space Systems Company**
  - **Phase A Study - Determine feasibility**
  - **Phase B Study - Conceptual design definition**
  - **Delta Phase B Study - Assess impact of new SS design**
- **Structural Dynamics Research Corporation**
  - **Develop simulation and evaluation methods**
- **University of Cincinnati**
  - **Modal parameter estimation techniques**
- **NASA Langley Research Center**
  - **Analytical simulation**
  - **Dynamic scale model test simulation**

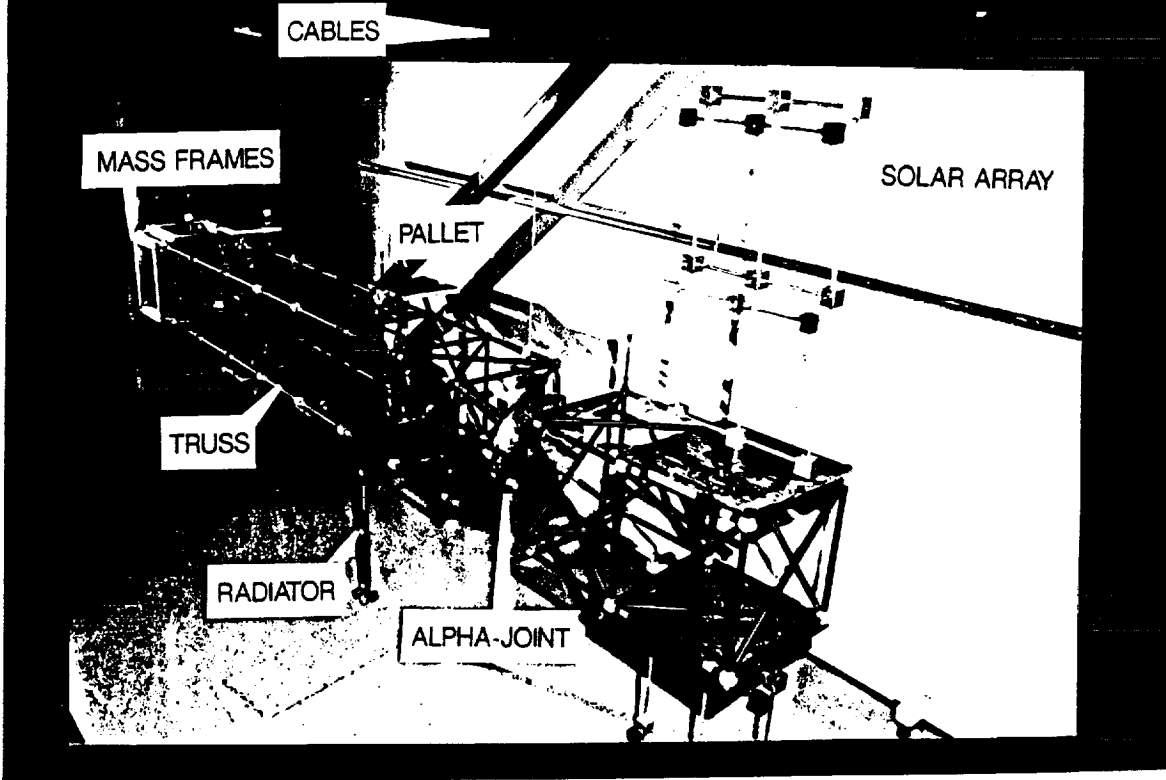
# SCHEDULE FOR STUDIES

TASKS	88				89				90				91				92				93			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Phase A Concept Definition Study	■▲▲▲																							
Phase B Selected Studies					■▲▲																			
Phase B Concept Definition Study									■▲▲▲▲▲															
Delta Phase B Concept Definition Study													■▲▲											
Phase C Preliminary Design and Analysis																	▲▲▲							

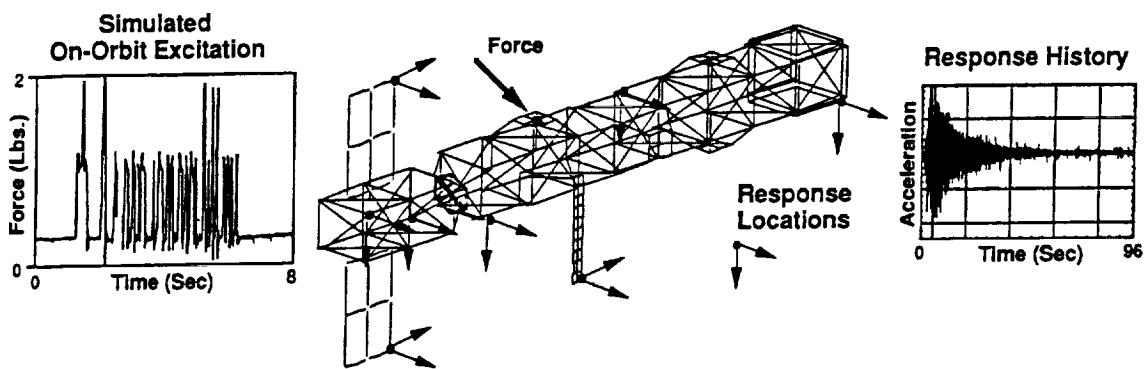
## LABORATORY SIMULATION USING SCALE MODELS



# 1/10-SIZE GENERIC SPACE STATION MODEL (GMB-2)



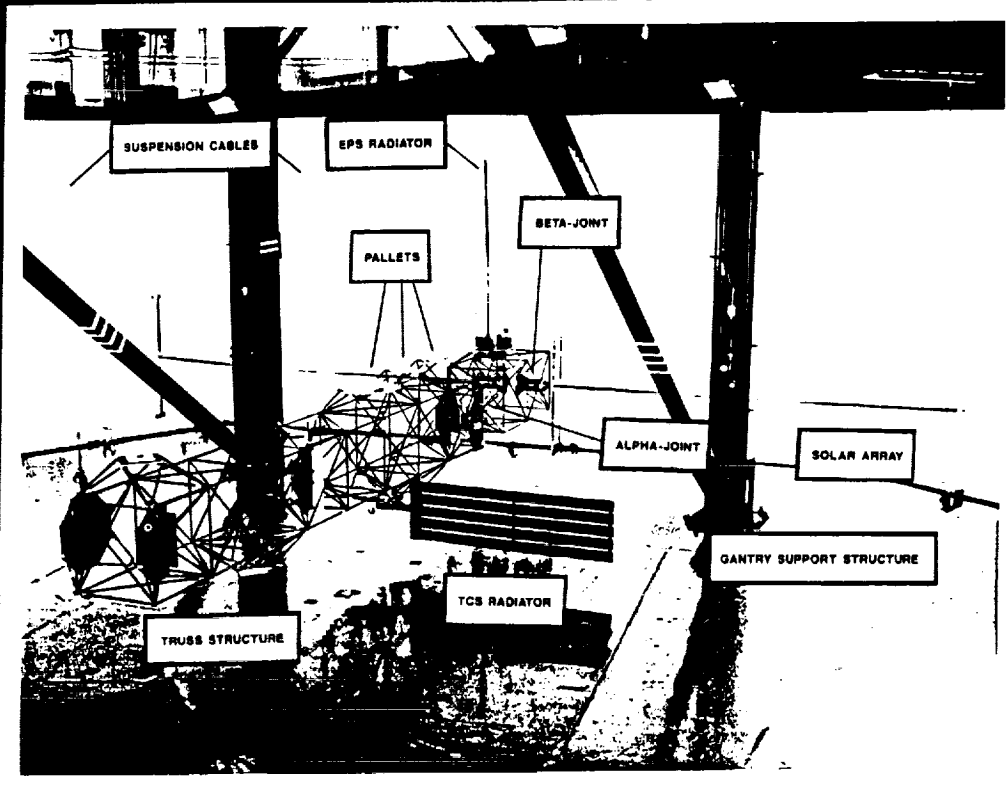
## MIE SIMULATIONS USING GENERIC MODEL



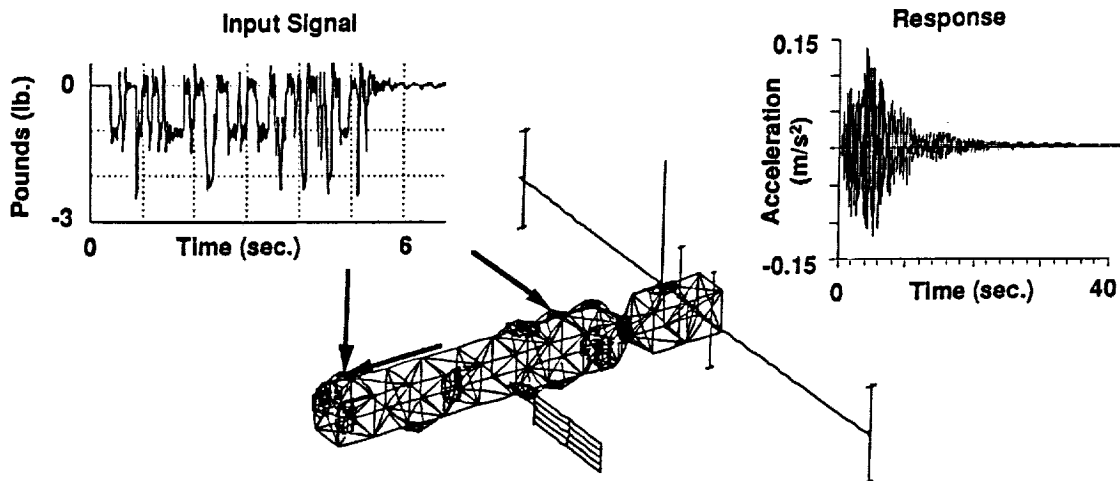
MIE simulations correlated well with modal test results

	<u>MODAL TESTS</u>	<u>MIE SIMULATIONS</u>
# of sensors	96	16
# of shakers	2	1
# of modes identified	20	16
# of primary modes	13	11

# DSMT HYBRID SCALE HMB-2F MODEL



## MIE SIMULATIONS USING HYBRID MODEL



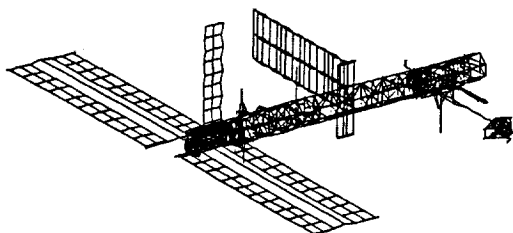
	<u>GVT</u>	<u>MIE</u>
No. of Sensors	107	13
No. of Shakers	3	3
No. of Modes Recovered	54	22



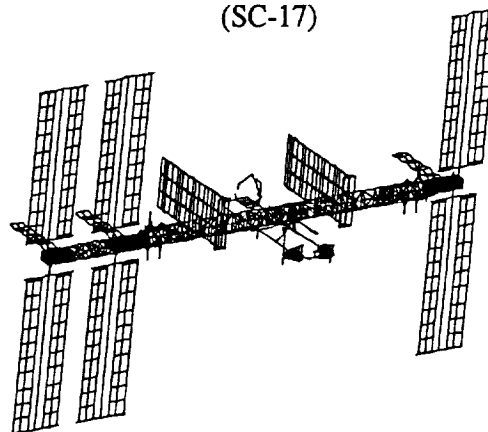
## BASELINE EXPERIMENT DESIGN

### FINITE ELEMENT MODELS

MTC+ Configuration  
(SC-7)



PMC Configuration  
(SC-17)



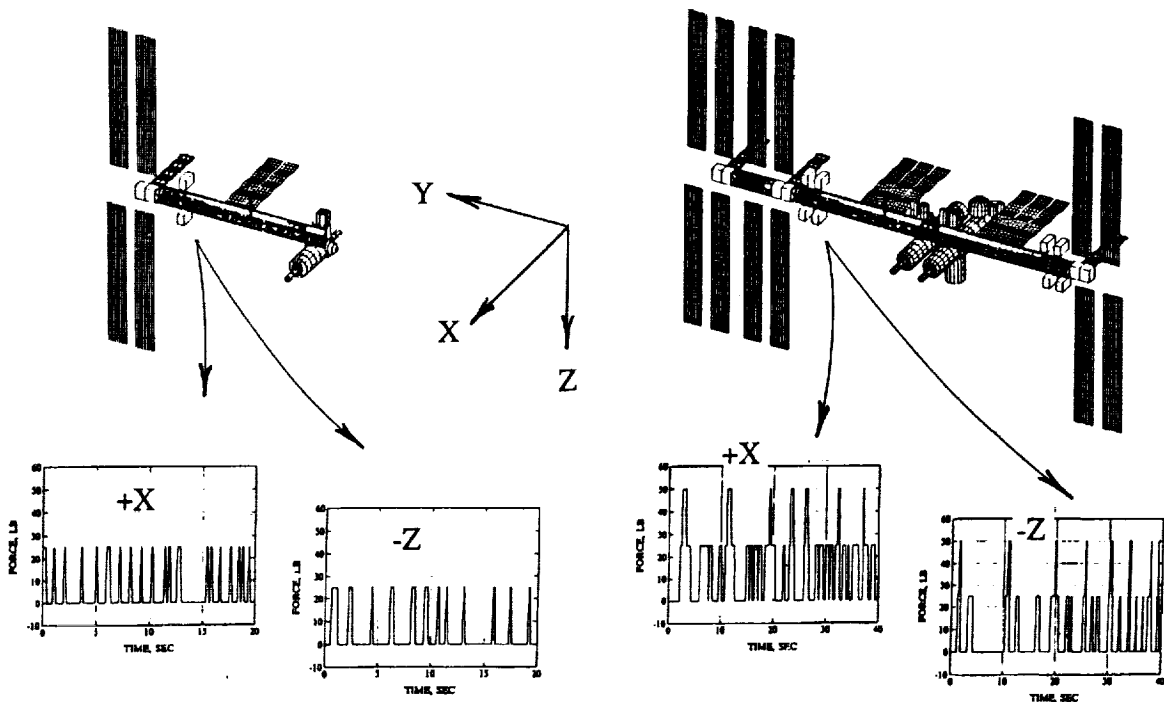
Degrees of Freedom in Preliminary Design Model

Unreduced	20500	52500
Reduced	996	2467

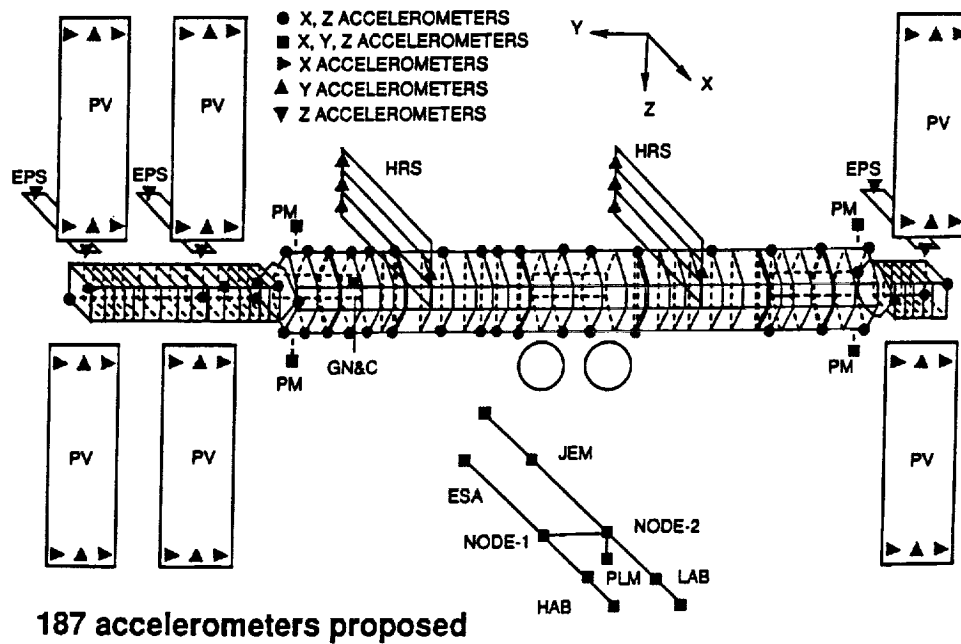
## SELECTION OF IMPORTANT MODES

- **Emphasis on global structural modes of integrated structure with frequencies below 5 Hz**
- **Several global mode indicators used in selection**
- **Resultant mode set includes truss bending and torsion modes, as well as solar array and radiator modes**
- **Frequencies of all modes below 2 Hz**
- **For MTC+: 13 Modes (0.53 - 2.09 Hz)**  
**For PMC: 18 Modes (0.17 - 1.32 Hz)**

## MIE RANDOM EXCITATION PATTERNS



## BASELINE MEASUREMENT SET FOR MIE Instrumentation Locations



## BASELINE SIMULATIONS

- Intended to demonstrate adequacy of baseline experiment design to identify important modes
- Simulated experimental data contained expected types and levels of data acquisition errors
- Eigensystem Realization Algorithm (ERA) used to extract modal parameters from time-domain free-decay responses
- Modal characteristics of all target modes for MTC+ identified
- All target modes except the two with highest frequencies identified for PMC

## **SUMMARY AND CONCLUDING REMARKS**

- **Modal Identification Experiment utilizing Space Station Freedom feasible**
- **Conceptual design of baseline experiment completed**
- **Simulations of experiment demonstrated adequacy of design to identify selected important modes**
- **If implemented, experiment would yield data of both engineering and research value**
- **Accelerometer complement proposed by SSFP as part of on-orbit verification instrumentation suite does not meet all MIE requirements**
- **Doubtful if additional sensors will be authorized**
- **Need to make best use of whatever number of accelerometers will be on Space Station**

**SELECTED OAST/OSSA SPACE EXPERIMENT ACTIVITIES IN  
SUPPORT OF SPACE STATION FREEDOM**

Presented by Richard DeLombard  
In-Space Technology Experiments  
NASA Lewis Research Center

**ABSTRACT**

The Space Experiments Division at NASA Lewis Research Center is developing technology and science space experiments for the Office of Aeronautics and Space Technology (OAST) and the Office of Space Sciences and Applications (OSSA). Selected precursor experiments and technology development activities supporting the Space Station Freedom (SSF) are presented.

The Tank Pressure Control Experiment (TPCE) is an OAST-funded cryogenic fluid dynamics experiment, the objective of which is to determine the effectiveness of jet mixing as a means of equilibrating fluid temperatures and controlling tank pressures, thereby permitting the design of lighter cryogenic tanks. The information from experiments such as this will be utilized in the design and operation of on board cryogenic storage for programs such as SSF.

The Thermal Energy Storage Flight Project (TES) is an OAST-funded thermal management experiment involving phase change materials for thermal energy storage. The objective of this project is to develop and fly in-space experiments to characterize void shape and location in phase change materials used in a thermal energy storage configuration representative of an advanced solar dynamic system design. The information from experiments such as this will be utilized in the design of future solar dynamic power systems.

The Solar Array Module Plasma Interaction Experiment (SAMPIE) is an OAST-funded experiment to determine the environmental effects of the low earth orbit (LEO) space plasma environment on state-of-the-art solar cell modules biased to high potentials relative to the plasma. Future spacecraft designs and structures will push the operating limits of solar cell arrays and other high voltage systems. SAMPIE will provide key information necessary for optimum module design and construction.

The Vibration Isolation Technology (VIT) Advanced Technology Development effort is funded by OSSA to provide technology necessary to maintain a stable microgravity environment for sensitive payloads on board spacecraft. The proof of concept will be demonstrated by laboratory tests and in low-gravity aircraft flights. VIT is expected to be utilized by many SSF microgravity science payloads.

The Space Acceleration Measurement System (SAMS) is an OSSA-funded instrument to measure the microgravity acceleration environment for OSSA payloads on the shuttle and SSF.



# SELECTED OAST/OSSA SPACE EXPERIMENT ACTIVITIES IN SUPPORT OF SPACE STATION FREEDOM

RICHARD DeLOMBARD  
NASA Lewis Research Center

SSF UTILIZATION CONFERENCE  
HUNTSVILLE, ALABAMA

AUGUST 3-6, 1992



*Space Experiments Division*

**SFSD**  
Space Flight Systems Directorate

## AGENDA

- INTRODUCTION
- TANK PRESSURE CONTROL EXPERIMENT
- THERMAL ENERGY STORAGE
- SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT
- VIBRATION ISOLATION TECHNOLOGY
- SPACE ACCELERATION MEASUREMENT SYSTEM
- CONCLUDING REMARKS

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## INTRODUCTION

- THE LeRC SPACE EXPERIMENTS DIVISION SUPPORTS SSF THROUGH:

OAST/SPACE EXPERIMENTS OFFICE-FUNDED  
*IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM*

OSSA/MSAD-FUNDED  
*MICROGRAVITY SCIENCE EXPERIMENTS*  
*ADVANCED TECHNOLOGY DEVELOPMENT ACTIVITIES*

- THIS PRESENTATION WILL COVER THESE SELECTED TOPICS:

OAST:

- TANK PRESSURE CONTROL EXPERIMENT
- THERMAL ENERGY STORAGE FLIGHT PROJECT
- SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT

OSSA:

- VIBRATION ISOLATION TECHNOLOGY
- SPACE ACCELERATION MEASUREMENT SYSTEM FOR SSF

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## TANK PRESSURE CONTROL EXPERIMENT

### TECHNOLOGY NEED:

- CONTROL OF TANK PRESSURE FOR CRYOGENIC FLUID MANAGEMENT

### OBJECTIVES:

- CHARACTERIZE FLUID DYNAMICS OF JET-INDUCED MIXING
- ESTABLISH LOW-GRAVITY MIXING TIMES TO EQUILIBRATE PRESSURE & TEMPERATURE



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## TANK PRESSURE CONTROL EXPERIMENT

### APPROACH:

- USE JET-INDUCED FLUID MIXING AS A MEANS OF CONTROLLING PRESSURE OF FREON 113 IN LOW-GRAVITY
- IMPLEMENT AS GAS-CAN EXPERIMENT WITH CONTRACT TO BOEING (OAST-FUNDED)

### STATUS:

- EXPERIMENT FLEW ON STS-43 IN AUGUST 1991
- POSITIVE RESULTS OBTAINED
- RE-FLIGHT PLANNED FOR STS-52 IN OCTOBER 1992
  - FOCUS ON SELF-PRESSURIZATION AND POOL BOILING AT LOW HEAT FLUXES
  - EXTEND MIXING DATA BASE TO LOWER FLOWS

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## THERMAL ENERGY STORAGE

### TECHNOLOGY NEED:

- MELT/FREEZE BEHAVIOR DATA BASE FOR PHASE CHANGE MATERIALS IN LONG DURATION LOW-GRAVITY ENVIRONMENT

### OBJECTIVES:

- CHARACTERIZE MELT/FREEZE BEHAVIOR OF PHASE CHANGE MATERIALS IN LOW-GRAVITY
- PROVIDE EXPERIMENTAL DATA TO VERIFY ANALYTICAL MODELS NOW UNDER DEVELOPMENT

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## THERMAL ENERGY STORAGE

### APPROACH:

- THERMALLY CYCLE TWO DIFFERENT PHASE CHANGE MATERIALS
  - LITHIUM FLUORIDE
  - FLUORIDE EUTECTIC
- IMPLEMENT IN-HOUSE AT NASA LEWIS AS GET-AWAY-SPECIAL PAYLOADS (OAST-FUNDED)
- FLY TWO EXPERIMENTS EACH IN 1994 AND 1996

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## SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT

### TECHNOLOGY NEED:

- DETERMINE THE EFFECTS OF LEO SPACE PLASMA ON SOLAR CELL MODULES

### APPROACH:

- EXPOSE SEVERAL TYPES OF MODULES TO SPACE PLASMA OVER A RANGE OF POTENTIALS
- IMPLEMENT IN-HOUSE AT NASA LEWIS (OAST-FUNDED)
- FLY AS CARGO BAY EXPERIMENT IN 1994

### OBJECTIVES:

- DETERMINE ARCING THRESHOLDS, RATES AND STRENGTHS
- DETERMINE PLASMA CURRENT COLLECTION CHARACTERISTICS
- MEASURE PARAMETERS FOR DATA ANALYSIS
- VALIDATION OF MODELS

---

## SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT

**STATUS:**

- EXPERIMENT UNDER DEVELOPMENT FOR OAST-2 MISSION
  
- SOLAR MODULES WILL INCLUDE:
  - SPACE STATION FREEDOM CELLS
  - ADVANCED PHOTOVOLTAIC SOLAR ARRAY CELLS
  - STANDARD SILICON CELLS (REFERENCE)

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## VIBRATION ISOLATION TECHNOLOGY

### TECHNOLOGY NEED/OBJECTIVE

PROVIDE THE REQUIRED TECHNOLOGY TO MAINTAIN A STABLE MICROGRAVITY ENVIRONMENT FOR SENSITIVE PAYLOADS OVER THE FREQUENCY RANGE APPLICABLE TO DISTURBANCES PRESENT IN SPACECRAFT.

### APPROACH

- DEFINE TECHNOLOGY REQUIREMENTS AND ASCERTAIN LIMITS OF CURRENT STATE OF THE ART METHODS.
  
- DEVELOP TECHNOLOGY VIA A GROUND BASED PROGRAM THAT MEETS THE REQUIREMENTS; EXPAND THE STATE OF THE ART.
  
- DEMONSTRATE THE PROOF OF CONCEPT IN A LABORATORY ENVIRONMENT AND IN LOW GRAVITY AIRCRAFT FLIGHTS.



## VIBRATION ISOLATION TECHNOLOGY

### STATUS

- **ACTIVELY CONTROLLED, MAGNETIC ISOLATION SYSTEM DEVELOPED IN LABORATORY,**
  - SIX DEGREES OF FREEDOM
  - INERTIAL AND POSITION FEEDBACK
  - ISOLATION DOWN TO MICROGRAVITY LEVELS AT 0.1 HZ
- **PROOF OF CONCEPT VERIFIED IN LOW GRAVITY PARABOLIC FLIGHTS DOWN TO 1 HZ**
  - FREQUENCY LIMITED BY LOW GRAVITY TIME AVAILABLE.
  - TWELVE FLIGHTS WITH 72 TRAJECTORIES FLOWN.
  - PERFORMANCE OF ISOLATION SYSTEM PREDICTABLE.
  - ISOLATION ACHIEVED DOWN TO NOISE FLOOR OF SYSTEM.
- **LOW FREQUENCY VERIFICATION (< 0.1 HZ) MUST BE DONE THROUGH FLIGHT EXPERIMENT.**



## SPACE ACCELERATION MEASUREMENT SYSTEM FOR SPACE STATION FREEDOM

### PROGRAMMATIC NEED:

- **MEASURE THE MICROGRAVITY ENVIRONMENT FOR OSSA SCIENCE PAYLOADS ON SPACE STATION FREEDOM**

### APPROACH:

- **REMOTE SENSORS LOCATED WITHIN EXPERIMENTS**
- **DATA RECORDED ON-BOARD AND/OR DOWN-LINKED TO GROUND CONTROL CENTER**
- **IMPLEMENTED IN-HOUSE AT NASA LEWIS (OSSA-FUNDED)**

### OBJECTIVE:

- **SUPPORT OSSA PRINCIPAL INVESTIGATORS WITH MICROGRAVITY ACCELERATION DATA**

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## SPACE ACCELERATION MEASUREMENT SYSTEM FOR SPACE STATION FREEDOM

### STATUS:

- SAMS UNITS CURRENTLY BEING FLOWN WITH OSSA SCIENCE EXPERIMENTS ON SHUTTLE MISSIONS
- NEW & IMPROVED INSTRUMENT BEING DEVELOPED FOR U.S. LABORATORY MODULE
- TYPICAL SPACE STATION FREEDOM EXPERIMENTS SUPPORTED:
  - SPACE STATION FURNACE FACILITY
  - COMBUSTION EXPERIMENTS MODULE
  - FLUID EXPERIMENTS MODULE

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## CONCLUDING REMARKS

- EXISTING OAST EXPERIMENTS ARE VIEWED AS PRECURSOR EXPERIMENTS FOR SPACE STATION FREEDOM
- VIBRATION ISOLATION TECHNOLOGY REQUIRES VALIDATION TO SUPPORT FUTURE FLUID PHYSICS & OTHER MICROGRAVITY SPACE EXPERIMENTS
- SPACE ACCELERATION MEASUREMENT SYSTEM WILL CONTINUE TO SUPPORT OSSA / MSAD EXPERIMENTS



**SPACECRAFT MATERIALS AND COATINGS EXPERIMENTS**

Presented by Don E. Avery  
Space Station Freedom Office  
NASA Langley Research Center

Prepared by Wayne S. Slemp  
Applied Materials Branch, Materials Division  
NASA Langley Research Center

**ABSTRACT**

The 5.8-year exposure data from the Long Duration Experiment Facility (LDEF) has demonstrated the benefits of long-term exposure in low Earth orbit (LEO) for understanding the behavior of spacecraft materials and coatings for use in extended space missions. The Space Station Freedom represents the next large area spacecraft available in NASA planned missions for obtaining this long-term space exposure data.

The advantages of using the Space Station Freedom for these studies are presented. Discrepancies between short-term flight exposure result from Shuttle Orbiter experiments and the long-term LDEF results are shown. The major objectives and benefits of conducting materials and coatings experiments on Space Station Freedom are emphasized.





# **SPACECRAFT MATERIALS AND COATINGS EXPERIMENTS**

**Wayne S. Siemp  
NASA Langley Research Center  
(804) 864-1334**

**Presented By**

**Don E. Avery  
NASA Langley Research Center**

**Space Station Freedom Utilization Conference  
Huntsville, Alabama  
August 3-6, 1991**

## **CONCLUSIONS FROM LDEF MATERIALS ANALYSIS**

- Atomic oxygen is major near-Earth orbital environmental factor leading to mechanical/optical property changes in materials
- All polymeric materials exhibit some mass loss from AO exposure
- Uncoated resin matrix composites display resin and fiber loss and deterioration in mechanical properties proportional to thickness loss
- Molecular structure of surviving polymeric resin and films unchanged
- Thin metallic coatings can prevent AO damage

## LESSONS LEARNED FROM LDEF EXPERIMENTS

- Leading edge surfaces are dominated by AO effects while surfaces greater than 110° are dominated by contamination and UV effects
  - Different exposure surfaces are needed for meaningful flight experiments
- Cannot confidently extrapolate long-term space effects on materials from short-term flight experiments like EOIM
  - Long-term exposure data are needed
- Confirmed suspected instability of polymeric materials to LEO atomic oxygen exposure
  - More data needed to support materials development programs for AO resistant materials
- More choices of protective coatings are needed to prevent AO damage to materials
  - Choices are very limited for large parts

## PASSIVE MATERIALS AND COATINGS EXPERIMENT

### Why Space Station Freedom?

- After initial development phase, Space Station Freedom presents a stable platform for materials exposures and acquisition of environmental data
- Only spacecraft available for long-term (>1 year) materials and coatings exposure
- Large areas available for exposure of materials and coatings
- Power and data storage available for use with active experiments
- Materials exposed real-time in same LEO environment where they are being used
- Ready access for material exchange and return of exposed materials to Earth for laboratory testing

# MATERIALS FLIGHT EXPERIMENTS ON SSF

## Objectives

- Establish a technology database for long-term effects of LEO environment on spacecraft materials and coatings
- Database will support:
  - Development of ground-based technology for accelerated long-duration environmental effects testing
  - Development of new materials and coatings with high resistance to atomic oxygen, solar UV, and particulate radiation
  - Development of Multiparameter Laboratory testing techniques. Example: AO + UV + vacuum + temperature cycling in one system
  - Alternate materials for advanced retro-fit or repair of Freedom

# MATERIALS FLIGHT EXPERIMENTS ON SSF

## Justification

- Multi-environment simulation of atomic oxygen, UV, vacuum, thermal cycling, micrometeoroid, debris, and particulate radiation is not technically feasible in ground-based laboratory testing
- Cannot confidently extrapolate long-term space effects from short-term accelerated flight data
  - FEP Teflon AO erosion 6 times greater on LDEF than predicted from EOIM-2 flight results
  - Epoxy matrix composites AO erosion on LDEF was 1/2 of erosion predicted from EOIM-2 flight results
- Long-term flight database needed to develop ground-based accelerated testing technology
  - LDEF provides only flight data available on materials exposed for 5-year mission lifetime

# MATERIALS FLIGHT EXPERIMENTS ON SSF

## Benefits

- Assist in development of new materials for 21st century
- Provide data for improved laboratory simulation of space environment
- Provide data to correlate highly accelerated testing of materials with real-time effects
- Verification of ground-based lifetime prediction
- Additional utilization of Space Station Freedom as a testing/exposure laboratory in space

## SUMMARY

- LDEF providing substantial long-term LEO exposure data on space environmental effects on materials
- LDEF underscore the need for long-term flight data
- Space Station Freedom only spacecraft manifested for long-term (>5 years) operation
- Materials experiment proposed for beneficial utilization of Space Station Freedom

**LONG DURATION SPACE MATERIALS EXPOSURE (LDSE)**

Presented by David Allen and Robert Schmidt  
Center on Materials for Space Structures  
Case Western Reserve University

**ABSTRACT**

The Center on Materials for Space Structures (CMSS) at Case Western Reserve University is one of seventeen Commercial Centers for the Development of Space. It was founded to: 1) Produce and evaluate materials for space structures, 2) Develop passive and active facilities for materials exposure and analysis in space, and 3) Develop improved material systems for space structures.

A major active facility for materials exposure is proposed to be mounted on the exterior truss of the Space Station Freedom (SSF). This Long Duration Space Materials Exposure (LDSE) experiment will be an approximately 6 1/2 ft x 4 ft panel facing into the velocity vector (RAM) to provide long term exposure (up to 30 years) to atomic oxygen, UV, micrometeorites, and other low earth orbit effects. It can expose large or small active (instrumented) or passive samples. These samples may be mounted in a removable Materials Flight Experiment (MFLEX) carrier which may be periodically brought into the SSF for examination by CMSS's other SSF facility, the Space Materials Evaluation Facility (SMEF) which will contain a Scanning Electron Microscope, a Variable Angle & Scanning Ellipsometer, a Fourier Transform Infrared Spectrometer, and other analysis equipment. These facilities will allow commercial firms to test their materials in space and promptly obtain information on their materials survivability in the LEO environment.



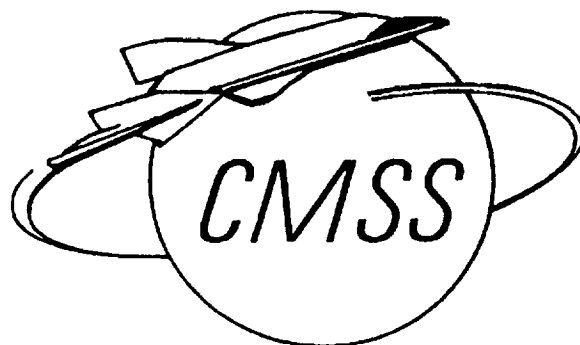
**LONG DURATION SPACE MATERIALS EXPOSURE  
(LDSE)**

**CENTER ON MATERIALS FOR SPACE STRUCTURES  
CASE WESTERN RESERVE UNIVERSITY**

*AUGUST 5, 1992*



**The Center on Materials for  
Space Structures**



**A Center for the Commercial  
Development of Space**

# CMSS GOALS

- Produce and Evaluate Materials For Space Structures
- Develop Passive and Active Facilities For Materials Exposure and Analysis in Space
- To Develop Improved Materials Systems For Space Structures



## CMSS PROPOSED FLIGHT PROGRAM

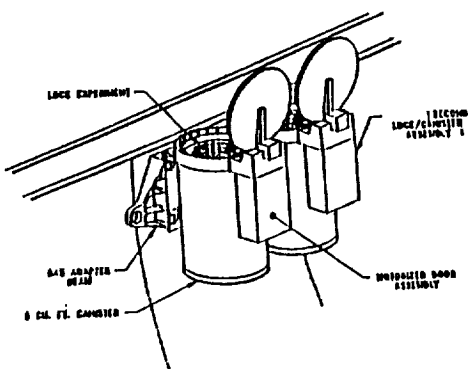
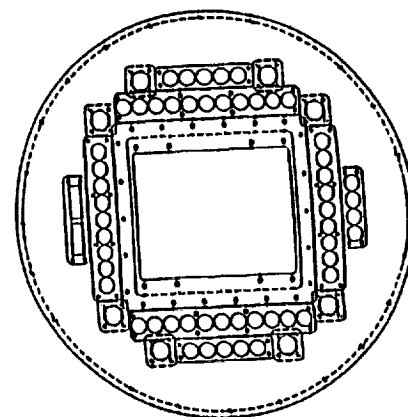
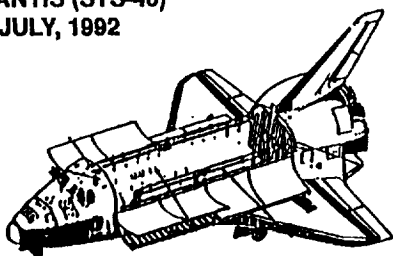
	1992	1993	1994	1995	1996	1997	1998	1999	2000
PASSIVE SHUTTLE	LDCE 1,2,3 STS-46 (July 92) 40 hrs	LDCE 4,5 STS-51 (Feb 93) 40 hrs	LDCE 6,7,8 STS-62 (Dec 93) 40 hrs						
ACTIVE FREE FLYER FROM SHUTTLE		MatLab-1-1 WSF-01 STS-60 Oct 93 45 hrs	MatLab-1-2 WSF-02 STS-70 (Jan 95) 60 hrs	MatLab-1-3 WSF-03 STS-78 (Oct 95) 60 hrs	MatLab-1-4 WSF-04 STS-90 (Jul 96) 60 hrs				
ACTIVE FREE FLYER ELV			Matlab-2-1 COMET-02 (Aug 94) 130 days						
ACTIVE SHUTTLE			CMSE-1 STS-68 (Oct 94) 40-80 hrs	CMSE-2 STS-75 (Jul 95) 40-80 hrs	CMSE-3 STS-83 (Aug 96) 40-80 hrs	CMSE-4 (1997) 40-80 hrs			
SPACE STATION						LDSE-1 (1997) 30 yrs.	LDSE-2 (1998) 30 yrs	LDSE-3 (1999) 30 yrs	LDSE-4 (2000) 30 yrs
LUNAR							LSCE (1998) 2-30 yrs		
DEEPER SPACE						DSCE MEO (1997) 5 yrs			





# Limited Duration Space Environment Candidate Materials Exposure (LDCE) Experiment LDCE-1,-2,-3

ATLANTIS (STS-46)  
JULY, 1992



- 351 Experiment Samples (3/4" & 1")
- 3 LDCE Disks
- 40 Hours of Exposure
- 128 Nautical Miles Altitude

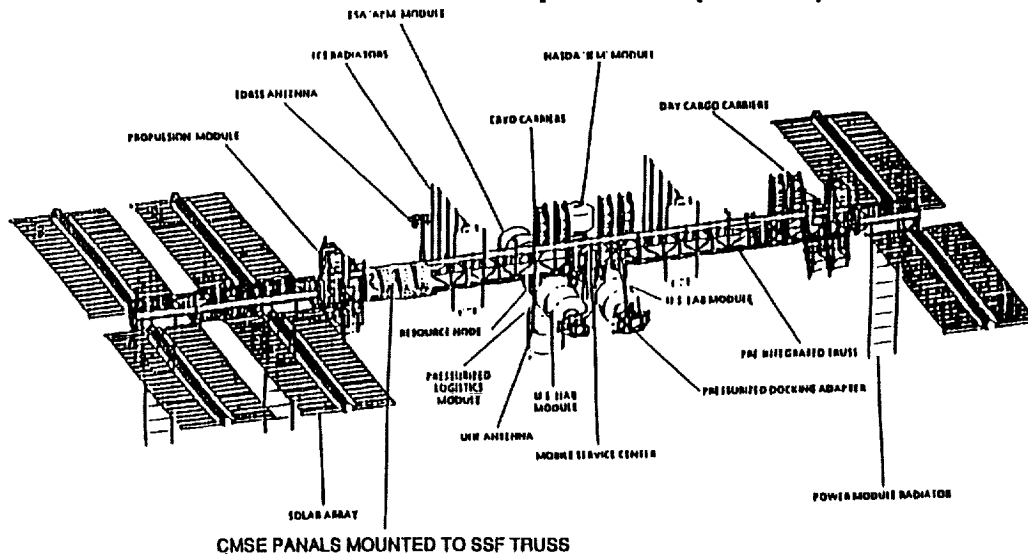


## LDCE SPACEFLIGHT SAMPLE DISTRIBUTION

<u>SPONSER</u>	<u>LDCE-1</u>	<u>LDCE-2</u>	<u>LDCE-3</u>
Alcan	2	4	—
Battelle Pacific Northwest Labs	3	7	—
Case Western Reserve University	5	11	6
Dow Chemical	1	1	—
Dow Corning	5	2	2
Duralcan	—	2	—
Hexcel Corporation	11	—	—
Hoechst-Celanese	1	1	—
J.A. Wollam Company	—	9	11
Jet Propulsion Laboratory	—	—	10
Lawrence Livermore National Labs	—	—	40
McGhan Nusil Corporation	—	—	23
Monsanto	2	2	—
NASA Lewis	—	2	—
Premix	1	1	—
Science Applied International Corporation	1	1	1
Texas A&M University	1	1	—
3M Corporation	8	6	—
TRW	1	1	—
University of Toronto	20	—	—
University of Washington	1	1	—
Westinghouse-Hanford	—	6	10
U.S. Army-WPAFB	97	35	—
<b>TOTAL SAMPLES</b>	<b>160</b>	<b>93</b>	<b>103</b>
View Factor	1	4	—
Capacity (Total number of specimens: 351)	159	89	103



# Long Duration Space Environment Candidate Materials Exposure (LDSE)



- CMSE Panels to be Mounted to Space Station Freedom Truss
- Approximately 6 Panels With 9000 Samples Exposed for up to 30 Years
- One per Year Starting In 1996



## LDSE OBJECTIVES

- To Provide a Long Term Materials Exposure Facility for Testing Large Numbers of Materials Samples in the Low Earth Orbit Environment

# LDSE BENEFITS

- **New Materials for Space**
  - Lightweight, Oxygen Resistant Structural Materials
  - Corrosion Resistant Materials
  - Self-Healing Protective Coatings
  - High Vacuum Tribological Materials
  - Long-Life Optical Coatings
- **New Materials for Earth**
  - Lightweight Oxygen Tanks for Firefighters
  - High Strength, Corrosion Resistant Pipes and Vessels for Lower Cost Factories
  - Long-Life, Self-Healing Paints and Coatings
  - New Permanently Lubricated Motors and Machines
  - Solar Cells for Home Power Generation



## LDSE OPERATIONAL SCENARIO

- **1st Launch in August, 1997 (LDSE-1)**
  - Launch of CMSE Type Panel Modified to Mount on Space Station Freedom Truss Pointed into Ram Direction.
- **Next Four Launches In FY 1998, 1999, 2000, and 2001 (LDSE -2, -3, -4, -5)**
  - Mount to Space Station Truss
  - Annual EVA's Required for LDSE-1 may Service LDSE-2 and LDSE-3
  - Two Additional EVA's required for LDSE-4, -5
- **Data Telemetered Through NASA-JSC to CWRU CMSS**

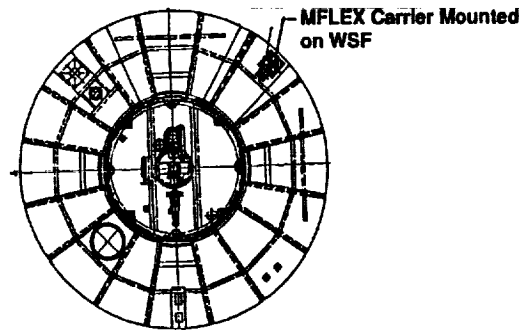
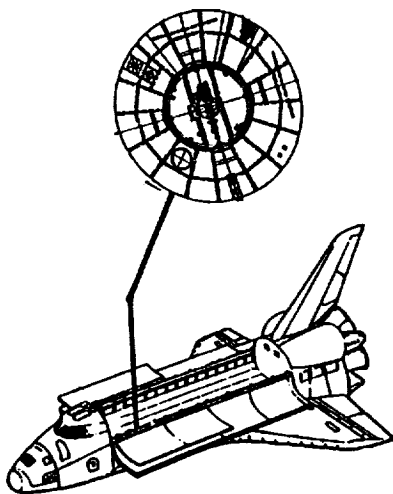


# The General Purpose Materials Flight Experiment Carrier Concept

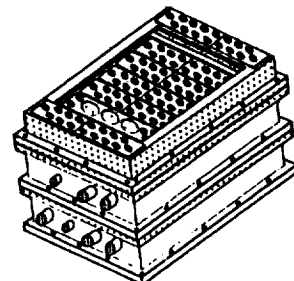
## MFLEX



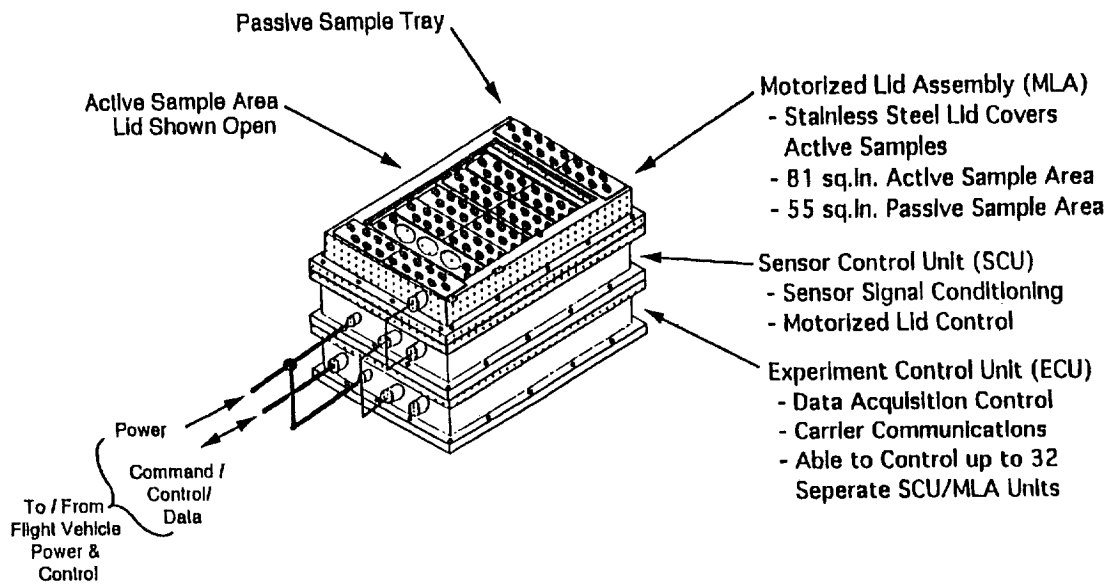
### MatLab-1 Experiment on the WakeShield Facility (WSF)



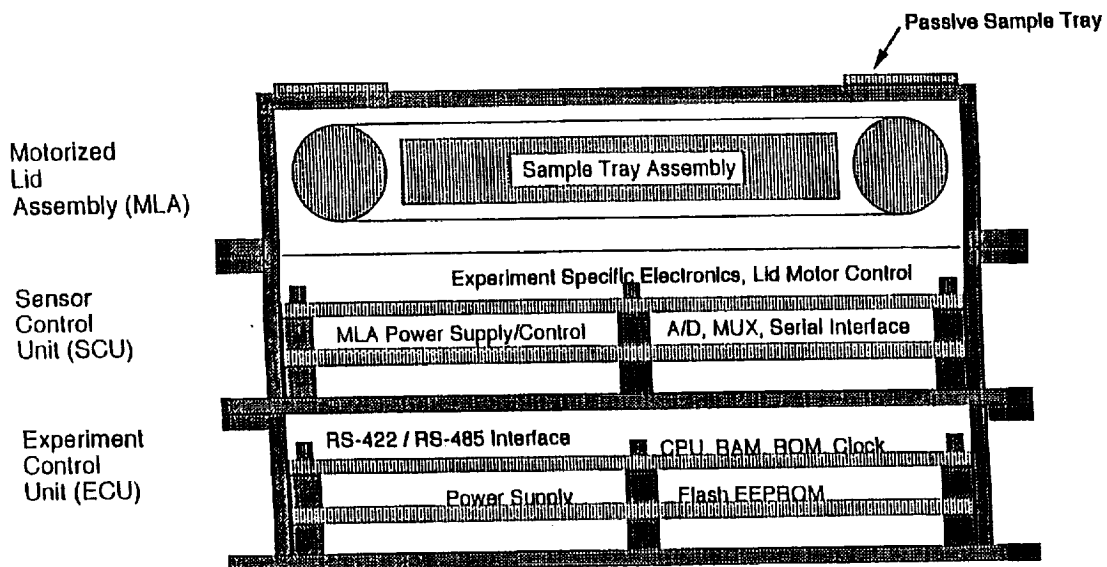
- Approximately 75 Instrumented Experiments
- Real Time Telemetry of Data
- Free Flyer Removes All Influence of Shuttle Environment
- 77 Hours of Exposure
- Flight on STS-60 Oct, 1993
- 190 Nautical Miles Altitude



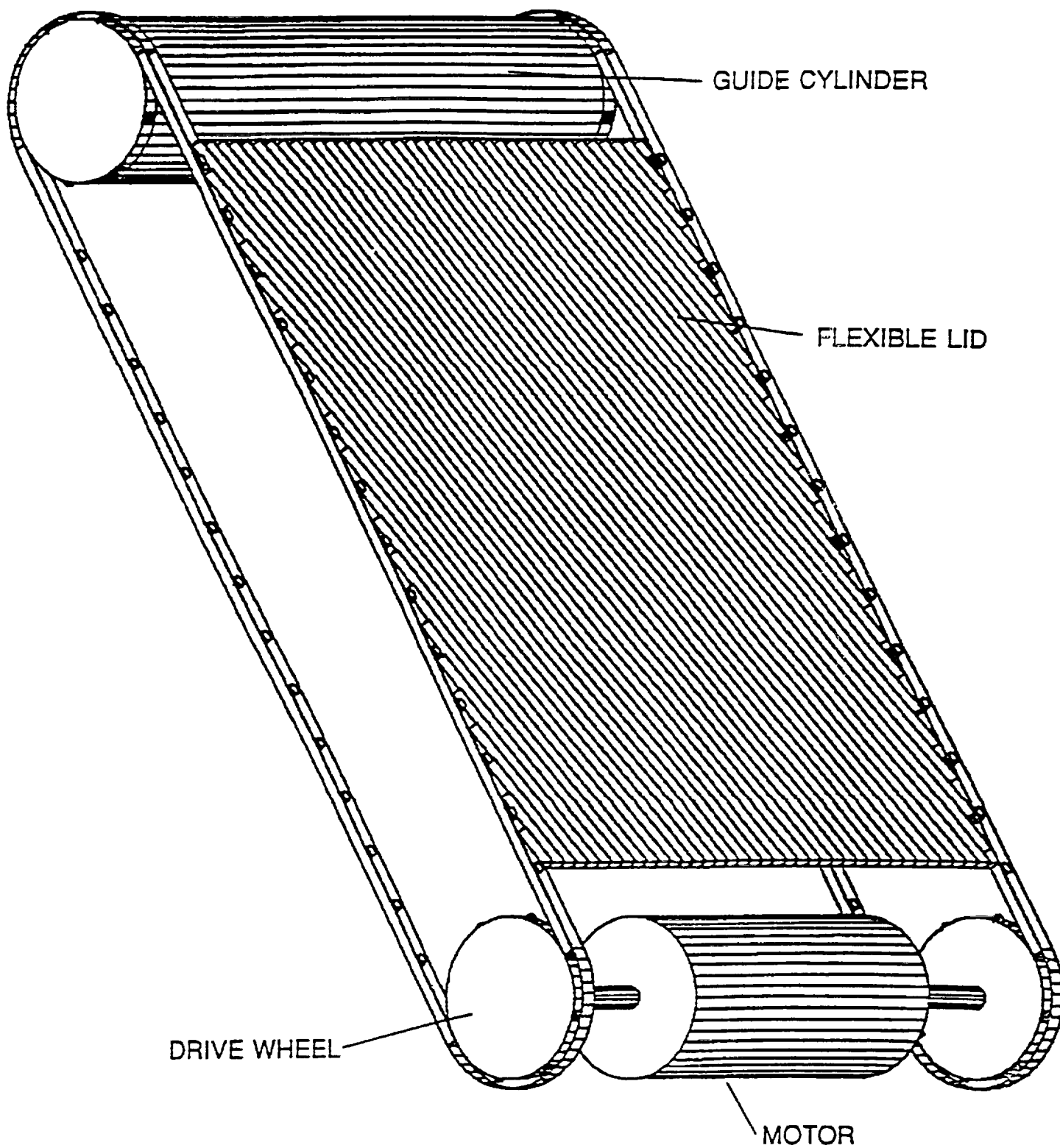
# MFLEX Base Configuration with MLA



## MFLEX Distributed Structural Concepts



# MOTORIZED LID ASSEMBLY



# **MFLEX Supports These Active Experiments**

- **68 Actinometers**
- **25 Strain Gauges**
- **5 Acoustic Emission Sensors**
- **72 Thermal Sensors**
- **24 Ultraviolet, Visible Light and Solar Diodes**

**The MFLEX can provide up to 194 data channels per Sensor Control Unit and can accommodate up to 32 Sensor Control Units**



**MFLEX Flight Experiments:**

- (11) MLA / SCA Test Assemblies
- (1) MLA / SCA / ECU Test Assembly
- (1) ECU controls all test assemblies
- 3 X 4 MFLEX packaging array

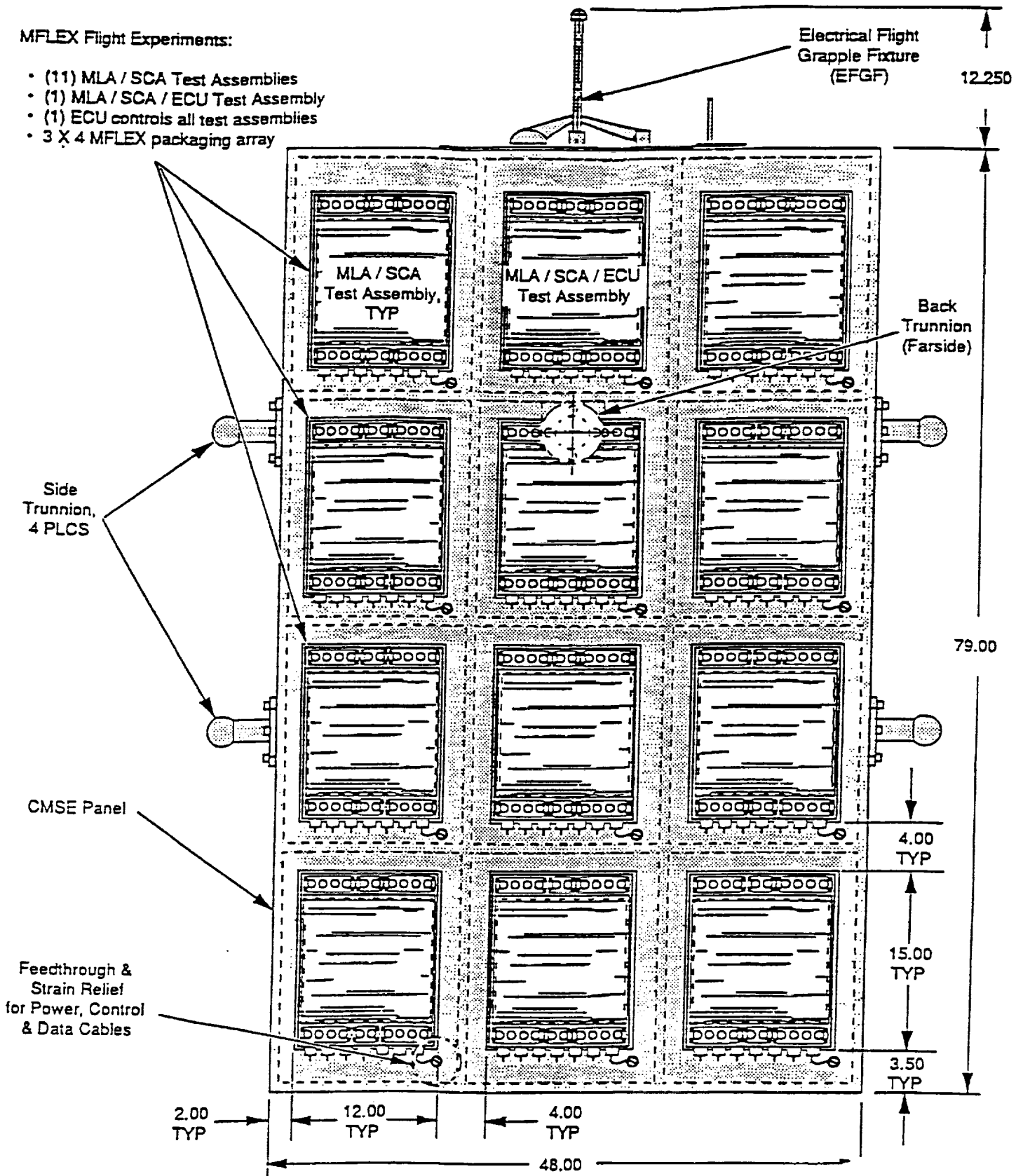
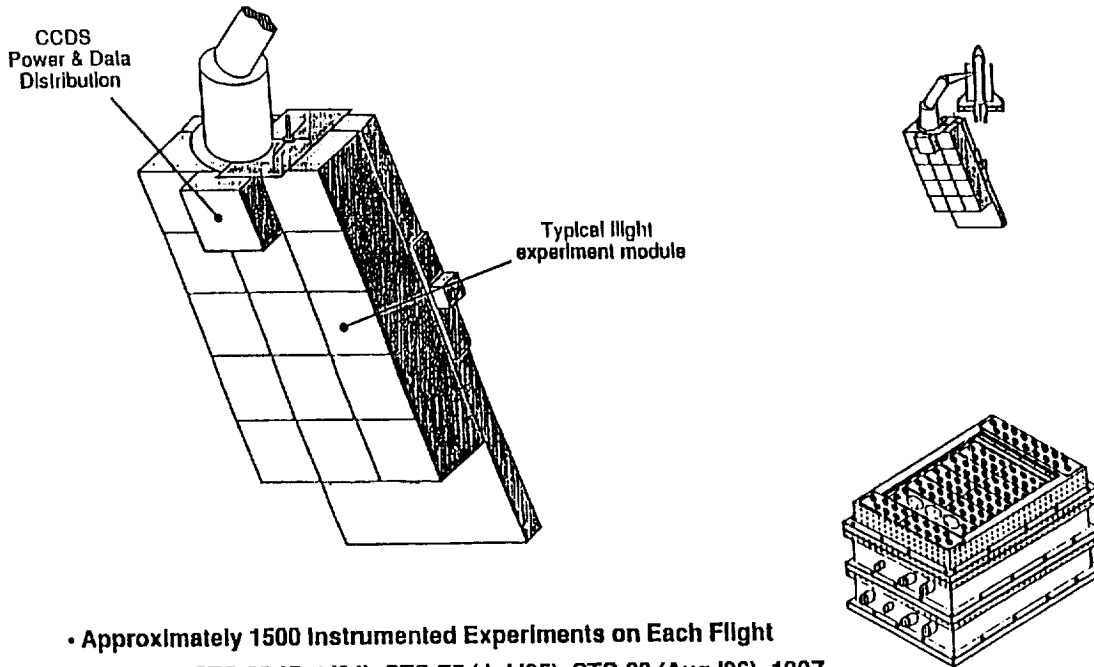


Figure 2 - CMSE Panel with Multiple MFLEX Experiments, Front View



FIGURE 1

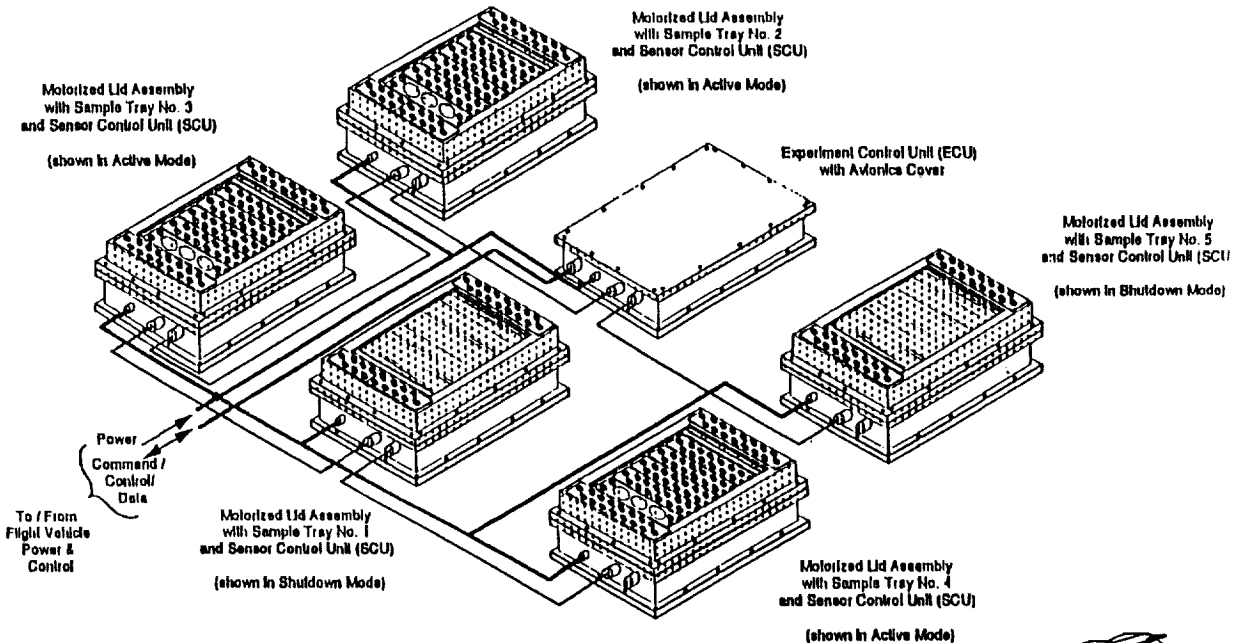
# Candidate Materials Space Exposure Experiment (CMSE)



- Approximately 1500 Instrumented Experiments on Each Flight
- Flying on STS-68 (Oct '94), STS-75 (Jul,'95), STS-83 (Aug,'96), 1997
- 40-80 Hours of Exposure



## MFLEX Flight Experiment Package Configured for Multiple Sample Trays



# LDSE PAYLOAD READINESS

- **Conceptual Design:** FY 1994
- **OCP Space Station Funding:** FY 1995
- **Detail Design:** FY 1995
- **Fabrication:** FY 1996
- **Testing:** FY 1997
- **1st Launch:** 4th Quarter FY 1997
- **Subsequent Launches:** 4th Quarter FY 1998 FY 1999, FY 2000, FY 2001



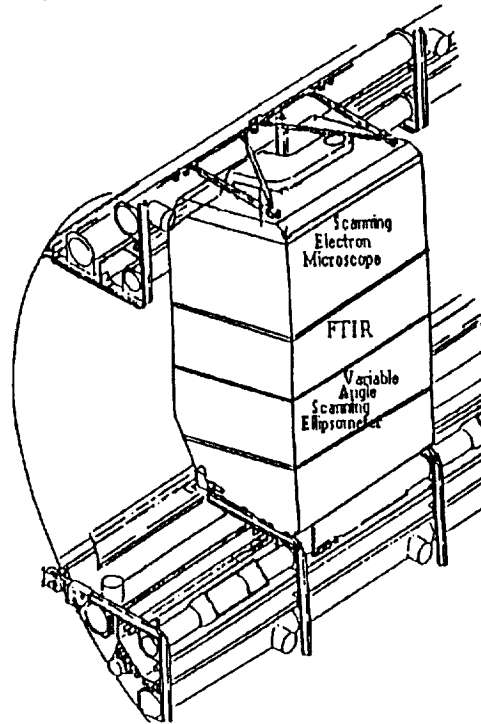
# LDSE REQUIRED RESOURCES

**Mass:** 430 lbs each (5 required)  
**Volume:** 79 in. tall x 48 in. wide x 12 in. deep  
**Power:** 1.7 KW Peak .784 KW Average  
**Nitrogen:** None  
**Liquid Heat Rejection:** None  
**Avionics Heat Rejection:** None  
**Water:** None  
**Venting:** None  
**Vacuum:** None  
**Refrigerated Storage:** None  
**Data Management:** 30 K bytes/min. for each LDSE Panel  
**Video:** Yes, 3x Camera Capability on Truss RMS  
**Uplink Command:** Yes Open and Close Switches  
**Microgravity Level:** N/A



# Space Materials Evaluation Facility (SMEF)

- Standard Double Rack Aboard  
Space Station Freedom
- Evaluation
  - Space Processed Materials
  - Space Exposed Materials
  - Other Experiment Support
- Equipment
  - Scanning Electron Microscope
  - Variable Angle Scanning Ellipsometer
  - Fourier Transform Infrared Spectrometer



**For Further Information**

**on LDSE**

**or Other CMSS Experiments**

**contact:**

**John F. Wallace**

**(216) 368-4222**

**Fax (216) 368-6329**





## POTENTIAL PRESSURIZED PAYLOADS; FLUID AND THERMAL EXPERIMENTS

Presented by Theodore D. Swanson  
Advanced Development and Flight Experiment Section  
NASA Goddard Space Flight Center

### ABSTRACT

Space Station Freedom (SSF) presents the opportunity to perform long term fluid and thermal experiments in a microgravity environment. This presentation provides perspective on the need for fluids/thermal experimentation in a microgravity environment, addresses previous efforts, identifies possible experiments, and discusses the capabilities of a proposed fluid physics/dynamics test facility.

Numerous spacecraft systems use fluids for their operation. Thermal control, propulsion, waste management, and various operational processes are examples of such systems. However, effective ground testing is very difficult. This is because the effect of gravity induced phenomena, such as hydrostatic pressure, buoyant convection, and stratification, overcome such forces as surface tension, diffusion, electric potential, etc., which normally dominate in a microgravity environment. Hence, space experimentation is necessary to develop and validate a new fluid based technology.

Two broad types of experiments may be performed on SSF; basic research and applied research. Basic research might include experiments focusing on capillary phenomena (with or without thermal and/or solutal gradients), thermal/solutal convection, phase transitions, and multiphase flow. Representative examples of applied research might include two-phase pressure drop, two-phase flow instabilities, heat transfer coefficients, fluid tank fill/drain, tank slosh dynamics, condensate removal enhancement, and void formation within thermal energy storage materials.

In order to better support such fluid/thermal experiments on board SSF, OSSA has developed a conceptual design for a proposed Fluid Physics/Dynamics Facility (FP/DF). The proposed facility consists of one facility rack permanently located on SSF and one experimenter rack which is changed out as needed to support specific experiments. This approach will minimize the on-board integration/deintegration required for specific experiments. The FP/DF will have acceleration/vibration compensation, power and thermal interfaces, computer command/data collection, a video imaging system, and a portable glovebox for operations. This facility will allow real-time astronaut interaction with the testing.



1992 SPACE STATION UTILIZATION CONFERENCE  
-AUGUST 3-6, 1992; HUNTSVILLE, ALABAMA-

**POTENTIAL PRESSURIZED PAYLOADS;  
FLUID AND THERMAL EXPERIMENTS**



THEODORE D. SWANSON

NASA/GODDARD



**OUTLINE**

- PROVIDE PERSPECTIVE ON NEED FOR FLUID/THERMAL PHYSICS EXPERIMENTATION IN A MICROGRAVITY ENVIRONMENT
- ADDRESS PREVIOUS EFFORTS
- IDENTIFY LIKELY TYPES OF EXPERIMENTS
- DISCUSS PROPOSED SPACE STATION FREEDOM TEST CAPABILITIES FOR FLUID PHYSICS/DYNAMICS

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# FLUID AND THERMAL EXPERIMENTS

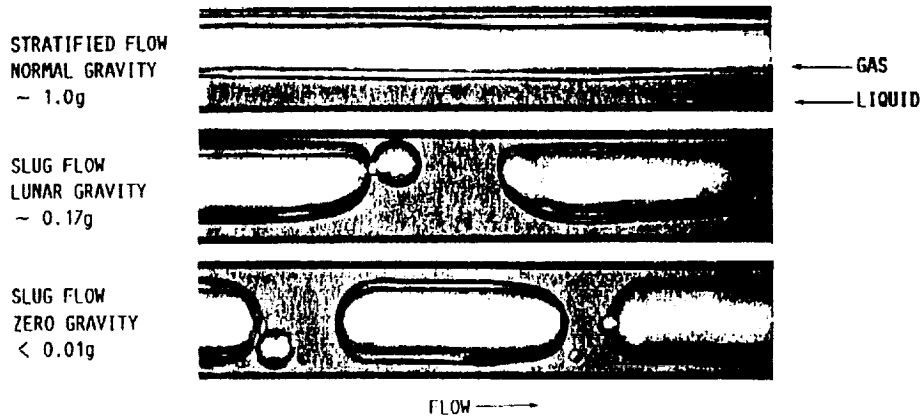
## BACKGROUND

- \* NUMEROUS SPACECRAFT SYSTEMS UTILIZE FLUIDS FOR OPERATION
  - THERMAL CONTROL, PROPULSION, WASTE MANAGEMENT, OPERATIONAL PROCESSES, ETC.
- \* GROUND TESTING SEVERELY COMPROMISED BY PRESENCE OF GRAVITY
  - HYDROSTATIC PRESSURE, BUOYANT CONVECTION, SEDIMENTATION, AND STRATIFICATION OVERCOME EFFECTS OF SURFACE TENSION, DIFFUSION PHENOMENA, ELECTRIC POTENTIAL, ETC.

BOTH BASIC SCIENCE AND SPACECRAFT TECHNOLOGY WILL BENEFIT FROM THE STUDY OF FLUID/THERMAL PHENOMENA IN A MICROGRAVITY ENVIRONMENT



## EFFECT OF GRAVITY ON FLOW REGIME



TWO-PHASE FLOW REGIMES DEMONSTRATING EFFECT OF DIFFERENT GRAVITY LEVELS  
(LEARJET FACILITY; AIR/WATER IN 1.27-CM-I.D. TUBE; SUPERFICIAL GAS VELOCITY, ~ 0.14 M/SEC; SUPERFICIAL LIQUID VELOCITY, ~ 0.07 M/SEC).





## FLUID AND THERMAL EXPERIMENTS

### -BACKGROUND, CONTINUED-

- \* PREVIOUS FLUID/THERMAL RESEARCH PROGRAMS OF THE 1960's, 1970's, AND EARLY 1980's IDENTIFIED MANY CRITICAL ISSUES, BUT THE PRIMARY EMPHASIS WAS ON SPECIFIC COMPONENTS AND SYSTEMS - NO GENERIC TECHNOLOGY BASE WAS DEVELOPED
- \* PREVIOUS WORKING GROUPS ALL IDENTIFIED SIMILAR NEEDS;
  - IN-SPACE RESEARCH, TECHNOLOGY, AND ENGINEERING WORKSHOP; OCTOBER 1985, WILLIAMSBURG
  - MICROGRAVITY FLUID MANAGEMENT SYMPOSIUM, SEPTEMBER, 1986, LeRC
  - WORKSHOP ON TWO-PHASE FLUID BEHAVIOR IN A SPACE ENVIRONMENT; JUNE, 1988, OCEAN CITY
  - IN-STEP 88; DECEMBER, 1988, ATLANTA



## PREVIOUS FLUID/THERMAL PHYSICS MICROGRAVITY EXPERIMENTATION

PREVIOUS MICROGRAVITY TESTING HAS GENERALLY BEEN OF VERY LIMITED TIME DURATION

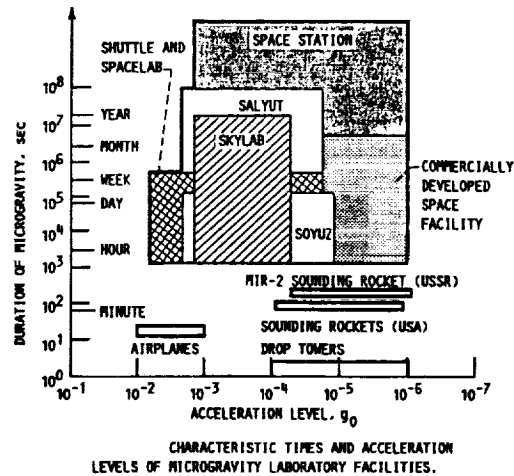
- \* DROP TOWERS - A FEW SECONDS
- \* AIRCRAFT - 20 TO 25 SECONDS
- \* SOUNDING ROCKETS, BALLONS - MINUTES
- \* SHUTTLE - A FEW DAYS
  - NASA/GODDARD TEMP 2A3 EXPERIMENT ON STS 46

MANY RESEARCHERS FEEL THAT WHILE A TEST DURATION OF SECONDS MAY BE ACCEPTABLE FOR SUCH PHENOMENA AS FLOW REGIMES, MUCH LONGER TIME DURATIONS ARE NEEDED TO STUDY OTHER PHENOMENA



# COMPARISON OF MICROGRAVITY ENVIRONMENTS

SPACE STATION FREEDOM OFFERS UNIQUE ENVIRONMENT FOR THERMAL/FLUID EXPERIMENTS



# TYPES OF EXPERIMENTS

TWO BROAD CATEGORIES OF EXPERIMENTS;

- \* BASIC RESEARCH
  - NO SPECIFIC APPLICATION; INVESTIGATION OF BASIC FLUID AND THERMAL PHENOMENA
- \* APPLIED SCIENCE
  - GOAL IS TO UNDERSTAND PHENOMENA SO AS TO SOLVE A GIVEN DESIGN PROBLEM



# BASIC SCIENCE EXPERIMENTS

## FIVE BROAD CLASSES;

- \* CAPILLARY PHENOMENA IN A ISOTHERMAL/ISO-SOLUTAL ENVIRONMENT
  - \* CAPILLARY PHENOMENA WITH THERMAL/SOLUTAL GRADIENTS
  - \* THERMAL/SOLUTAL CONVECTION
  - \* FIRST AND SECOND ORDER PHASE TRANSITIONS IN A STATIC FLUID
  - \* MULTIPHASE FLOW
- 
- \* REFERENCE; LOW-GRAVITY FLUID PHYSICS: A PROGRAM OVERVIEW  
LEWIS RESEARCH CENTER, CLEVELAND, OHIO



# APPLIED SCIENCE EXPERIMENTS

## REPRESENTATIVE EXAMPLES

- \* TWO-PHASE PRESSURE DROP
- \* TWO-PHASE FLOW INSTABILITIES
- \* TWO-PHASE FLOW THROUGH LINES, DUCTS, AND FITTINGS
- \* HEAT TRANSFER COEFFICIENTS
- \* FLUID TANK FILL/DRAIN
- \* FLUID TANK SLOSH DYNAMICS
- \* FLUID REORIENTATION WITHIN A TANK
- \* CONDENSATE REMOVAL ENHANCEMENT
- \* VOID FORMATION/DISTRIBUTION IN THERMAL ENERGY STORAGE MATERIALS

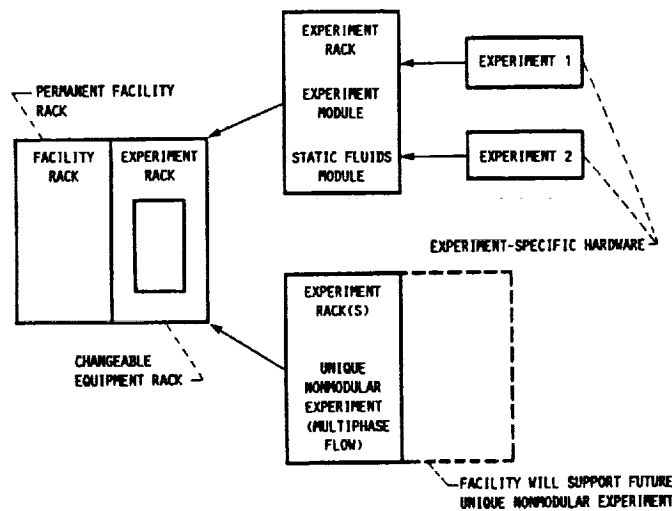


# PROPOSED SPACE STATION FREEDOM FLUID PHYSICS RESEARCH CAPABILITIES\*

- \* NASA'S OSSA TASKED LeRC TO CONDUCT A WORKSHOP TO DEFINE A FLUID PHYSICS/DYNAMICS FACILITY (FP/FD) FOR SSF
- \* RESULTING CONCEPTUAL DESIGN IS A MODULAR, TWO RACK FACILITY;
  - FACILITY RACK; PERMANENT, BUT UPGRADABLE
  - EXPERIMENT RACK; EXPERIMENT SPECIFIC MODULES AND EQUIPMENT
- \* TWO-RACK CONCEPT CHOSEN BECAUSE;
  - MAXIMIZES VOLUME THAT CAN BE REORIENTED WITH RESPECT TO THE QUASI-STEADY STATE ACCELERATION VECTOR
  - MINIMIZES ON-BOARD INTEGRATION/DEINTEGRATION EFFORT FOR EXPERIMENT SPECIFIC HARDWARE
- \* REFERENCE; NASA TECHNICAL MEMORANDUM, "STATUS REPORT ON CONCEPTUAL DESIGN FOR THE SPACE STATION FREEDOM FLUID PHYSICS/DYNAMICS FACILITY"



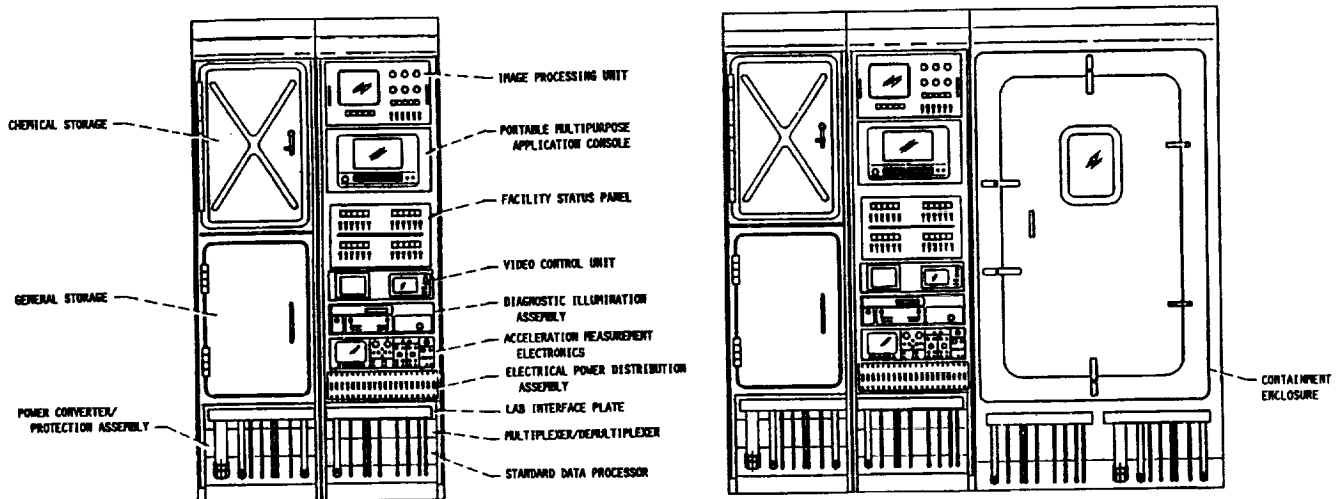
## MODULAR CONCEPT FOR PROPOSED SSF FLUID PHYSICS/DYNAMICS FACILITY\*



- \* REFERENCE; NASA TECHNICAL MEMORANDUM, "STATUS REPORT ON THE CONCEPTUAL DESIGN FOR THE SPACE STATION FREEDOM FLUID PHYSICS/DYNAMICS FACILITY"



# LAYOUT OF PROPOSED SSF FLUID PHYSICS/DYNAMICS FACILITY



## REPRESENTATIVE EXPERIMENTS SUGGESTED FOR FP/DF

- \* SURFACE TENSION INDUCED INSTABILITIES
- \* SURFACE TENSION DRIVEN CONVECTION
- \* FREE SURFACE PHENOMENA
- \* BUBBLE/DROPLET DYNAMICS
- \* THERMAL AND DOUBLE DIFFUSE CONVECTION
- \* MULTIPHASE FLOW
- \* FIRST ORDER TRANSITIONS
- \* CHEMICAL DEPOSITION
- \* THERMAL GRADIENT EFFECTS ON ENTRY-FLOW
- \* FLUID PHENOMENA DURING SOLIDIFICATION
- \* FLUID MIXTURE HEAT AND MASS TRANSFER



## SSF MICROGRAVITY ENVIRONMENT

- \* NO FIRM MICROGRAVITY REQUIREMENT YET ESTABLISHED
- \* ANTICIPATED ENVIRONMENT HAS THREE ELEMENTS;
  - QUASI-STEADY ACCELERATION (10-5 G's)
    - 10-5 G's, 37+ DEGREES
    - THREE MAJOR FACTORS;
      - GRAVITY GRADIENT
      - ROTATIONAL
      - ATMOSPHERIC DRAG
- \* OSCILLATORY ACCELERATIONS
  - ROTATING MACHINERY, CREW ACTIVITIES, STRUCTURAL
- \* TRANSIENT ACCELERATIONS
  - CREW, THRUSTER FIRINGS, VENTING, DOCKING, EQUIPMENT ON/OFF

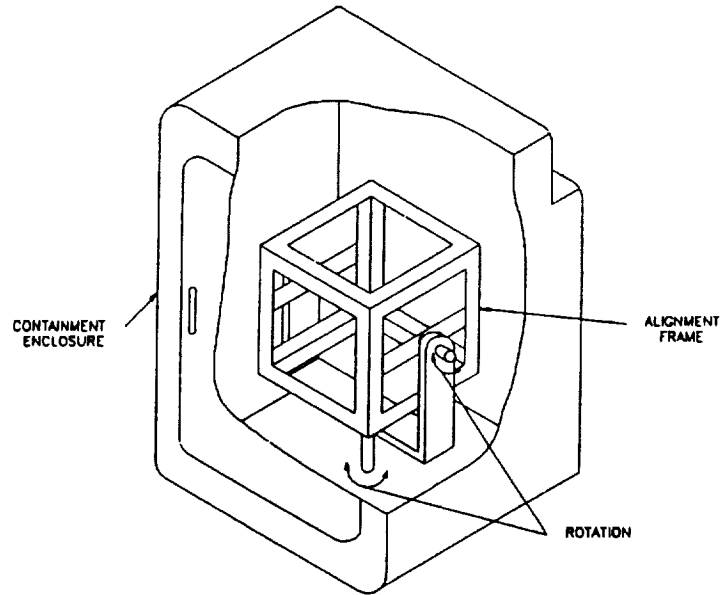


## PROPOSED FP/DF CAPABILITIES

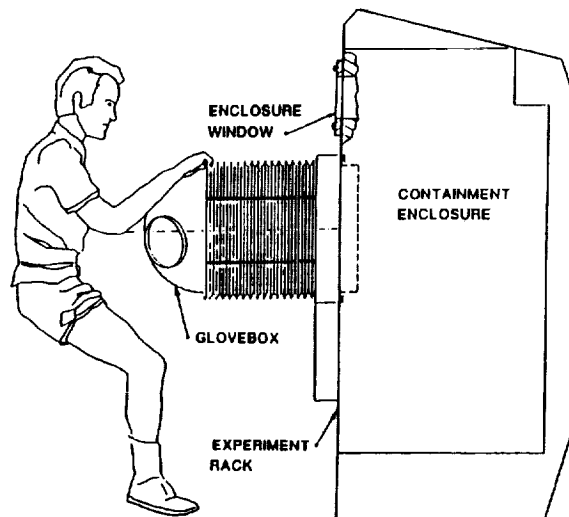
- \* ROTATING QUASI-STEADY ACCELERATION ALIGNMENT SYSTEM (68 CM DIA.)
- \* PASSIVE VIBRATION ISOLATION TECHNIQUES
- \* POWER; 6 KW OF 120 VDC TO FACILITY RACK,  
3 KW OF 120 VDC TO EQUIPMENT RACK,  
28 VDC AND 400 HZ AC AS REQUIRED
- \* THERMAL; INTERFACE HEAT EXCHANGER, COLD PLATE,  
AIR-TO-AIR COOLING
- \* FP/DF COMPUTER - NODE ON SSF COMPUTER; THREE  
DATA LINKS, UP TO 100 MB/SEC,  
VARIETY OF SENSOR ACCOMMODATIONS
- \* VIDEO IMAGING SYSTEM
- \* PORTABLE GLOVEBOX



## PROPOSED SSF FP/DF QUASI-STEADY ACCELERATION ALIGNMENT SYSTEM



## PROPOSED SSF FP/DF PORTABLE GLOVEBOX CONCEPT





## BENEFITS OF SSF FLUID PHYSICS/DYNAMICS FACILITY

- \* LONG DURATION (MONTHS-YEARS)
- \* MICROGRAVITY AT LEVEL REPRESENTATIVE OF LARGE SPACE STRUCTURES
- \* CREW AVAILABILITY FOR OPERATIONS
- \* REAL TIME HUMAN OBSERVATION
- \* CREW AVAILABLE FOR MODIFICATION/REPAIR
- \* INCREASED TEST MATRIX FLEXIBILITY



## ISSUES FOR FLUIDS/THERMAL TESTING ON SSF

- \* ACCELERATIONS OF  $10^{-5}$  TO  $10^{-6}$  G's MAY BE LARGE ENOUGH TO AFFECT SOME PROCESSES
  - IMPACT UNKNOWN
- \* SAFETY CONCERNS LIMIT USE OF OPERATING FLUIDS TO BENIGN FLUIDS SUCH AS WATER, ALCOHOL, R-113, AND SILICON OILS
- \* MODERATE PHYSICAL SIZE



**O-G LIFE SUPPORT FOR SPACE STATION FREEDOM**

Presented by Matthew Kolodney  
Lockheed Engineering and Sciences Company  
NASA Johnson Space Center

**ABSTRACT**

Optimal design of spacecraft environmental control and life support systems (ECLSS) for long-duration missions requires an understanding of microgravity and its long-term influence on ECLSS performance characteristics. This understanding will require examination of the fundamental processes associated with air revitalization and water recovery in a microgravity environment. Short-term testing can be performed on NASA's reduced gravity aircraft (a KC135), but longer tests will need to be conducted on the shuttle or Space Station Freedom.

Conceptual designs have been prepared for ECLSS test beds that will allow extended testing of equipment under microgravity conditions. Separate designs have been formulated for air revitalization and water recovery test beds. In order to allow testing of a variety of hardware with minimal alteration of the beds themselves, the designs include storage tanks, plumbing, and limited instrumentation that would be expected to be common to all air (or water) treatment equipment of interest. In the interest of minimizing spacecraft/test bed interface requirements, the beds are designed to recycle process fluids to the greatest extent possible. In most cases, only cooling water and power interfaces are required.

A volume equal to that of two SSF lockers was allowed for each design. These bed dimensions would limit testing to equipment with a 0.5- to 1.5-person-equivalent throughput. The mass, volume, and power requirements for the air revitalization test bed are estimated at 125-280 kg, 1.0-1.4 m<sup>3</sup>, and 170-1070 W. Corresponding ranges for the water recovery test bed are 325-375 kg, 1.0-1.1 m<sup>3</sup>, and 350-850 W. These figures include individual test articles and accompanying hardware as well as the tanks, plumbing, and instrumentation included in the bed designs. Process fluid weight (i.e. water weight) is also included.



# ZERO - G LIFE SUPPORT RESEARCH

M. Kolodney, Lockheed Engineering and Sciences Co.

L. Dall-Bauman, NASA-JSC

Presented at

Space Station Freedom Utilization Conference

Huntsville AL

August 3-6, 1992

## RATIONALE

- Optimal design of spacecraft ECLSS for long-duration missions requires an understanding of microgravity and its long-term influence on ECLSS performance.
- Such understanding requires examination of fundamental processes associated with air revitalization and water recovery in a microgravity environment.
- Short-term testing can be performed on NASA's reduced-gravity aircraft (KC135), but longer tests will need to be conducted on the shuttle or SSF.

## CONSTRAINTS

- Bed must fit in two adjacent station lockers, each with dimensions 0.91 m x 0.99 m x 1.83 m.
  - Limited space available means that full-scale (i.e. 4-person) hardware cannot be tested.
- SSF-test bed interfaces limited to
  - electric power
  - cooling water at 4°C
  - air

## COMMONALITY

- Separate beds have been designed for testing ARS and WRMS equipment.
  - Vastly different flow rates and compressibilities require dissimilar equipment, line sizing, and instrumentation.
    - A common test bed would require parallel flow paths and equipment to allow circulation of gases and liquids.
- Many air revitalization processes are continuous, while most water recovery subsystems include batch processes.

## TEST BED CLOSURE

- Due to limited SSF- test bed interfacing, test bed should be closed to the greatest extent possible.
- In some cases, full closure may be unrealistic.
  - Example: Bosch reactor
    - To close bed with respect to carbon, solid carbon would have to be recovered and oxidized to CO<sub>2</sub>.
    - To close bed with respect to hydrogen, product water would have to be electrolyzed.
    - Equipment necessary to close test bed would drive mass, volume, and power requirements beyond limits of bed.

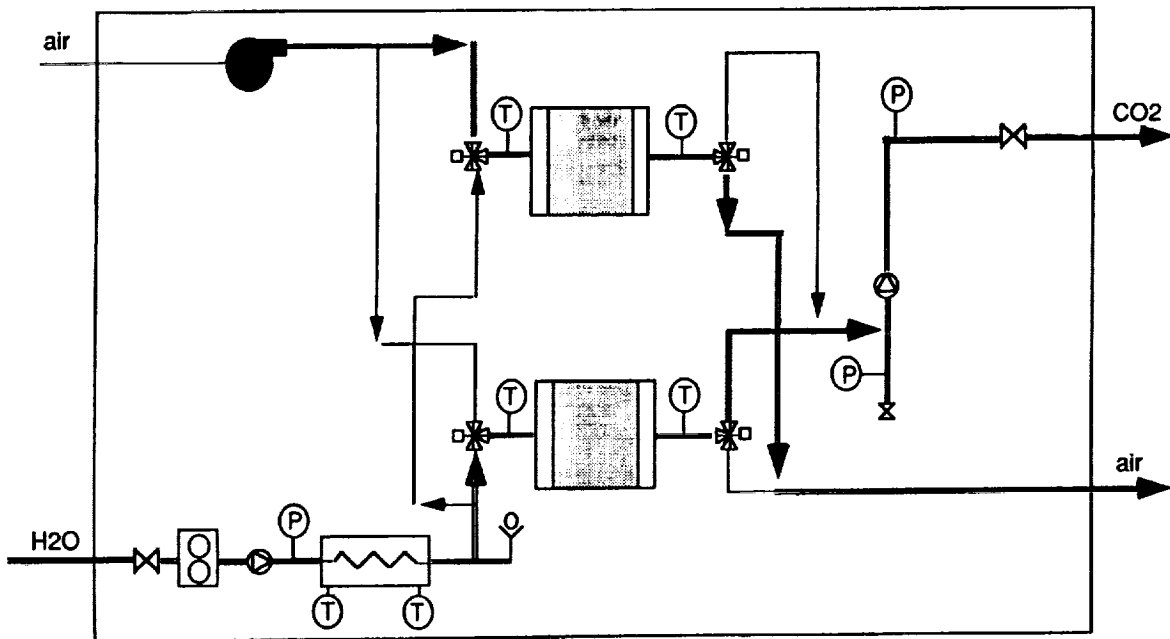
## BED DESIGN PHILOSOPHY

- Test beds have been designed in a modular fashion in order to allow testing of a variety of equipment.
- To allow testing of different hardware with minimal bed modification, bed designs include storage tanks, plumbing, and limited instrumentation expected to be common to all equipment of interest.
- Each bed allows space for insertion of "experiment packages", which will include test articles as well as instrumentation, plumbing, and controls specific to test articles.

## ARS TEST BED HARDWARE

- surge/storage tank
- CO<sub>2</sub> and O<sub>2</sub> sensors
- condensing heat exchanger
- humidifier
- adsorbent bed
- fan
- electric heater
- control package

## SCHEMATIC OF POSSIBLE EXPERIMENT PACKAGE



adapted from final report on SAWD II, SVHSER 10634

### ARS TEST BED MASS, VOLUME, AND POWER SUMMARY

	Mass (kg)	Volume (m3)	Power (W)
test bed	93	0.8	129
experiment package	32 - 187	0.2 - 0.6	41 - 941
<b>TOTAL</b>	<b>125 - 280</b>	<b>1.0 - 1.4</b>	<b>170 - 1070</b>

### WRMS TEST BED HARDWARE

- |                        |           |                            |
|------------------------|-----------|----------------------------|
| • feed/product tank    |           | • feed pump                |
| • pretreatment storage |           | • pretreatment pump        |
| • posttreatment        |           | • filter                   |
| • two heat exchangers  | <b>OR</b> | • temperature control bath |
| • control package      |           |                            |

## SUMMARY

- Long-term testing of life support hardware under microgravity conditions is essential for design of optimal life support systems.
- Separate test beds have been designed to enable testing of ARS and WRMS hardware on SSF.
- ARS test bed requirements are estimated at 125 - 280 kg, 1.0 - 1.4 m<sup>3</sup>, and 170 - 1070 W.
- WRMS test bed requirements are estimated at 325 - 375 kg, 1.0 - 1.1 m<sup>3</sup>, and 350 - 850 W.
- The above estimates include test articles and accompanying hardware in addition to tanks, plumbing, and instrumentation contained in bed infrastructure.



**WP-2 ATTACHED PAYLOAD ACCOMMODATIONS**

Presented by Jim Scheib  
Space Station Division  
McDonnell Douglas

**ABSTRACT**

The presentation provides an overview of the current SSFP attached payload accommodations on the U.S. truss. The overview includes discussions on the four attach sites, the power architecture, thermal control, DMS provisions and the mechanical attach mechanism. The presentation concludes with a description of a McDonnell Douglas concept for an attached payload pallet designed to take advantage of the four sites and existing SSF hardware. This presentation should provide the payload community with a basic understanding of the SSF attached payload utility ports and aid in attached payload concept development.



# WP-2 ATTACHED PAYLOAD ACCOMMODATIONS

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June 1992

Jim Scheib, Manager  
User Engineering Integration  
MDSSC Space Station Division  
(714) 896-3311 x60457

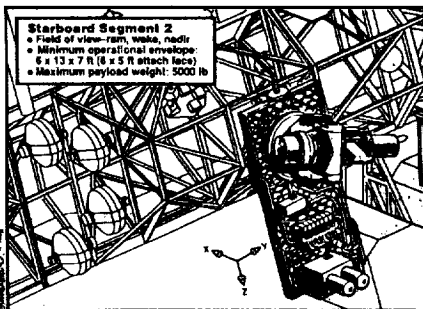
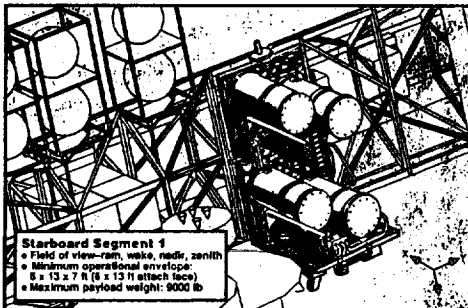
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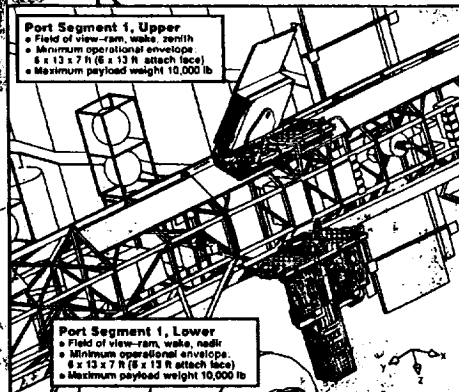
MCDONNELL DOUGLAS



Accommodations\*

- Power: 3 kW each site, 6 kW aggregate
- Data: 1553 local bus—256 kbps down (FDDI scarring potential)
- Use of common station attachment mechanism (modified propulsion module assembly structure)

\*Pallets and payloads are representative only



Space Station Freedom  
WP-2 Pre-Integrated Truss  
Attached Payload Accommodations

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## NOVEMBER 12 SSCB AND ATTACHED PAYLOAD CR

- The November 12 SSCB and the parameters set forth in the Attached Payload CR #BB003113B require accommodations for attached payload as follows:
  - Number of sites: at least 4 separate sites for attached payloads
    - Viewing: view nadir, zenith, ram and wake direction without significant occultation by SSMB
    - Clearance Envelopes: attach faces of about 5x6 ft on S2 and 6x13 ft on the S1 and P1 sites, and 7 ft height at each site
  - Utility Ports: each site contains at least 1 port
    - Power: 3 kW peak per port (redundant power feed)  
6 kW total peak aggregate supplied to all ports
    - Thermal: payload provided
    - Data: 1553 Payload Local Bus with external FDDI network fibers and cables for later hook up
    - Mechanical Attachment: each attached payload site will contain 1 suitable mechanical attachment

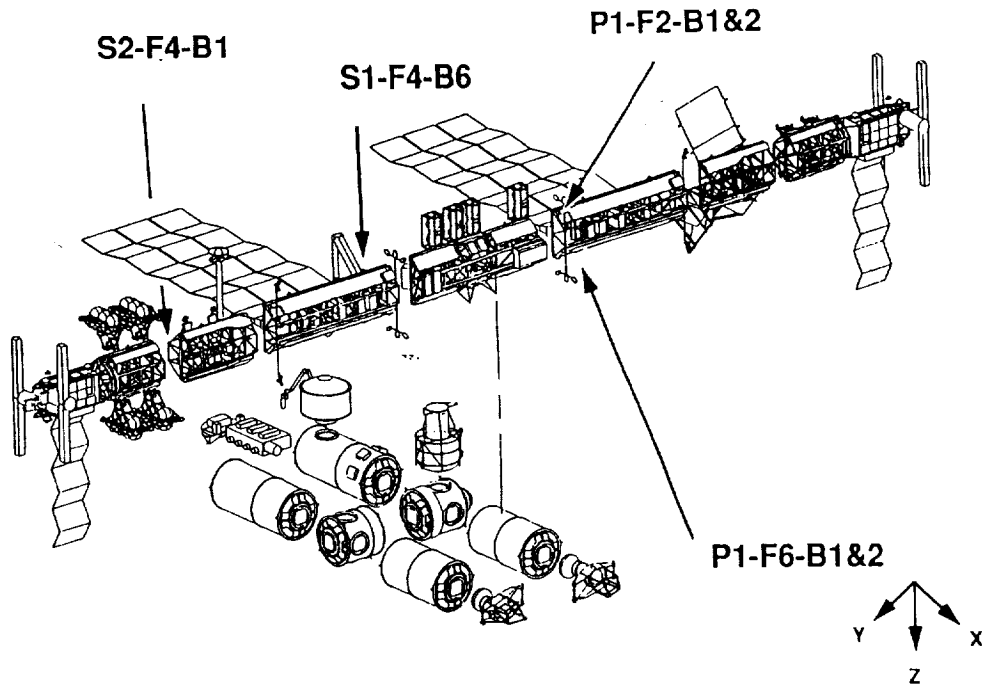
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## ATTACHED PAYLOAD UTILITY PORTS

- Starboard (MTC) Locations:
  - S2-F4-B1: pre-integrated attachment on Face 4 (5' x 6' attach face) with viewing in the Nadir and Wake directions (potential for Ram and Zenith viewing also)
  - S1-F4-B6: attachment over the grapple fixtures with no structural impact (6' x 13' attach face), viewing in Nadir, Zenith, Ram and Wake directions
- Port (post MTC) Locations:
  - P1-F2- B2: attachment over the utility trays (6' x 13' attach face), unobstructed view in Zenith, Ram and Wake directions
  - P1-F6- B2: attachment over the utility trays (6' x 13' attach face), unobstructed view in Nadir, Ram and Wake directions, common with P1-F2 location

Note: all sites provide a minimum height of 7 ft - see operational envelopes pages 10 through 12

# ON-ORBIT CONFIGURATION SHOWING PRIME PAYLOAD ATTACHMENT SITES

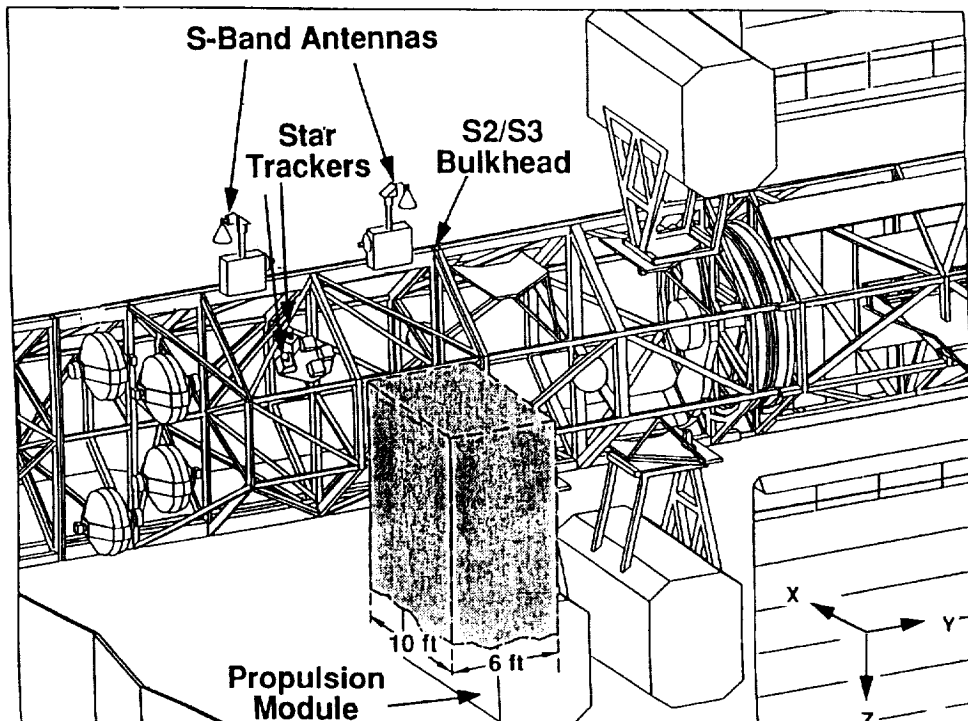


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# S2 (MB-2) SEGMENT ATTACHED PAYLOAD OPERATIONAL ENVELOPE

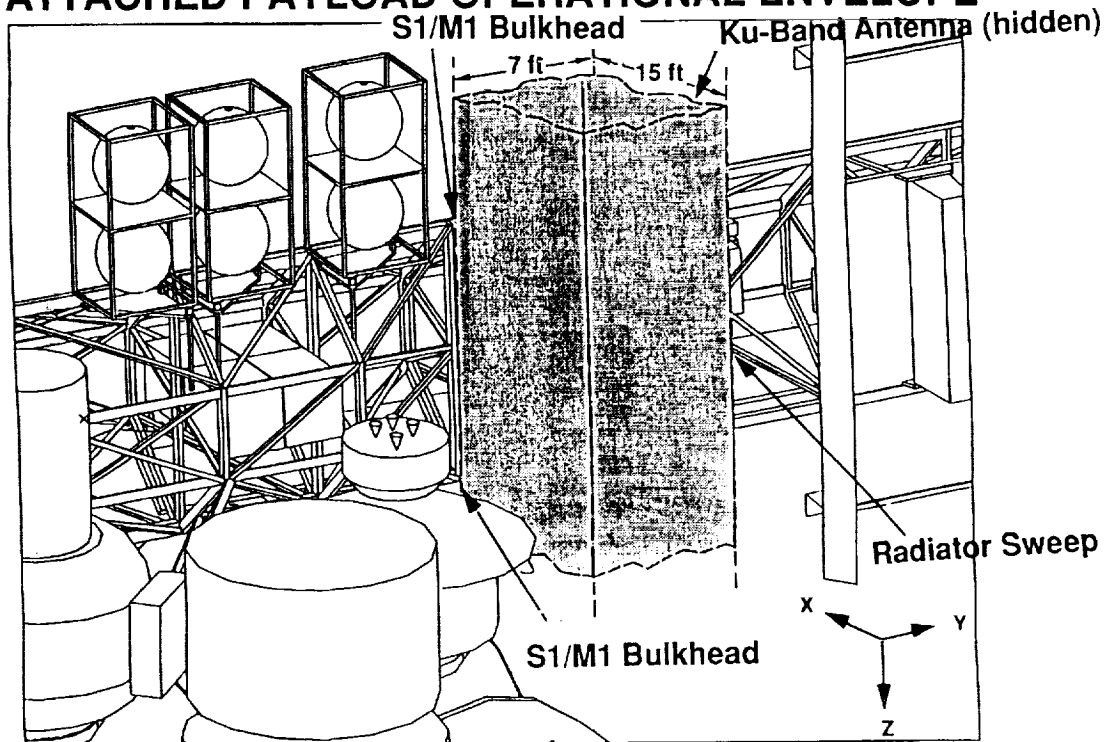


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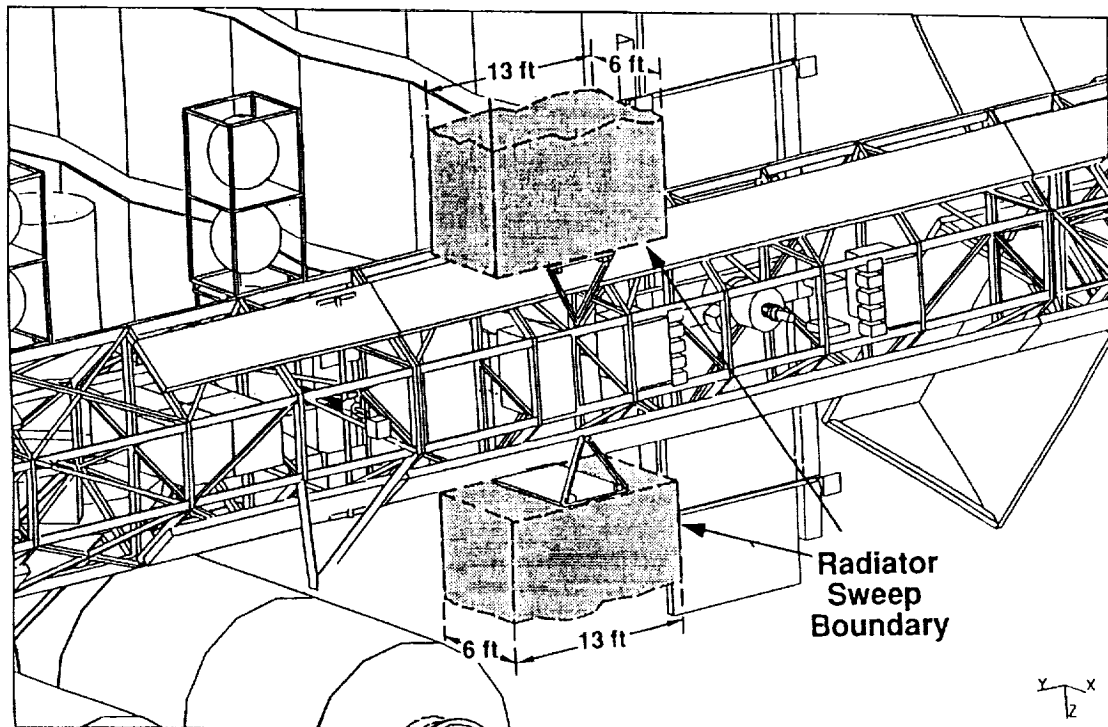
# S1 (MB-3) SEGMENT ATTACHED PAYLOAD OPERATIONAL ENVELOPE



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# P1 (MB-8) SEGMENT ATTACHED PAYLOAD OPERATIONAL ENVELOPE



420

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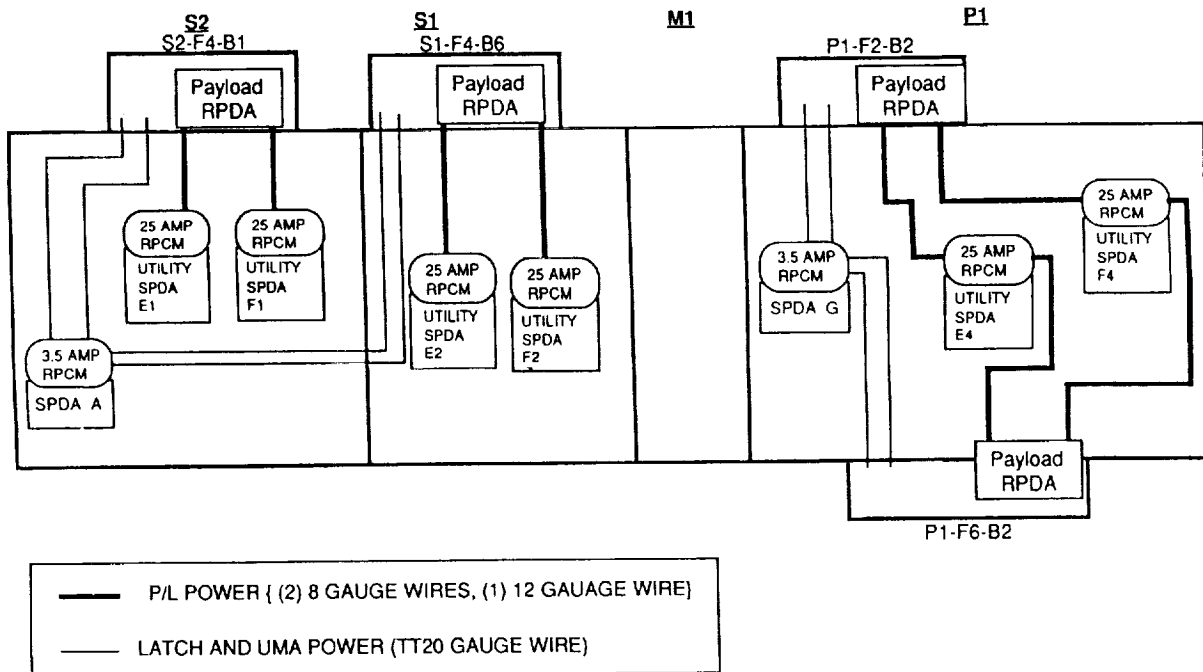
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# POWER ACCOMMODATIONS APPROACH

- The existing Electrical Power System (EPS) design was used
  - No new DC to DC Converter Units (DDCUs) are required, which would also require adding new Main Bus Switching Units (MBSUs)
  - Existing Secondary Power Distribution Assemblies (SPDAs) already in place along the truss are used
  - No impact on the growth of the overall EPS system to PMC
- Power accommodations provide payloads with continuous power (power levels depend on Station loads but do not exceed 6 kW total)
  - Each port is connected to a utility SPDA on each side of the truss making the ports single failure tolerant (in case of SPDA failure up to 500 Watts may be available)
  - If a utility SPDA fails on one side of the Station and the Mobile Transporter is using the utility SPDA on the other side, no keep-alive power to payloads can be guaranteed

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## PROPOSED ATTACHED PAYLOAD POWER ARCHITECTURE



# ATTACHED PAYLOAD THERMAL CONTROL

- Payloads are required to provide their own thermal control
- Payloads must be assessed on an individual basis to determine thermal effects at the appropriate attached site and orientation. The following considerations must be addressed:
  - Operational/non-operational temperature ranges experienced by the payload components or its individual ORUs
  - What types of thermal coatings/insulation can be used to enhance the desired temperature range
  - What size radiators are needed to dissipate heat and what size heaters are needed to make-up heat
- Design-to thermal optical properties, radiator sizes, and insulation requirements at each payload site must be determined by integrating the payload model into a full Space Station model to properly size Passive Thermal Control Systems (PTCS) for each payload
- Preliminary thermal analyses for two example payloads: the Cosmic Dust Collection Facility and the Orbital Debris Collision Warning System were performed under this study

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## DMS ACCOMMODATIONS

- SSCB has baselined 1553 local bus service
- FDDI scarring is possible but has not been finalized yet
- Interface Description:
  - DMS accommodations are provided by extending two 1553 local busses from SDP 7 in the Lab Element Control Workstation rack in the U.S. Lab
    - One 1553B bus to the port APP sites and a second separate 1553B bus to the starboard APP sites
  - The two Local Busses share the same Bus Interface Unit (BIU) with separate Bus Interface Adapters (BIA) to service each of the Payload Local Busses

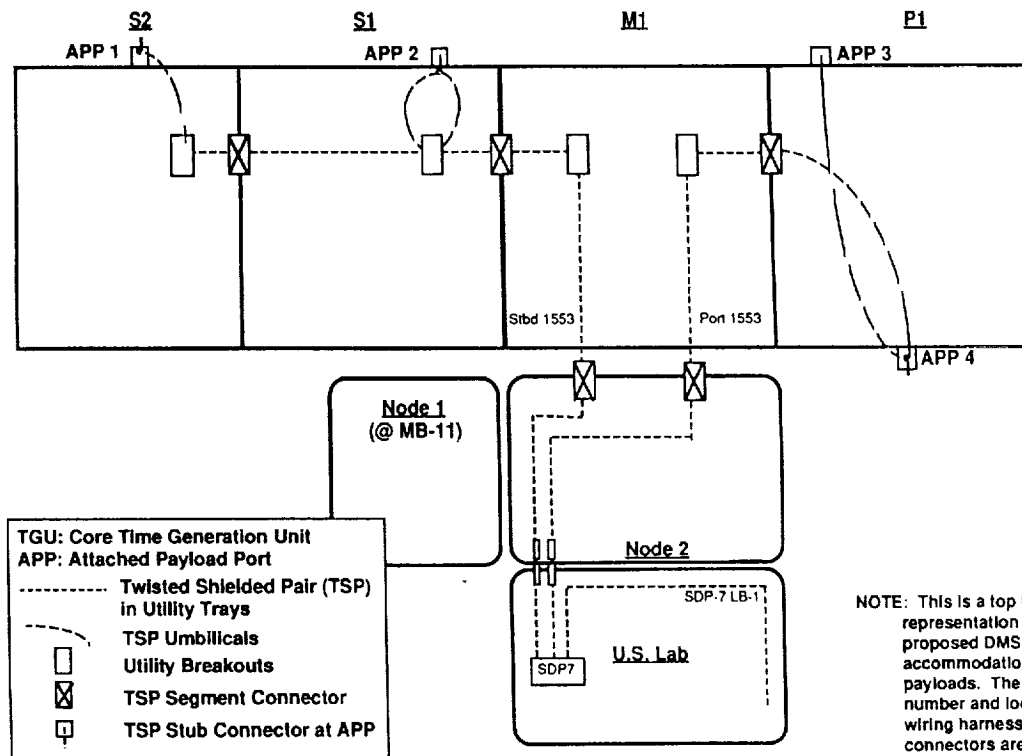
Note: requires the addition of one BIU in SDP-7

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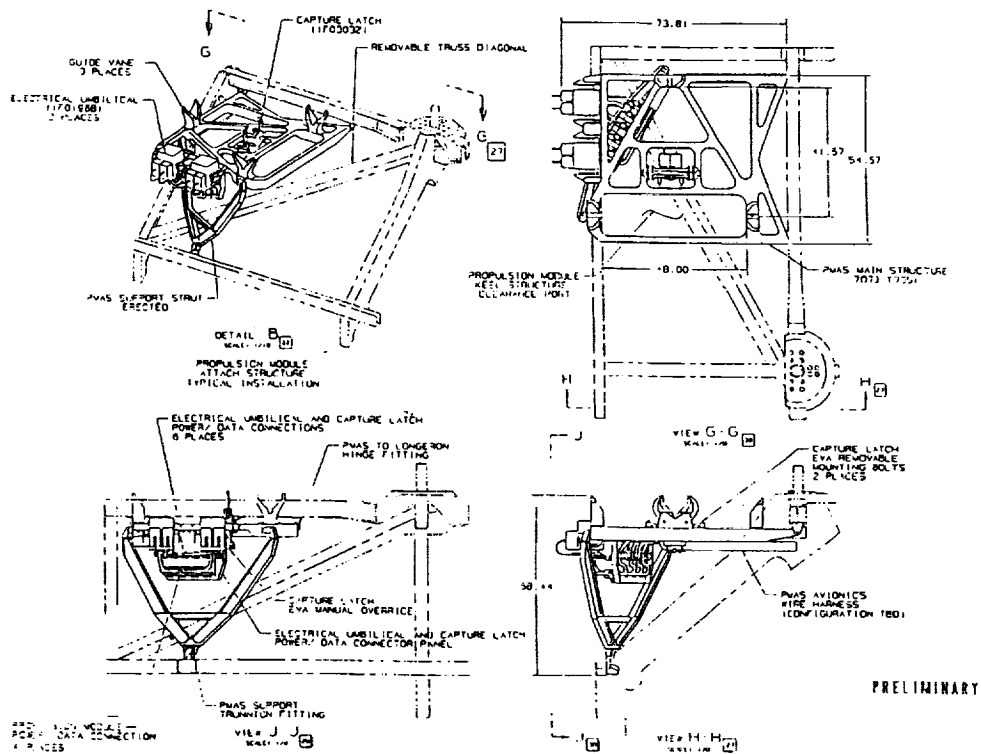
# 1553 ATTACHED PAYLOAD LOCAL BUS ARCHITECTURE



## ATTACHMENT ACCOMMODATIONS SUMMARY

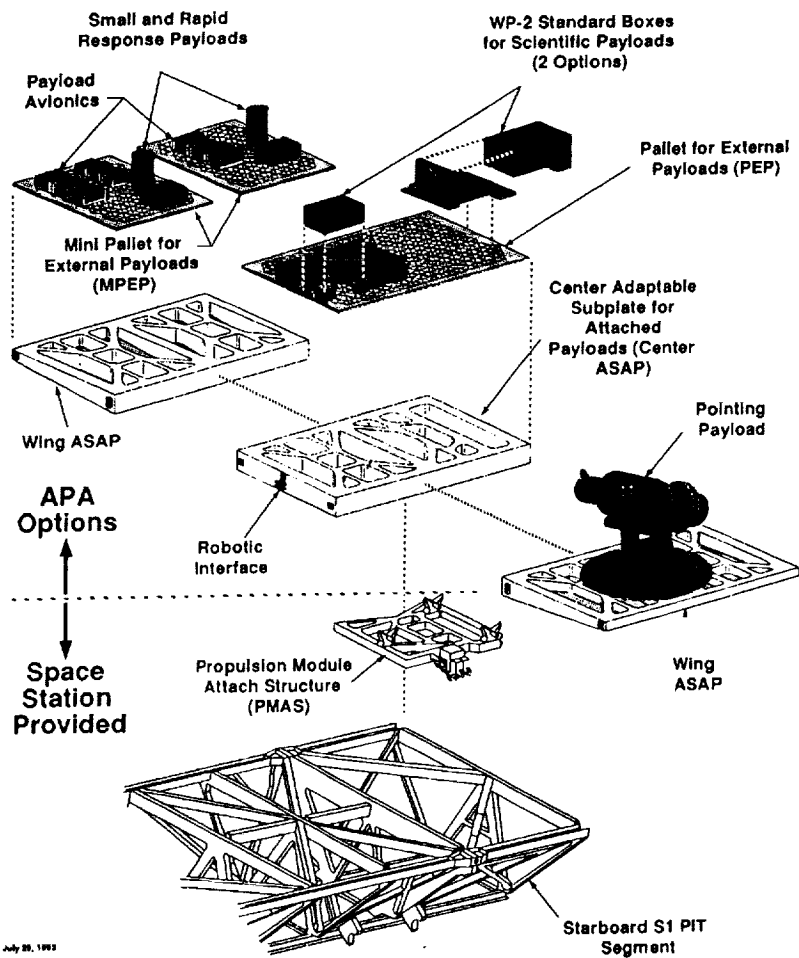
- Accommodations include provisions for Propulsion Module Attach Structure (PMAS) at each payload port
  - PMAS is composed of mechanical latch, umbilical mechanism, guide vanes, wire harness and support structure
  - PMAS and support structure are not pre-integrated and are installed with EVA at the time of payload first use
  - Installation of attached payload pallet to PMAS will utilize the RMS for positioning and EVA for final alignment
  - PMAS standard attachment interface provides payload community with the flexibility to connect single or multiple payloads at each location (e.g. large payloads, gas cans or SARR pallet)
  - On segment P1 faces 2 and 6 the PMAS and the payload(s)/payload pallet will swing away from the utility trays if on-orbit utility tray servicing is ever necessary

# PROPULSION MODULE ATTACH STRUCTURE (PMAS)



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*SESSION 3:  
MICROGRAVITY RESEARCH AND  
BIOTECHNOLOGY*

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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 5, 1992*

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## RESEARCH OBJECTIVES, OPPORTUNITIES AND FACILITIES FOR MICROGRAVITY SCIENCE

Presented by Robert J. Bayuzick  
Office of Space Science and Applications  
NASA Headquarters and Vanderbilt University

### ABSTRACT

Microgravity Science in the U.S.A. involves research in fluids science, combustion science, materials science, biotechnology and fundamental physics. The purpose is to achieve a thorough understanding of the effects of gravitational body forces on physical phenomena relevant to those disciplines. This includes the study of phenomena which are usually overwhelmed by the presence of gravitational body forces and, therefore, chiefly manifested when gravitational forces are weak. In the pragmatic sense, the research involves gravity level as an experimental parameter.

Calendar year 1992 is a landmark year for research opportunities in low earth orbit for Microgravity Science. For the first time ever, three Spacelab flights will fly in a single year. IML-1 was launched on January 22; USML-1 was launched on June 25; and, in September, SL-J will be launched. A separate flight involving two cargo bay carriers, USMP-1, will be launched in October. From the beginning of 1993 up to and including the Space Station era (1997), nine flights involving either Spacelab or USMP carriers will be flown. This will be augmented by a number of middeck payloads and get away specials flying on various flights.

All of this activity sets the stage for experimentation on Space Station Freedom. Beginning in 1997, experiments in Microgravity Science will be conducted on Station. Facilities for doing experiments in protein crystal growth, solidification and biotechnology will all be available. These will be joined by middeck-class payloads and the microgravity glove box for conducting additional experiments. In 1998, a new generation protein crystal growth facility and a facility for conducting combustion research will arrive. A fluids science facility and additional capability for conducting research in solidification, as well as an ability to handle small payloads on a quick response basis, will be added in 1999. The year 2000 will see upgrades in the protein crystal growth and fluids science facilities. From the beginning of 1997 to the fall of 1999 ( the "man-tended capability" era), there will be two or three utilization flights per year. Plans call for operations in Microgravity Science during utilization flights and between utilization flights. Experiments conducted during utilization flights will characteristically require crew interaction, short duration and less sensitivity to perturbations in the acceleration environment. Operations between utilization flights will involve experiments that can be controlled remotely and/or can be automated. Typically, the experiments will require long times and a pristine environment. Beyond the fall of 1999 (the "permanently-manned capability" era), some payloads will require crew interaction; others will be automated and will make use of telepresence.





NASA Headquarters  
 Office of Space Science and Applications  
 Microgravity Science and Applications Division

**Microgravity Science and Applications Division  
 Research Objectives, Opportunities, and Facilities**

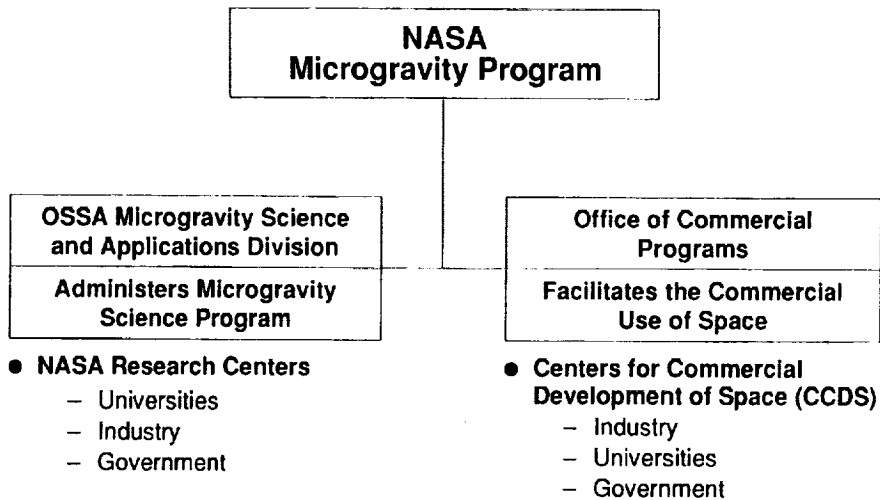
Presented to:  
**Space Station Freedom Utilization Conference  
 August 3 - 6, 1992  
 Huntsville, Alabama**

**Robert J. Bayuzick**

9207.005 01CAW 07/18/92



**NASA Microgravity Program**



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## Program Goal



**Develop a comprehensive research program in fluids science, combustion science, materials science, biotechnology, and fundamental physics for the purpose of attaining a structured understanding of gravity-dependent physical phenomena and those physical phenomena made obscure by the effects of gravity.**

9207.005.03CAW 07/18/92 -[9111.002.14CAW 11/04/91]- -[9107.016.05CAW 07/19/91]-

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## Fluid Dynamics and Transport Phenomena Research Areas



- **Multiphase flow and heat transfer**
- **Suspension/colloid/granular media mechanics**
- **Solid-fluid interface dynamics**
- **Capillary phenomena**
- **Magneto/electrohydrodynamics**
- **Transport phenomena**





## Combustion Science Research Areas



- Ignition, smolder, solid materials
- Gaseous diffusion flames
- Gaseous premixed flames
- Heterogeneous (particles and droplets)
- Metals and combustion synthesis

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## Materials Science Research Areas



**Electronic and Photonic Materials**

**Metals and Alloys**

**Glasses and Ceramics**

or

**Crystal Growth**

**Solidification Fundamentals**

**Thermophysical Properties**

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## Biotechnology Research Areas



- Cell physiology
- Cell differentiation
- Protein crystal growth
- Biological separations

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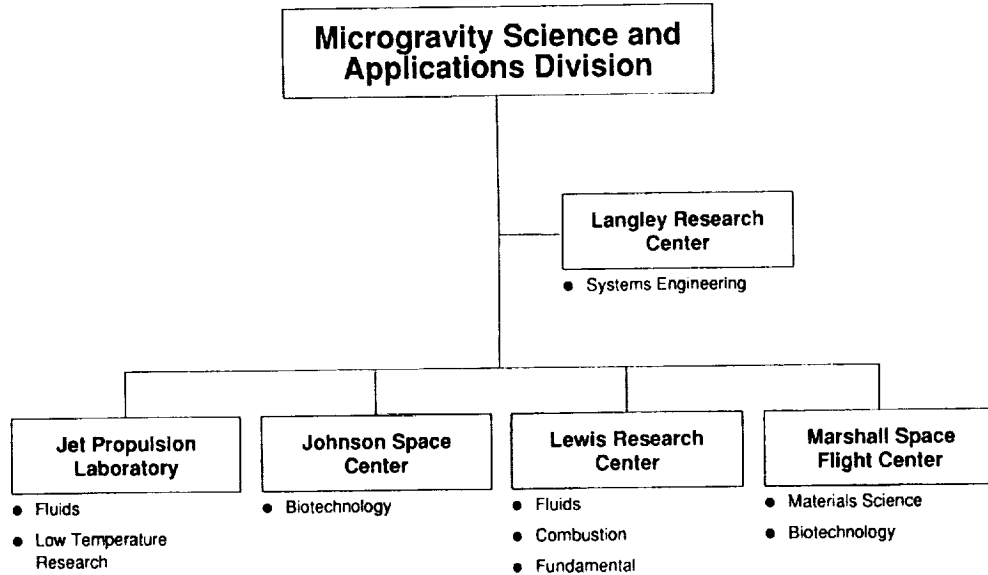
## Fundamental Physics Research Areas



- Critical point phenomena
- Gravitational physics



# NASA Centers Supporting The Microgravity Science and Applications Division



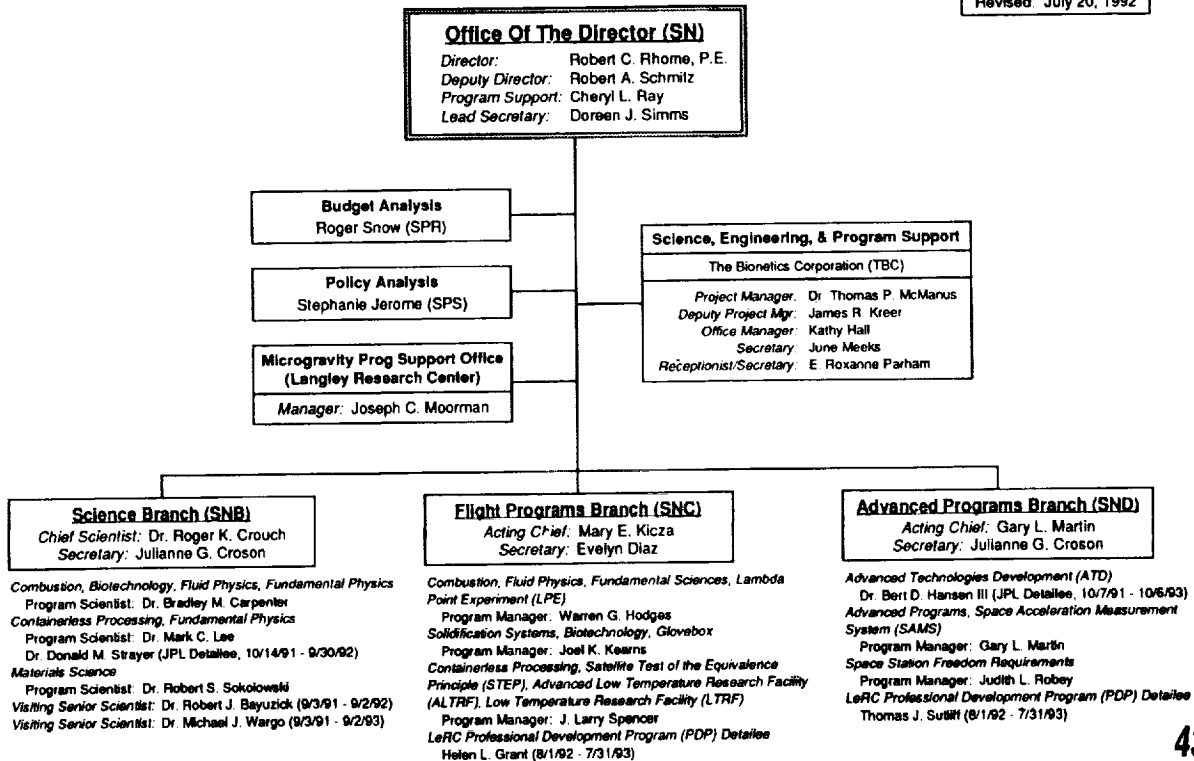
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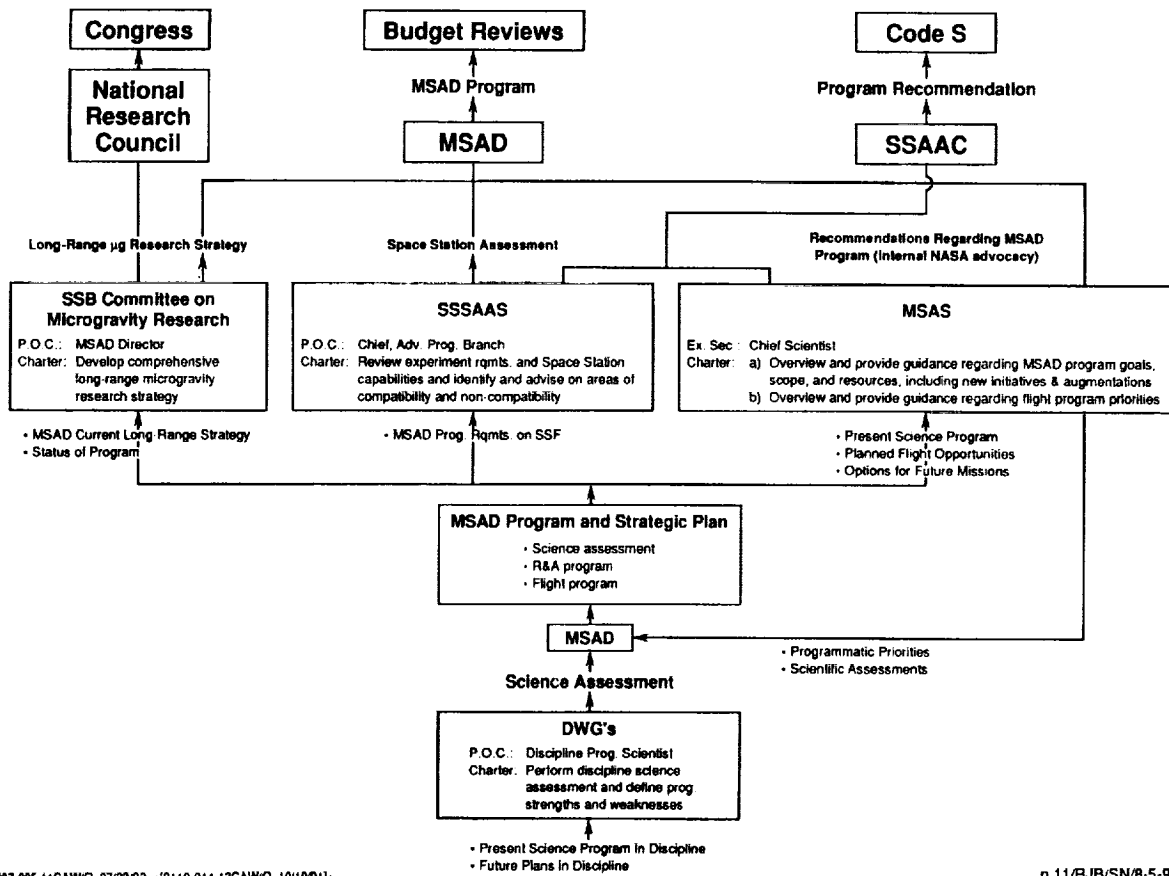
## Microgravity Science and Applications Division



Revised: July 20, 1992



9207-005-10CAW/O 07/20/92



## FLIGHT OPPORTUNITIES -- THE PRESENT



### ● Four MSAD missions in CY92:

**IML-1** – successful mission: January 22 - 30, 1992

**USML-1** – successful mission: June 25 - July 9, 1992

**Spacelab-J**

**USMP-1**



## International Microgravity Laboratory (IML-1) Microgravity Science and Applications Experiments



Apparatus/Experiment	Acronym	Principal Investigator	Country of Origin
• Fluids Experiment System	FES		U.S.A.
– A Study of Solution Crystal Growth in Low Gravity	TGS	Dr. R. B. Lal	U.S.A.
– Casting and Solidification Technology	CAST	Dr. M. H. McCay	U.S.A.
• Vapor Crystal Growth System	VCGS	Dr. L. van den Berg	U.S.A.
• Mercuric iodide Crystal Growth	MICG	Dr. R. Cadoret	France
• Protein Crystal Growth	PCG	Dr. C. Bugg	U.S.A.
• Organic Crystal Growth Facility	OCGP	Dr. Kanbayashi	Japan
• Cryostat	CRY		Germany
– Protein Crystal Growth in Cryostat		Dr. McPherson	U.S.A.
– B-galactosidase/Inhibitor-Single Crystal Growth		Dr. W. Littke	Germany
– Crystal Growth of Electrogenic Membrane Protein Bacteriorhodopsin		Dr. G. Wagner	Germany
• Critical Point Facility	CPF		ESTEC
– Critical Fluid Thermal Equilibrium		Dr. A. Wilkinson	U.S.A.
– Heat and Mass Transport at the Critical Point		Dr. D. Beysens	France
– Light Scattering and Interferometry Experiments		Dr. A. Michels	Netherlands
• Space Acceleration Measurement System	SAMS	Dr. R. DeLombard	U.S.A.

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## U.S. Microgravity Laboratory (USML-1) Microgravity Science and Applications Experiments



Apparatus/Experiment	Developer	Principal Investigator
• Crystal Growth Furnace (CGF)	MSFC	
– Orbital Processing of High Quality Cd-Te		D. Larson
– Crystal Growth of II-VI Semiconducting Alloys by Solidification		A. Lehoczyk
– Study of Dopant Segregation Behavior During Growth of Ga-As in Microgravity		D. Matthiesen
– Vapor Growth of Hg-Cd-Te in Microgravity		H. Wiedemeier
• Drop Physics Module (DPM)	JPL	
– Science and Technology of Surface Controlled Phenomena		R. Apfel
– Drop Dynamics Investigation		T. Wang
– Measurement of Liquid-Liquid Interfacial Tension of a Compound Drop		M. Weinberg
• Protein Crystal Growth (PCG)	MSFC	C. Bugg
• Solid Surface Combustion Experiment (SSCE)	LeRC	R. Altenkirch
• Surface Tension Driven Convection (STDCE)	LeRC	S. Ostrach
• Glovebox Experiment Module (GEM)	MSFC	17 experiments
• Zeolite Crystal Growth (ZCG)	Battelle Adv. Materials Center	A. Sacco
• Generic Bioprocessing Apparatus (GBA)	Center for Bioserve Technology	L. Stodleck
• Astroculture (ASC)	Wisconsin Ctr. for Auto. & Robotics	T. Tibbets
• Space Acceleration Measurement System (SAMS)	LeRC	R. DeLombard

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**Spacelab J (SL-J)  
Microgravity Science Experiments**



Apparatus/Experiment	Acronym	Country of Origin
Acoustic Levitation Furnace	ALF	Japan
Bubble Behavior Experiment Unit	BBU	Japan
Crystal Growth Experiment Furnace	CGF	Japan
Free Flow Electrophoresis Unit	FFEU	Japan
Gas Evaporation Experiment Facility	GEF	Japan
Gradient Heating Furnace	GHF	Japan
Image Furnace	IMF	Japan
Liquid Drop Experiment Facility	LDF	Japan
Marangoni Convection Experiment Unit	MCU	Japan
Organic Crystal Growth Experiment Facility	OCF	Japan
Pool Boiling Experiment (GAS)	PBE	U.S.
Protein Crystal Growth	PCG	U.S.
Space Acceleration Measurement System	SAMS	U.S.
Solid Surface Combustion Experiment	SSCE	U.S.

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**U.S. Microgravity Payload (USMP-1)  
Microgravity Science and Applications  
Experiments**



Apparatus/Experiment	Developer	Principal Investigator
• Lambda Point Experiment (LPE)	JPL	J. Lipa
• MEPHISTO	CNES	J. Favler
– The Morphological Stability and In Situ Monitoring of Binary Alloy Solidification		G. Abbaschian
– In-Situ Monitoring of Crystal Growth		
• Space Acceleration Measurement System (SAMS)	LeRC	R. DeLombard



# Microgravity Science and Applications Division Baseline Plan: 1994 - 2004



FUNDAMENTAL SCIENCE		MATERIALS SCIENCE		BIOTECHNOLOGY		
SPACE MISSIONS	<b>Condensed Matter Physics</b>	Lambda Point Experiment Critical Fluid Light Scattering Experiment Critical Fluid Viscosity Measurement Experiment Low Temperature Research Facility Satellite Test of Equivalence Principle	<b>Metals and Alloys</b>	Isothermal Dendrite Growth Experiment TEMPUS (F) Large Isothermal Furnace (F) Space Station Furnace Facility	<b>Cell Science</b>	RAMSES (F) Detailed Supplemental Objectives Bioreactor Biotechnology Facility
	<b>Fluids &amp; Transport Phenomena</b>	Surface Tension Driven Convection Experiment Drop Physics Module Critical Point Facility (F) Bubble, Drop, and Particle Unit (F) Geophysical Fluid Flow Cell Mechanics of Granular Materials Advanced Fluids Middecks Advanced Fluids Module Fluid Physics/Dynamics Facility Modular Containerless Processing Facility	<b>Glasses and Ceramics</b>	Drop Physics Module Modular Containerless Processing Facility	<b>Macro-molecular Crystal Growth</b>	Protein Crystal Growth Crystall (F) Advanced Protein Crystal Growth Advanced Protein Crystal Growth Facility
	<b>Combustion Science</b>	Solid Surface Combustion Experiment Advanced Combustion Middecks Advanced Combustion Module Modular Combustion Facility	<b>Electronic &amp; Photonic Materials</b>	Crystal Growth Furnace MEPHSTO (F) Advanced Automated Directional Solidification Furnace Programmable Multitron Furnace Space Station Furnace Facility		
<b>SO &amp; DA</b>	Space Acceleration Measurement System Glovebox Experiment Module		Acceleration Characterization and Analysis Project Orbital Acceleration Research Experiment			
<b>R &amp; A</b>	Drop Tubes/Towers		Parabolic Flights		Sounding Rockets	
<b>ATD</b>	Advanced Furnace Technology Vibration Isolation Technology		Non-Contact Temperature Measurement Combustion/Fluids Diagnostics		Laser Light Scattering Experiment Interface Measurements	

(F) - Foreign Hardware

☐ - Space Station Freedom Facility

9207 005 17CAW 07/30/92 -[9110.014.07CAW 10/10/91]- -[9107.016.11CAW 07/19/91]-

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## Microgravity Science and Applications Division Planning Manifest

CY91	CY92	CY93	CY94	CY95
<b>SLS-1</b> (STS-40) LD - 6/5/91 SAMS SSCE-2 GaAs (GAS)	<b>IML-1</b> (STS-42) LD - 1/22/92 FES/VCGS SAMS PCG CRYOSTAT (I) CPF (I) MIGC (I) OCGF (I)	<b>SL-D2</b> (STS-55) LRD - 1/27/93 BIOLABOR (I)	<b>IML-2</b> (STS-66) LRD - 7/30/94 APCF (I) SAMS TEMPUS (I) BDPU (I) FFEU/TEI-HT (I) RAMSES (I) CPF (I) LIF (I) VIBES (I) QSAM (I)	<b>USML-2</b> (STS-73) LRD - 5/6/95 SAMS CGF GFFC STDCE GBX MGM APCG CVTE
	<b>USML-1</b> (STS-50) LD - 6/25/92 PCG DPM CGF STDCE SSCE-4 SAMS GBX OARE		<b>USMP-2</b> (STS-62) LRD - 1/25/94 AADSF (A-1) IDGE CFLSE SAMS SAMS MEPHISTO (I)	<b>SL-E1</b> (STS-70) LRD - 1/28/95 Coop Prog
	<b>SL-J</b> (STS-47) LRD - 8/12/92 PCG SAMS SSCE-5 PBE Proto. (GAS)			<b>USMP-3</b> (STS-72) LRD - 4/4/95 AADSF (A-2) SAMS SAMS MEPHISTO (I)
	<b>USMP-1</b> (STS-52) LRD - 9/24/92 LPE SAMS SAMS MEPHISTO (I) CVTE-1 (U)			

### NOTES:

- (LRD) Launch Readiness Dates and STS flight numbers from SSP Baseline Manifest, Mar. 20, 1992
- (LD) Launch Date
- (I) indicates non-U.S. hardware on which U.S. investigators are flying (International)
- (U) indicates U.S. non-MSAD hardware in which MSAD investigators are flying
- + indicates enhanced/upgraded version
- \* Will not fly if Space Station is available
- ☐ Candidate transition hardware

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**Microgravity Science and Applications Division  
Planning Manifest**

CY96	CY97	CY98	CY99	CY00
	<b>USML-3</b> <b>(STS-___)</b> <b>LRD - ___/___/97</b> STDCE+ APCG CGF+ SAMS GBX DCE	<b>USMP-5</b> <b>(STS-97)</b> <b>LRD - 3/18/98</b> IDGE+ SAMS SAMS AADSF (A-2) MEPHISTO (I)	<b>USMP-6</b> <b>(STS-___)</b> <b>LRD - ___/___/___</b> MEPHISTO (I) AADSF (A-1) SAMS SAMS LTRF-20	<b>USMP-7</b> <b>(STS-___)</b> <b>LRD - ___/___/___</b> AADSF (A-2) SAMS SAMS
	<b>SL-E2</b> <b>(STS-94)</b> <b>LRD - 11/18/97</b> Coop. Prog.			
	<b>USMP-4</b> <b>(STS-86)</b> <b>LRD - 1/25/97</b> AADSF (A-1) IDGE+ SAMS SAMS MEPHISTO (I)			

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**Microgravity Science and Applications Division  
Planning Manifest**

CY91	CY92	CY93	CY94	CY95
<b>MIDDECK</b> <b>OR GAS</b>  <b>(STS-37)</b> <b>LD - 4/5/91</b> PCG-III-4  <b>(STS-43)</b> <b>LD - 8/2/91</b> SSCE-3 PCG-III-5 SAMS-1  <b>(STS-48)</b> <b>LD - 9/12/91</b> PCG-II-2  <b>(STS-44)</b> <b>LD - 11/24/91</b> Cell Cult. DSO	<b>MIDDECK</b> <b>OR GAS</b>  Cell Cult. DSO (1)  <b>(STS-45)</b> <b>LD - 3/24/92</b> GaAs (GAS)  <b>(STS-54)</b> <b>12/3/92</b> SSCE-6	<b>MIDDECK</b> <b>OR GAS</b>  SAMS (4/yr) APCG (4/yr) APCF (I) Coop. Prog. (1/yr)  <b>(STS-___)</b> <b>2/93</b> SSCE-7  <b>Spacehab-1</b> <b>(STS-57)</b> <b>LRD - 4/22/93</b> SAMS CVTE-2 (U) Cell Cult. DSO PBE (GAS)  <b>(STS-58)</b> <b>LRD - 6/22/93</b> Cell Cult. DSO  <b>Spacehab-2</b> <b>(STS-60)</b> <b>LRD - 10/21/93</b> SAMS  <b>(STS-___)</b> <b>7/93</b> SSCE-8	<b>MIDDECK</b> <b>OR GAS</b>  SAMS (3/yr) APCG (4/yr) Cell Cult. DSO PBE (GAS) CVTE-3 (U) APCF (I) Coop. Prog. (1/yr)  <b>(STS-___)</b> MGM SAMS  <b>SOUNDING</b> <b>ROCKET</b> Pool Fires	<b>MIDDECK</b> <b>OR GAS</b>  SAMS (3/yr) APCG (3/yr) Coop. Prog. (2/yr) Smoldering (GAS)  <b>SOUNDING</b> <b>ROCKET</b> Pool Fires (2/yr)   <b>FREEFLYER</b>  <b>(STS-71)</b> <b>LRD - 2/21/95</b> EURECA-2L (I) Coop. Prog.



**Microgravity Science and Applications Division  
Planning Manifest**

CY96	CY97	CY98	CY99	CY00
MIDDECK OR GAS	MIDDECK OR GAS	MIDDECK OR GAS	MIDDECK OR GAS	MIDDECK OR GAS
SAMS (4/yr) APCG (4/yr) Coop. Prog. (2/yr) Smoldering (GAS)	SAMS (2/yr) APCG (3/yr) DARTFire (2/yr) AFMD1-1 PMZF (2/yr) AFMD2-1 Coop. Prog. (2/yr)  (STS-_) MGM SAMS	DCE PMZF Bioreactor	AFMD1-2 PMZF (2/yr) Bioreactor AFMD2-2	PMZF (2/yr) Bioreactor MSMD-1
	SSF	SSF	SSF	SSF
	APCG SAMS SSF TBD Middeck Class BTF SSFF (C1)(M1)	APCGF (C1) SSFF (C1)(M1) FPDF/MCF (C1) - Comb 1 SAMS SSF	APCGF (C1) SSFF (C1)(M1)(M2) FPDF/MCF (C1) - Comb 1 - Fluid 1 SRR SAMS SSF	APCGF (C2) SSFF (C1)(M1)(M2) FPDF/MCF (C1) - Comb 2 - Fluid 2 SRR SAMS SSF
FREEFLYER	FREEFLYER	FREEFLYER	FREEFLYER	FREEFLYER
		(STS-_) EURECA-3L (I) Coop. Prog.  FSFF		FSFF STEP

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**Microgravity Science and  
Applications Division**

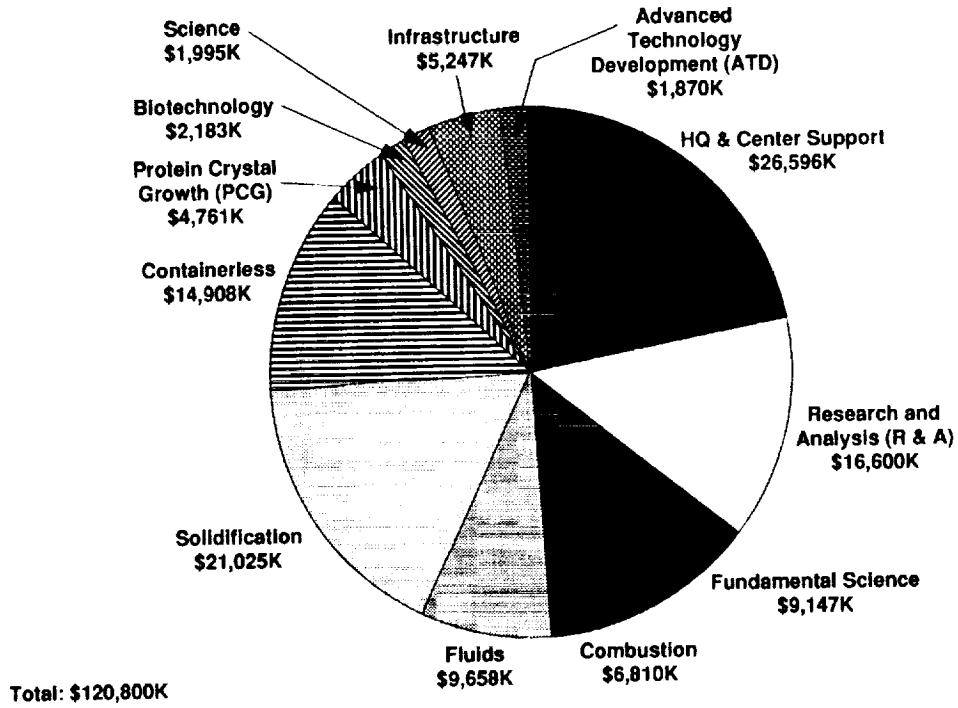


**Planned Research Announcements**

Calendar Year:	<u>91</u>	<u>92</u>	<u>93</u>	<u>94</u>	<u>95</u>	<u>96</u>	<u>97</u>
<b>Combustion Science</b>			▽		▽		
<b>Biotechnology</b>	▼			▽			▽
<b>Fluids and Transport</b>	▼		▽			▽	
<b>Materials Science</b>	▼		▽			▽	
<b>Fundamental Science</b>	▼			▽			▽
<b>Ground-Based Research</b>		▽	▽	▽	▽	▽	▽
<b>Combustion</b>			.	.		.	.
<b>Biotechnology</b>		.	.	.	.		
<b>Fluids and Transport</b>		.		.	.		.
<b>Materials Science</b>		.		.	.		.
<b>Fundamental</b>		.	.		.	.	



# Microgravity Science and Applications Division FY92 Budget by Program



9207.005-23CAW 07/30/92 -[9205-016-10CAW 05/18/92]- -[9111-007-10CAW 11/13/91]-

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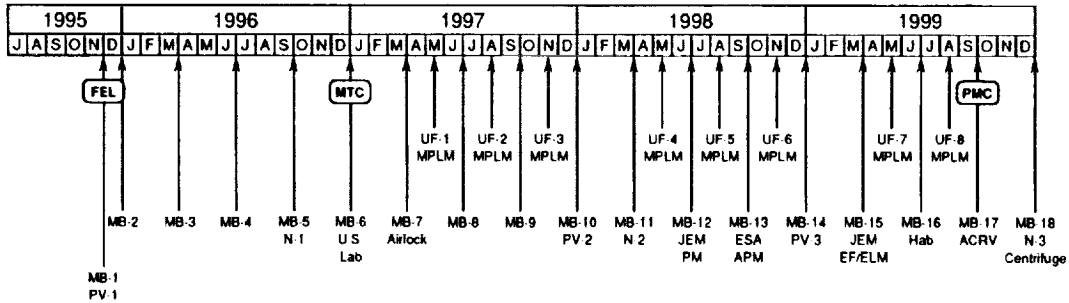
## Microgravity Science and Applications Space Station Facilities



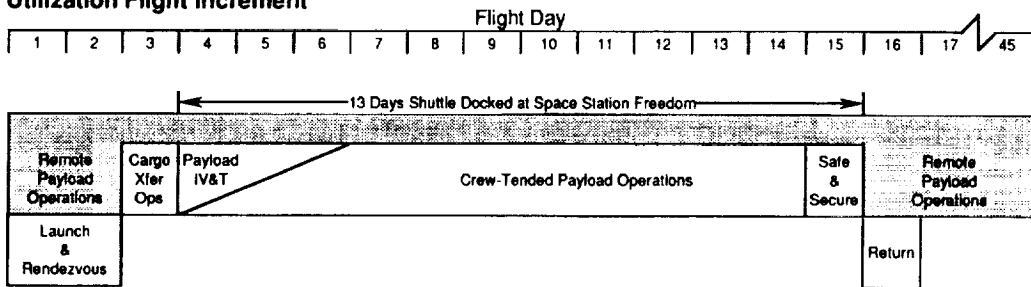
# Integrated Launch Schedule



## Overall Flight Sequence



## Utilization Flight Increment



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# MSAD Space Station Payload Traffic Model (April 1992)



	CY 1997	CY 1998	CY 1999	CY 2000	
Protein Crystal Growth	APCG	APCG C1	APCG	APCG C1, APCG C2	APCG = Advanced Protein Crystal Growth
Solidification Research	SSFF C1, M1		M2		APCGF = Advanced Protein Crystal Growth Facility
Fluids & Combustion		Comb 1, FPDF/MCF C1	Fluid 1	Fluid 2, Fluid 1	BTF = Biotechnology Facility
Containerless Processing	← UNDER REVIEW →				Comb = Combustion Module
Small & Rapid Response			SRR 1		Fluids = Fluids Module
Middeck-Class Payloads with SAMS SSF *	MDC, MDC				FPDF = Fluid Physics/Dynamics Facility
Biotechnology	BTF				MCF = Modular Combustion Facility
SSF-Provided Microgravity Glovebox	MGBX				MCPF = Modular Containerless Processing Facility

MDC = Middeck-Class Payloads

MGBX = Microgravity Glovebox

SAMS = Space Acceleration Measurement System

SRR = Small and Rapid Response Payloads

C = Core

M = Module

Returned Hardware (stippled)

Space Station-Unique Hardware (white)

Transition Hardware (Assume MPE/Interface Adaptor provided by SSF) (hatched)

\* SAMS SSF is Station-unique hardware, not transition hardware



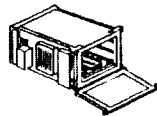
- Evaluate the effects of gravity on the growth of protein crystals
- Study physics/dynamics of macromolecular crystal growth
- Support biotechnology research by growing high quality macromolecular protein crystals which can be used for x-ray crystallography

9207 005 27CAW 07/30/92 -[9112 017 33CAW 12/12/91]- -[9112 015 44CAW 12/11/91]-

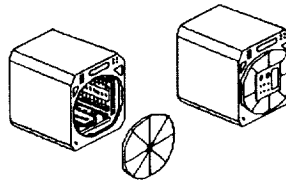
p 27/RJB/SN/8-5-92



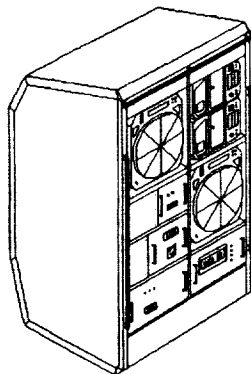
Protein Crystal Growth Program Evolution



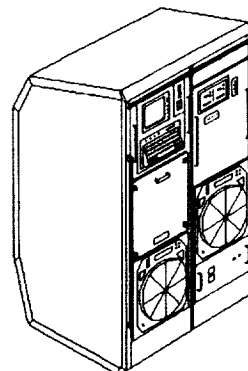
**PCG (current)**  
Protein Crystal Growth  
Middeck Refrigerator/  
Incubator Module with  
Vapor Diffusion Apparatus



**APCG (1993 - 1997)**  
Advanced Protein Crystal Growth  
Middeck using Thermal Enclosure  
System (TES) for PI-specific crystal  
growth hardware



**APCG transition  
(1997)**  
TES units modified  
for flight in SSF



**APCGE (1998 - 2000)**  
Advanced Protein Crystal Growth  
Facility for SSF  
Host Facility for Advanced Thermal  
Enclosures, PI-specific Crystal Growth  
Hardware



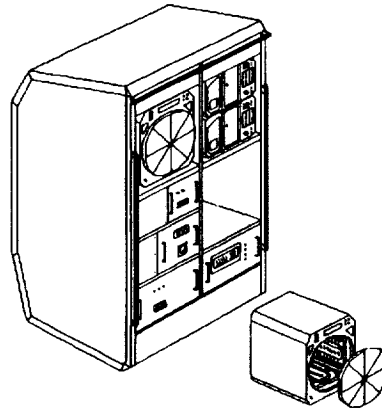
## Advanced Protein Crystal Growth (APCG) Payload Description (1997 - 1998)



- Power 0.5 kW nominal/1 kW peak
- Mass 300 kg
- Volume 1 rack

### TRANSITION HARDWARE

2 Thermal Enclosure System (TES) units with crystal growth apparatus  
SSFP provides adapter hardware, integration



- APCG plans to accommodate second generation crystal growth hardware in TES units
  - Vapor Diffusion Apparatus
  - Thermally-controlled batch process
  - Liquid-liquid diffusion
  - Dynamically-controlled systems
- Automated experiment initiation and deactivation

9207-005-29CAW 07/30/92 -[9204-019-07CAW 04/10/92]- -[9201-028-07DR 01/31/92]-

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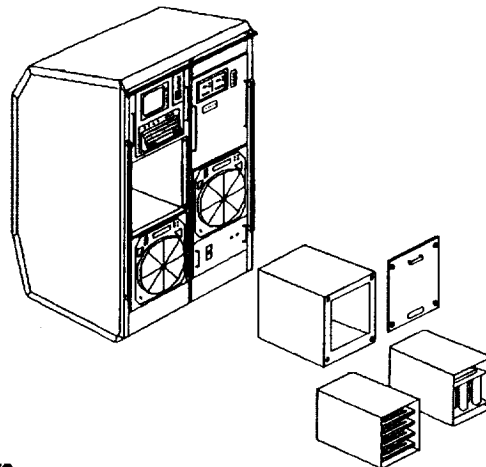


## Advanced Protein Crystal Growth Facility (APCGF) Payload Description (1998 - 2000+)



- Power 2.1 kW nominal/2.4 kW peak
- Mass 616 kg
- Volume 1 rack

Space Station-unique hardware  
Advanced thermal enclosures  
Enhanced diagnostic systems with imaging capability



- Third generation protein crystal growth hardware
  - May accommodate a larger number of experiments than APCG by using advanced thermal enclosures
  - Can accommodate current TES, new thermal enclosures, or PI-supplied thermal enclosures for long-duration crystal growth, and enhanced diagnostics
  - Automated experiment initiation and deactivation

9207-005-30CAW 07/30/92 -[9204-019-08CAW 04/10/92]- -[9201-028-08DR 01/31/92]-



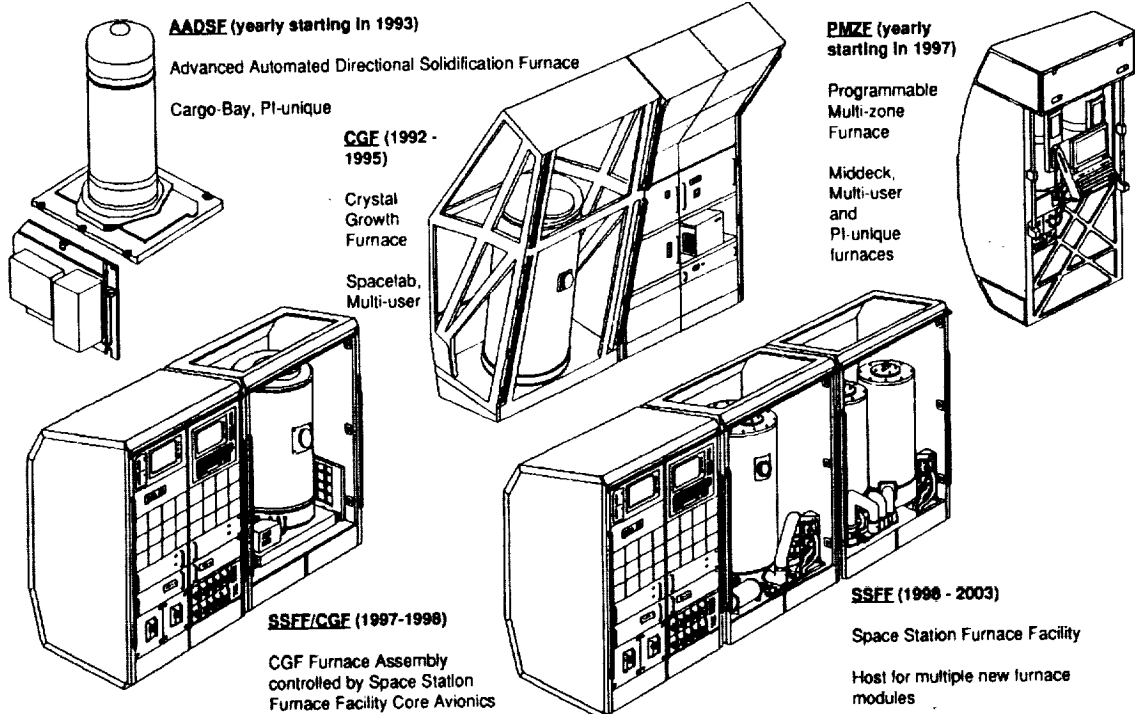
- Gain understanding of the mechanisms which correlate directional solidification parameters and materials properties for various technologically important materials
- Explore potential for utilization of low gravity environment to develop unique materials or materials structures which have unique, crafted properties
- Measure thermophysical properties of materials

8207-005 31CAW 07/30/92 -[9112-017-23CAW 12/12/91]- -[9112-015 34CAW 12/11/91]-

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Solidification Research  
Program Evolution

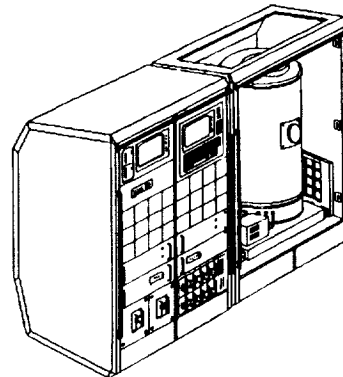




## Space Station Furnace Facility/Crystal Growth Furnace Payload Description (1997 - 1998)



- **Power** 2.0 kW nominal/4.0 kW peak
- **Mass** 1050 kg
- **Volume** 2 racks
- 1 Rack - Core Space Station-unique controls, power conditioning and diagnostics
- 1 Rack CGF furnace
  - Pressure vessel with flexible glovebox
  - Reconfigurable furnace module
  - Furnace translation mechanism
  - Automated sample exchange mechanism (up to six samples)



- Gradient zone thickness can be optimized before launch, and a heat extraction plate can be included to obtain steeper gradients
- Interface demarcation will be available by mechanical and current pulsing

9207.005.33CAW 07/30/92 -[9204.019.13CAW 04/10/92]- +[9201.028.13DR 01/31/92]+

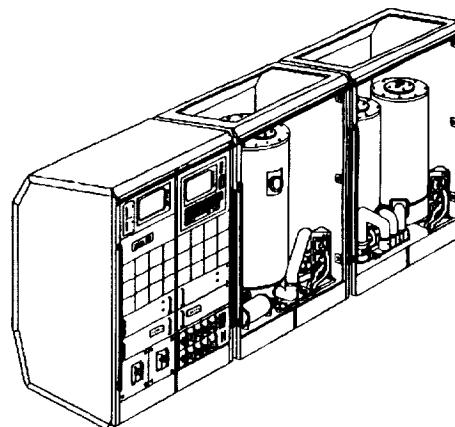
p 33/RJB/SN/8-5-92



## Space Station Furnace Facility (SSFF) Payload Description (1999 - 2003)



- **Power** 6.5 kW nominal/9.0 kW peak
- **Mass** 1,350 kg
- **Volume** 3 racks
- 1 Rack - Core Space Station-unique controls, power conditioning and diagnostics
- 1 Rack Furnace Module 1
- 1 Rack Furnace Module 2



- **Furnace Modules -- to be determined from NASA Research Announcement/ Announcement for Opportunity (NRA/AO) selection -- first PI selections in August 1992**
- **Modules being considered**
  - Upgraded programmable Multi-Zone Furnace (used for planning purposes)
  - Transparent Furnace
  - Bridgman with Quench
  - Float-Zone Crystal Growth Furnace

9207.005.34CAW 07/30/92 -[9204.019.14CAW 04/10/92]- +[9201.028.14DR 01/31/92]+



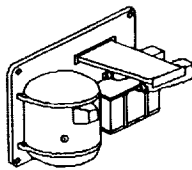
- Provide better understanding of fundamental theories of combustion processes and phenomena, such as:
  - Premixed gaseous fuel combustion
  - Laminar and turbulent diffusion flames
  - Flame spreading and smoldering with solid fuels
  - Flame spreading over liquid pools
  - Effectiveness of fire extinguishing techniques
  - Droplet, particle, and spray combustion
  - Metals combustion
  
- Provide scientific and engineering data for a variety of combustion related applications, such as spacecraft fire safety

9207.005 3SCAW 07/30/92 -[9112.017.42CAW 12/12/91]- -[9112.015.53CAW 12/11/91]-

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### Combustion Program Evolution



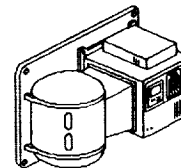
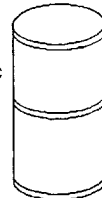
**SSCE (1990-present)**

Solid Surface Combustion Experiment  
Middeck, PI-specific

**Smoldering GAS (1995)**

Smoldering combustion experiment

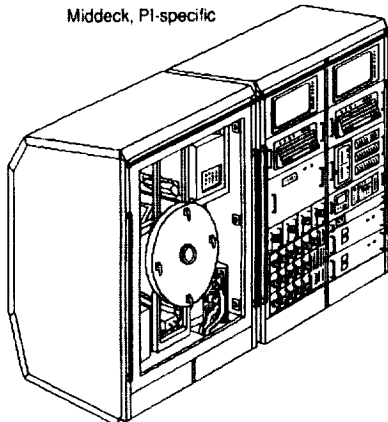
Get-away special payload, PI-specific



**ACMD (1997)**

Advanced Combustion Middeck

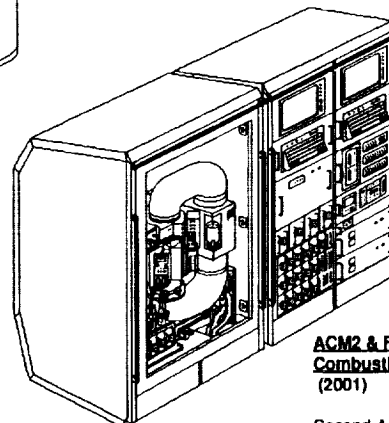
Middeck, multi-user



**ACM1 & Fluids/  
Combustion Core  
(1998 - 2000)**

Advanced Combustion Module

Core systems support multi-user combustion modules



**ACM2 & Fluids/  
Combustion Core  
(2001)**

Second Advanced Combustion Module

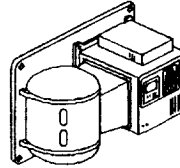




## Advanced Combustion Middeck Payload



- Power 120 W
- Mass 400 kg
- Volume 4 middeck lockers



- A CoDR was held in December 1991
- Will have the capability to do multiple experiment samples intensified video for low luminosity
- Studying the capability for chamber atmosphere clean-up

9207 005 37CAW 07/30/92 -[9204 019 19CAW 04/10/92]- -[9201 028 19DR 01/31/92]-

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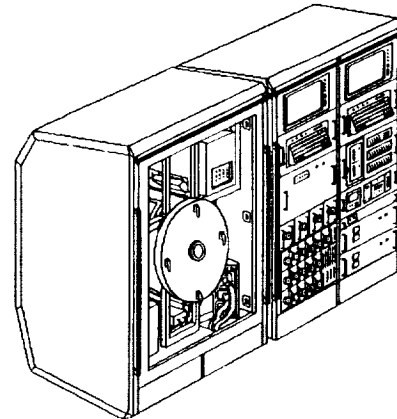
## Modular Combustion Facility (MCF) Payload Description (1998 - 2000)



- Power 1.5 kW nominal/2.3 kW peak
- Mass 1,400 kg
- Volume 2 racks

### TRANSITION HARDWARE

- 1 Rack - Core Shares a common core with the fluids module
- 1 Rack Module 1 - Combustion experiment rack



- The combustion experiment rack will house a generic combustion chamber with investigation-specific equipment
  - Nozzles for burning of gases
  - Sample holders for solid fuels experiment
- The combustion chamber will have ports to accommodate different modular diagnostics systems:
  - CCD video system
  - Infrared imager
  - Schlieren imaging system
  - Temperature measuring probes
  - Gas sampling probes

9207 005 38CAW 07/30/92 -[9204 019 20CAW 04/10/92]- -[9201 028 20DR 01/31/92]-



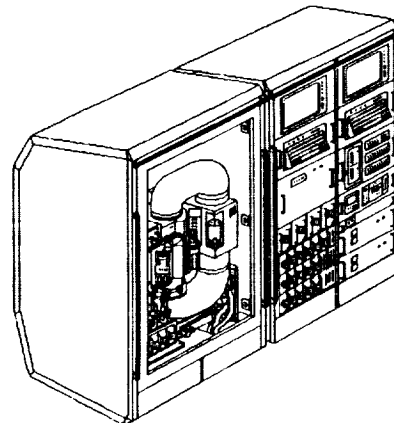
## Modular Combustion Facility (MCF) Payload Description (2001+)



- **Power** 5 kW nominal/7.1 kW peak
- **Mass** 1,400 kg
- **Volume** 2 racks

### STATION-UNIQUE HARDWARE

- 1 Rack - Core Core 2 shared with fluid modules
- 1 Rack Module 2 - combustion experiment rack



- **Module 2 to be determined from NRA/AO selection**
- **Two candidate experiment racks under study**
  - Quiescent Combustion Chamber
  - Low-Speed Combustion Tunnel

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## Fluid Physics and Dynamics Science Utilization



- **Provide advances in theories of fluid physics**
- **Provide improvements in thermophysical property measurement**
- **Provide scientific and engineering data related to fluids-related applications and systems**
- **Experiments may cover a broad area of interest:**
  - Isothermal-isosolutal capillary phenomena
  - Capillary phenomena with thermal/solutal gradients
  - Thermal solutal convection and diffusive flows
  - First order phase transitions in a static fluid
  - Multi-phase flow

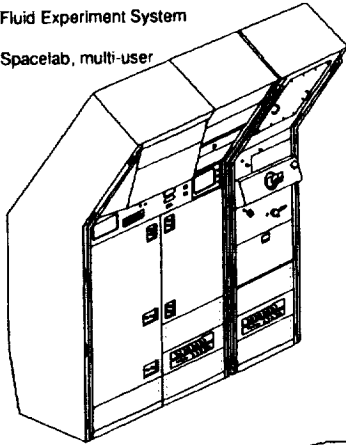


# Fluids Program Evolution



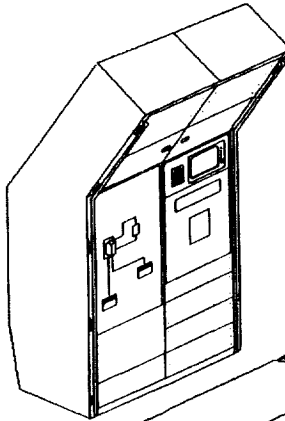
**EES (1985, 1992)**

Fluid Experiment System  
Spacelab, multi-user



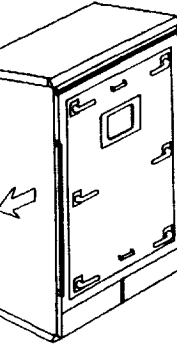
**STDCE (1992, 1995, 1997)**

Surface Tension  
Driven Convection  
Experiment  
Spacelab, PI-specific



**PBE (1992 - 1994)**

Pool Boiling Experiment  
Get-away special  
payload, PI-specific



**AEM (1999)**

Advanced Fluids  
Module for SSF  
Multi-user module added  
to Fluids/Combustion  
core facility

9207.005-41CAW 07/30/92 -[9204-019-22CAW 04/10/92]- -[9201-028-22DR 01/31/92]-

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# Fluid Physics Dynamics Facility (FPDF) Payload Description (1999+)



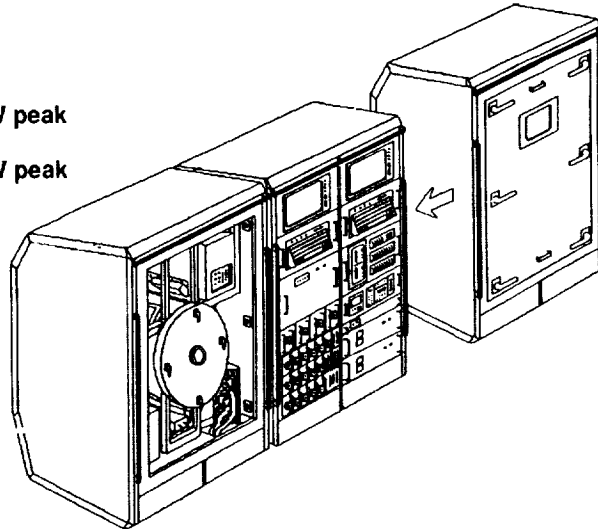
- **Power** Fluids Module 1:  
2.0 kW nominal/3.0 kW peak  
Fluids Module 2:  
5.9 kW nominal/9.5 kW peak

- **Mass** 700 kg

- **Volume** 1 rack

Core shared with MCF

- 1 Rack Fluids Module-1 (1999)  
Changed out for  
Fluids Module-2 (2000)



- **Modules 1 and 2** -- to be determined by AO/NRA selection
- **Two candidate experiment racks under study**
  - Support dynamic fluid experiments in a multi-phase apparatus
  - Vibration isolation containment enclosure for sealed-cell experiments

9207.005-42CAW 07/30/92 -[9204-019-26CAW 04/10/92]- -[9201-028-26DR 01/31/92]-



# Containerless Processing Science Utilization



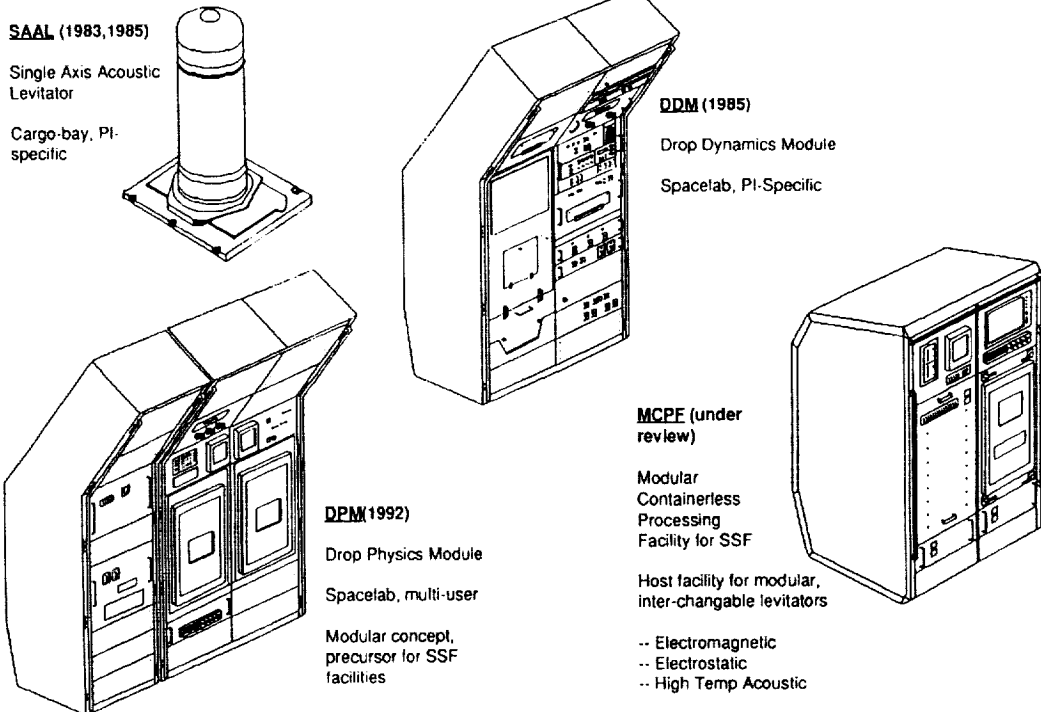
- Accommodate experiments requiring the positioning and manipulation of materials without physical contact with container walls
- Conduct research on properties and phenomena that on Earth are seriously affected by container contamination, container-generated nucleations, and gravity effects

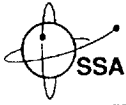
9207 005 43CAW 07/30/92 -[9112-017-30CAW 12/12/91]- -[9112-015-41CAW 12/11/91]-

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## Containerless Program Evolution





## Modular Containerless Processing Facility (MCPF) Payload Description (under review)



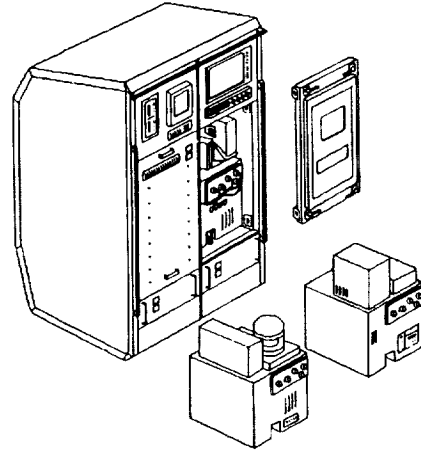
● **Power** 2.5 kW nominal/3.0 kW peak

● **Mass** 700 kg

● **Volume** 1 rack

Sample positioning devices

Diagnostics and control



- Levitation modules to position the sample may be electrostatic, electromagnetic, acoustic fields, or a hybrid combination
- Gain understanding in vast area of physical sciences ranging from the behavior of liquid drops in space, the measurement of thermophysical properties of materials, and the characterization of metals, glasses, and ceramics heated to temperatures up to 2700°C

9207 005 45CAW 07/20/92 -[9204-019-3]CAW 04/10/92]- [9201-028-3]U11 01/31/92]

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## Biotechnology Science Utilization



- Study cell function and differentiation in a low mechanical stress environment
- Culture end-differentiated tissue models for studies of genetic regulations

9207 005 46CAW 07/20/92 -[9112-017-47CAW 12/12/91]- [9112-015-58CAW 12/11/91]

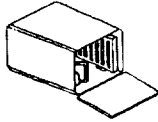


# Biotechnology Program Evolution



IEE (1984, 1988)

Isoelectric Focusing  
Middeck, PI-specific



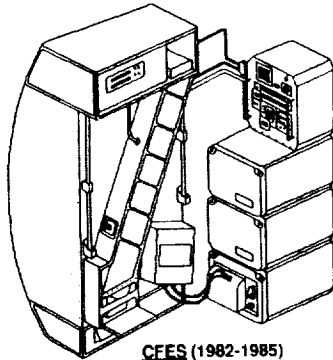
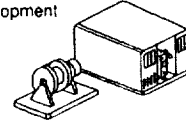
PPE (1982, 1988)

Phase Partitioning  
Experiment  
Middeck, PI-specific

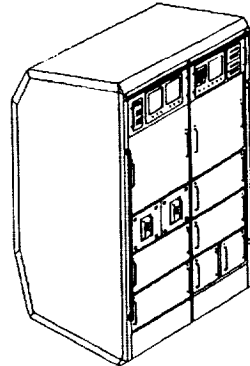


Bioreactor (DSO in 1991  
future flights TBD)

Rotating wall cell culturing system  
Middeck, multi-user  
Awaiting results of 1991  
Biotechnology NRA to determine  
future flight development



CFES (1982-1985)  
Continuous Flow  
Electrophoresis System  
Middeck



BTf (1997)

Biotechnology Facility for SSF  
Host Facility for future  
investigations in:  
Cell culturing  
Cell separations  
Future areas of Biotechnology



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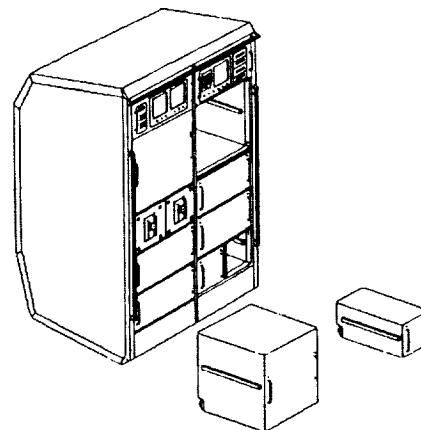
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# Biotechnology Facility Payload Description (1997+)



- Power TBD kW nominal and peak
- Mass 700 kg
- Data TBD Kbits/sec
- Volume 1 rack



- The BTf will accommodate a series of PI-developed, self-contained biotechnology experiments. BTf "services" will include power conditioning and distribution, video and data processing, and basic gases and fluids.
- Concept may serve as the basis for a Small and Rapid-Response (SRR) Payload (1999)



## "Middeck Class" Payloads (1997+)

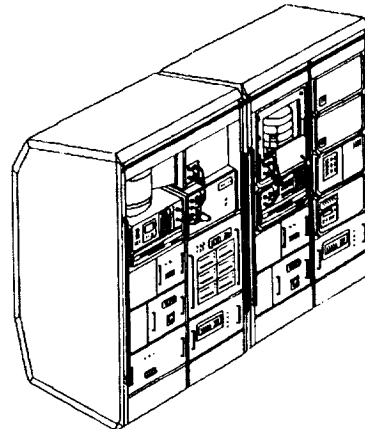


- Power TBD kW nominal and peak
- Mass TBD
- Data TBD Kbits/sec
- Volume 2 racks

### TRANSITION HARDWARE

Middeck-class experiments

SSFP provides adapter hardware, integration



- The SSFP-provided Middeck Class Payload Adapter (MDC) will host a series of small to moderate-scale microgravity experiments by providing an interface that emulates the Shuttle middeck

Experiments in Fluids and Transport Phenomena, Combustion, Materials Science

- MDC Accommodations will be similar to those provided by the SSFP interface hardware used for the APCG Transition Payload

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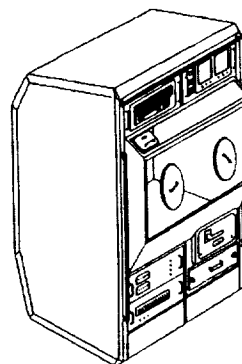
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## SSFP-Provided Microgravity Glovebox (1997+)

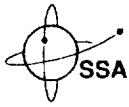


- Power TBD kW nominal and peak
- Mass 700 kg
- Data TBD Kbits/sec
- Volume 1 rack



- The SSFP-Provided Materials Science Glovebox (MSG) provides an enclosed work space isolated from the SSF ambient environment for handling microgravity science samples and hardware
- The MSG will accommodate a series of small-scale microgravity science experiments and technology demonstrations
- MSG services will include video and film cameras with appropriate lighting, temperature control and heat rejection in the work volume, power outlets for use by experiments and apparatus for recovering fluid spills

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Utilization Flights

- **All Microgravity Science and Applications Division (MSAD) payloads plan to operate during utilization flights**
- **Some operations will be very similar to Spacelab**
  - High-speed film cameras for data storage
  - Discipline-emphasis crew skills
- **Operations unlike Spacelab**
  - On-orbit rack changeout
  - Logistics/resupply (gases), sample harvesting, and changeout for return
  - Experiment set up for ground-tended runs

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Unmanned Operations

- **All MSAD payloads except combustion plan to operate during ground-tended operations**
- **Payloads will require uplink communications**
  - For initiating run sequences
  - Power on/off
  - Restart experiment run
- **Payloads will require downlink**
  - Monitoring experiment runs
  - Health and safety
  - Quick-look analysis





## Operational Intent of MSAD-MTC



- **Two to three 16-day utilization flights each year**
- **Operation of facilities during utilization flights**
  - Experiments requiring crew interaction
  - Shorter duration experiments
  - Experiments that are less sensitive to "noisy" acceleration environment
- **Operations between utilization flights (ground-tended periods)**
  - Experiments that can be controlled remotely and/or automated
  - Longer duration experiments
  - Experiments requiring a pristine environment
- **Operations during assembly flights**
  - Conducted on a non-interference basis
  - May be limited to changing out samples and setting up experiments to be initiated later

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## Operational Intent of MSAD-PMC



- **Payloads requiring crew interactions**
- **Automated payloads utilizing telescience methods**
- **Crew time is a limited resource**

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- **Science return from MSAD payloads will begin in 1997 after launch of the U.S. Laboratory and will continue through 2000+**
  - MSAD plans to conduct a broad range of experiments during the unmanned periods prior to PMC, during utilization flights, and PMC and beyond on SSF
- **Science operations conducted during the utilization flights will be similar to Spacelab flights except for the added tasks of collecting and securing of samples, experiment setup for unmanned runs, and rack/module equipment changeout**
- **Unmanned operations will require automation of payloads and telescience but minimal two-way communications between MSAD payloads and the ground is intended**

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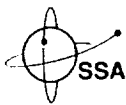
**Microgravity Science and Applications  
Program Summary**



- **Active, growing, diverse program**
- **Areas of research**
  - Biotechnology
  - Combustion
  - Fluids Science
  - Fundamental Physics
  - Materials Science
- **Continuing to find new experimental possibilities**
  - Encouraging science community to participate
  - Soliciting science proposals through NRA's
  - Facilitating their development
- **Collaborating with the international science community**
  - Sharing use of facilities
- **Looking forward to an exciting decade in microgravity research**

## Back Up Charts

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### Science Planning Process



- **Community involvement in the program**
  - Four DWG's plus Microgravity Subcommittee to Space Science and Applications Advisory Committee (SSAAC)
- **National Academy of Sciences**
  - Microgravity Science Committee of the Space Studies Board
    - Established in 1988
    - First meeting in 1990
  - Development of long-term strategy for microgravity sciences
- **Integrate microgravity initiatives into OSSA program**
  - SSAAC review and advice
  - OSSA Strategic Plan



## SSB Committee on Microgravity Research Membership List



### Chairperson

**William A. Sirignano** (6/94)  
Dean, School of Engineering  
University of California at Irvine  
*[Combustion]*

**Franklin D. Lemkey** (6/92)  
Materials Technology Laboratory  
United Technologies Research  
Center  
*[Metals]*

**Thomas A. Steitz** (6/94)  
Department of Molecular Biophysics  
and Biochemistry  
Yale University  
*[Protein Crystallography]*

**Richard C. Hart**  
Space Studies Board  
National Academy of Science

**Simon Ostrach** (6/94)  
Department of Mechanical and  
Aerospace Engineering  
Case Western Reserve University  
*[Fluid Flow and Transfer]*

**Warren C. Strahle** (6/94)  
School of Aerospace Engineering  
Georgia Institute of Technology  
*[Combustion]*

**Robert A. Brown** (6/92)  
Head of Chemical Engineering  
Mass Institute of Technology  
*[Fluid Dynamics & Elec Mats Model]*

**Morton B. Panish** (6/94)  
Distinguished Member of the  
Technical Staff  
AT&T Bell Laboratories  
*[Electronic Materials]*

**Julia R. Weertman** (6/94)  
Department of Materials Science  
and Engineering  
Northwestern University  
*[Metals]*

**Martin E. Glicksman** (6/94)  
Department of Materials Science  
Rensselaer Polytechnic University  
*[Metals]*

**John D. Reppy** (6/94)  
Laboratory of Atomic and Solid  
State Physics  
Cornell University  
*[Physics]*

*[Biotechnology]*

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## Membership of Microgravity Science and Applications Subcommittee (MSAS)



**Chair:** **Dudley Saville**  
Chemical Engineering Department  
Princeton University

**Exec. Secretary:** **Roger Crouch**  
NASA Headquarters  
MSAD Chief Scientist

### MEMBERS

**Gary Gilliland**  
National Institute for Standards and Technology  
Center for Advanced Research in Biotechnology  
Biotechnology DWG Chair

**Gerard Faeth**  
Dept. Aerospace Engineering  
University of Michigan  
Combustion DWG Chair

**Stephen H. Davis**  
Department of Engineering Sciences and Applied  
Mathematics  
Northwestern University  
Fluids & Transport DWG Chair

**John Perepezko**  
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Materials Science DWG Chair

**Simon Ostrach**  
Department of Mechanical and Aerospace Engineering  
Case Western Reserve University

**Alexander Mcpherson**  
Department of Biochemistry  
University of California

## MEMBERS

## AFFILIATION

7/21/92

<b>Chairman:</b> Dr. Charles A. Fuller	University of California, Davis
<b>Executive Secretary:</b> Dr. Edmond M. Reeves	NASA Headquarters
Dr. Charles E. Bugg	University of Alabama at Birmingham
Dr. Robert J. Bayuzick	NASA Headquarters (Visiting Scientist)
Dr. Charles R. Chappell	Marshall Space Flight Center
Dr. Benton C. Clark	Martin Marietta Astronautics Group
Dr. Earl L. Cook	3M Corporation
Dr. Alan C. Eckbreth	United Technologies Research Center
Dr. John E. Estes	University of California, Santa Barbara
Dr. Jeffrey A. Hoffman	Johnson Space Center
Dr. Shannon W. Lucid	Johnson Space Center
Dr. Herman Merte, Jr.	University of Michigan
Dr. Cary Mitchell	Purdue University
Dr. Robert W. Phillips	NASA Headquarters (Visiting Scientist)
Dr. Sam L. Pool	Johnson Space Center
Dr. David Robertson	Vanderbilt University
Dr. Marc E. Tischler	University of Arizona



## Discipline Working Groups



- **Biotechnology**

Chair: Dr. Gary Gilliland (NIST)

Vice-Chair: Dan Carter (MSFC)

- **Combustion**

Chair: Dr. Gerard Faeth (University of Michigan)

Vice-Chair: Kurt Sacksteder (LeRC)

- **Fluids and Transport**

Chair: Stephen H. Davis (Northwestern University)

Vice-Chair: Bob Thomson (LeRC)

- **Materials Science**

Chair: John Perepezko (University of Wisconsin)

Vice-Chair: Frank Szofran (MSFC)



## Materials Science Discipline Working Group



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**Dr. Frank Szofran (Vice-Chair)**  
*Space Science Laboratory  
NASA Marshall Space Flight Center*

**Prof. Tim Anderson**  
*Dept. of Chemical Engineering  
University of Florida at Gainesville*

**Dr. Richard Hopkins**  
*Science and Technology Center  
Westinghouse Electric Corporation*

**Dr. Reid Cooper (ad hoc assignment)**  
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**Dr. Robert Schaefer**  
*Materials Science and Engineering Laboratory  
National Institute of Standards and Technology*

**Prof. Jonathan Dantzig**  
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**Dr. Rohit Trivedi**  
*Ames Laboratory  
Iowa State University*

**Prof. Dennis Readey**  
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**Prof. Peter Voorhees**  
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Northwestern University*

**Dr. John Hurt**  
*Division of Materials Research  
National Science Foundation*

**ESA Representative**  
*Dr. Jean Jacques Favier  
CEREM/DEM - Section d'Etudes de la Solidification  
et de la Cristallinogenese, Grenoble*

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## Fluid Dynamics Discipline Working Group



**Prof. Stephen H. Davis (Chair)**  
*Dept. of Engineering Sciences and Applied  
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*NASA Lewis Research Center*

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**Prof. Paul Nietzel**  
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**Dr. John Huang**  
*Exxon Research and Engineering Company*

**Prof. Harry Swinney**  
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**Prof. Richard Lahey**  
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**ESA Representative**  
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Director de la Strategie et de l'Evaluation  
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## Combustion Discipline Working Group



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University of Michigan*

**Mr. Kurt Sacksteder (Vice-Chair)**  
*NASA Lewis Research Center*

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*College of Engineering  
Mississippi State University*

**Prof. Robert Santoro**  
*Mechanical Engineering Dept.  
Pennsylvania State University*

**Dr. Raymond Friedman**  
*Factory Mutual Research*

**Prof. Mitchell Smooke**  
*Dept. of Mechanical Engineering  
Yale University*

**Prof. Jack Howard**  
*Dept. of Chemical Engineering  
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**Prof. Forman Williams**  
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University of California at San Diego*

**Prof. C. K. Law**  
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**ESA Representative**  
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CNRS - Laboratoire de Combustion et Systemes  
Reactifs, Orleans*

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## Biotechnology Discipline Working Group



**Dr. Gary Gilliland (Chair)**  
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**Dr. Daniel Carter (Vice-Chair)**  
*NASA Marshall Space Flight Center*

**Dr. Colette Freeman**  
*Division of Cancer Biology, Diagnosis, and  
Centers  
National Cancer Institute*

**Dr. F. L. Suddath**  
*Vice-President for Information Technology  
Georgia Institute of Technology*

**Dr. Scott Power**  
*Director of Biochemistry  
Genencor International*

**Dr. Patricia Weber**  
*Central Research and Development Dept.  
Dupont-Merck Pharmaceutical Company*

**Dr. Frank Putnam**  
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**ESA Representative**  
*Prof. P. G. Pighetti  
Universita di Milano, Dipartimento di Scienze e  
Tecnologie Biomediche, Sez. Chimica  
Organica, Milano*

**Prof. Lola Reid**  
*Dept. of Molecular Pharmacology  
Albert Einstein College of Medicine*

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# Membership of Discipline Working Groups (DWG's)



## DWG

≈ 8 - 12 members

— Chair	Unaffiliated (desired)
— Ex Officio Member	Discipline Program Scientist
— Vice-Chairperson	Center Scientist
— 4 Members	Principal Investigator(s) (2 maximum)
— Member	Industry Academia Other Government



**SPACE STATION FREEDOM COMBUSTION RESEARCH**

Presented by G.M. Faeth  
Department of Aerospace Engineering  
The University of Michigan

**ABSTRACT**

Extended operations in microgravity, on board spacecraft like Space Station Freedom, provide both unusual opportunities and unusual challenges for combustion science. On the one hand, eliminating the intrusion of buoyancy provides a valuable new perspective for fundamental studies of combustion phenomena. On the other hand, however, the absence of buoyancy creates new hazards of fires and explosions that must be understood to assure safe manned space activities. These considerations - and the relevance of combustion science to problems of pollutants, energy utilization, waste incineration, power and propulsion systems, and fire and explosion hazards, among others - provide strong motivation for microgravity combustion research.

The intrusion of buoyancy is a greater impediment to fundamental combustion studies than to most other areas of science. Combustion intrinsically heats gases with the resulting buoyant motion at normal gravity either preventing or vastly complicating measurements. Perversely, this limitation is most evident for fundamental laboratory experiments; few practical combustion phenomena are significantly affected by buoyancy. Thus, we have never observed the most fundamental combustion phenomena - laminar premixed and diffusion flames, heterogeneous flames of particles and surfaces, low-speed turbulent flames, etc. - without substantial buoyant disturbances. This precludes rational merging of theory, where buoyancy is of little interest, and experiments, that always are contaminated by buoyancy, which is the traditional path for developing most areas of science. The current microgravity combustion program seeks to rectify this deficiency using both ground-based and space-based facilities, with experiments involving space-based facilities including: laminar premixed flames, soot processes in laminar jet diffusion flames, structure of laminar and turbulent jet diffusion flames, solid surface combustion, one-dimensional smoldering, ignition and flame spread of liquids, drop combustion, and quenching of panicle-air flames.

Unfortunately, the same features that make microgravity attractive for fundamental combustion experiments, introduce new fire and explosion hazards that have no counterpart on earth. For example, microgravity can cause broader flammability limits, novel regimes of flame spread, enhanced effects of flame radiation, slower fire detector response, and enhanced combustion upon injecting fire extinguishing agents, among others. On the other hand, spacecraft provide an opportunity to use "fire-safe" atmospheres due to their controlled environment. Investigation of these problems is just beginning, with specific fire safety experiments supplementing the space-based fundamental experiments listed earlier; thus, much remains to be done to develop an adequate technology base for fire and explosion safety considerations for spacecraft.



**Space Station Freedom Utilization Conference  
Marshall Space Flight Center  
Huntsville, Alabama; August 1992**

**SPACE STATION FREEDOM  
COMBUSTION RESEARCH**

**G. M. Faeth  
Department of Aerospace Engineering  
The University of Michigan  
Ann Arbor, Michigan**

**INTRODUCTION**

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## **RELEVANCE OF COMBUSTION SCIENCE**

### **SEVERAL CONCERNS MOTIVATE FUNDAMENTAL COMBUSTION RESEARCH:**

- **Combustion-generated pollutants are re-emerging as a major problem.**
- **New combustion technologies are needed for effective energy utilization.**
- **Municipal and hazardous waste incineration is needed to replace landfills and storage.**
- **Fire and explosion hazards remain a source of excessive injuries, and loss of life and property on earth.**
- **New combustion technologies are needed for advanced aircraft and spacecraft propulsion systems.**
- **Current understanding of fire and explosion hazards in spacecraft is very limited.**

## **OPPORTUNITIES AND CHALLENGES**

### **THE MICROGRAVITY ENVIRONMENT OF SPACECRAFT OFFERS BOTH OPPORTUNITIES AND CHALLENGES TO COMBUSTION SCIENCE:**

- **The implications of microgravity experimentation are as important as the development of computers and optical diagnostics.**
- **Increased activity in space implies new fire and explosion hazards beyond our earth-bound technology base.**

## COMBUSTION SCIENCE OPPORTUNITIES

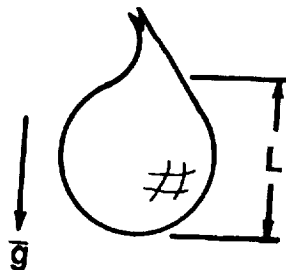
### BUOYANCY LIMITATIONS OF MOTIONLESS FLAMES

BUOYANCY IS AN INTRUSION BECAUSE FEW PRACTICAL FLAMES ARE BUOYANT:

- Buoyant/molecular transport is given by the Grashof number:

$$Gr = \Delta\rho g L^3 / (\rho \nu^2)$$

- For flames,  $\Delta\rho/\rho \sim 1$ , while  $Gr \ll 1$  for negligible buoyancy.



- At atmospheric pressure, this implies:  
 $L < \text{Order } (100 \mu\text{m})$

EXPERIMENTS ON SUCH SCALES CAN NOT BE RESOLVED BY EXISTING, OR ANTICIPATED, COMBUSTION INSTRUMENTATION.

# BUOYANCY LIMITATIONS OF PROPAGATING FLAMES

THE CRITERION FOR NEGLIGIBLE BUOYANCY EFFECTS DIFFERS FOR PROPAGATING FLAMES:

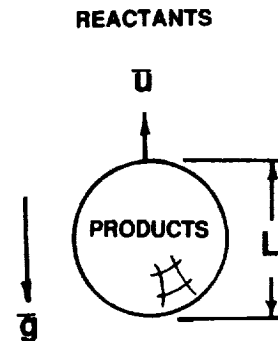
- Buoyant/propagation convection is given by the Richardson number:

$$Re = \Delta\rho gL / (\rho u^2)$$

- For flames,  $\Delta\rho/\rho \sim 1$ ,  $L > 10$  mm while  $Ri \ll 1$  for negligible buoyancy

- This implies:

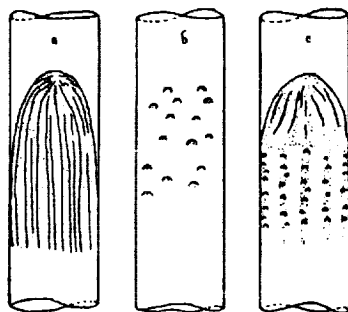
$u > \text{Order (1 m/s)}$ .



THIS IS COMPARABLE TO MAXIMUM BURNING VELOCITIES BUT PRECLUDES STUDIES NEAR FLAMMABILITY LIMITS.

## FLAMMABILITY LIMITS

BUOYANCY HAS THWARTED ATTEMPTS TO UNDERSTAND FLAMMABILITY LIMITS — AN IMPORTANT FUNDAMENTAL PROPERTY OF FLAMES:



Lean Flammability Limits  
(% Fuel in Air)<sup>a</sup>

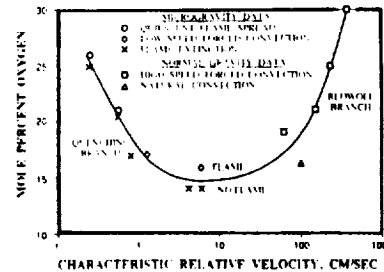
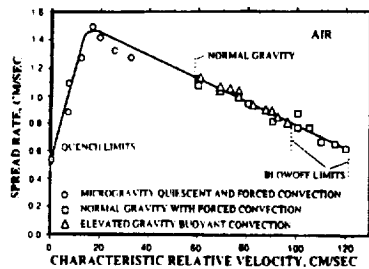
Config.	Methane	Propane
Downward	5.85	2.20
Upward	5.25	2.15
Microgravity	5.25	2.06

<sup>a</sup>From Strehlow et al. (1986)

- Upward propagation exhibits obvious instabilities but buoyancy affects all flame orientations.
- Lean limits generally are lower in microgravity than normal gravity for hydrocarbons, except for methane.

## FLAME SPREAD ALONG SOLID SURFACES

FLAME SPREAD ALONG SURFACES IS AFFECTED BY BUOYANCY, AMBIENT OXYGEN CONCENTRATION AND OPPOSING FLOW ALONG THE SURFACE:



- Microgravity conditions allow a low velocity regime to be reached that is inaccessible at normal gravity.
- Spread rates are highest and flammability limits are lowest in this low velocity regime.

NOTABLY, THE LOW VELOCITY REGIME IS TYPICAL OF NORMAL VENTILATION CONDITIONS ON SPACECRAFT.

## BUOYANCY LIMITATIONS OF CONVECTING FLAMES

BUOYANCY PREVENTS STUDY OF LOW REYNOLDS NUMBER FLAMES:

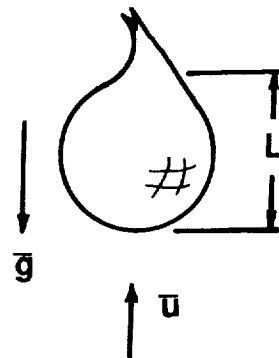
- The characteristic Reynolds number of a forced flame is:

$$Re = Lu/v = (Gr/Ri)^{1/2}$$

- For  $L$  ca. 10 mm,  $Gr = \text{Order } (10^3)$  while  $Ri < \text{Order } (10^{-1})$  for negligible buoyancy.

- This implies:

$$Re > \text{Order } (10^2)$$

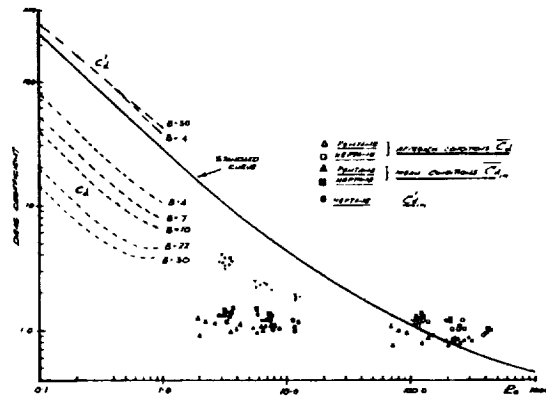


THUS, THE STOKES FLOW REGIME ( $Re < 1$ ) IS NOT ACCESSIBLE, WHILE THE LARGE  $Re$  LIMITS SPATIAL RESOLUTION AND CAUSES TRANSITION TO TURBULENCE.

# CONVECTIVE DROP COMBUSTION

**BUOYANCY HAS PREVENTED RESOLUTION OF EFFECTS OF CONVECTION ON DROP BURNING RATES — AN IMPORTANT HETEROGENEOUS FLAME:**

- Exact theories are limited to low Reynolds numbers.
- Buoyancy prevents reaching low Reynolds numbers for experimentation.
- Deformation and internal circulation intrude at accessible Reynolds numbers.

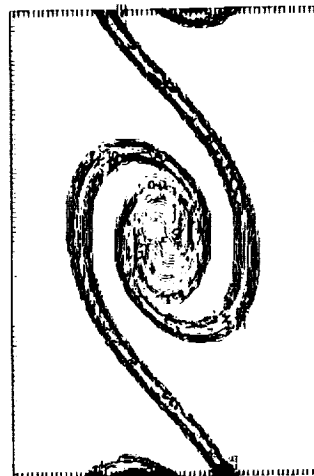


**THUS, CONTROVERSIES ABOUT CONVECTIVE EFFECTS CONTINUE; ONLY EXPERIMENTS IN MICROGRAVITY CAN RESOLVE THIS ISSUE.**

# TURBULENT COMBUSTION

**TURBULENT COMBUSTION IS THE FOREMOST UNRESOLVED PROBLEM OF COMBUSTION SCIENCE:**

- Numerical simulations are limited to low Reynolds number conditions.
- Buoyancy immediately accelerates combusting flows to high Reynolds numbers.
- Computer development rates imply 50-100 years before feasible experiments can be simulated.



**EXPERIMENTS IN MICROGRAVITY CAN ACCOMPLISH THE MERGER MUCH SOONER AND OFFER VALUABLE INSIGHTS OF THEIR OWN.**



## **COMBUSTION SCIENCE CHALLENGES**

### **PERSPECTIVES ON SPACECRAFT FIRE SAFETY**

**"FIRE IS ONE OF THE MOST FEARED HAZARDS IN SPACECRAFT."**

**"...STRICT LIMITATIONS ON ACCEPTABLE MATERIALS, AND STRINGENT HIGH-SAFETY-FACTOR OPERATING PROCEDURES ALL CAN RESTRAIN USEFUL ACTIVITIES IN SPACE MISSIONS."**

**"PRESENT SPACECRAFT FIRE-SAFETY PROCEDURES ARE ADEQUATE, TO THE EXTENT OF THE LIMITED KNOWLEDGE OF FIRE BEHAVIOR IN THE MILIEU OF SPACE ... FUTURE SPACECRAFT CONCEPTS, HOWEVER, WILL MAKE MORE DEMANDS ON FIRE SAFETY."**

**R. Friedman and K. R. Sacksteder  
NASA/LeRC, 1988**

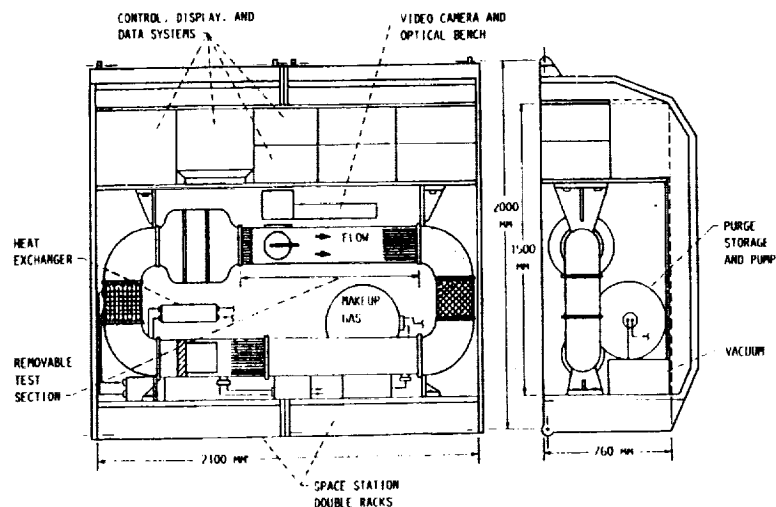
## EFFECTS OF MICROGRAVITY ON FLAMES

**FIRE HAZARDS IN MICROGRAVITY DIFFER FROM OUR EARTH-BOUND EXPERIENCE:**

- Flammability limits and flame spread rates are not the same, and can be less conservative.
- Flame volumes are much larger, and flame radiation is more dominant, if forced flows are absent.
- Limited space enhances problems of smoldering fires whose properties are not understood in microgravity.
- The response of fire detectors is slower, and the effect of fire extinguishing agents is modified.
- Aerosols do not settle, yielding conditions having no counterpart on earth, and greater fire hazards.

## SPACE STATION FREEDOM FLOW LOOP FACILITY

**THIS FACILITY IS DESIGNED FOR FLAMMABILITY STUDIES WITH VARIABLE FORCED VELOCITIES:**



## **FIRE-SAFE ATMOSPHERES**

- **Atmospheres that support life but not combustion are known, and are used successfully for underwater systems.**
- **Thus, fire hazards would be left behind on earth if the same approach could be developed for spacecraft.**
- **This is not feasible — near term — due to system complications and uncertainties of flame properties and human factors.**
- **The implications of fire-safe and inerting atmospheres are enormous; defining them should have high priority.**

## **SUMMARY**

# CURRENT MICROGRAVITY COMBUSTION SCIENCE FLIGHT PROGRAM<sup>a</sup>

Title	Investigator	Affiliation
Solid Surface Combustion <sup>b</sup>	R.A. Altenkirch	Miss. State U.
One-Dimensional Smoldering	A.C. Fernandez-Pello	UC-Berkeley
Soot Processes in Jet Flames	G.M. Faeth	U/Michigan
Laminar & Turbulent Jet Flames	M.Y. Bahadori	SAIC
Laminar Flames: Limits	P.D. Ronney	Princeton U.
Liquid Pool Flames	H. D. Ross	NASA/LeRC
Combustion of Pure Fuel Drops	F.A. Williams	UC-San Diego
Combustion of Blended Drops	A. Gökalp	CNES
Dust-Air Mixture Flames	J.H.S. Lee	McGill U.

<sup>a</sup>The glove-box facility on USML-2 also has been used for preliminary tests of flame spread, smoldering and liquid combustion.

<sup>b</sup>Flown on the Space Shuttle.

## SUMMARY

- Gravity has impeded fundamental understanding of combustion more than most areas of science; access to microgravity should yield major breakthroughs.
- Flames in microgravity are very different from our earth-bound experience; rational safety considerations for spacecraft require an improved technology base.
- Fire-safe atmospheres could permanently eliminate fire hazards from future spacecraft; this interdisciplinary research problem merits high priority.

## MICROGRAVITY FLUID PHYSICS RESEARCH IN THE SPACE STATION FREEDOM ERA

Presented by Bradley M. Carpenter  
Office of Space Science and Application  
NASA Headquarters

### ABSTRACT

Microgravity fluid physics covers an exciting range of established and potential fields of scientific research. Areas in which the Microgravity Science and Applications Division of NASA's Office of Space Science and Applications is currently supporting research include: multiphase flow and phase change heat transfer, behavior of granular media and colloids; and interface dynamics, morphological stability, and contact line phenomena. As they contribute to our knowledge of fluid behavior, advances in these areas will enhance our understanding of materials processing on Earth and in space, and will contribute to technologies as diverse as chemical extraction, the prediction of soil behavior in earthquakes, and the production of oil reservoirs.

NASA's primary platform for research in microgravity fluid physics will soon be the Fluid Physics/Dynamics Facility on Space Station Freedom. This facility shares a rack for control and utilities with the Modular Combustion Facility, and has one rack for experiment-unique instruments. It is planned to change out the content of the experiment-unique rack at intervals on the order of one year. In order to obtain a maximum return on the operation of the facility during these intervals, the research community must carefully plan and coordinate an effort that brings the efforts of many investigators to bear on problems of particular importance. NASA is currently working with the community to identify research areas in which microgravity can make a unique and valuable contribution, and to build a balanced program of research around these areas or thrusts. Selections will soon be made from our first solicitation for research in fluid dynamics and transport phenomena. Additional solicitations will be released in the future. These solicitations will build the research community that will make Space Station Freedom a catalyst for scientific and technological discovery, and offer U.S. scientists in many disciplines a unique opportunity to participate in space science.





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## Microgravity Fluid Physics Research in the Space Station Freedom Era

Presentation to the  
Space Station Freedom Utilization Conference  
5 August 1992

Bradley M. Carpenter  
Program Scientist  
Microgravity Science and  
Applications Division

hwk/5.8.92/1



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### Focus Areas for Microgravity Fluid Physics Research:

- Multiphase Flow and Heat Transfer
- Interface Dynamics
- Complex Fluids

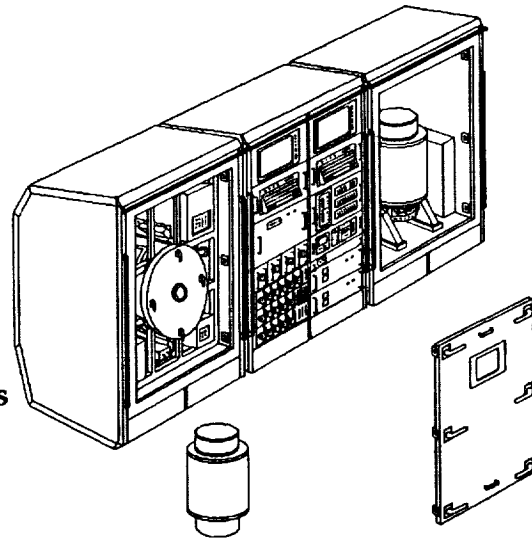
### Applications of Fluid Physics Research:

- Materials Processing
- Fluids Engineering and Space Fluids Management
- Geotechnical and Environmental Engineering



## Space Station Research: The Fluid Physics/Dynamics Facility

- Currently planned as part of a three-rack complex with the Modular Combustion Facility
- Core rack shared with the Modular Combustion Facility provides utilities, control, and data management support
- One rack hosts experiment-specific instrumentation
- Maximizing utilization of instrument capabilities within operational increments requires focussed and coordinated research activities



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## Development of Fluid Physics Research, 1991-2000

- Space research opportunities are framed by instrument development and operational constraints
- In order to maximize the value of our space resources, we must build a coherent program from ground-based activities to instrument capabilities
- Development of working group and workshop recommendations for research priorities begin the process of structuring the research program
- A research solicitation released in 1991 identified six potential thrust areas for research in fluid dynamics and transport phenomena. 207 proposals were submitted in response. The 40-50 selected proposals will form the first generation of an evolving program
- 1991 Thrust Areas:
  - Capillary Phenomena
  - Multiphase Flow and Heat Transfer
  - Diffusive Transport
  - Magneto/Electrohydrodynamics
  - Colloids and Nucleation Phenomena
  - Solid-Fluid Interface Dynamics

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## Opportunities for Microgravity Fluid Physics Research

- Research solicitations for ground-based research and flight experiments in fluid physics (NASA Research Announcements, NRA's) planned for calendar 1993, 1996, 1999
- NRA's for limited ground-based support open to the entire microgravity program will be released annually beginning in early 1993
- Flight experiment concepts are normally developed through extensive ground-based research, often using aircraft, drop tubes, or other short-duration facilities
- Building a comprehensive program of ground-based research to provide candidates for flight and to support planned and potential flight experiments has high priority

hmc/hw/FS&F/75



**MATERIALS SCIENCE RESEARCH IN MICROGRAVITY**

Presented by Professor John H. Perepezko  
Department of Materials Science and Engineering  
University of Wisconsin-Madison

**ABSTRACT**

There are several important attributes of an extended duration microgravity environment that offer a new dimension in the control of the microstructure, processing and properties of materials. First, when gravitational effects are minimized, buoyancy driven convection flows are also minimized. The flows due to density differences, brought about either by composition or temperature gradients will then be reduced or eliminated to permit a more precise control of the temperature and the composition of a melt which is critical in achieving high quality crystal growth of electronic materials or alloy structures. Secondly, body force effects such as sedimentation, hydrostatic pressure and deformation are similarly reduced. These effects may interfere with attempts to produce uniformly dispersed or aligned second phases during melt solidification. Thirdly, operating in a microgravity environment will facilitate the containerless processing of melts to eliminate the limitations of containment for reactive melts. The noncontacting forces such as those developed from electromagnet, electrostatic or acoustic fields can be used to position samples. With this mode of operation, contamination can be minimized to enable the study of reactive melts and to eliminate extraneous crystal nucleation so that novel crystalline structures and new glass compositions may be produced. In order to take advantage of the microgravity environment for materials research it has become clear that reliable processing models based on a sound ground based experimental experience and an established thermophysical property data base are essential.





## Materials Science Research in Microgravity

Professor John H. Perepezko  
Department of Materials Science and Engineering  
University of Wisconsin-Madison  
1509 University Avenue  
Madison, WI 53706

Space Station Freedom Utilization Conference  
Huntsville, Alabama

August 3-6, 1992

### MATERIALS SCIENCE DISCIPLINE

#### Goals

- Develop the basic understanding of relationships between microstructure and properties of materials during microgravity processing.
- Apply process modeling and advanced processing concepts to achieve designed microstructures.

#### Objectives

- Utilize the microgravity environment to advance the understanding of materials processing, including phase transformations during solidification and deposition, transport phenomena and structure-property relationships.



Microgravity Environment	Materials Response
• Buoyancy Driven Convection Flows Minimized	Precise Temperature and Composition Control for High Quality Crystals
• Body Force Effects Minimized	Uniform Spacing and Alignment in Multiphase Materials
• Containerless Melt Processing	Eliminate Contamination and Nucleation Due to Containment
• Interfacial Phenomena	Wetting and Surface Energy Driven Flows

### Benchmark Materials



### Priorities

#### Technological Applications

- > Containerless Processing
- > Directional Solidification/Crystal Growth
- > Casting

#### Science Knowledge Base

1. Solidification Kinetics and Undercooling
2. Microstructural Morphology/Prediction
3. Process Analysis and Modeling
4. Interfacial Phenomena

#### Critical Support Base

- Ground based experience
- Thermophysical property data



## Research Areas

- Solidification Kinetics and Undercooling
  - Nucleation
  - Undercooling
  - Metastable Phase Development
  - Competitive Growth
  - Microstructural Transitions
  - Glass Formation
  
- Microstructural Morphology/Prediction
  - Plane Front Solidification
    - > Single Crystals
    - > Aligned Composites
    - > Phase Spacing



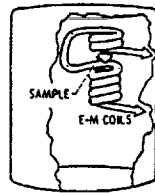
- Interface Instability
  - > Cells
  - > Dendrites
  - > Segregation
  
- Microstructural Scale
  - > Coarsening/Coalescence
  - > Scaling Laws
  
- Process Analysis and Modeling
  - > Macrosegregation
  - > Heat and Mass Transport Analysis
  - > Structure Prediction



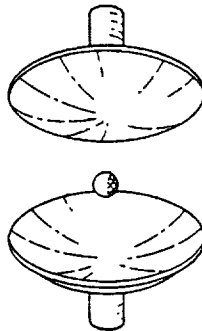
• Interfacial Phenomena

- > Surface Energy Driven Flows  
(Temperature or Composition Gradients)
- > Particle Incorporation
- > Wetting Behavior
- > Bubble Formation - Porosity Control
- > Joining Applications

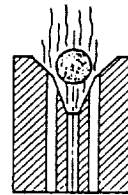
8-5. CONTAINERLESS PROCESSING TECHNIQUES



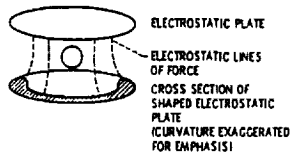
(A) ELECTROMAGNETIC



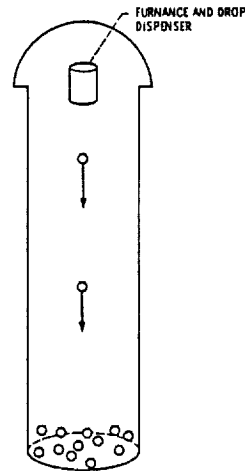
(B) ACOUSTIC



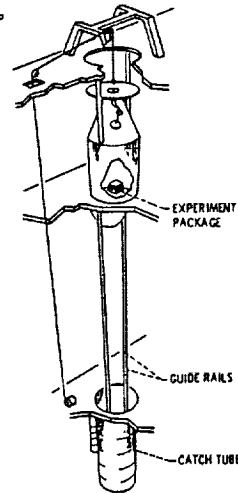
(C) AERODYNAMIC



(D) ELECTROSTATIC



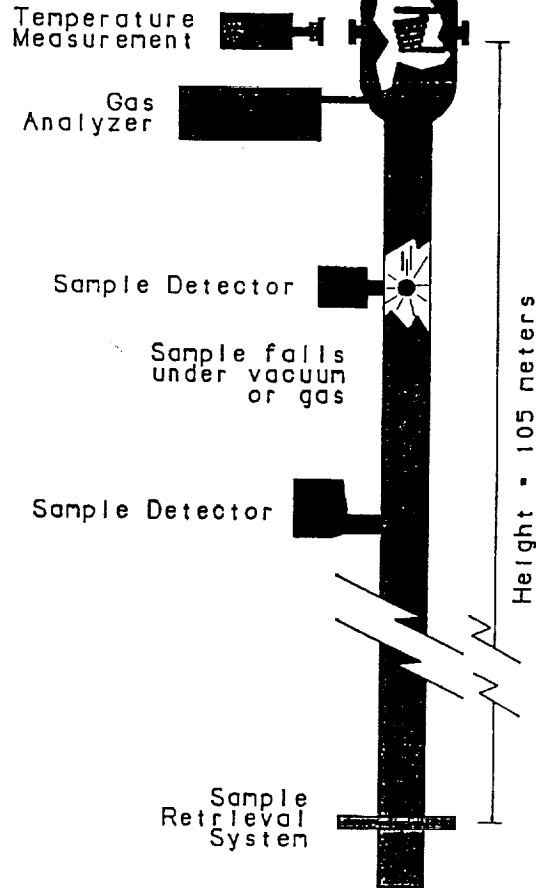
(E) DROP TUBE



(F) DROP TOWER

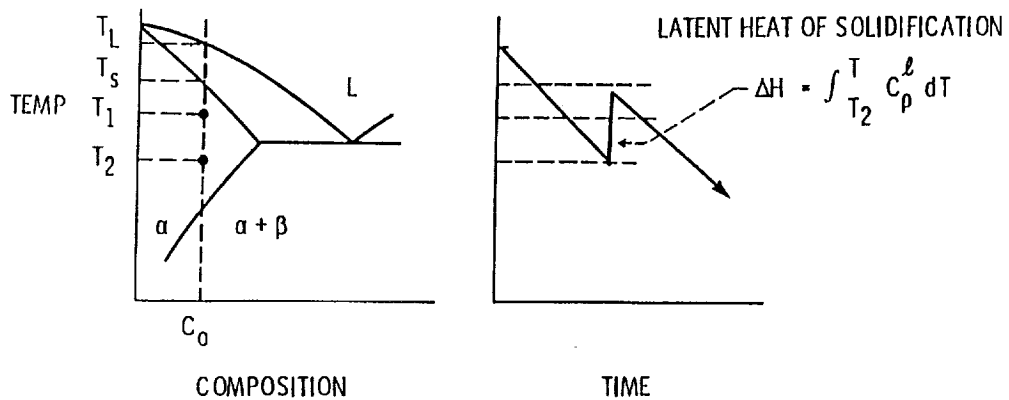


Containerless Melting by  
Electromagnetic Levitation



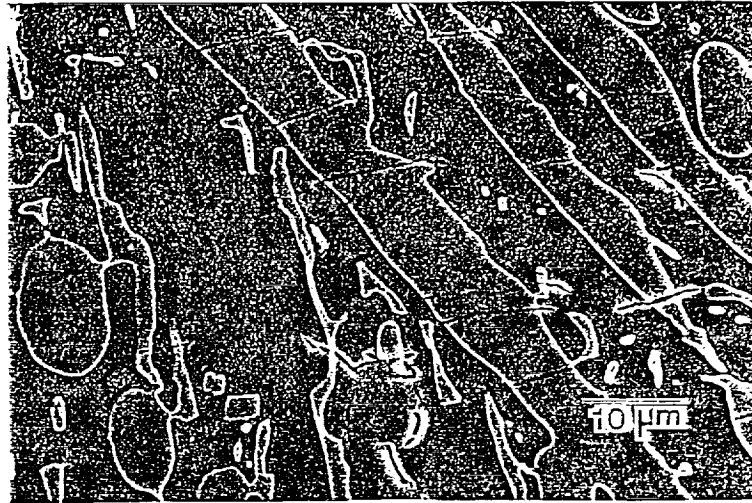
Marshall Space Flight Center  
4.6 second Drop Tube Facility

B. SUPERCOOLING (UNDERCOOLING)

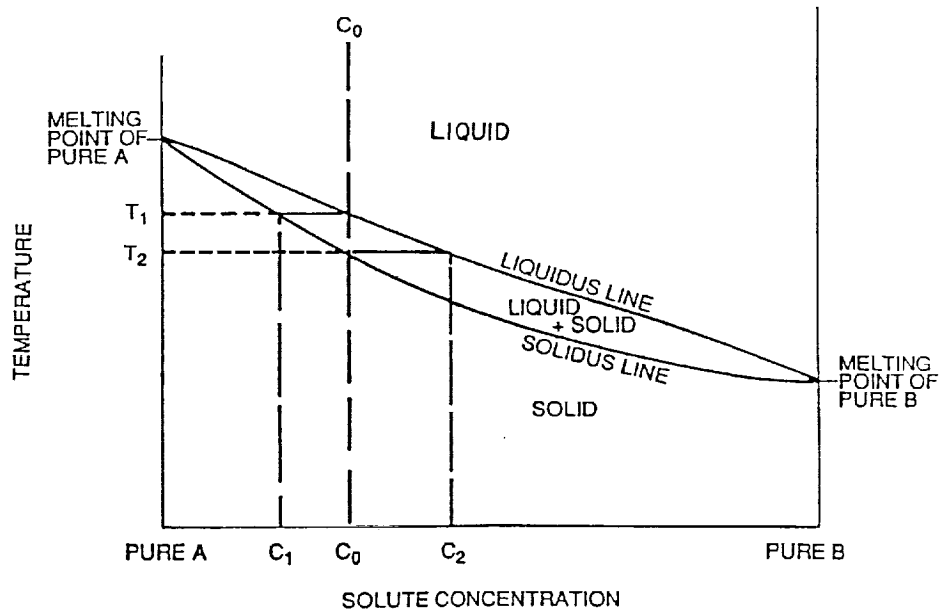
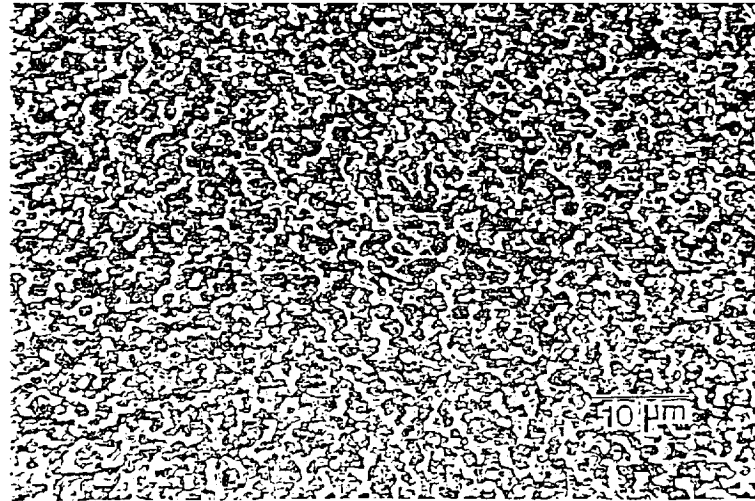


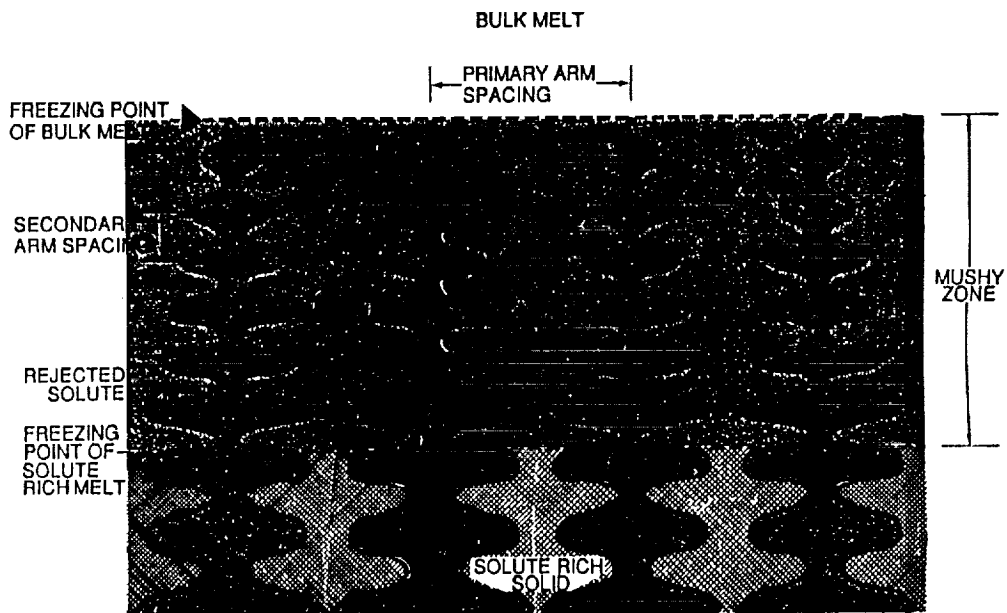
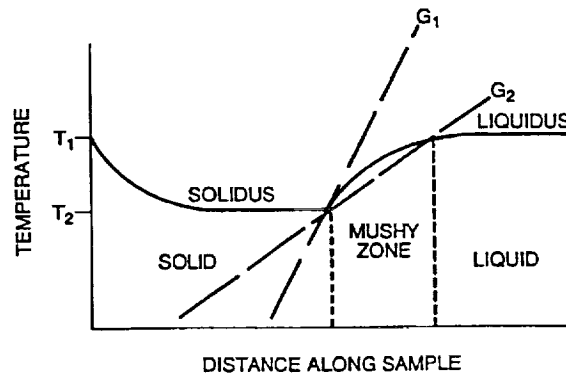
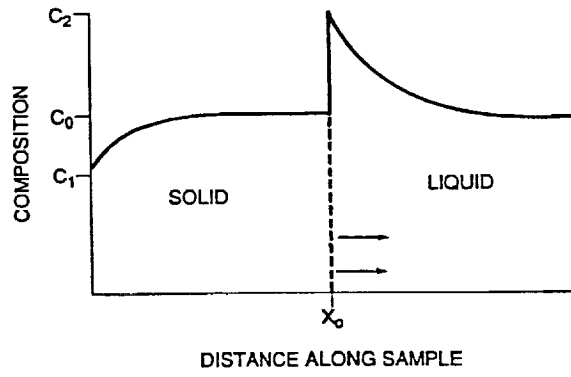
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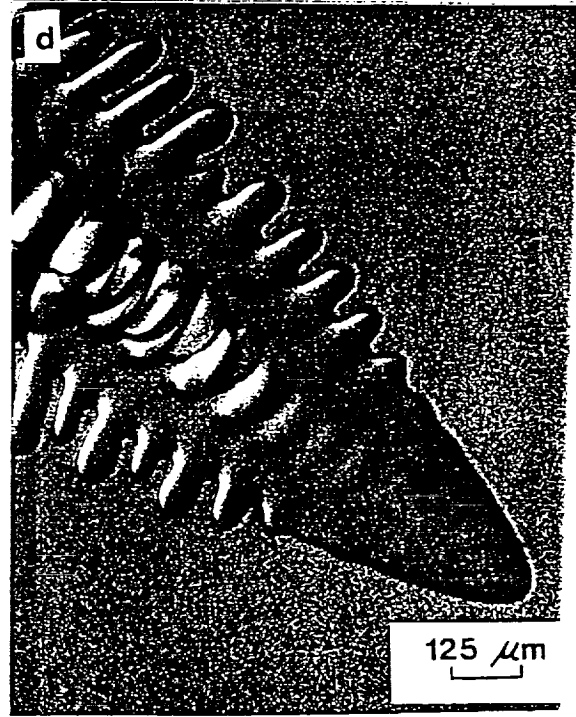
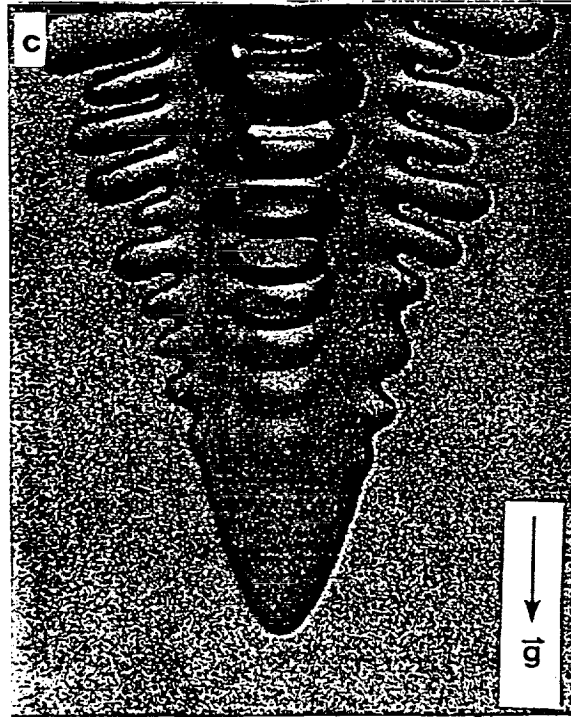
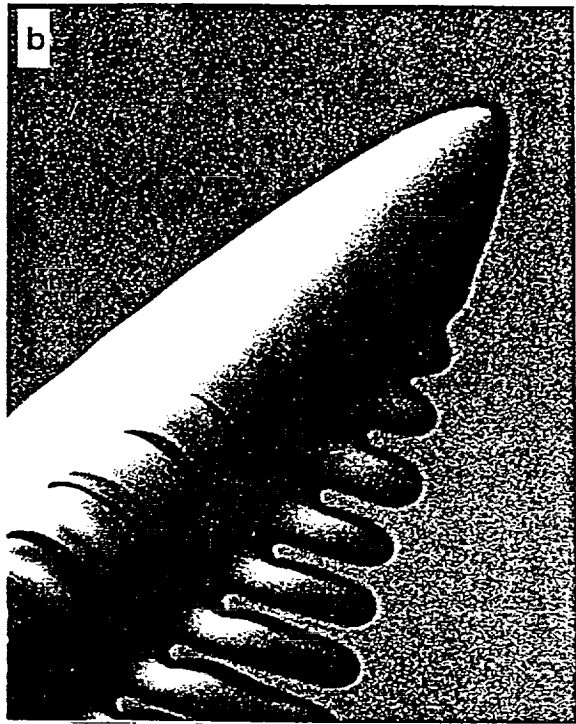
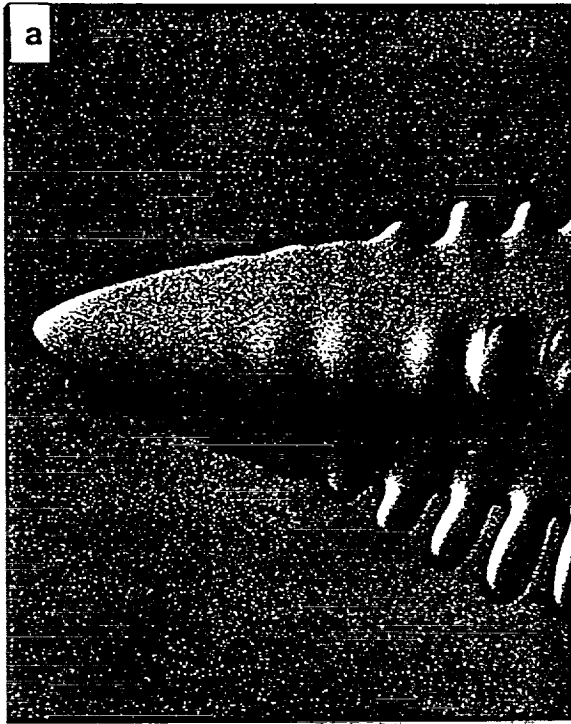
As-Cast



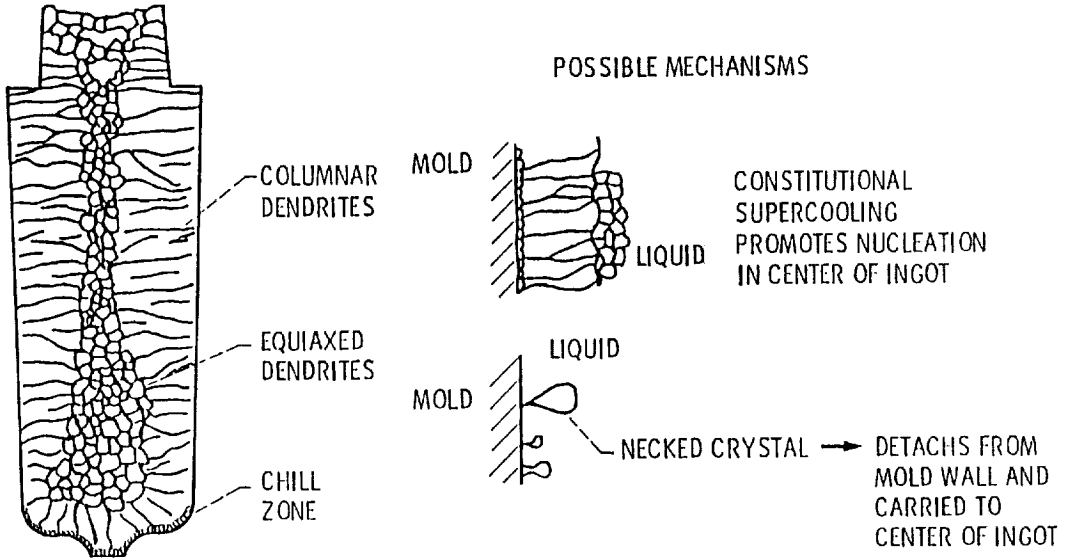
Drop Tube Processed  
( $\Delta T = 530K$ )







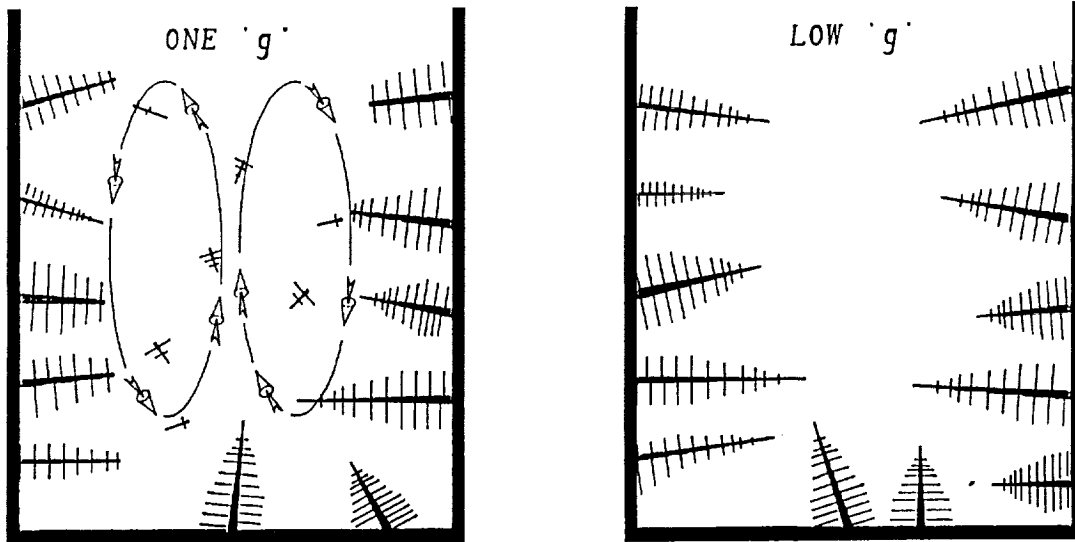
G-1. COLUMNAR - EQUIAXED TRANSITION



CD-85-16842

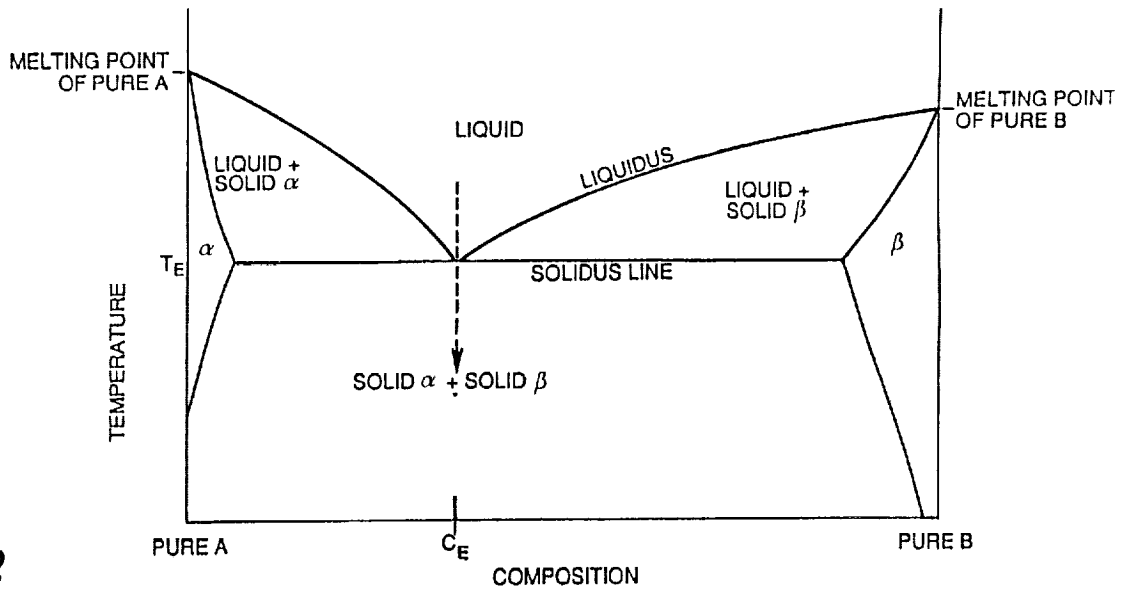
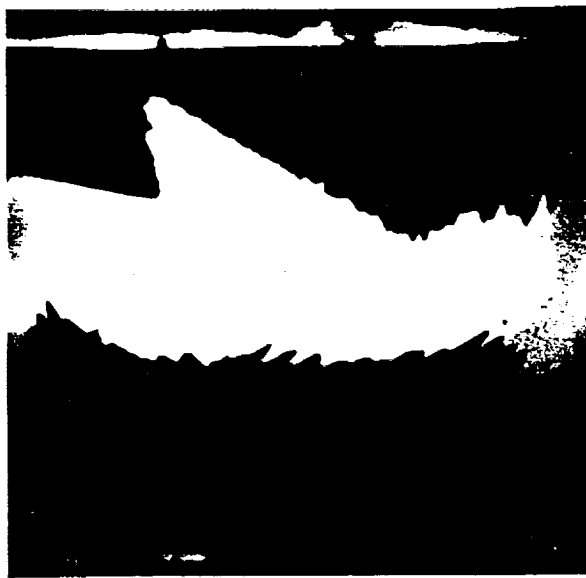
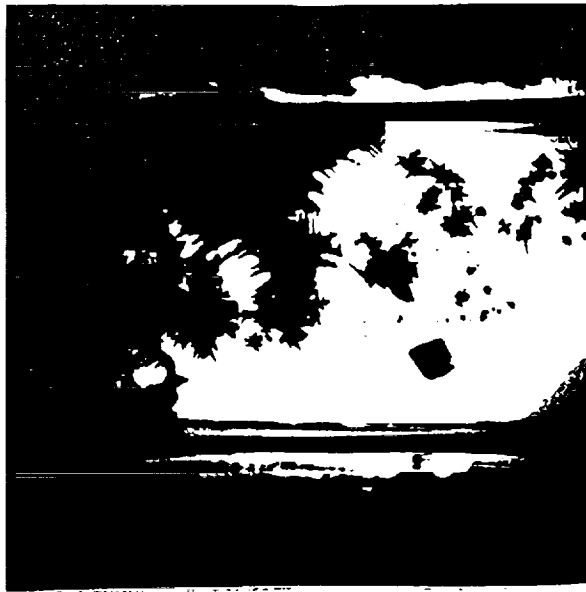
NASA  
C-88-12974

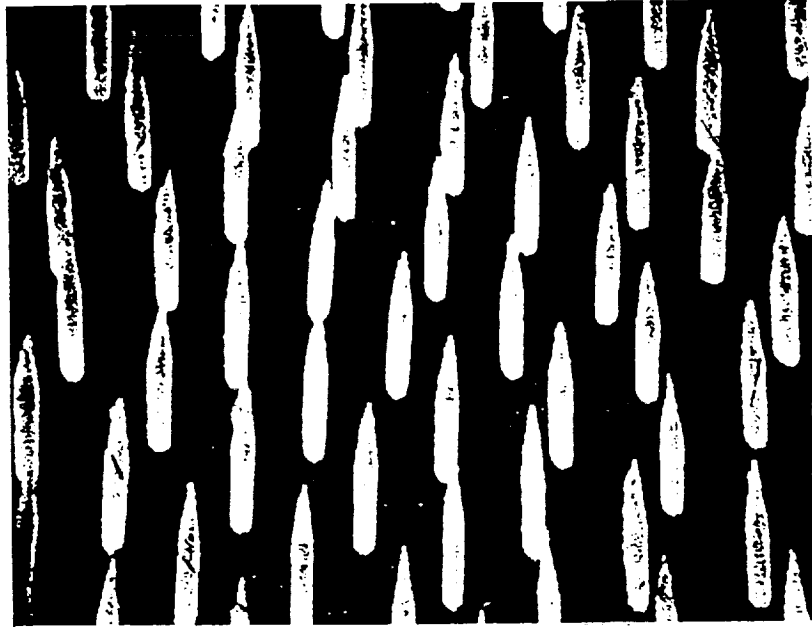
GRAIN MULTIPLICATION



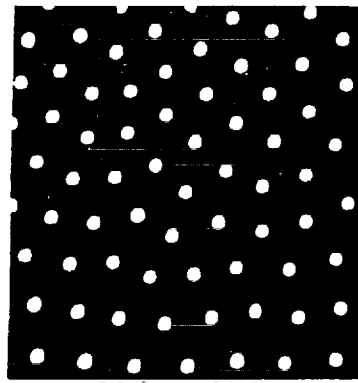
Convection causes melting or breaking off of dendrite tips.

Dendrites grow with minimal convective disturbance

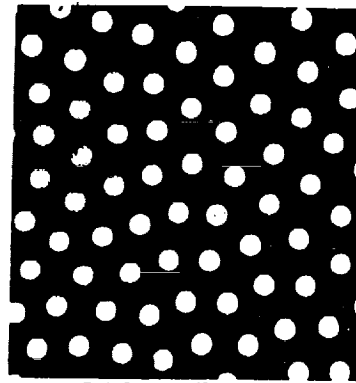




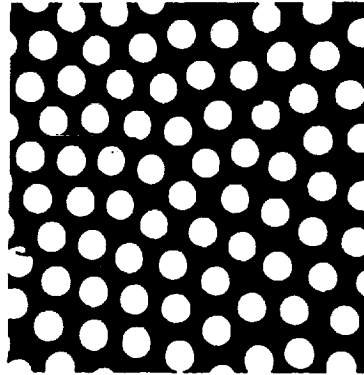
Examples of in situ composites. An electron emitter formed from 0.3 micron tungsten single crystal fibers embedded in a zirconia matrix is shown at the top. A section of a nickel-based superalloy used for turbine blades is shown at the bottom. The matrix material has been etched away to reveal the single crystal tantalum carbide reinforcing fibers that allow the blade to operate for longer times at higher temperatures. Such structures can generally be made on earth only at the eutectic composition. Microgravity offers the possibility of extending the range of compositions to optimize the resulting structure. (Photographs courtesy of General Electric)



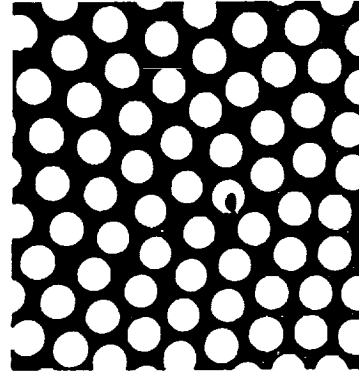
22.6 $\mu$ m 31 Hours



34.9 $\mu$ m 50 Hours



50.7 $\mu$ m 78 Hours



60.0 $\mu$ m 91 Hours

Hole Diameter vs. Time  
10% HNO<sub>3</sub>

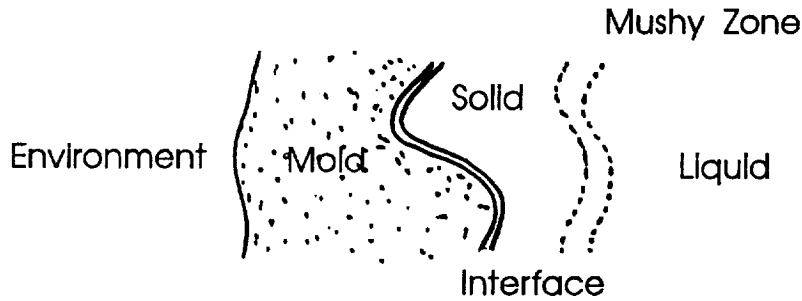


### Process Analysis and Modeling

- Assess role of individual variables
- Control and Vary Independently Process Parameters
- Reduce Complex Processes to Fundamental Units
- Explore Regimes Unavailable to Experiment
- Design Experiments to Emphasize Phenomena of Interest
- Interpret Results
- Improve Yield from Microgravity Experiments



# Solidification Processes



Heat Transfer Coefficients  
Interface, environment

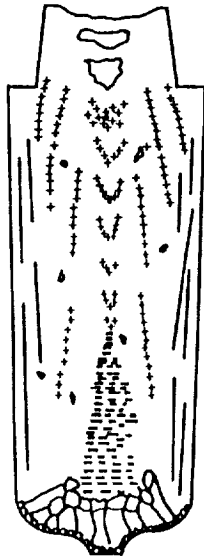
Heat evolution  
Mushy zone model

Material properties

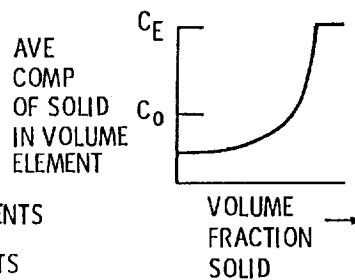
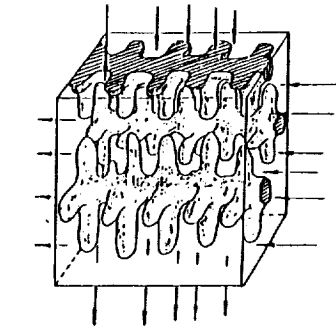
## G - 3. SEGREGATION

### MACROSEGREGATION

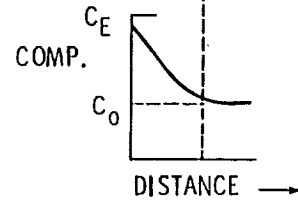
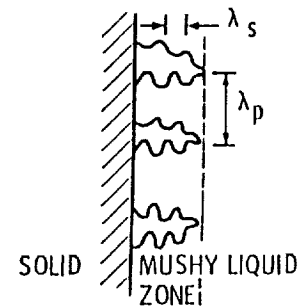
$$\bar{V} = -\frac{K}{\mu g_L} (\nabla p + \rho_L \bar{g})$$



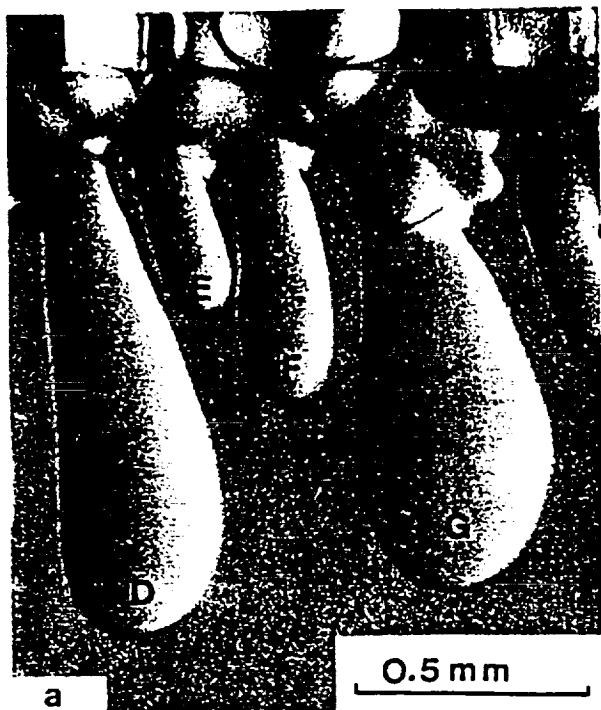
- + ENRICHMENT OF ALLOYING ELEMENTS
- DEPLETION OF ALLOYING ELEMENTS



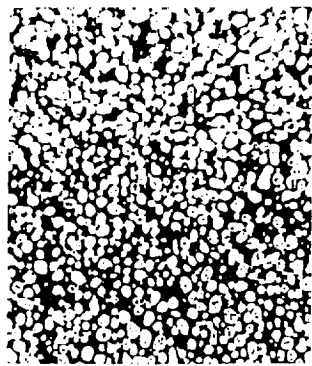
### MICROSEGREGATION



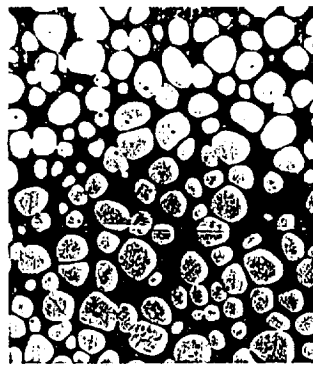
# A-1. DENDRITE COARSENING



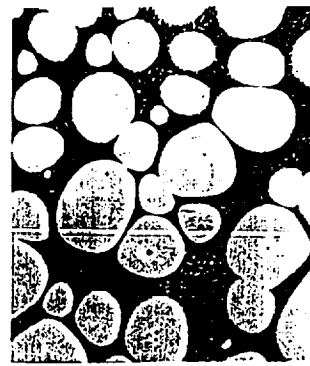
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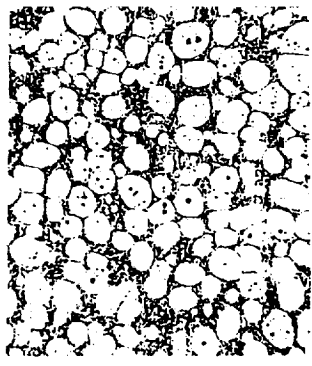
250  $\mu\text{m}$  5 min.



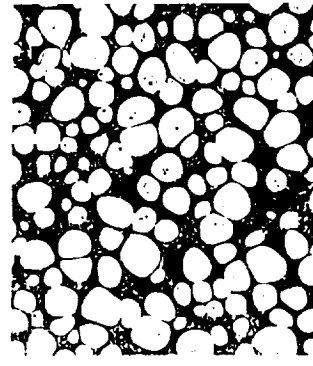
250  $\mu\text{m}$  75 min.



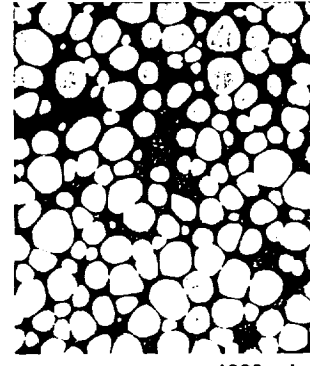
250  $\mu\text{m}$  1020 min.



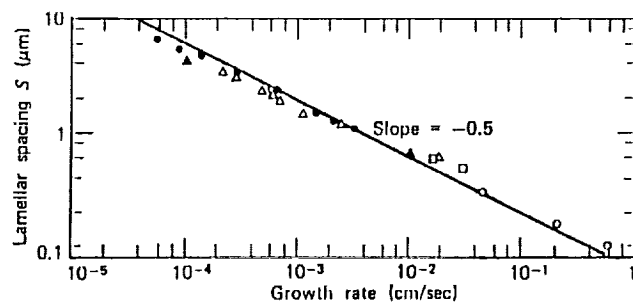
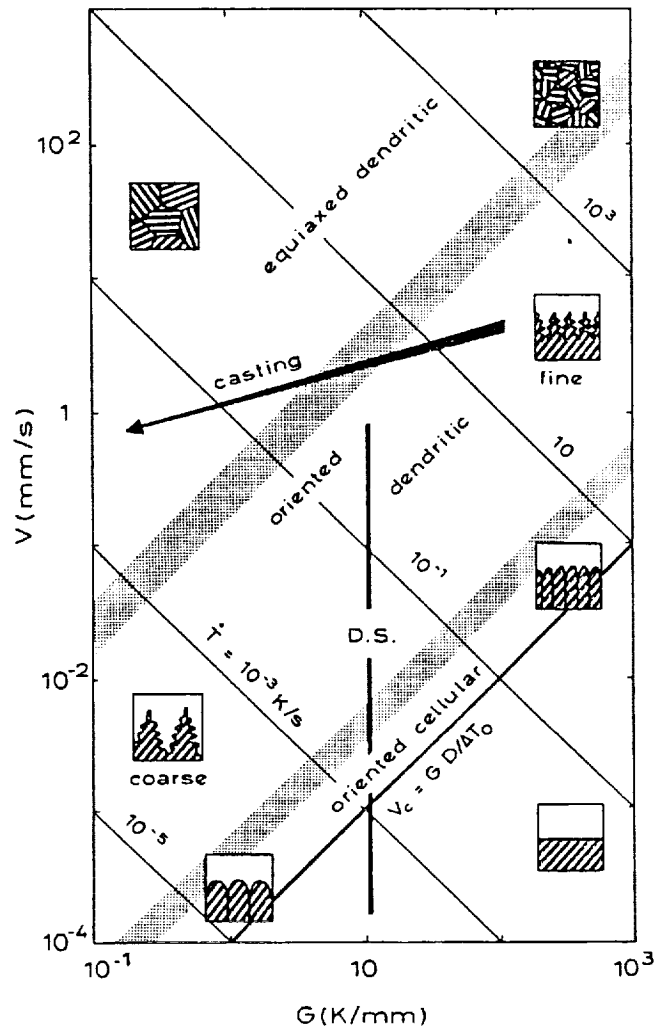
100  $\mu\text{m}$  5 min.



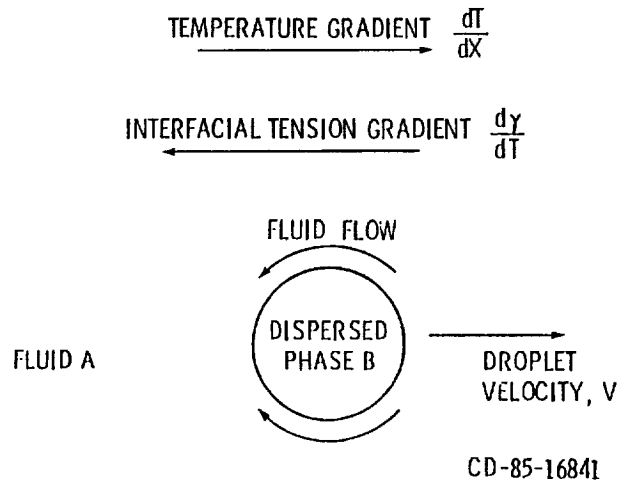
250  $\mu\text{m}$  75 min.



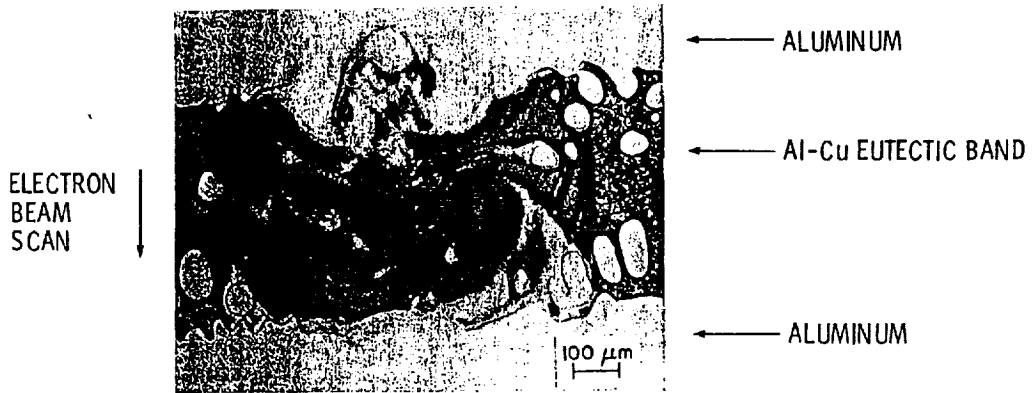
595  $\mu\text{m}$  1020 min.



C-4. THERMAL MIGRATION



G-4. SURFACE TENSION DRIVEN FLOW



CD-85-16838



## Thermophysical Properties

- Emissivity, Electrical Conductivity, Optical Properties
- Calorimetry
  - Specific heats
  - Heats of mixing, formation, transformations, ...
- Transport Coefficients
  - thermal conductivity
  - viscosity
  - diffusion constants
- Density Data
- Thermodynamic Moduli
  - thermal expansion coefficients
  - compressibility, etc.
- Vapor Pressures and Activity Coefficients
- Surface Tension/Interfacial Energies



## Research Opportunities

- Electrodeposition
- Powder Processing
- Joining
- Novel Materials
- Extraterrestrial Materials

**PROTEIN CRYSTAL GROWTH IN MICROGRAVITY**

Presented by Daniel Carter  
Biophysics Branch  
NASA Marshall Space Flight Center

**ABSTRACT**

The overall scientific goals and rationale for growing protein crystals in microgravity will be discussed. Data on the growth of human serum albumin crystals which were produced during the First International Microgravity Laboratory (IML- 1 ) will be presented. Potential scientific advantages of the utilization of Space Station Freedom will be discussed.





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# PROTEIN CRYSTAL GROWTH

## Space Station Utilization Conference

Daniel C. Carter

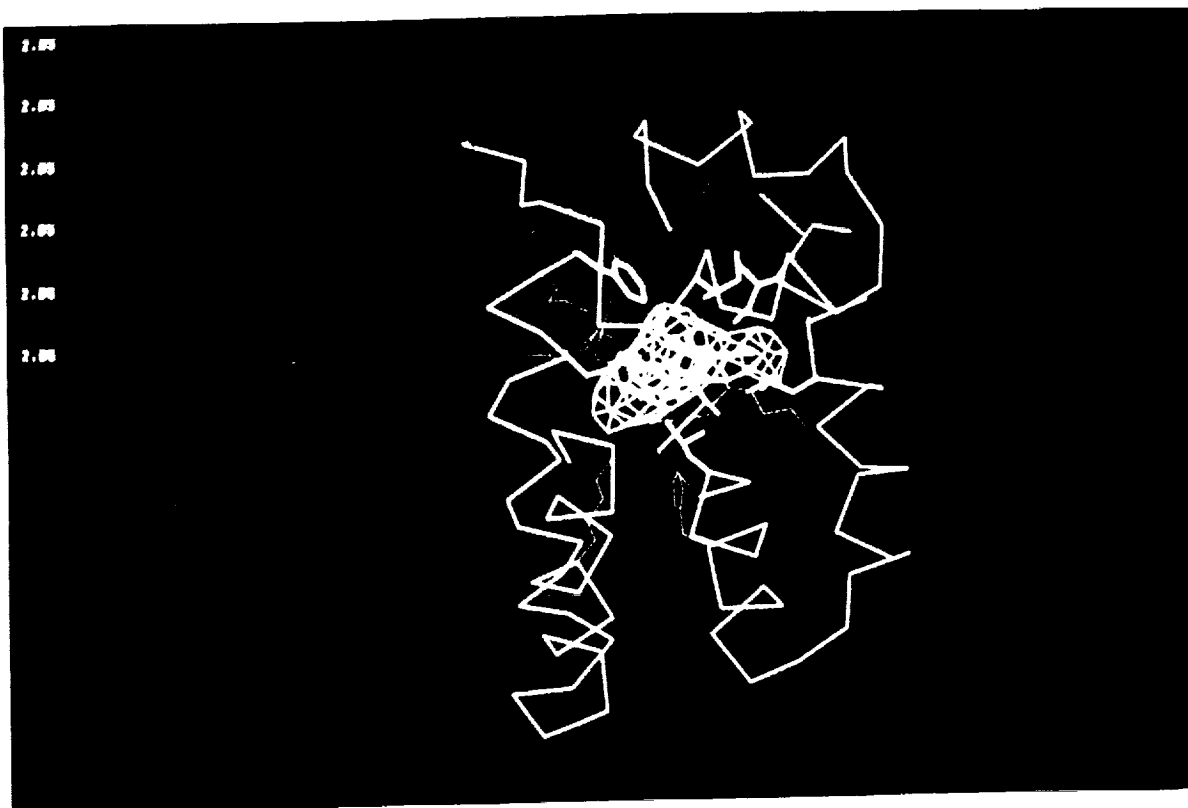
### IMPORTANCE:

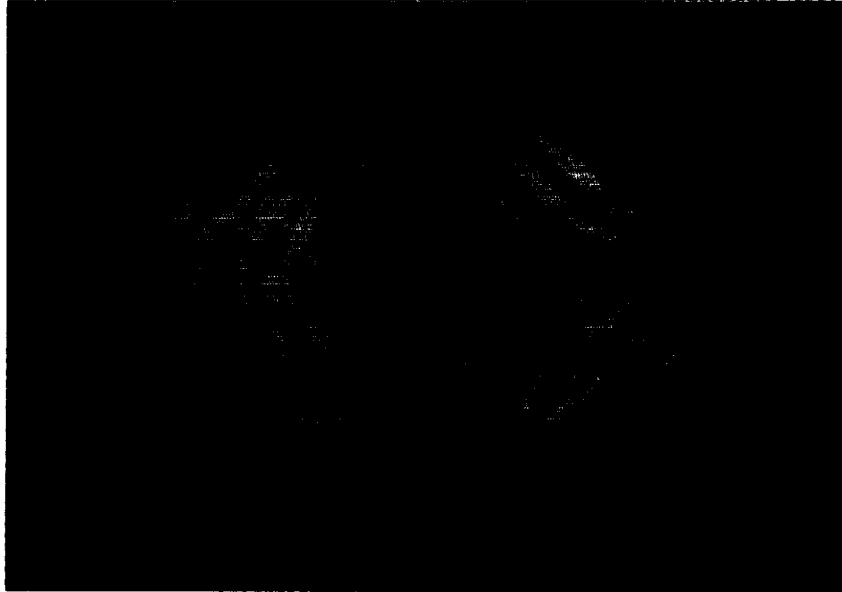
#### Scientific application of crystals

- a. Fundamental importance in molecular biology - understanding how enzymes function etc.
- b. Knowledge of accurate atomic structures of - proteins of key importance in rational drug design

#### Crystal properties and growth processes

- a. Understanding important influences on the growth of high quality protein crystals by using gravity as an experimental variable
- b. What properties of the crystals are different, e.g., resolution, defect structure, mosaicity





## **PROBLEM:**

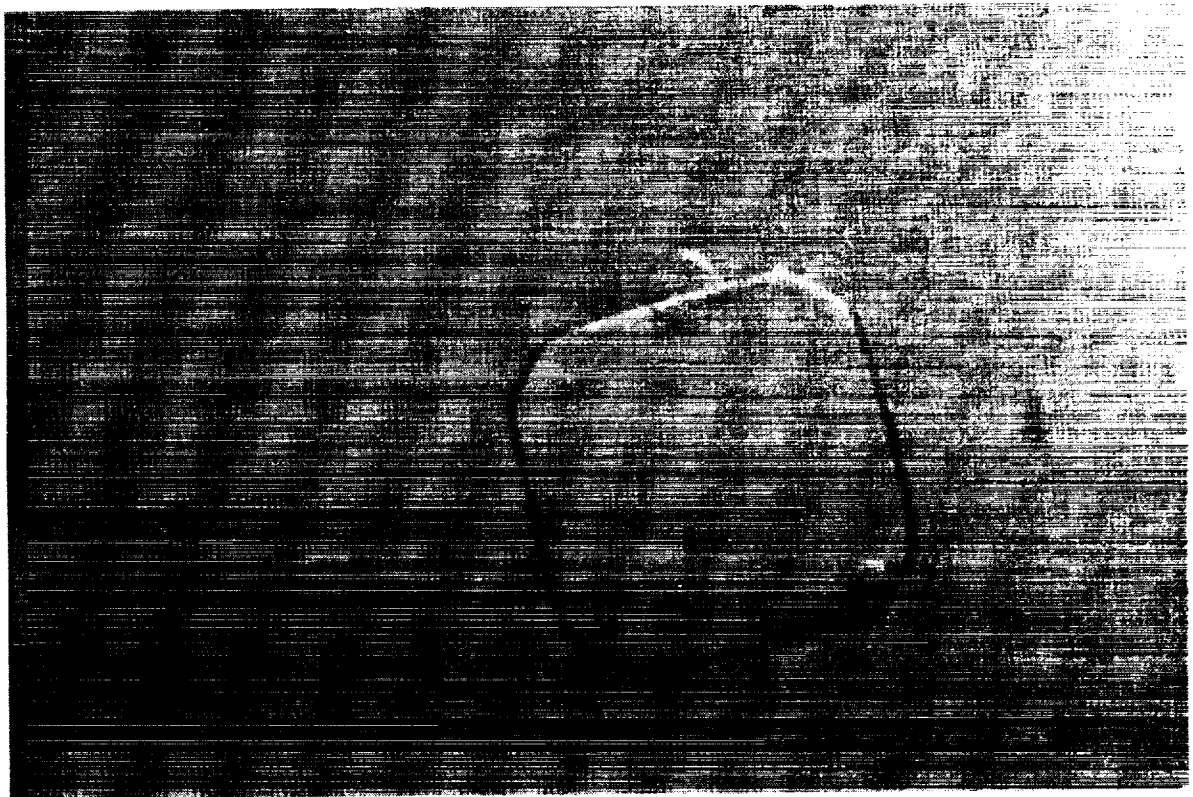
**Growth of high quality protein crystals for application in atomic structure determination by x-ray and neutron diffraction**

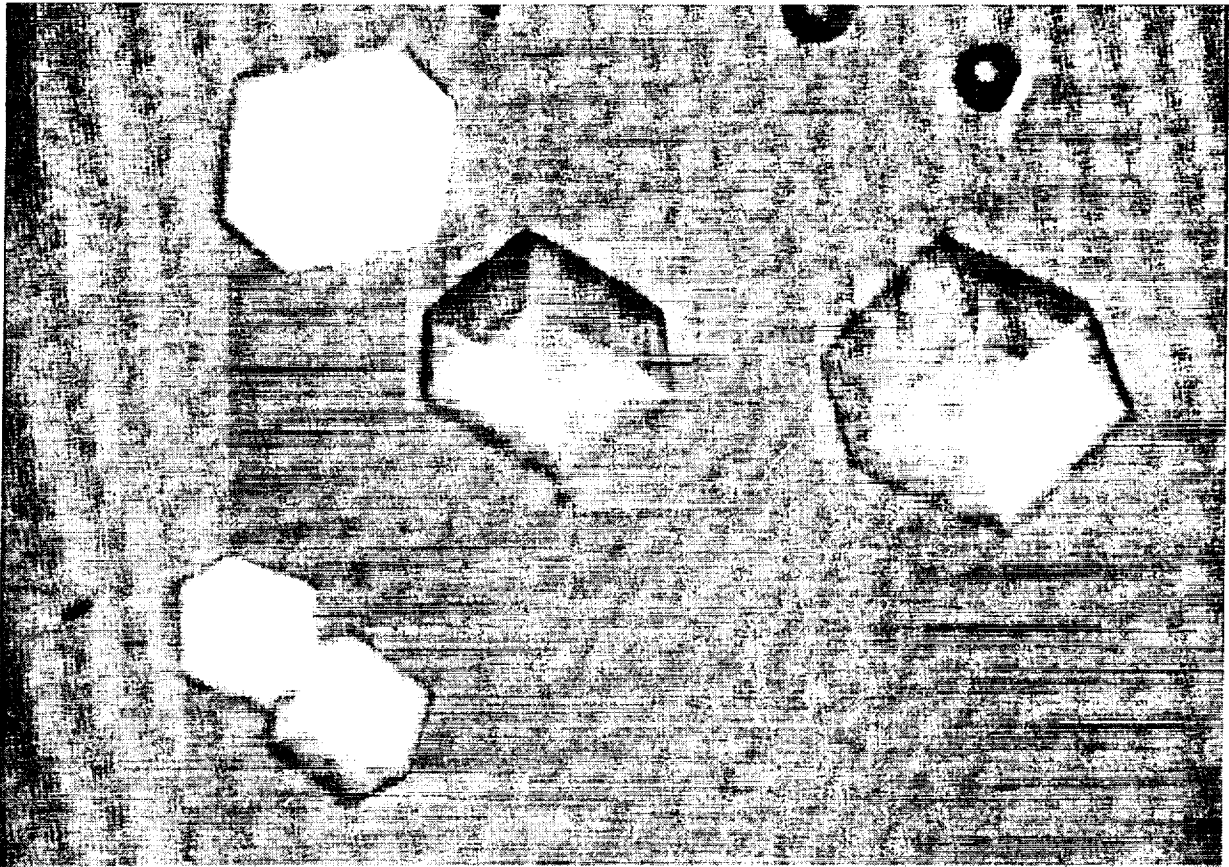
### **Rationale**

- a. Reduction of solutal convection
- b. Elimination of sedimentation effects

### **Approach**

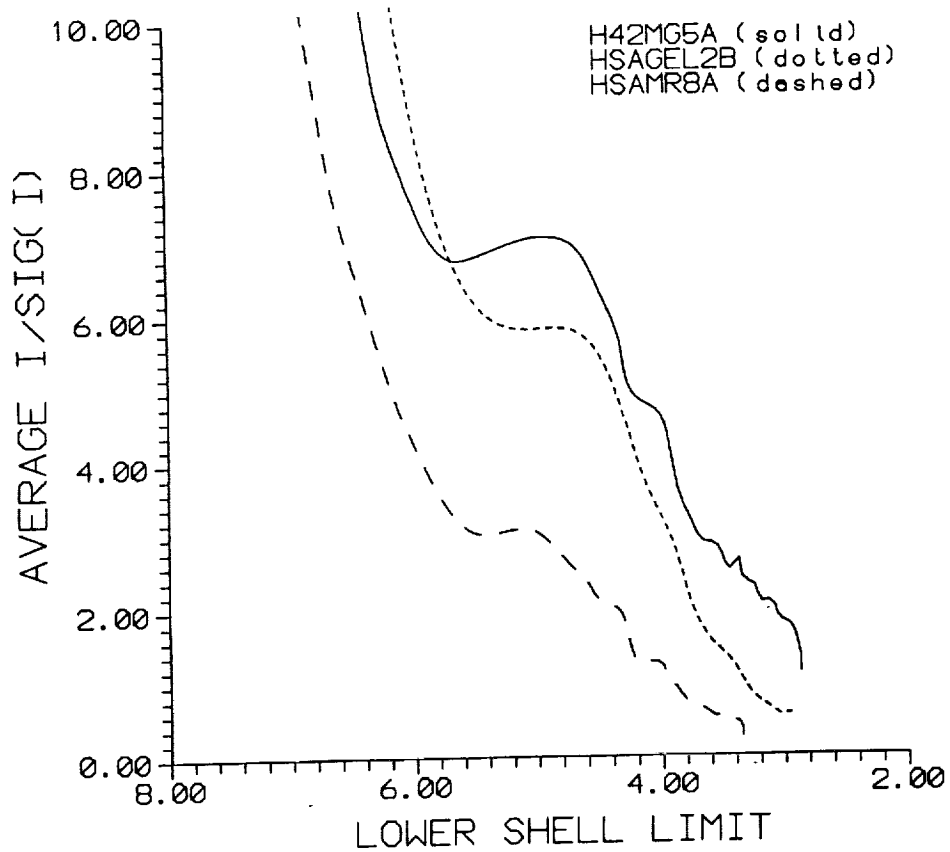
**Vapor diffusion/equilibration method - small multiuser  
Co-Investigator hardware**





## **BENEFITS/SCIENTIFIC RESULTS**

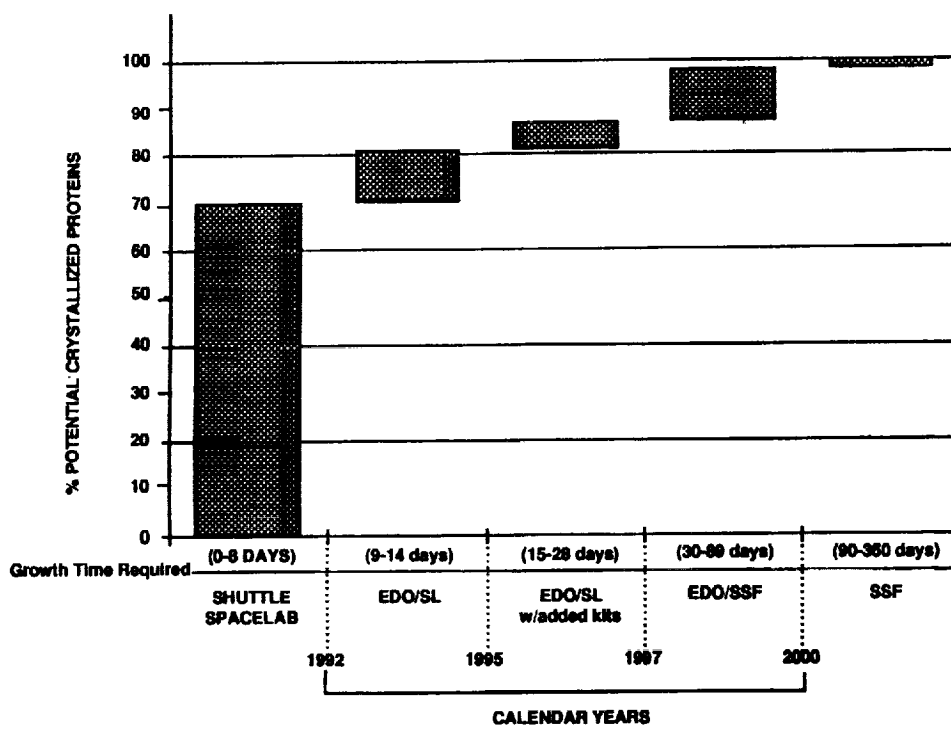
- **Several crystal structures have now been refined to significantly higher resolution than previously obtainable by similar ground-based methods.**
- **Recent success with the longer duration IML-1 mission have produced additional important examples**



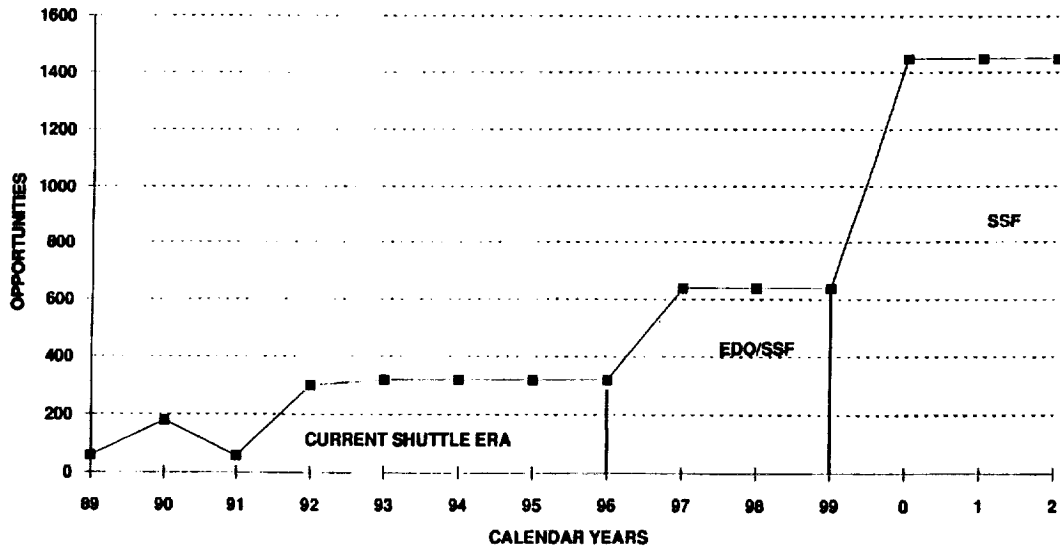
## RELEVANCE TO SPACE STATION

- Protein crystal growth is an experimental science. It will advance at a rate commensurate with number of experiments. Timely human interaction essential to progress
- Many proteins require growth periods from one to several months.

**PROTEIN STUDY POTENTIALS vs. MISSION DURATION  
(1025 CANDIDATE PROTEINS)**



**PROTEIN CRYSTAL GROWTH SAMPLE OPPORTUNITIES**







**OFFICE OF COMMERCIAL PROGRAMS' RESEARCH ACTIVITIES  
FOR SPACE STATION FREEDOM UTILIZATION**

Presented by James A. Fountain  
Office of Commercial Programs  
NASA Headquarters

**ABSTRACT**

One of the Objectives of the Office of Commercial Programs (OCP) is to encourage, enable, and help implement space research which meets the needs of the U.S. industrial sector. This is done mainly through seventeen Centers for the Commercial Development of Space (CCDSs) which are located throughout the United States. The CCDSs are composed of members from U.S. companies, universities, and other government agencies. These Centers are presently engaged in industrial research in space using a variety of carriers to reach low Earth orbit. One of the goals is to produce a body of experience and knowledge that will allow U.S. industrial entities to make informed decisions regarding their participation in commercial space endeavors. A total of 32 items of payload hardware have been built to date. These payloads have flown in space a total of 73 times.

The carriers range from the KC-135 parabolic aircraft and expendable launch vehicles to the Space Shuttle. This range of carriers allows the experimenter to evolve payloads in complexity and cost by progressively extending the time in microgravity. They can start with a few seconds in the parabolic aircraft and go to several minutes on the rocket flights, before they progress to the complexities of manned flight on the Shuttle. Next year, two new capabilities will become available: COMET, an expendable-vehicle-launched experiment capsule that can carry experiments aloft for thirty days; and SPACEHAB, a new Shuttle borne module which will greatly add to the capability to accommodate small payloads.

All of these commercial research activities and carrier capabilities are preparing the Office of Commercial Programs to evolve those experiments that prove successful to Space Station Freedom. OCP and the CCDSs are actively involved in Space Station design and utilization planning and have proposed a set of experiments to be launched in 1996 and 1997. These experiments are to be conducted both internal and external to Space Station Freedom and will investigate industrial research topics which range from biotechnology to electronic materials to metallurgy. Some will be designed to make maximum use of the quiescent microgravity conditions in the "ground-tended" phases during the early years of Space Station Freedom operations.



**NASA OFFICE OF COMMERCIAL PROGRAMS'  
RESEARCH ACTIVITIES FOR SPACE STATION FREEDOM**

Presented at the

**Space Station Freedom Utilization Conference**

**Session 3: Discipline Perspectives: Microgravity Research  
and Biotechnology**

**Von Braun Civic Center  
Huntsville, AL**

By

**James A. Fountain  
Marshall Space Flight Center  
Huntsville, AL**

**Program Manager, Commercial Utilization of Space Station Freedom  
for the  
Office of Commercial Programs  
NASA Headquarters  
Washington, DC**

**August 5, 1992**



**OFFICE OF  
COMMERCIAL  
PROGRAMS**



**SPACE  
STATION  
FREEDOM**

**SPACE STATION FREEDOM PAYLOAD SPONSORS**

- **JAPAN - NASDA**
- **EUROPEAN SPACE AGENCY - ESA**
- **CANADA - CSA**
- **UNITED STATES - NASA**
  - *Office of Commercial Programs - OCP (Code C) - 28%*
  - **Office of Space Science and Applications - OSSA (Code S) - 52%**
  - **Office of Aeronautics and Space Technology - OAST (Code R) - 12%**
  - **Office of Space Flight - OSF (Code M) - 8%\***
  - **Office of Space Systems Development - OSSD (Code D) - 8%\***

\* Shared between OSF and OSSD



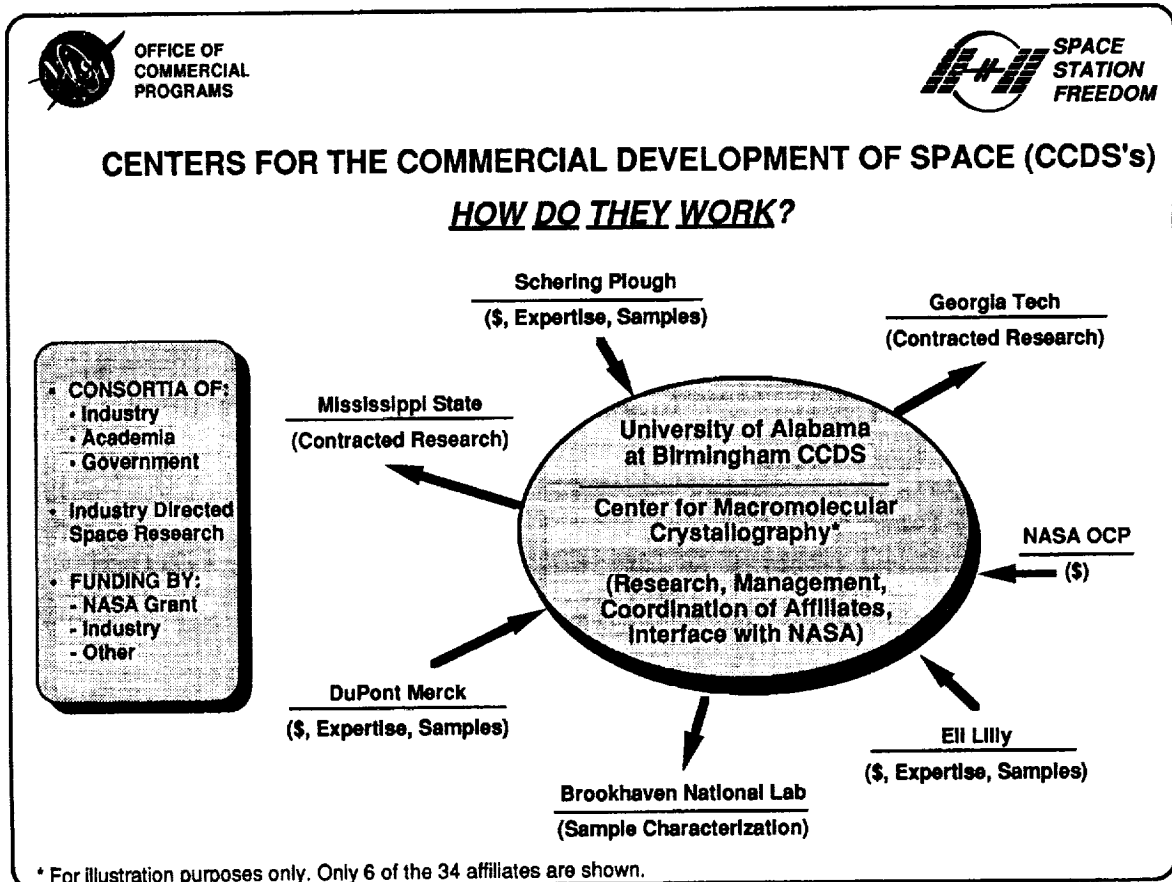
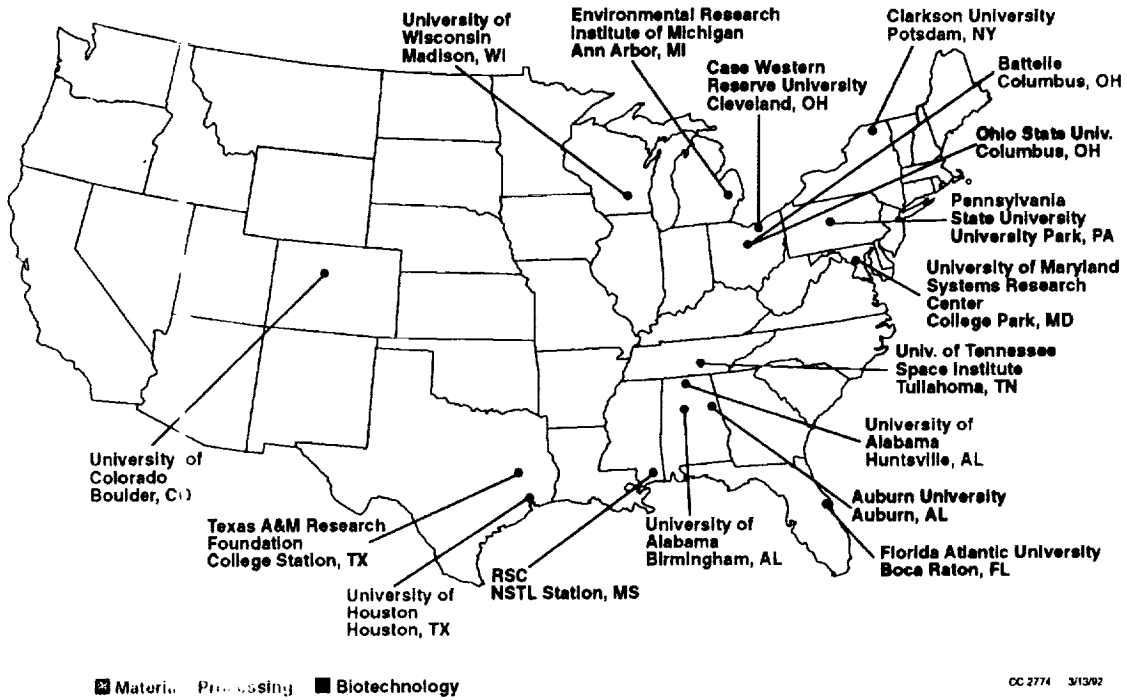
**OFFICE OF  
COMMERCIAL  
PROGRAMS**



**SPACE  
STATION  
FREEDOM**

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# Centers for Commercial Development of Space (CCDS)



**Auburn**

Solar Furnace Satellite  
Crystal Growth of Electronic Materials  
Computational Modeling of Casting Processes

**Battelle**

Solution Crystal Growth  
Polymer Composites  
Float Zone Crystal Growth - CdTe  
Zeolite Crystal Growth  
Doped Non-Linear Optic Substrates  
Investigations into Polymer Membranes

**Bioserve**

Plant Growth Apparatus  
Blood Rheology Experiment  
Generic Bioprocessing Module  
Autonomous Biomedical Test Apparatus

**Case Western**

Materials Exposure - Basic, Advanced, & Applied

**Clarkson**

Zeolite Crystal Growth  
Low-Temp Solidification  
Liquid Encapsulated Melt Zone  
Directional Solidification - CdTe  
Chemical Vapor Transport - CdTe  
Commercial Solution Growth Facility

**CSTAR**

Cryogenic Fluid Management  
Electric, Chemical Propulsion  
Industrial Laser System Applications

**Florida Atlantic**

Transmission Techniques

**Ohio State**

Remote Sensing & Mapping

**Penn State**

Blomodule  
Telemedicine  
Bioprocessors  
Bone Densitometry  
Physiological Systems Experiment  
Light Stimulator & Photon Detector  
Commercial Electrophoresis System

**SpARC**

Autonomous Rendezvous & Docking  
Automated Microgravity Materials Processing

**SRSC**

Remote Sensing & Applications

**SYEC**

Chemical, Molecular Beam Epitaxy Growth

**Texas A&M**

Micro Heat Pipe Evaluation  
Frozen Startup of Heat Pipe  
Microwave Power Transmission

**University of Alabama-Birmingham**

Protein Crystal Growth

**University of Alabama-Huntsville**

Polymer Foam  
Atomic Oxygen  
Electrodeposition  
3-D Accelerometer  
Immiscible Polymers  
Nuclear Track Detectors  
Space Experiment Facility  
Non-Linear Optical Materials  
Sintered & Alloyed Materials  
High-Temp Superconductors  
Materials Dispersion Apparatus

**University of Maryland**

Hybrid Networks

**WCSAR**

Astroculture™  
Bioregenerative Water System

CC-2929 2/6/92



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## THE CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE (CCDS)

### A MAJOR OBJECTIVE:

*To produce a body of knowledge and experience  
that will allow U.S. industrial entities to make  
informed decisions regarding their participation  
in commercial space endeavors*

## COMPARISON OF COMMERCIAL OPTIONS

**A Private Entity May Ask:**

***What options do I have to participate in a commercial space endeavor, and what are the relative comparisons of:***

- 1. Risk to my investment?**
- 2. Cost of participating?**
- 3. Retention of Intellectual Property?**

	Join a CCDS	Negotiate a Joint Endeavor Agreement	Negotiate A Commercial Reimbursable Agreement
1. Risk	lower	←	→ higher
2. Cost	lower	←	→ higher
3. Intel. Prop.	keep some	←	→ keep all

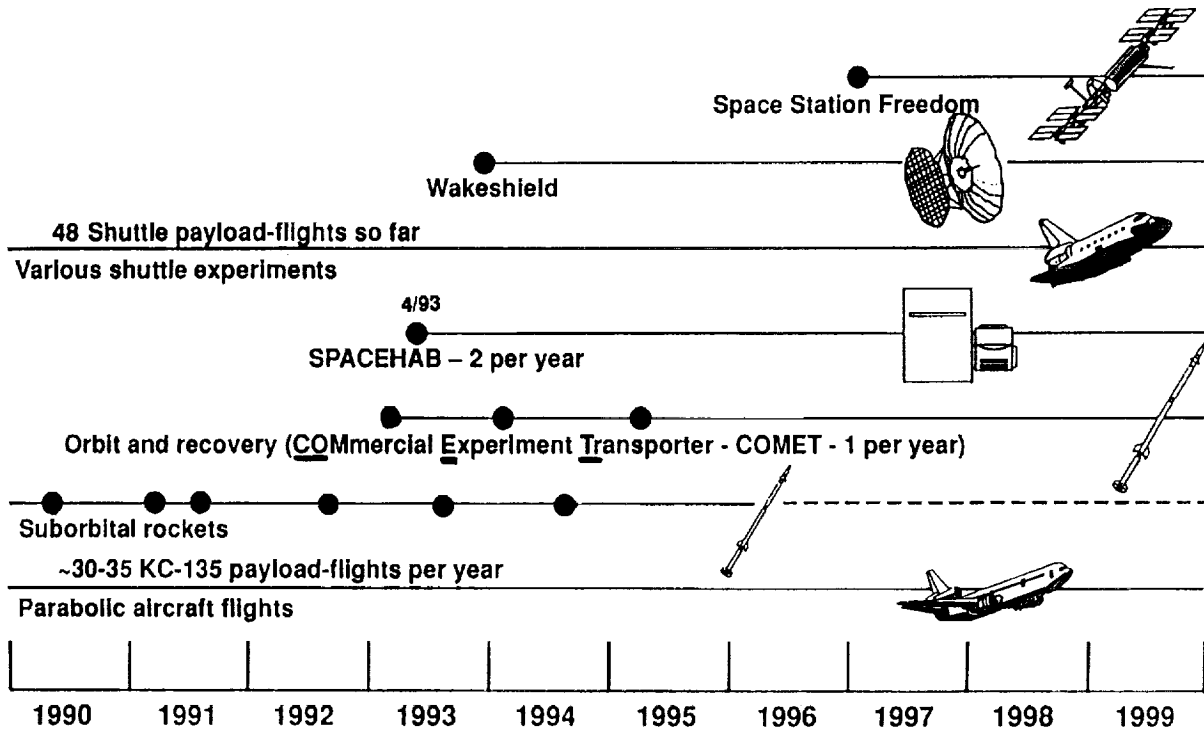
**HOW DO WE GET OUR EXPERIMENTS TO SPACE?**

**HOW DO WE GET OUR EXPERIMENTS TO SPACE?**

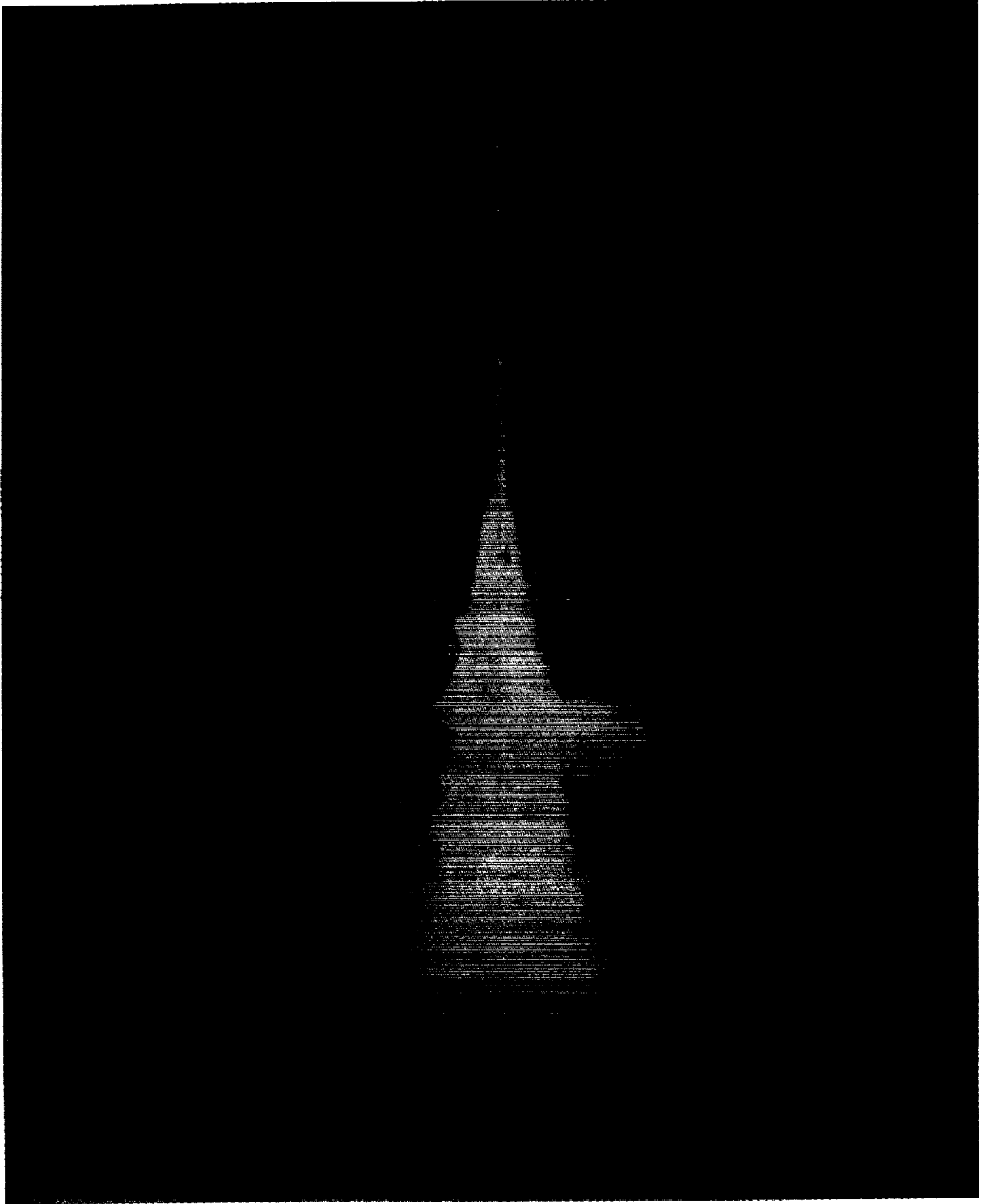
**HOW DO WE GET OUR EXPERIMENTS TO SPACE?**

**HOW DO WE GET OUR EXPERIMENTS TO SPACE?**

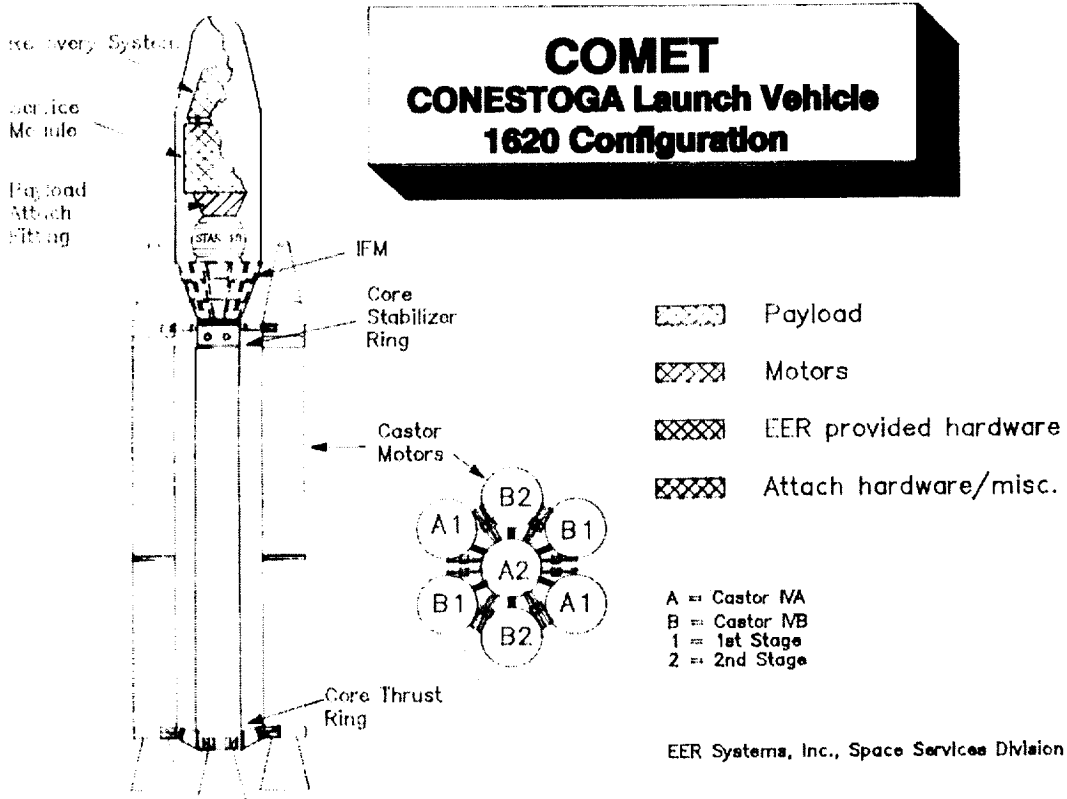
# Commercial Payload Evolution to Space Station

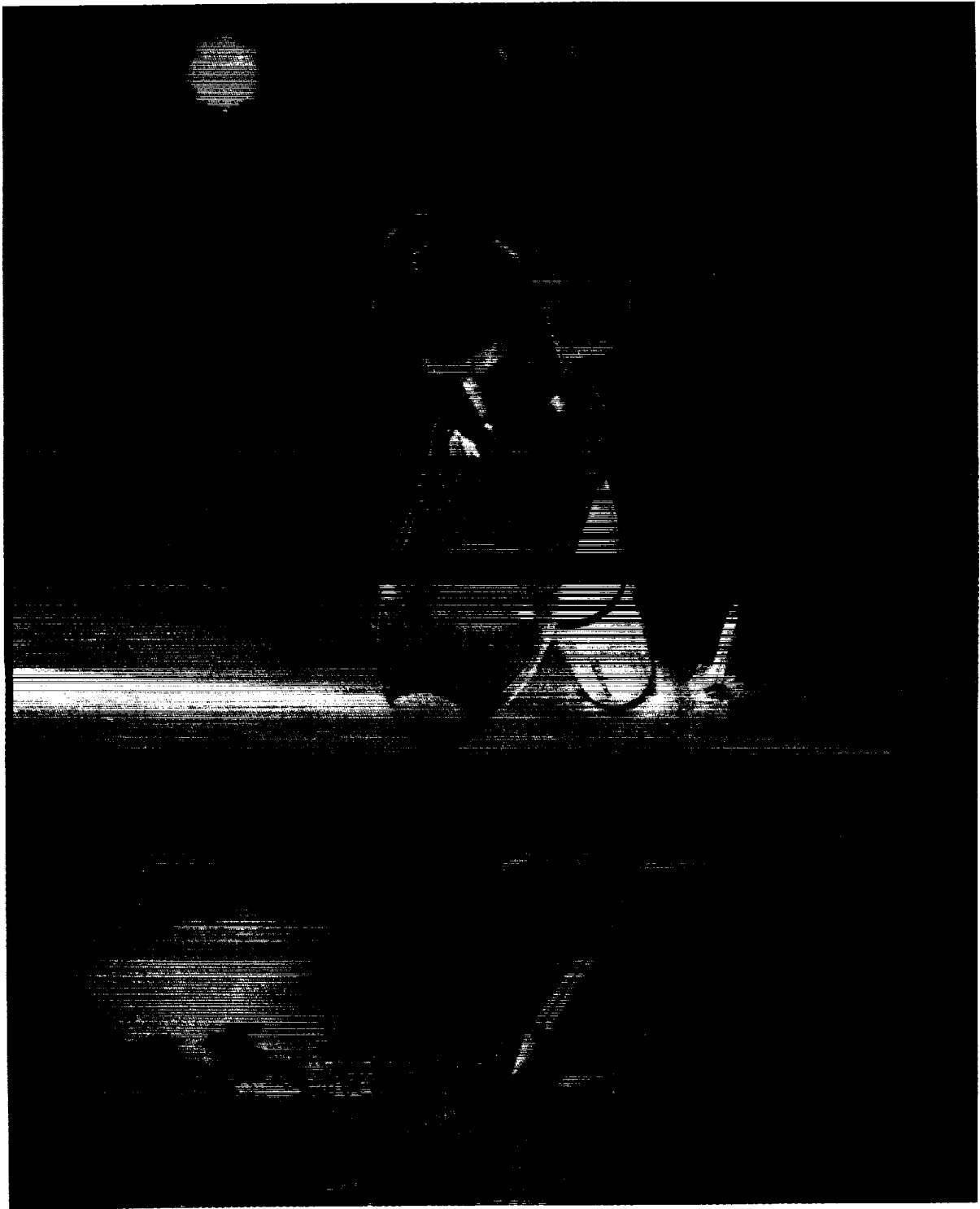


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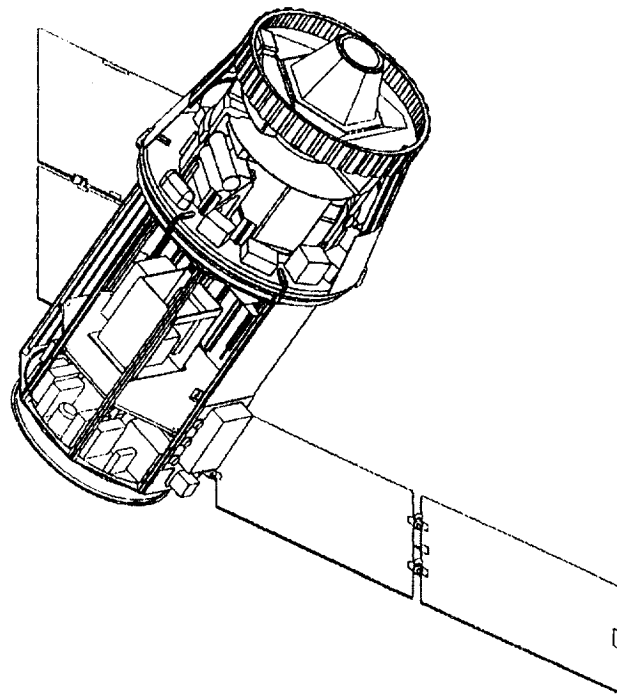
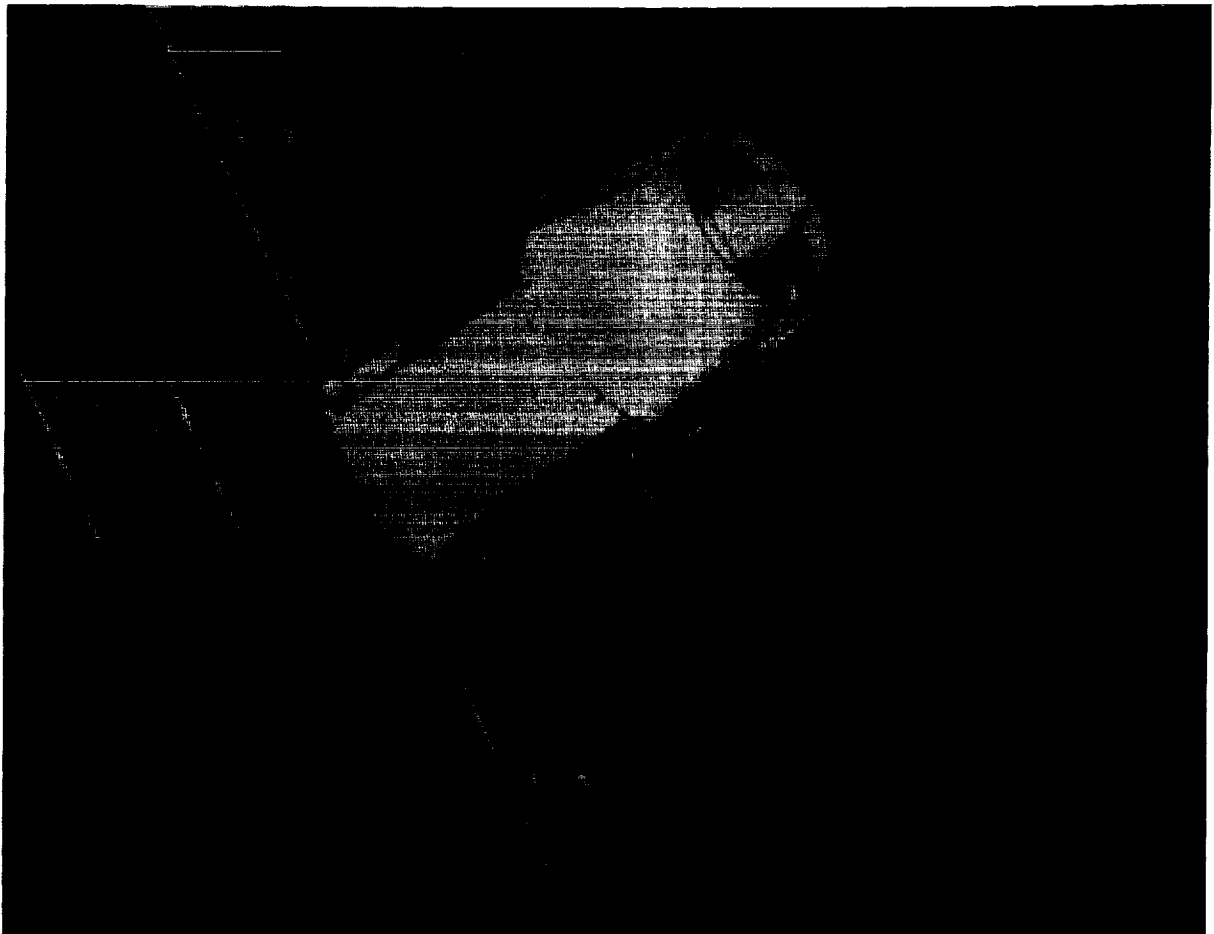
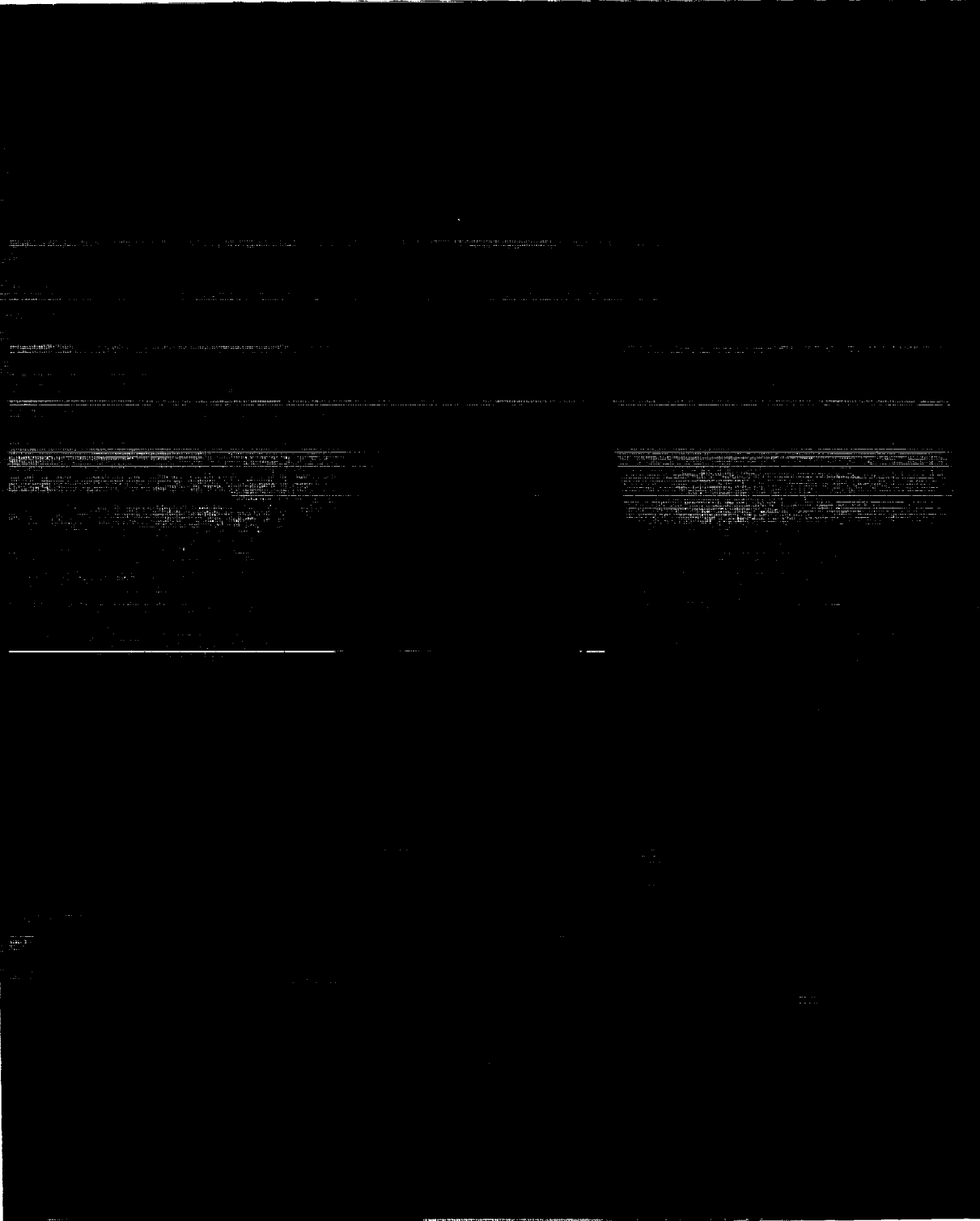
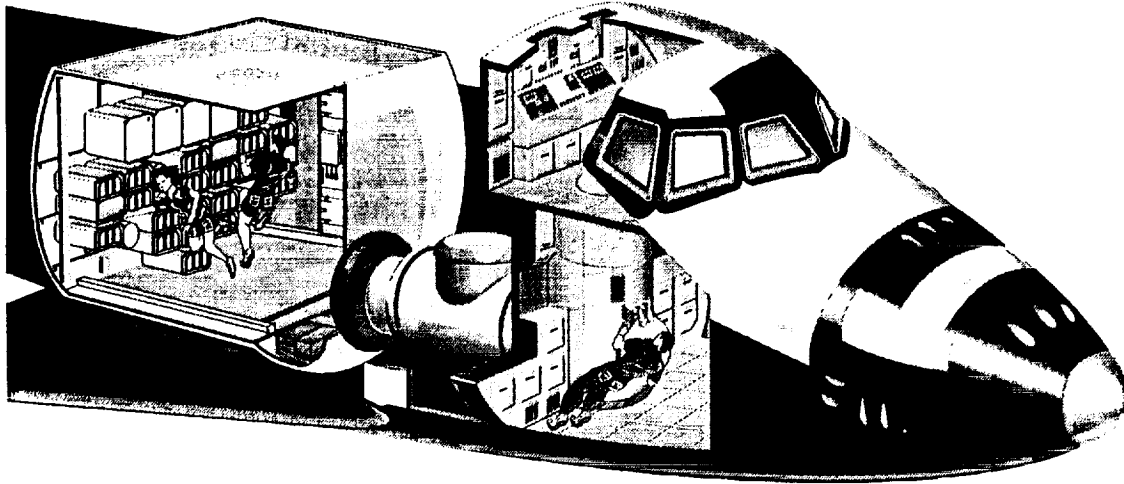


Figure I.4-2 Cutaway View of COMET FreeFlyer





# SPACEHAB Module



## Payload Resources

### CONFIGURATIONS

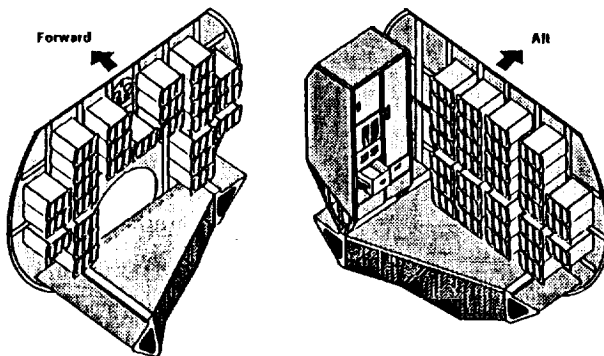
#### All Locker Configuration

71 lockers (max)

#### Rack & Locker Configurations

1 rack / 61 lockers (max)

2 racks / 51 lockers (max)



Mission planning will assess the compatibility of payloads in order to maximize the resources provided to each.

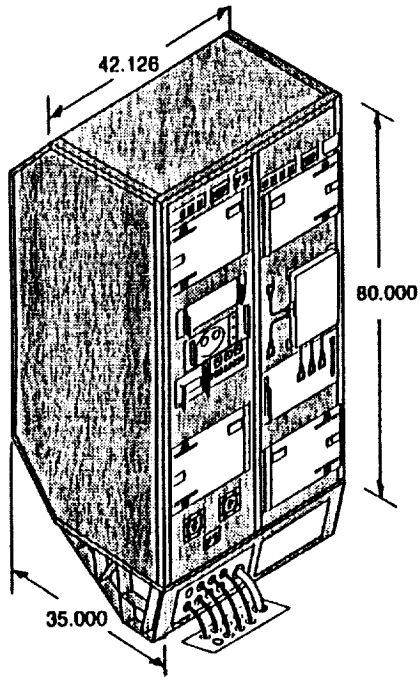
### TOTAL PAYLOAD RESOURCES

<b>Mass:</b>	English 3000 lb	Metric 1360 kg
<b>Volume:</b>	1100 ft <sup>3</sup>	31.1 m <sup>3</sup>
<b>Power*:</b>		
DC:	1750 - 3500 W	
Asc/Des	300 - 625 W	
AC:	690 VA	
<b>Cooling:</b>		
Air:	2000 W	
Water**:	4000 W	
<b>Crew:</b>	2	
<b>Other:</b>		
	• Command/data subsystems	
	• Fire detection/suppression	
	• Vacuum venting	

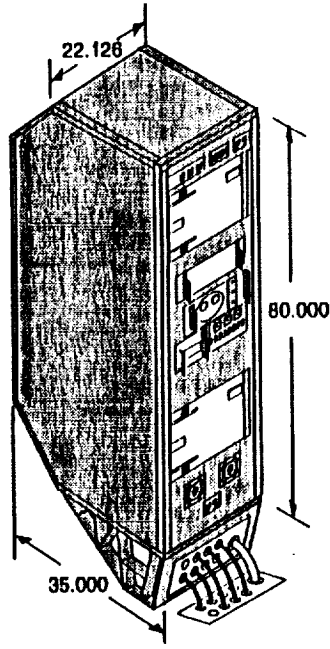
\* With 2 Orbiter Feeders, DC = 3150 W

\*\* Maximum water cooling level includes 2 kW plus whatever air capability is not used. (The orbiter can provide up to 6 kW cooling total on a special case basis.)

# Spacehab Racks



**Double Rack**  
(45 cu. ft., 1209 lb Experiment)



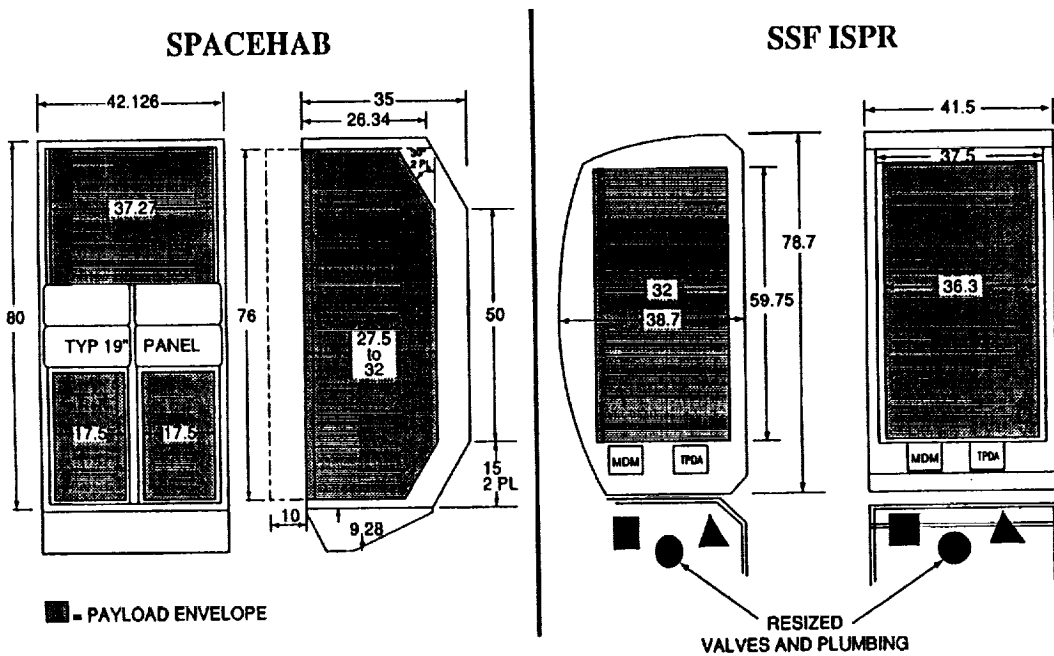
**Single Rack**  
(22.5 cu. ft., 655 lb Experiment)

**SPACEHAB**

**MODONNELL DOUGLAS**

## TRANSITION OF SPACEHAB PAYLOADS TO SSF

### RACK PAYLOAD ENVELOPES



## TRANSITION OF SPACEHAB PAYLOADS TO SSF

### RACK COMPARISON SUMMARY

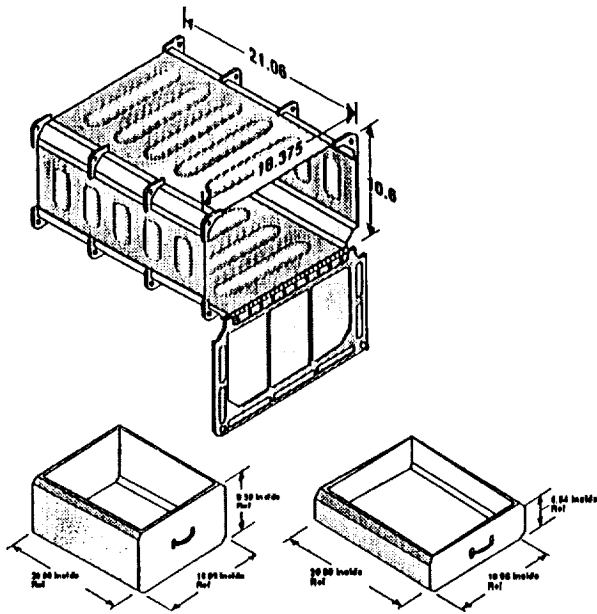
SPACEHAB		SPACE STATION FREEDOM
80 in. (2032 mm) High 42.126 in. (1070 mm) Wide 35 in. (889 mm) Deep 9.28 in. (235.71 mm) Base	<b>EXTERNAL RACK ENVELOPE</b>	78.7 in. (1999 mm) High 41.5 in. (1054.1 mm) Wide 38.7 in. (983 mm) Deep No Base
57 cu. ft. (1.61 cu. m) Inside Envelope  45 cu. ft. (1.27 cu. m) Design Volume	<b>RACK PAYLOAD VOLUME</b>	55 cu. ft. (1.55 cu. m) Inside Envelope  40 cu. ft. (1.13 cu. m) Max Rectangular Volume
19.9 sq. ft. (1.85sq. m) Single Bay  18.7 sq. ft. (1.74 sq. m) Double Bay	<b>FRONT OPENING FOR PAYLOADS</b>	15.8 sq. ft. (1.47 sq. m) Single Bay  15.0 sq. ft. (1.39 sq. m) Double Bay
EIA-RS-310-C	<b>FRONT PANEL MOUNTING STANDARD</b>	EIA-RS-310-C
17.73 in. (450.34 mm) Single Bay  37.73 in. (958.34 mm) Double Bay	<b>FRONT FLANGE OPENING</b>	17.75 in. (450.85 mm) Single Bay  37.5 in. (952.5 mm) Double Bay
1250 lbs. (567 kg)	<b>LOAD CARRYING CAPABILITY</b>	882lbs. (400 kg) Standard 1534 lbs. (700 kg) Optional

## TRANSITION OF SPACEHAB PAYLOADS TO SSF

### RACK COMPARISON SUMMARY

SPACEHAB		SPACE STATION FREEDOM
Rack Base, Front	<b>UTILITY INTERFACE PANEL</b>	Pass Through Panel inside Rack, Interface Panel on Rack Standoff
1 kw (average) 2 kw (peak) 28 Volts DC	<b>DC POWER</b>	3, 6, or 12 kw 120 Volts DC User provides power conversion
690 VA, 400 hz	<b>AC POWER</b>	None
2, 4, 8, 16 kbps (48 mbps optional) User provides Dedicated Experiment Processor	<b>COMMAND AND DATA</b>	16 mbps (48 mbps total) 1553 Data Bus Standard 802.4 FDDI Optional User purchases MDM User Provides Dedicated Experiment Processor if required
1 kw average per rack 2 kw total module	<b>RACK AIR COOLING</b>	1.2 kw max per rack 3.6 kw total module
1 kw	<b>PAYLOAD WATER LOOP CAPACITY</b>	8 kw
1.4 E-5 Torr to 1.0 E-6 Torr	<b>VACUUM</b>	10 E-3 Torr

# Locker Capacity



<b>Mass:</b>	<u>English</u>	<u>Metric</u>
Standard Accom	42 lbs	20.9 kg
Design Limit	60 lbs	27.2 kg
<b>C.G.:</b>	14 in <sup>4</sup>	35.6 cm
<b>Volume:</b>		
Entire Locker	2.0 ft <sup>3</sup>	0.057 m <sup>3</sup>
Small Tray	0.9 ft <sup>3</sup>	0.025 m <sup>3</sup>
Large Tray	1.9 ft <sup>3</sup>	0.054 m <sup>3</sup>

Data: Accommodated through manifesting of compatible payloads.

D.C. Power  
On Orbit: 115 W (Continuous)  
180 W (Peak) for TBD Min  
@ 28 +/-4 VDC

Ascent/Descent\*\*

Cooling: Payload heat generation above 60W  
requires forced air cooling.

**SPACEHAB had the capability of accommodating Middeck locker payloads without modification**

**SPACEHAB<sup>®</sup>**

**MCDONNELL DOUGLAS**

## Flight Schedule

Flight 1	April 1993
Flight 2	October 1993
Flight 3	April 1994
Flight 4	October 1994
Flight 5	March 1995
Flight 6	August 1995

**Subsequent Flights will be Scheduled to Satisfy Market Demands.**

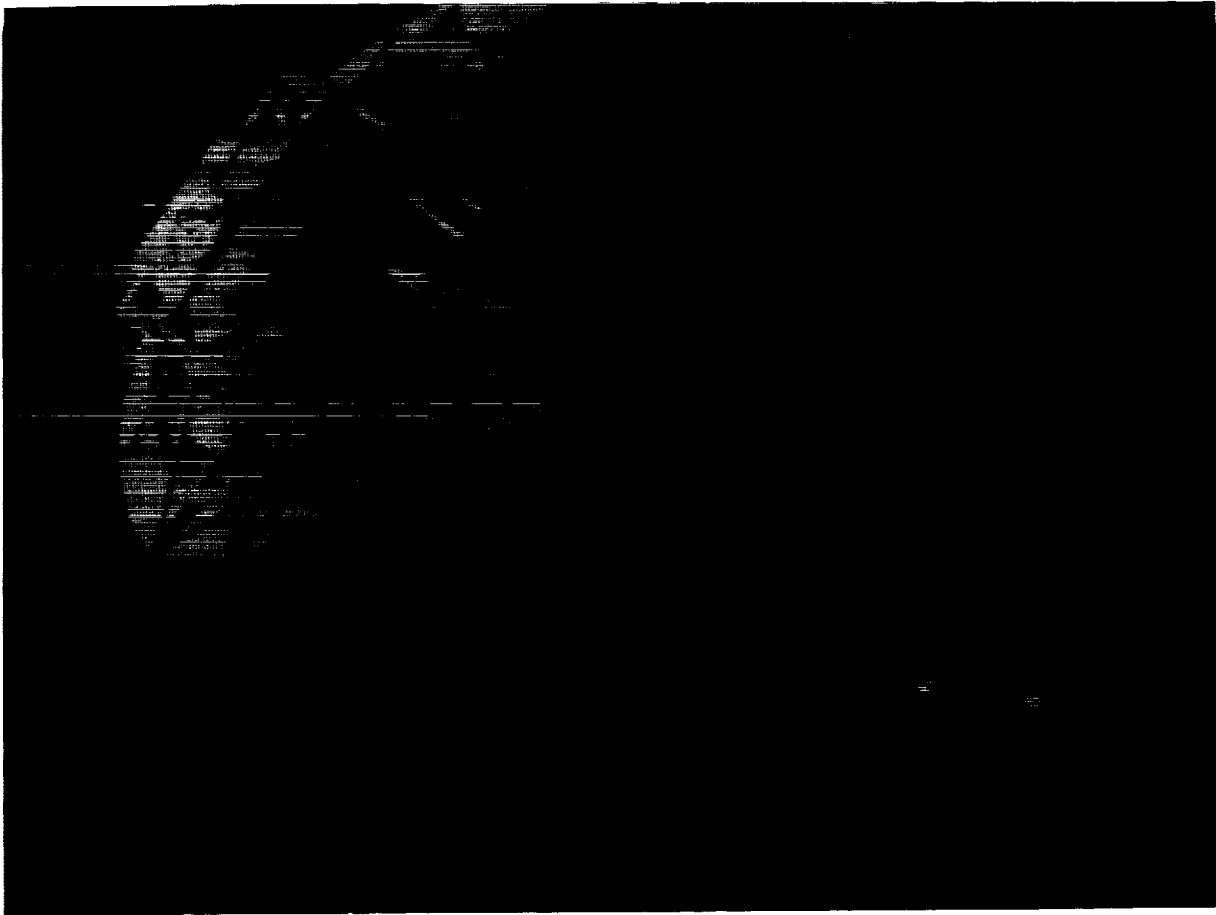
**SPACEHAB<sup>®</sup>**

**MCDONNELL DOUGLAS**

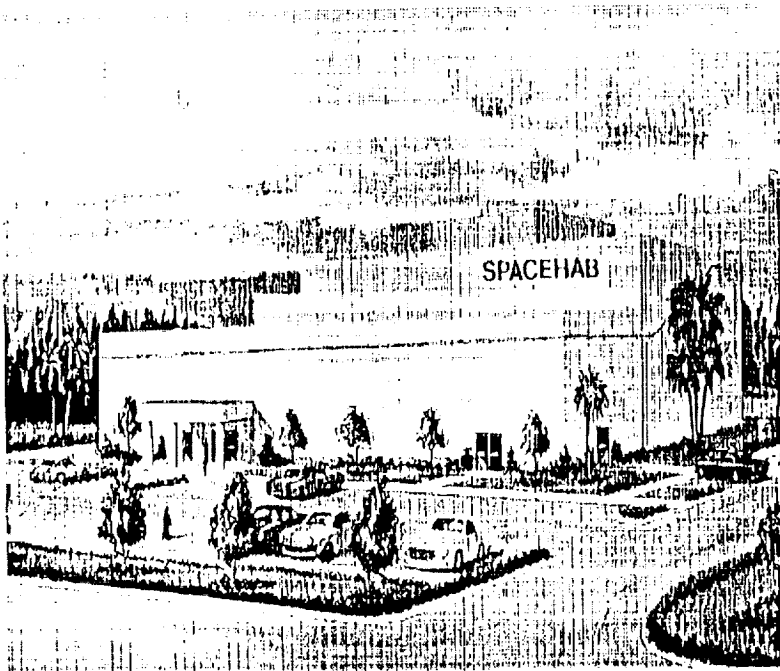




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## SPACEHAB Payload Processing Facility (SPPF)



- 35,000 square feet of payload integration, test, training & support facilities
- 6,000 square feet of Customer Work Area (CWA), subdivided into industrial secure rooms
- **Shipping / Receiving** provided for receipt of hardware.
- **Clean Room** - 100K class conditions in shipping / receiving, CWAs, & integration hall
- General classrooms, conference rooms, copiers, and fax machine available for use on shared basis.
- **Availability date:** 3/1/91
- **Located** on commercial site near KSC.


## FLIGHTS OF U.S. COMMERCIAL PAYLOADS

PAYLOAD NAME	No. Of FLIGHTS	MISSION(S)
1 ASTROCULTURE	1	STS 50
2 AUTOMATED GENERIC BIOPROCESSING APPARATUS	2	Consort 3, 4
3 BIOMODULE	2	Consort 3, 4
4 BIOSERVE INSTRUMENTATION MATERIALS DISPERSION APP.	2	STS 37, 43
5 CONTINUOUS FLOW ELECTROPHORESIS (I, II, & III)	7	STS 4, 6, 7, 8, 12, 16, 23
6 DEMIXING OF IMMISCIBLE POLYMERS MIXER	2	Consort 1, 3
7 DIFFUSIVE MIXING OF ORGANIC SOLUTIONS	2	STS 14, 23
8 DIRECTED POLYMERIZATION APPARATUS (USML-1 GBX exper.)	1	STS 50
9 ELASTOMER-MODIFIED EPOXY RESINS HEATERS	2	Consort 1, 3
10 ELECTRODEPOSITION CELLS	4	Consort 1, 3, 4, STS 40 (GAS 105)
11 EQUIPMENT FOR CONTROLLED LIQUID PHASE SINTERING	1	Consort 4
12 FLUID EXPERIMENT APPARATUS	2	STS 30, 32
13 FOAM-FORMATION DEVICE	2	Consort 1, 3
14 GELATION OF SOLS: APPLIED MICROGRAVITY RESEARCH	1	STS 42
15 GENERIC BIOPROCESSING APPARATUS	1	STS 50
16 PROTEIN CRYSTAL GROWTH (Hand-Held, VDA, PCF, CRIM, GBX)	14*	STS 16, 19, 23, 24, 26, 29, 32, 31, 37, 43, 48, 42, 50
17 INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSES	2	Consort 3, 4
18 INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING	7	STS 31, 41, 43, 48, 42, 45, 50
19 MATERIALS DISPERSION APPARATUS	3	Consort 1, 3, 4
20 METAL SINTERING FURNACE	1	Consort 1
21 NON-LINEAR OPTICAL CRYSTAL GROWTH (DAN) - UAH/IBM	1	STS 40 (GAS 105)
22 NON-LINEAR OPTICAL CRYSTAL GROWTH (NCA) - UAH/TBE	1	STS 40 (GAS 105)
23 PHYSICAL VAPOR TRANSPORT OF ORGANIC SOLIDS	2	STS 20, 26
24 PHYSIOLOGICAL SYSTEMS EXPERIMENTS	1	STS 41
25 PLASMA PARTICLE GENERATION	1	Consort 3
26 POLYMER CURING EXPERIMENT	1	Consort 4
27 POLYMER MORPHOLOGY	1	STS 34
28 POLYMER THIN FILMS	2	Consort 3, STS 40 (GAS 105)
29 SEPARATION OF AQUEOUS PHASES	1	STS 40 (GAS 105)
30 SPACE FORMED STRUCTURAL BEAM (Foam Formation Device)	1	Consort 4
31 YEAST EXPERIMENT	1	STS 40 (GAS-105)
32 ZEOLITE CRYSTAL GROWTH	1	STS 50
<b>32 TOTAL PAYLOAD HARDWARE ITEMS</b>	<b>73 TOTAL NUMBER OF PAYLOAD FLIGHTS**</b>	

16-Jul-92


- \* The Protein Crystal Growth experiments were shared between the OCP and OSSA  
 \*\* A payload-flight = one flight of one payload. Therefore, one flight with 3 payloads = 3 payload-flights

Shuttle - 48  
 Count -  $\frac{25}{73}$

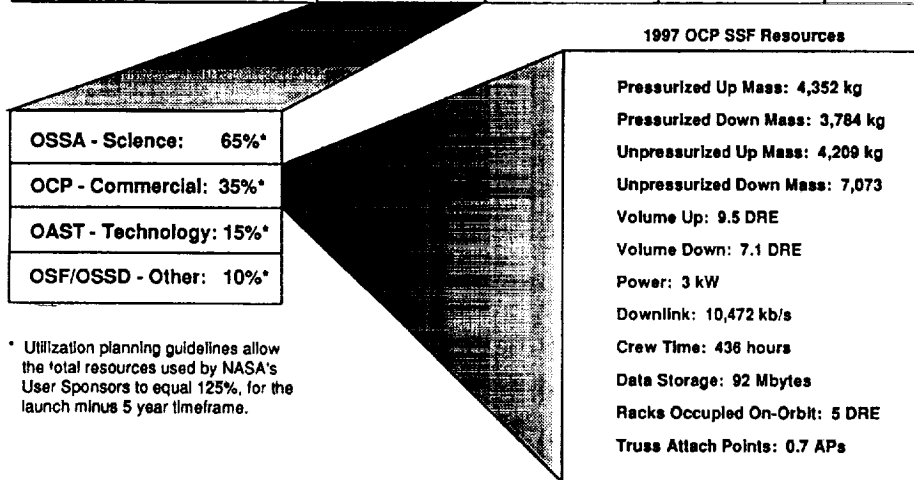


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### SSF RESOURCE ALLOCATIONS

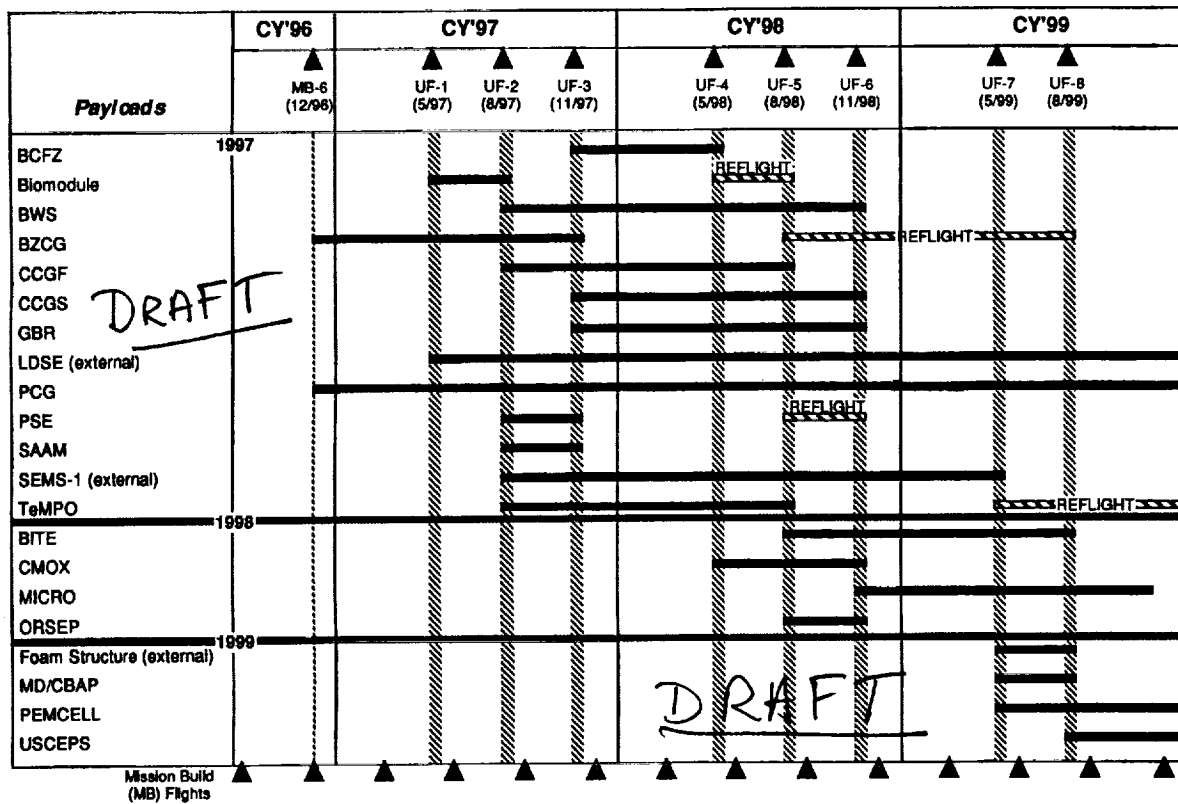


	NASA U.S.A.	MOSST Canada	ESA Europe	STA Japan
Utilization Resources	71.4%	3%	12.8%	12.8%



\* Utilization planning guidelines allow the total resources used by NASA's User Sponsors to equal 125%, for the launch minus 5 year timeframe.

# DRAFT OCP FLIGHT MANIFEST FOR SSF



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The Office of Commercial Programs is Producing

- *A body of applications-oriented scientific knowledge*
- *An experience base in payload flight hardware development and integration*
- *A complement of payload hardware*
- *Transportation systems and carriers*

that will allow us to transition to Space Station Freedom

## LARGE SCALE CRYSTALLIZATION OF PROTEIN PHARMACEUTICALS IN MICROGRAVITY VIA TEMPERATURE CHANGE\*

Presented by Marianna M. Long, Ph.D.  
Center for Macromolecular Crystallography  
University of Alabama at Birmingham

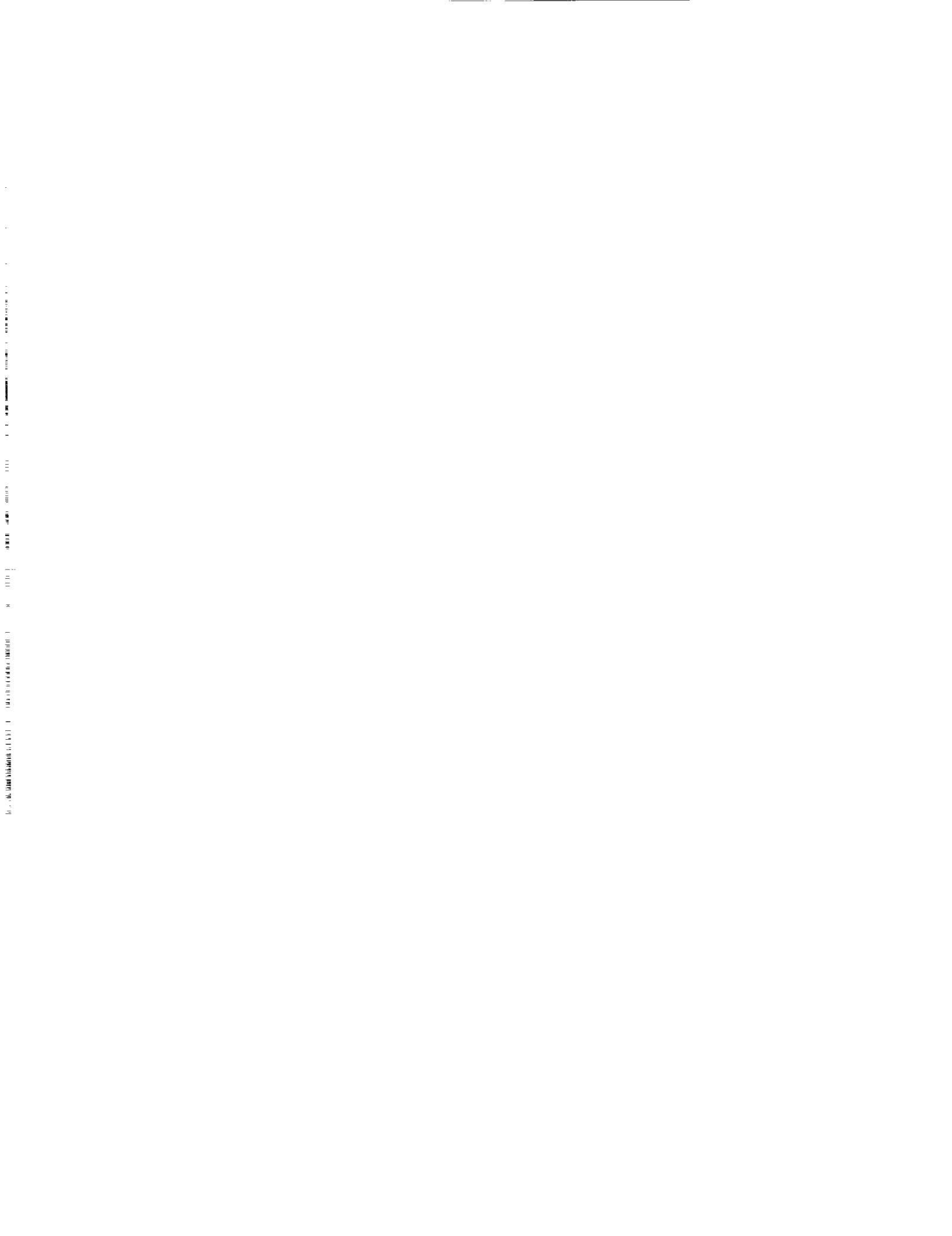
### ABSTRACT

The major objective of this research effort is the temperature driven growth of protein crystals in large batches in the microgravity environment of space. Pharmaceutical houses are developing protein products for patient care, for example, human insulin, human growth hormone, interferons and tissue plasminogen activator or TPA, the clot buster for heart attack victims. Except for insulin, these are very high value products; they are extremely potent in small quantities and have a great value per gram of material. It is feasible that microgravity crystallization can be a cost recoverable, economically sound final processing step in their manufacture.

Large scale protein crystal growth in microgravity has significant advantages from the basic science and the applied science standpoints. Crystal growth can proceed unhindered due to lack of surface effects. Dynamic control is possible and relatively easy. The method has the potential to yield large quantities of pure crystalline product. Crystallization is a time honored procedure for purifying organic materials and microgravity crystallization could be the final step to remove trace impurities from high value protein pharmaceuticals. In addition, microgravity grown crystals could be the final formulation for those medicines that need to be administered in a timed release fashion. Long lasting insulin, insulin lente, is such a product. Also crystalline protein pharmaceuticals are more stable for long-term storage. Temperature, as the initiation step, has certain advantages. Again, dynamic control of the crystallization process is possible and easy. A temperature step is non-invasive and is the most subtle way to control protein solubility and therefore crystallization. Seeding is not necessary. Changes in protein and precipitant concentrations and pH are not necessary. Finally, this method represents a new way to crystallize proteins in space that takes advantage of the unique microgravity environment.

The hardware design for the Protein Crystallization Facility (PCF) entails four polysulfone cylinders (500, 200, 100, 50 ml total volume) of different heights and same diameters. The aluminum cap of each cylinder is apposed to the heating element of the R/IM and the temperature is decreased from 40°C to 22°C early in the mission for insulin, the sample used for STS-37 and STS-3. The four cylinder sizes resulted in four different temperature gradients. On STS-37, the temperature was ramped down in four steps over 23 hours, while on STS-43 the ramp was in one step.

The results from these two flights showed that the hardware performed perfectly, many crystals were produced and they were much larger than their ground grown controls. Morphometric analysis was done on over 4,000 crystals to establish crystal size, size distribution and relative size. Space grown crystals were remarkably larger than their earth grown counterparts and crystal size was a function of PCF volume. For example, for the largest volume PCF (500 ml) from STS-37, the space crystals were 10 times bigger than controls while for the smallest volume (50 ml) they were 2 times bigger. That size distribution for the space grown crystals was a function of PCF volume may indicate that ultimate size was a function of temperature gradient. Since the insulin protein concentration was very low, 0.4 mg/ml, the size distribution could also be following the total amount of protein in each of the PCFs. X-ray analysis showed that the bigger space grown insulin crystals diffracted to higher resolution than their ground grown controls. When the data were normalized for size, they still indicated that the space crystals were better than the ground crystals.



**CENTER FOR  
MACROMOLECULAR CRYSTALLOGRAPHY**

**A NASA CENTER FOR THE COMMERCIAL DEVELOPMENT  
OF SPACE**

**PROTEIN CRYSTALLIZATION  
FACILITY  
(PCF)**

**Presentation by Marianna M. Long**

**Space Station Freedom  
Utilization Workshop**

**Huntsville, Alabama  
August 4-6, 1992**

# PROTEIN CRYSTALLIZATION FACILITY

(PCF)

## OBJECTIVES

- To grow protein crystals in large batches
- To use temperature as the means to initiate and control protein crystal growth

# PROTEIN CRYSTALLIZATION FACILITY

(PCF)

## ADVANTAGES OF LARGE SCALE PROTEIN CRYSTAL GROWTH

- No surface effects to interfere with crystal growth
- Easy dynamic control is possible
- Yields large quantities of large, very pure crystals
  - Purity of protein is achieved
  - Uniformity of size of protein crystal is possible
  - Patentability is enhanced and this stimulates commercial interest



# PROTEIN CRYSTALLIZATION FACILITY (PCF)

## ADVANTAGES OF TEMPERATURE IN PROTEIN CRYSTAL GROWTH

- Dynamic control is possible
- Non-invasive, most subtle way to control protein solubility
- No seeding is necessary
- No changes in [protein], [precipitant], or pH are necessary
- Represents a new way to crystallize proteins that takes advantage of microgravity environment

# PROTEIN CRYSTALLIZATION FACILITY (PCF)

## HARDWARE DESIGN

- Polysulfone with neoprene O-rings
- 4 cylinders: 500ml,200ml,100ml,50ml
- All have the same diameter with different heights
- The metal cap of each cylinder is apposed to the heating element of the R/IM and the temperature is decreased from 40C to 22C early in flight
- Insulation is around each cylinder
- The 4 sizes will result in 4 different temperature gradients

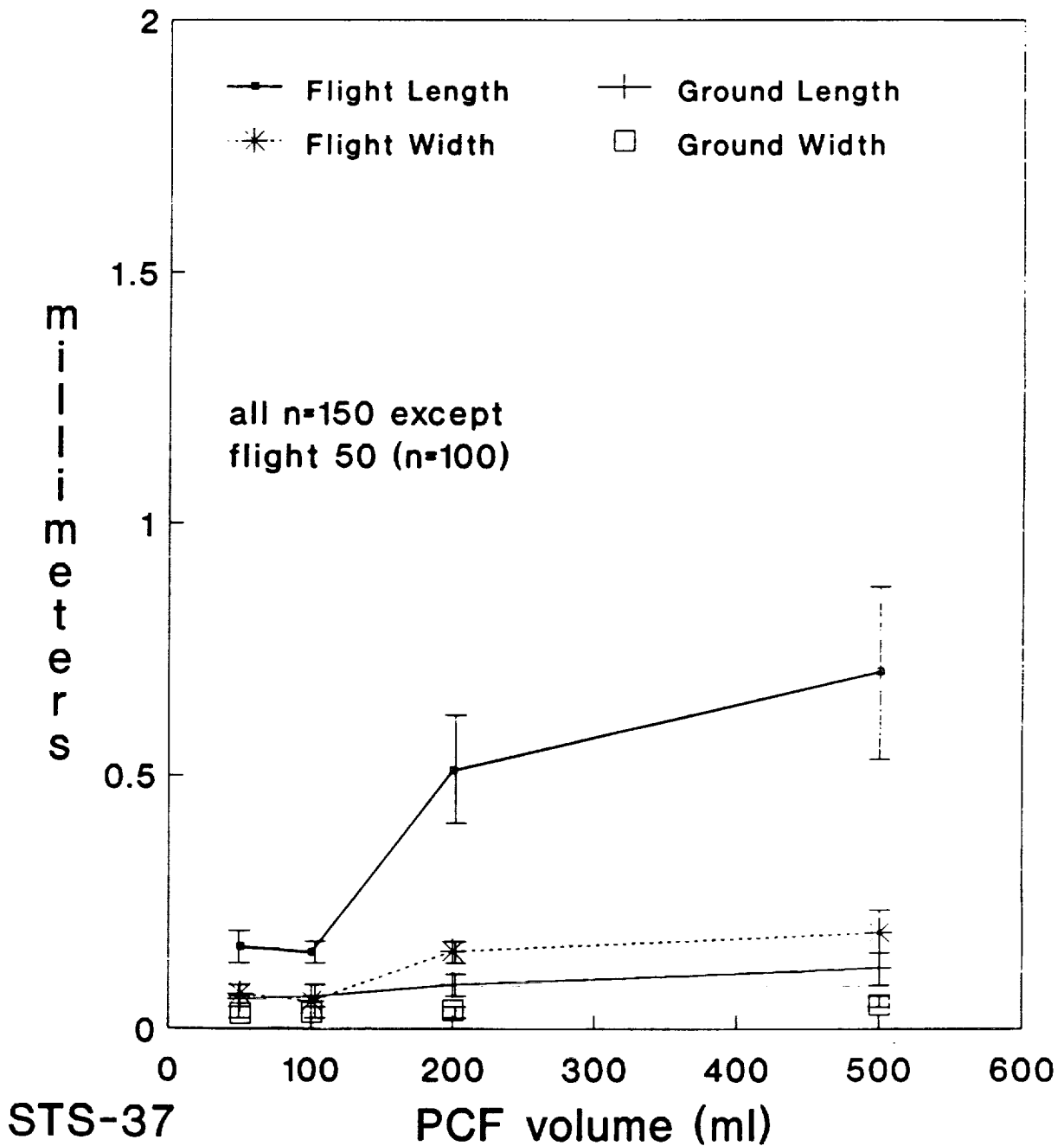
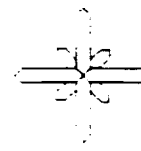
PROTEIN CRYSTALLIZATION FACILITY  
(PCF)

TEMPERATURE STEPS

STS-37

<u>TIME</u>	<u>TEMP STEP</u>
L+3	40->36C
L+9	36->32C
L+19	32->28C
L+26	28->22C

# Length and Width of "Rosette" Crystals



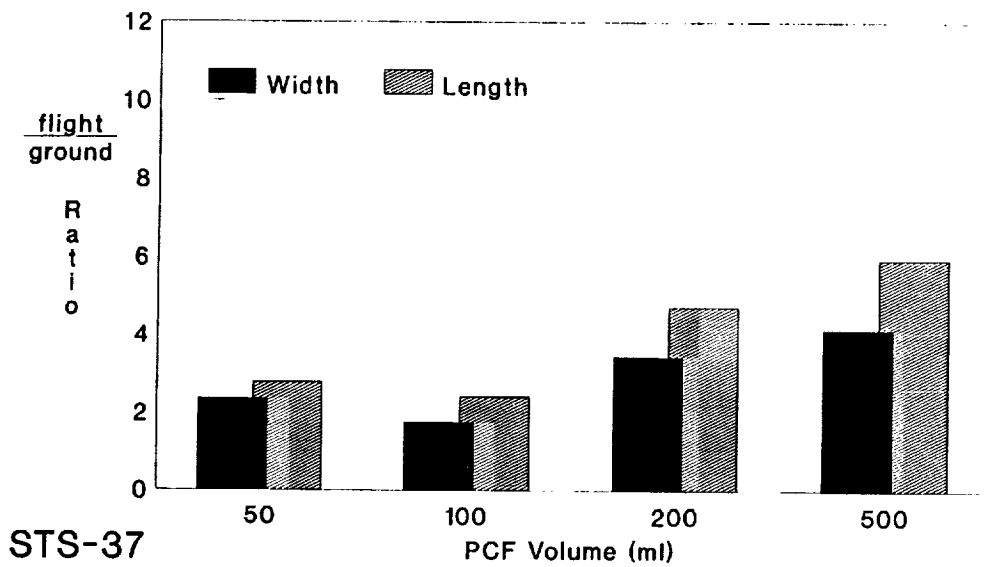
# Comparison of Flight to Ground "Rosette" Crystals

by:  $\frac{\text{flight crystals}}{\text{ground crystals}}$

PCF	Length	Width
500	5.94	4.13
200	4.71	3.43
100	2.40	1.74
50	2.76	2.34

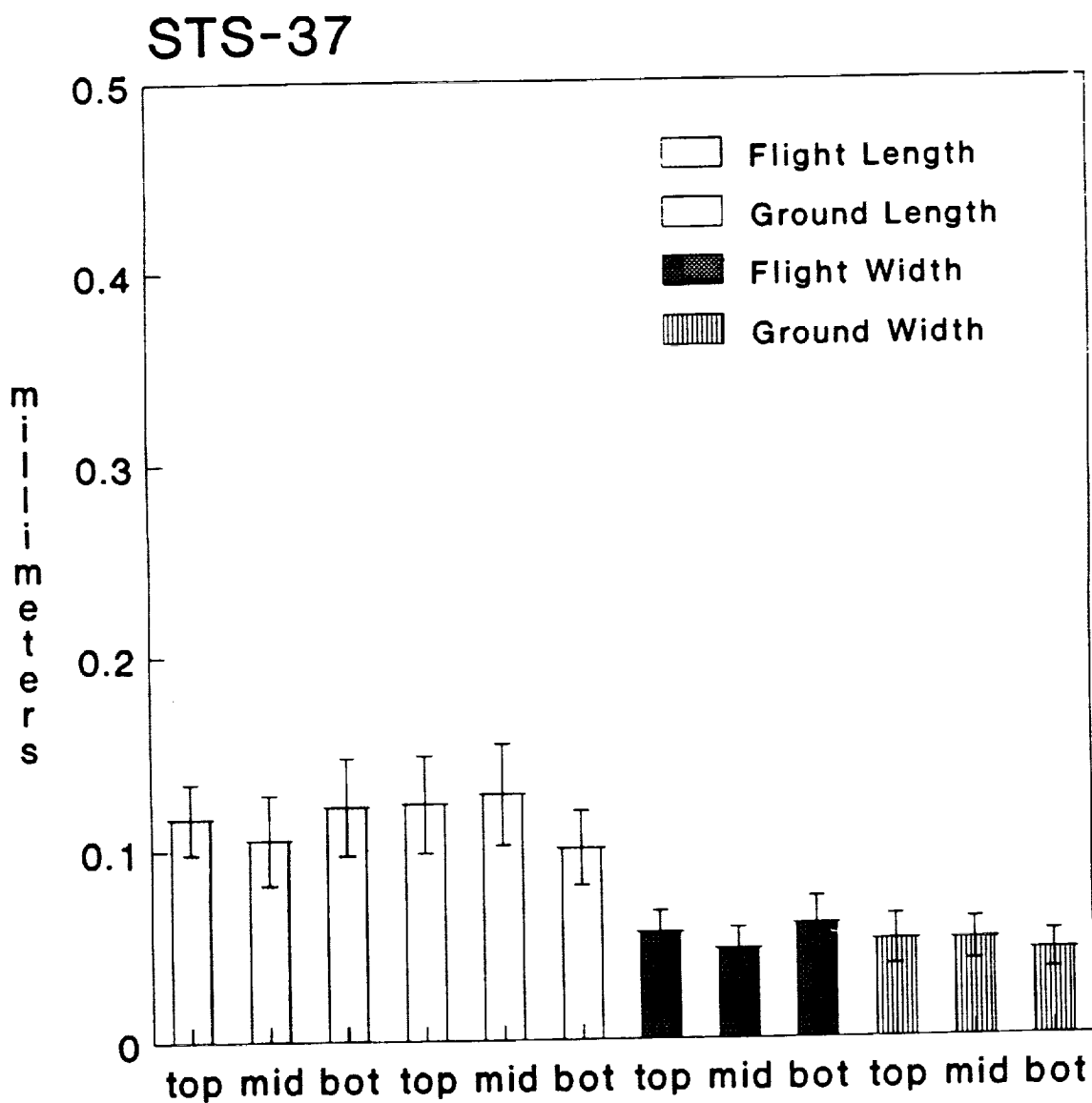
**STS-37**

# Comparison of Flight to Ground "Rosette" Crystals

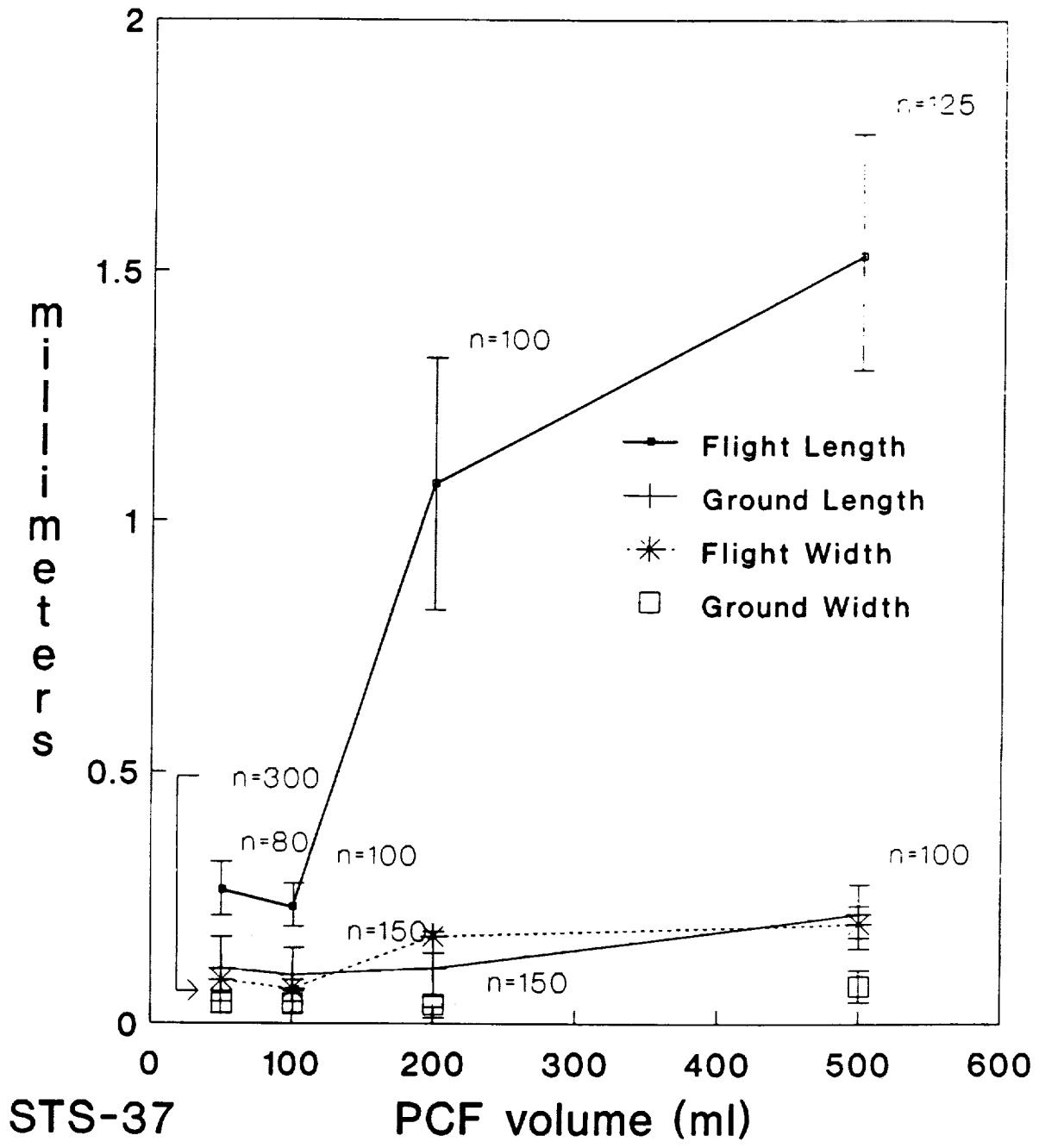
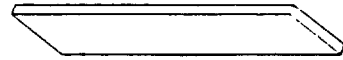


STS-37

# "Rosette" Crystal Size on Side of 500ml PCF Relative to Location Down Long Axis



# Length and Width of Single Crystals



# Comparison of Flight to Ground Single Crystals

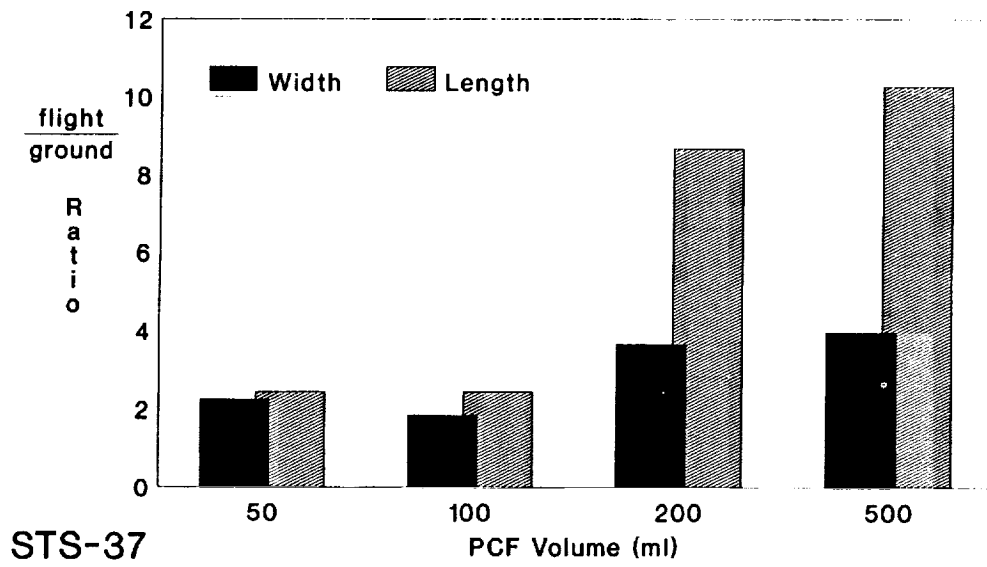
by:  $\frac{\text{flight crystals}}{\text{ground crystals}}$

PCF	Length	Width
500	10.26	3.96
200	8.66	3.66
100	2.42	1.84
50	2.42	2.24

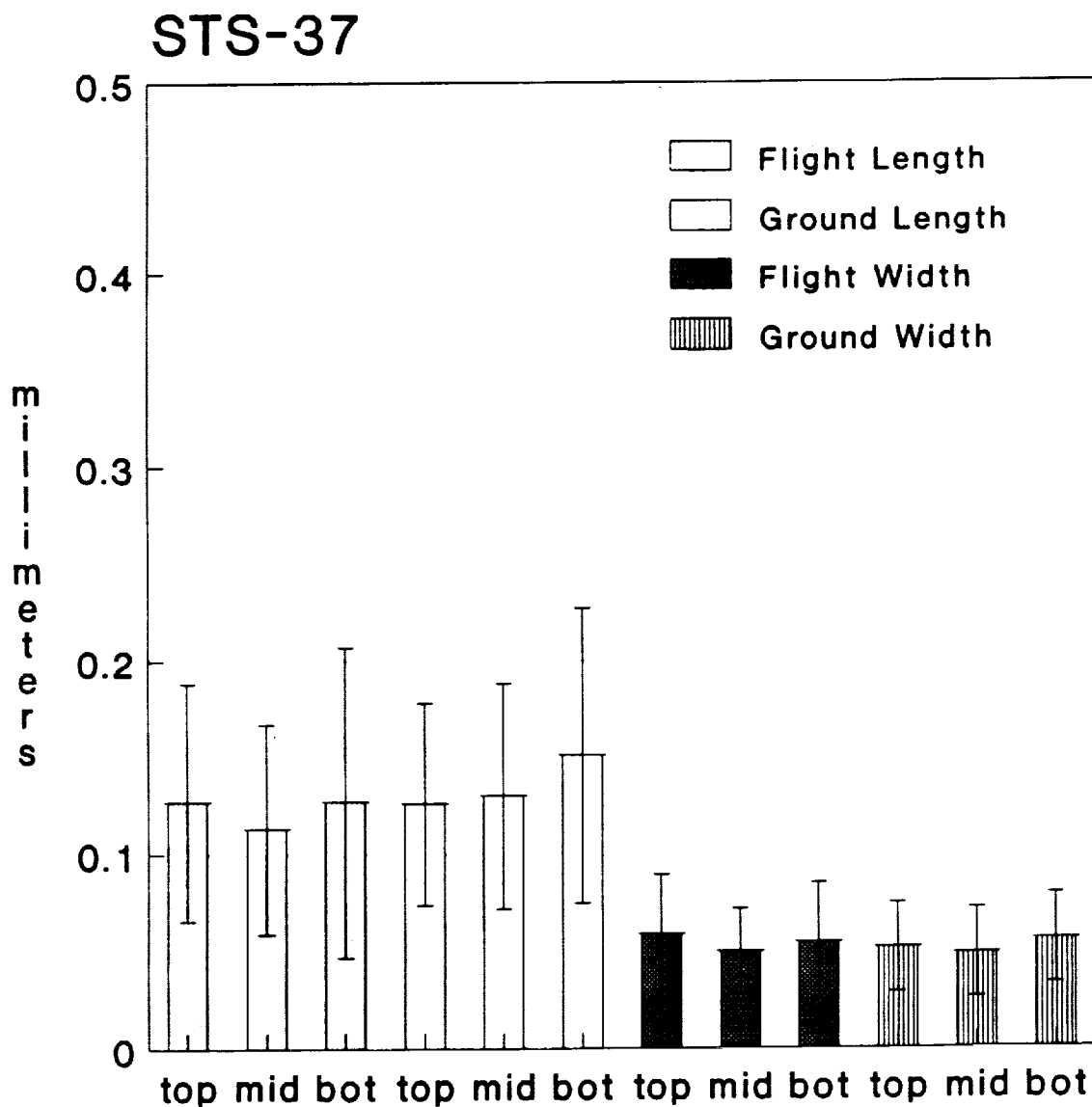
STS-37

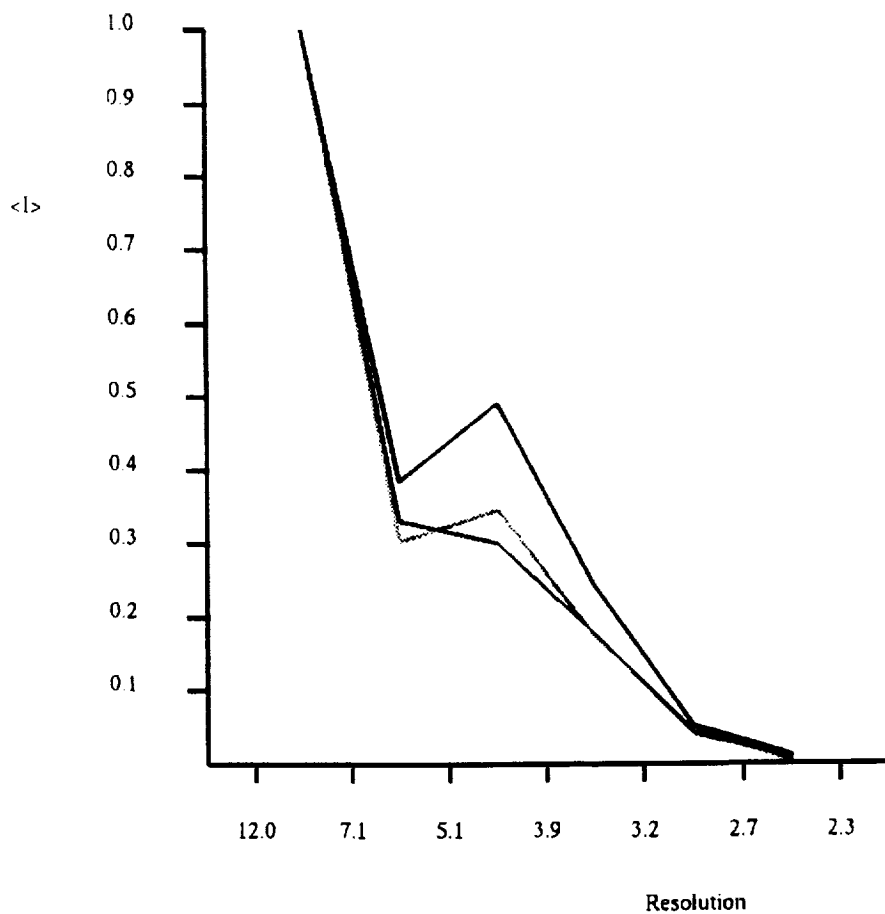


# Comparison of Flight to Ground Single Crystals



# Single Crystal Size on Side of 500ml PCF Relative to Location Down Long Axis





PROTEIN CRYSTALLIZATION FACILITY  
(PCF)

TEMPERATURE STEPS

STS-43

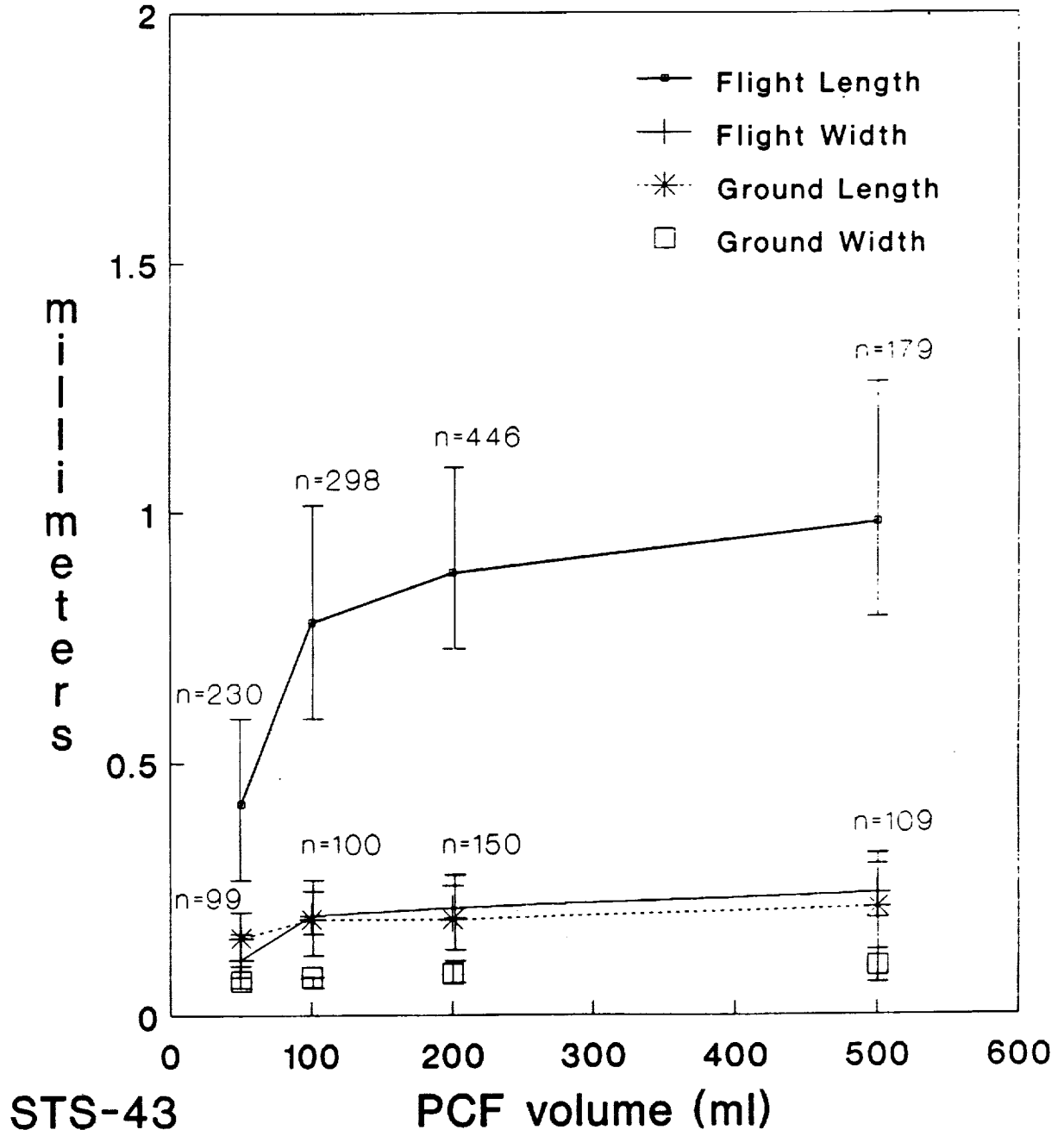
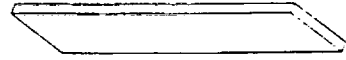
TIME

TEMP STEP

L+4

40-→22C

# Length and Width of Single Crystals



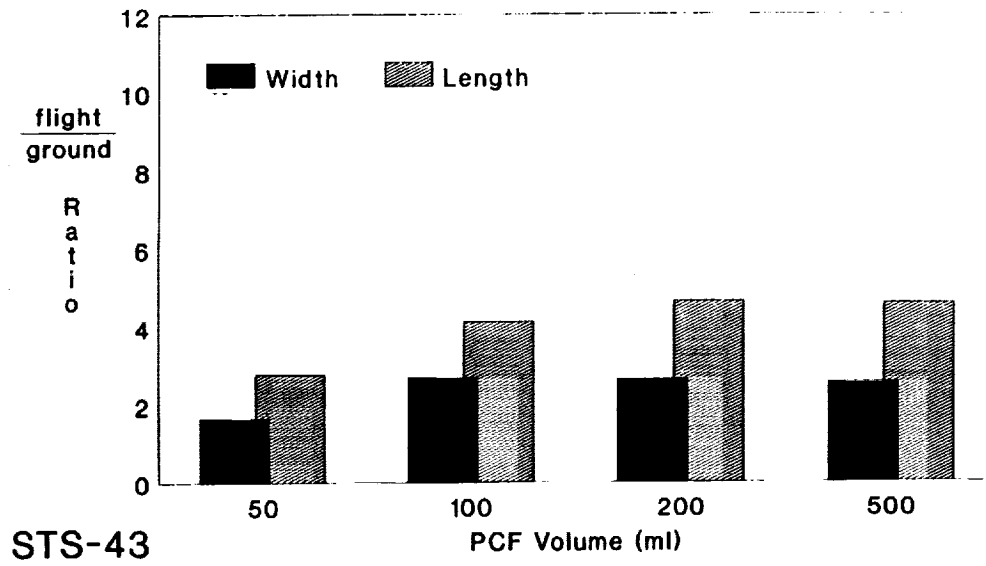
# Comparison of Flight to Ground Single Crystals

by:  $\frac{\text{flight crystals}}{\text{ground crystals}}$

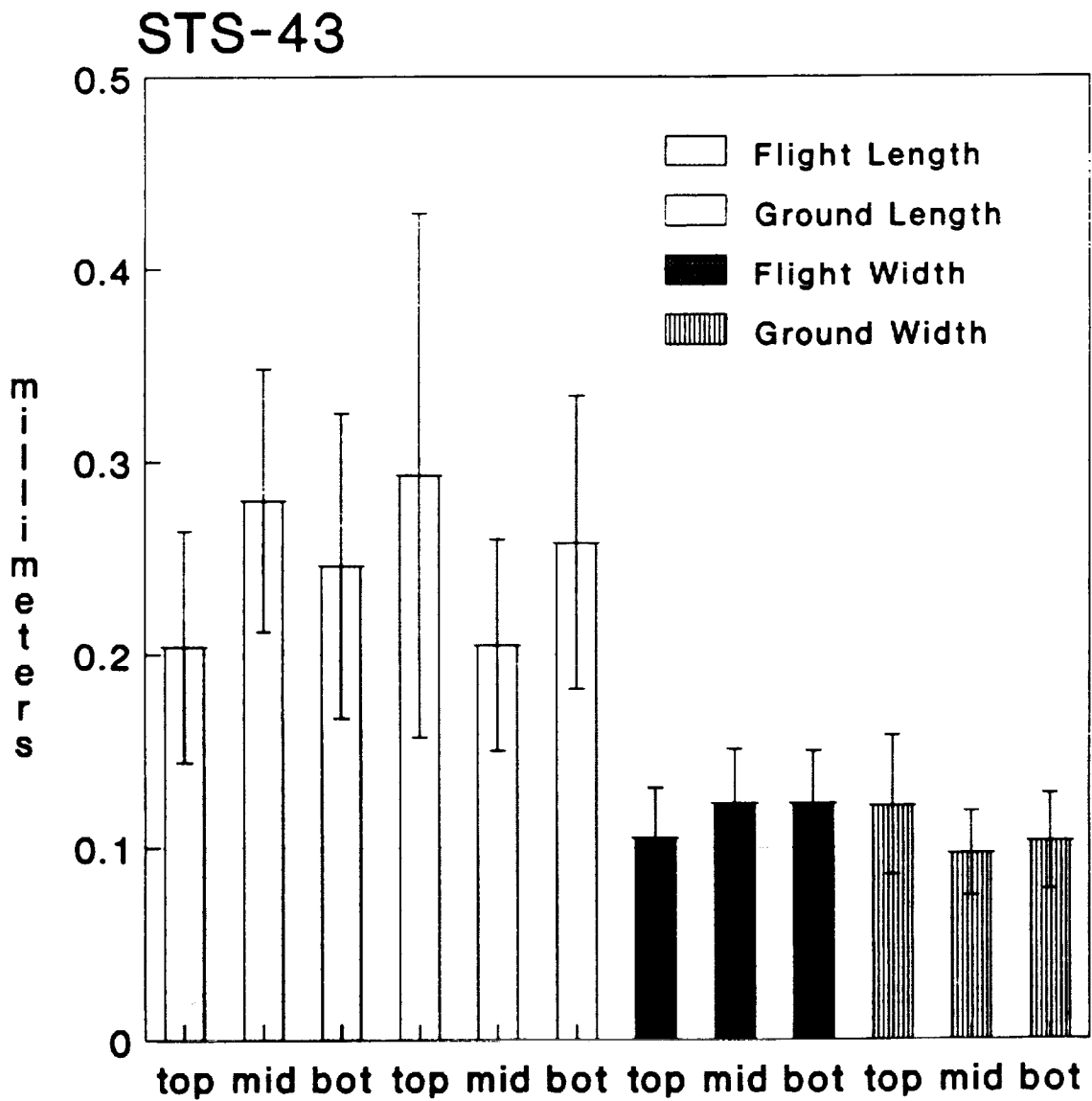
PCF	Length	Width
500	4.58	2.55
200	4.65	2.64
100	4.12	2.68
50	2.76	1.65

STS-43

# Comparison of Flight to Ground Single Crystals

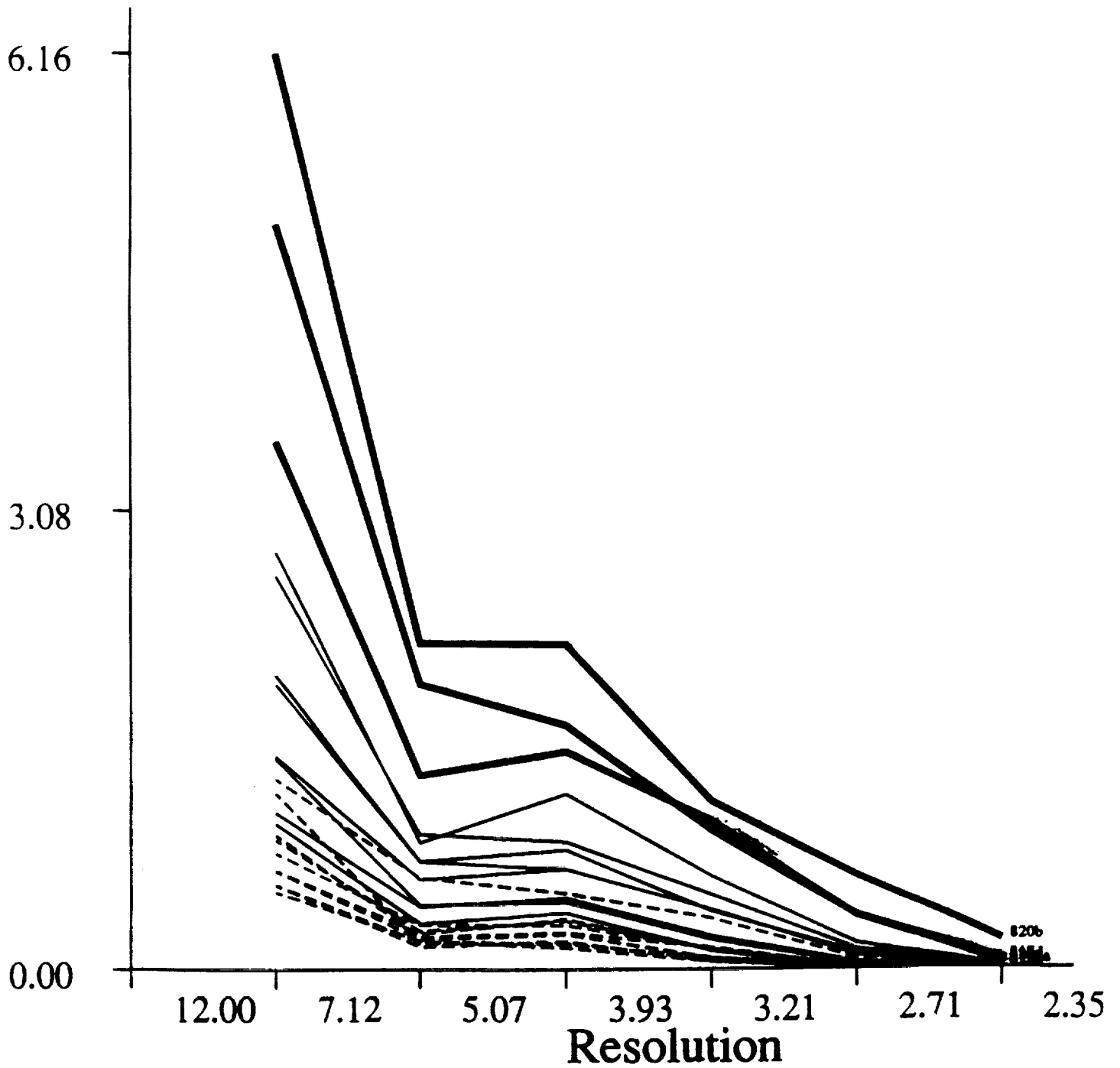


# Single Crystal Size on Side of 500ml PCF Relative to Location Down Long Axis



$\langle I \rangle$  in bin (peaks  $> 5\sigma$ ,  $\sigma$  units)

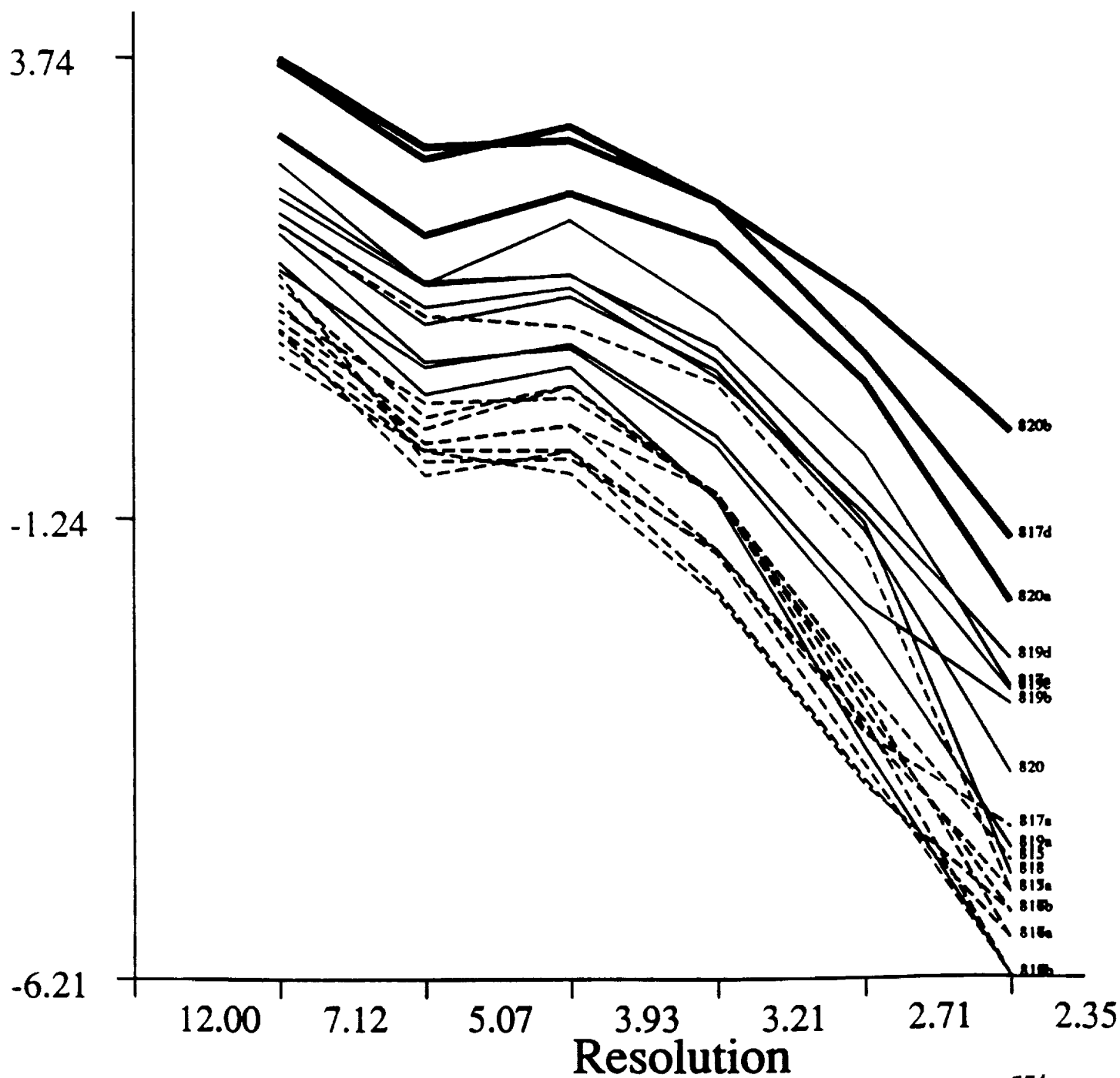
Ground Based            - - - - -  
Space Crystals        - - - - -  
Giants of Space        - - - - -





$\log\langle I \rangle$  in bin (peaks  $> 5\sigma$ , raw units)

Ground Based            - - - - -  
Space Crystals        - - - - -  
Giants of Space        - - - - -



# PROTEIN CRYSTALLIZATION FACILITY

(PCF)

## PROTEIN TO BE CRYSTALLIZED

- Insulin, at 0.4 mg/ml, in phosphate buffer, will be the first protein to fly in the PCF
- The temperature is decreased from 40C to 22C early in the flight

## COMMERCIAL OPPORTUNITIES IN BIOSEPARATIONS AND PHYSIOLOGICAL TESTING ABOARD SPACE STATION FREEDOM

Presented by Dr. W. C. Hymer  
Center for Cell Research  
A NASA Center for the Commercial Development of Space  
The Pennsylvania State University

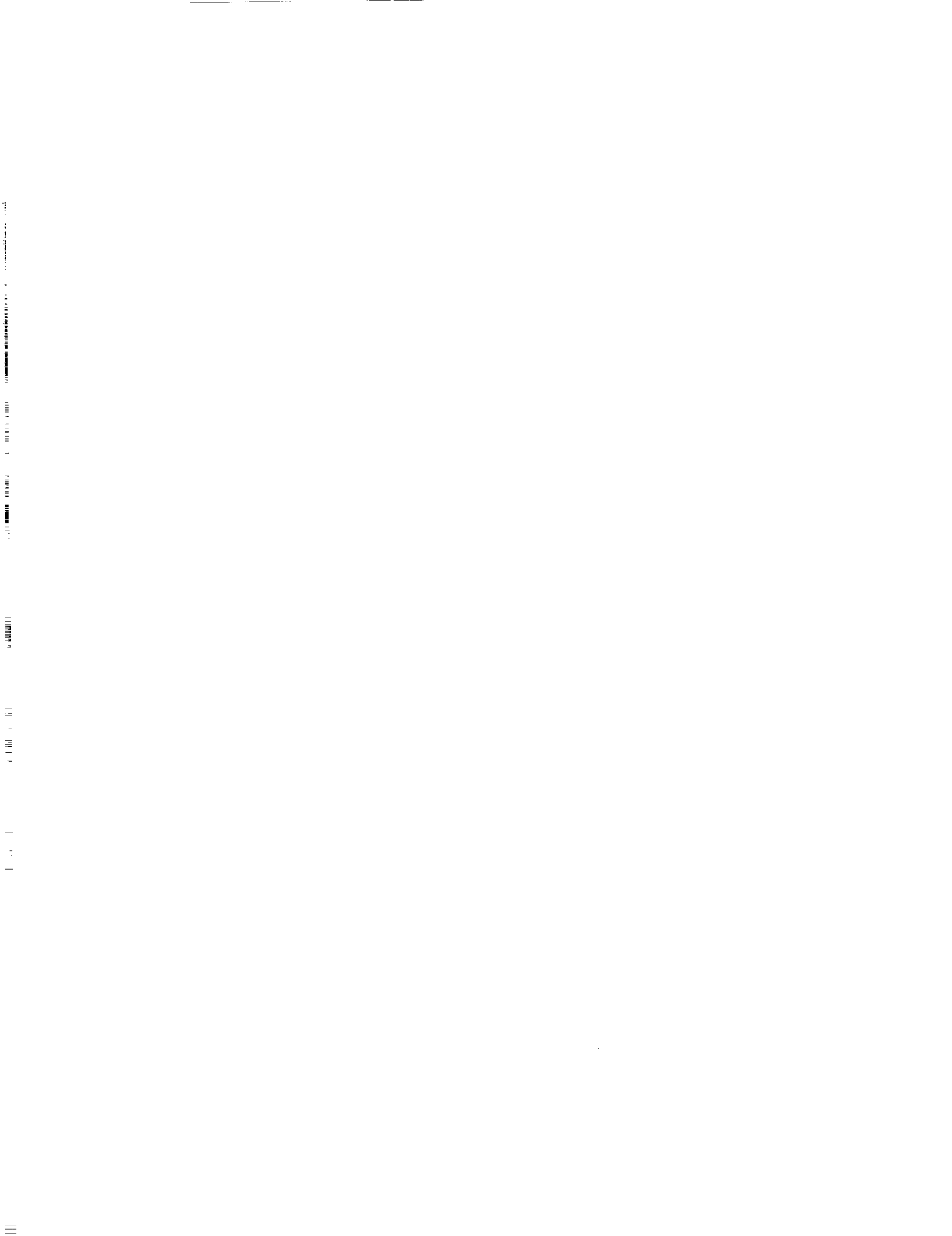
### ABSTRACT

The Center for Cell Research (CCR) is a NASA Center for the Commercial Development of Space which has as its main goal encouraging industry-driven biomedical/biotechnology space projects. Space Station Freedom (SSF) will provide long duration, crew-tended microgravity environments which will enhance the opportunities for commercial biomedical/biotechnology projects in bioseparations and physiological testing.

The CCR bioseparations program, known as USCEPS (for United States Commercial Electrophoresis Program in Space), is developing access for American industry to continuous-flow electrophoresis aboard SSF. In space, considerable scale-up of continuous free-flow electrophoresis is possible for cells, subcellular particles, proteins, growth factors and other biological products. The lack of sedimentation and buoyancy-driven convection flow enhances purity of separations and the amount of material processed/time.

Through the CCR's physiological testing program, commercial organizations will have access aboard SSF to physiological systems experiments (PSEs); the Penn State Biomodule; and telemicroscopy. Physiological systems experiments involve the use of live animals for pharmaceutical product testing and discovery research. The Penn State Biomodule is a computer-controlled minilab useful for projects involving live cells or tissues and macromolecular assembly studies, including protein crystallization. Telemicroscopy will enable staff on Earth to manipulate and monitor microscopic specimens on SSF for product development and discovery research or for medical diagnosis of astronaut health problems.

Space-based product processing, testing, development and discovery research using USCEPS and CCR's physiological testing program offer new routes to improved health on Earth. Direct crew involvement in biomedical/biotechnology projects aboard SSF will enable better experimental outcomes. The current data base shows that there is reason for considerable optimism regarding what the CCDS program and the biomedical/biotechnology industry can expect to gain from a permanent manned presence in space.



# THE CENTER FOR CELL RESEARCH

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COMMERCIAL OPPORTUNITIES IN BIOSEPARATIONS AND  
PHYSIOLOGICAL TESTING ABOARD SSF

SPACE STATION FREEDOM UTILIZATION CONFERENCE

PENNSTATE



AUGUST 5, 1992

PENNSTATE



THE CENTER FOR  
CELL RESEARCH

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NASA

CODE C

CODE S

CODE... ..

17 CCDS

CCR

NASA CODE C MISSION

"...TO SEEK AND ENCOURAGE, TO THE MAXIMUM EXTENT POSSIBLE,  
THE FULLEST COMMERCIAL USE OF SPACE."

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555



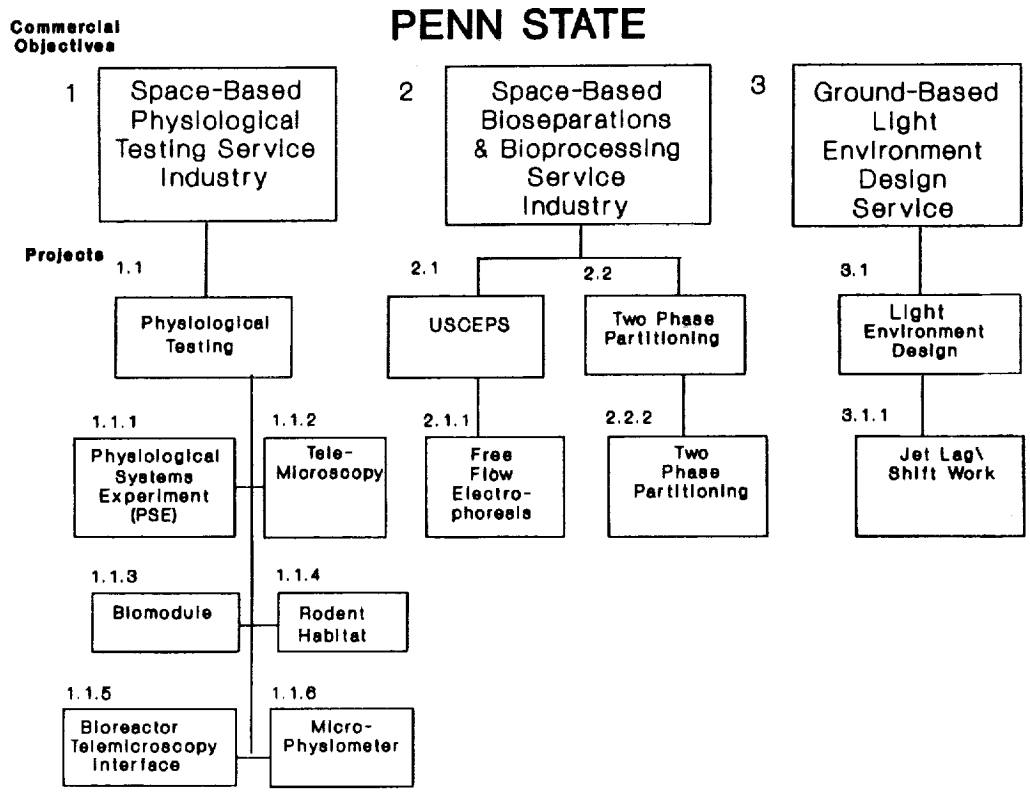
**CCR COMMERCIAL PARTNER PROGRAM  
FOR  
PRODUCT TESTING AND INDUSTRY-DRIVEN DISCOVERY RESEARCH**

- 1. FLIGHT ACCESS**
- 2. EXPERIMENT PLANNING AND POST FLIGHT ANALYSIS**
- 3. PAYLOAD PLANNING, INTEGRATION, MISSION MANAGEMENT**
- 4. FLIGHT CERTIFIED HARDWARE**
- 5. INTELLECTUAL PROPERTY AGREEMENTS**
- 6. SUPPORT**



**MAIN GOAL: ASSIST INDUSTRY IN PLANNING AND ACCOMPLISHING  
BIOTECHNOLOGY/BIOMEDICAL SPACE PROJECTS**

**BIOSEPARATION  
PHYSIOLOGICAL TESTING  
ILLUMINATION**



**SPACE BIOTECHNOLOGY: OPPORTUNITIES FOR  
INVESTIGATIONS IN CELLULAR PHYSIOLOGY  
AND BIOSEPARATIONS**



## WHY SPACE BIOTECHNOLOGY

### PHYSIOLOGICAL TESTING

EXPOSING ANIMALS AND MAN TO SURPRISINGLY SHORT PERIODS OF MICROGRAVITY CAUSES PHYSIOLOGICAL CHANGES WHICH RESEMBLE HUMAN DISEASES, SUCH AS OSTEOPOROSIS, MUSCLE WASTAGE, ABNORMAL HORMONE SECRETION, LOWERED IMMUNE FUNCTION AND AGING. SPACEFLOWN ANIMALS AND CELLS CAN BE USED AS MODELS FOR THESE CONDITIONS.



## OBSERVED MICROGRAVITY EFFECTS

### SOUNDING ROCKETS

7 MINUTES  $\mu\text{G}$ '

#### CELL PHYSIOLOGY

Hybridoma production  $\uparrow$   
Oncogene expression  $\downarrow$   
PKC pathway  
Microtubule dysfunction  
Electrophoretic cell separation  $\uparrow$

### U.S. SPACE SHUTTLE/RUSSIAN SATELLITE

7-14 DAYS  $\mu\text{G}$

#### ANIMAL PHYSIOLOGY

Bone demineralization  
Muscle atrophy  
Immune dysfunction  
Endocrine dysfunction  
Low hematocrit  
Loss of body fluids  
Altered liver enzymes  
Wound healing  $\downarrow$   
Bone breaking  $\downarrow$

### SKYLAB-MIR

3-12 MONTHS  $\mu\text{G}$

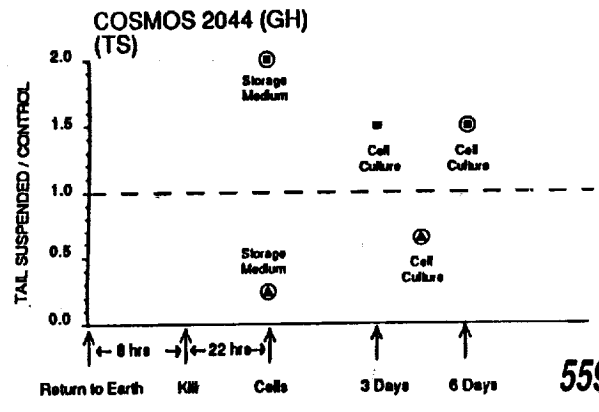
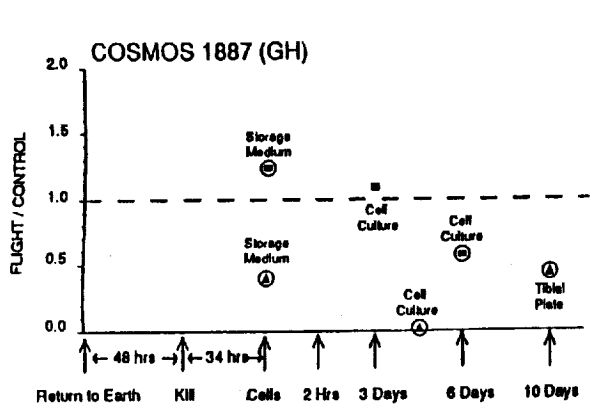
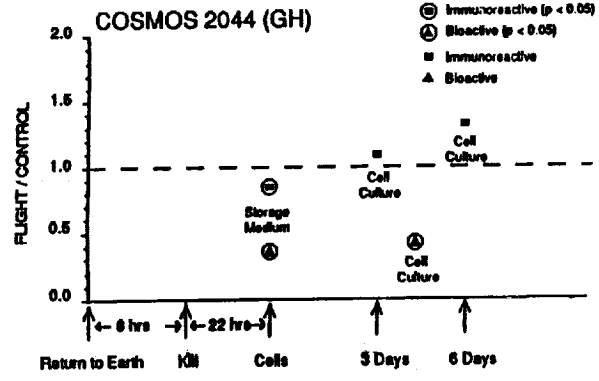
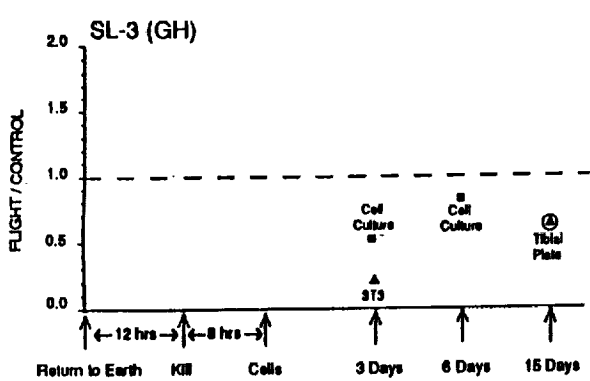
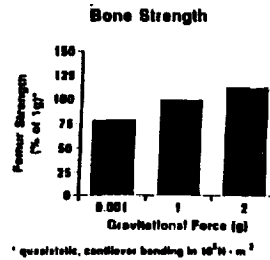
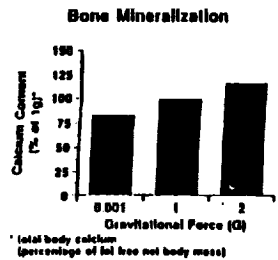
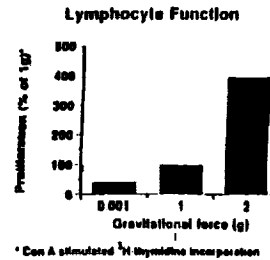
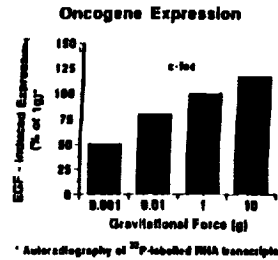
#### EFFECTS IN HUMANS

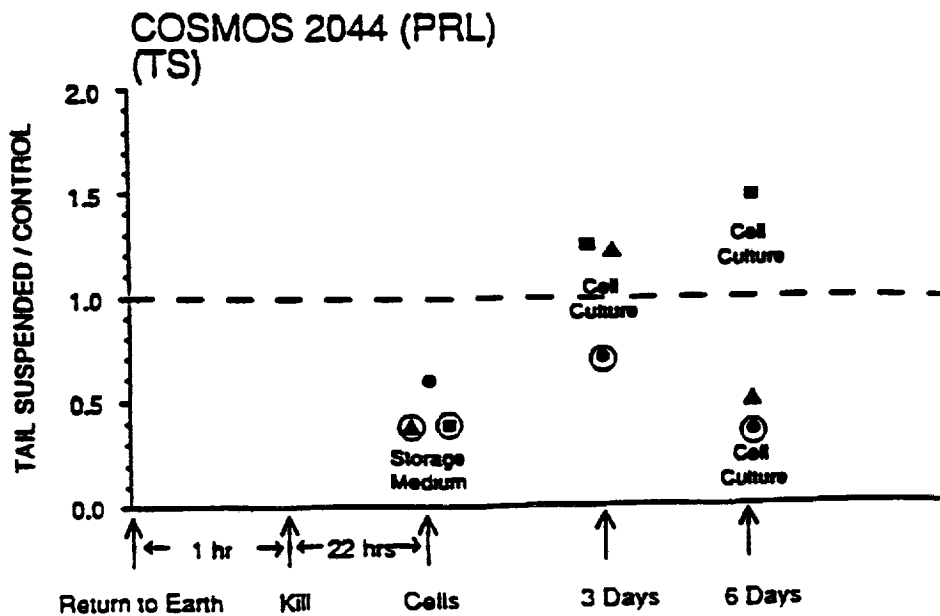
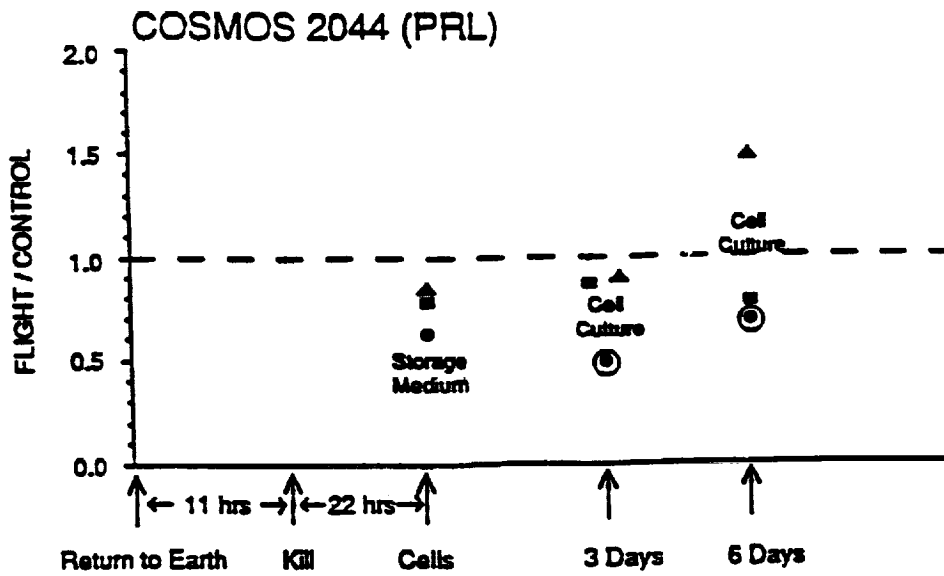
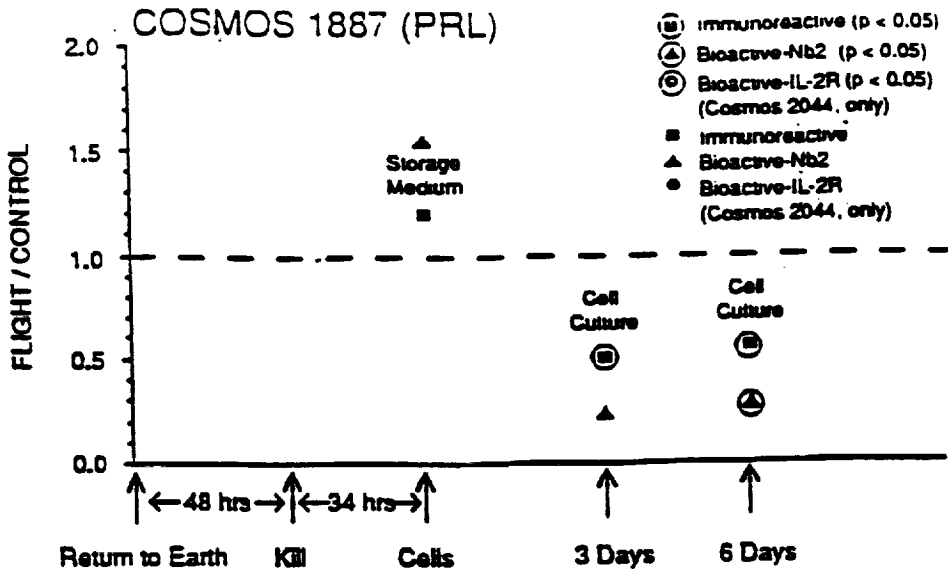
Spinal decompression  
Edema  
Negative calcium balance  
Muscle weakness  
Cardiovascular changes  
Neurovestibular changes

$\mu\text{g} = 10^{-6}\text{G}$



# OBSERVED MICROGRAVITY EFFECTS







## SINGLE CELLS IN REDUCED GRAVITY

- BACTERIAL PROLIFERATE MORE RAPIDLY
- BACTERIAL CONJUNCTION RATE INCREASED
- INCREASED RESISTANCE OF E. COLI TO ANTIBIOTICS
- REDUCTION IN SPORULATION RATE
- 4 FOLD INCREASE IN PROLIFERATION OF PARAMECIUM TETRAURELIA
- VIRTUAL TOTAL SUPPRESSION OF BLASTOGENIC RESPONSE IN T-LYMPHOCYTES EXPOSED TO CON-A
- RAT PITUITARY CELLS SHOW 20 FOLD SUPPRESSION OF BASAL GH RELEASE POSTFLIGHT
- 5 FOLD INCREASE IN GAMMA-INTERFERON PRODUCTION IN  $\mu$ G
- INCREASE IN MEMBRANE FUSION EVENTS (HYBRIDOMA)
- DECREASED GLUCOSE CONSUMPTION IN HUMAN EMBRYONIC LUNG FIBROBLASTS



## FIRST COMMERCIAL PHYSIOLOGICAL TESTING

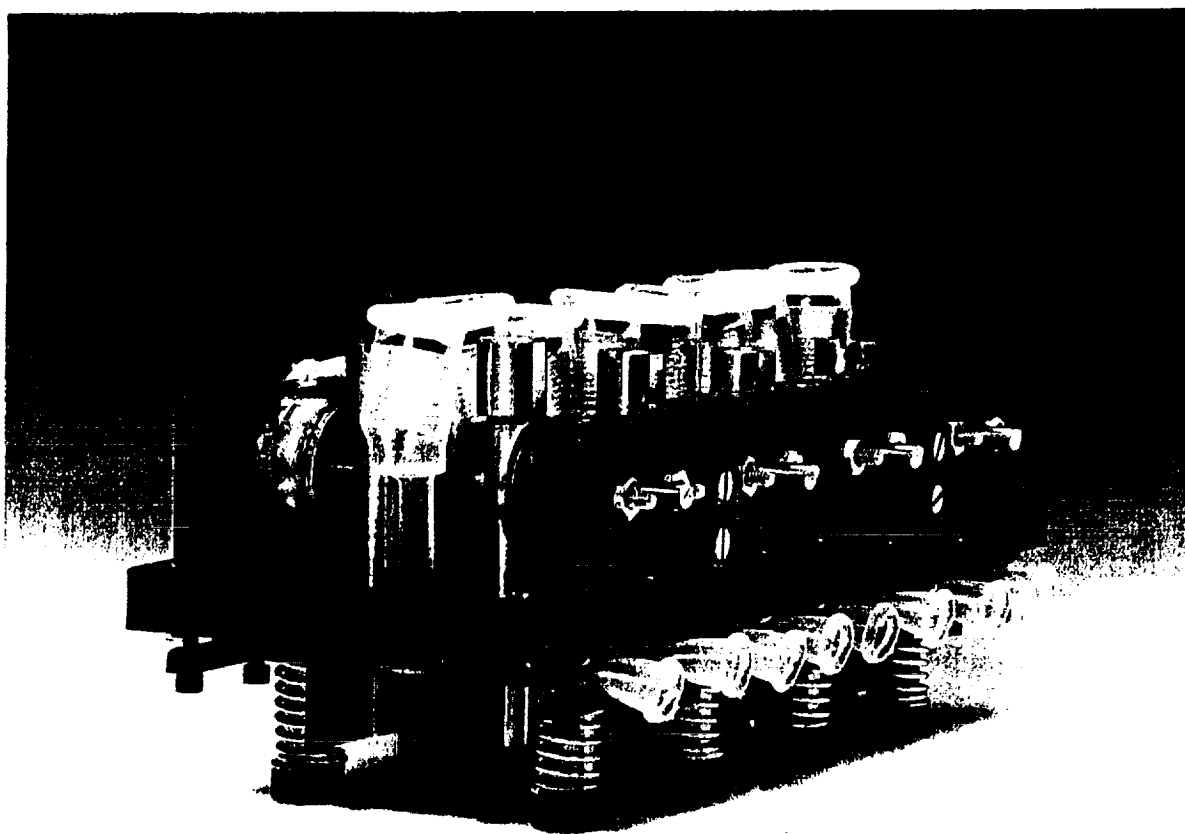
### EXPERIMENT IN SPACE

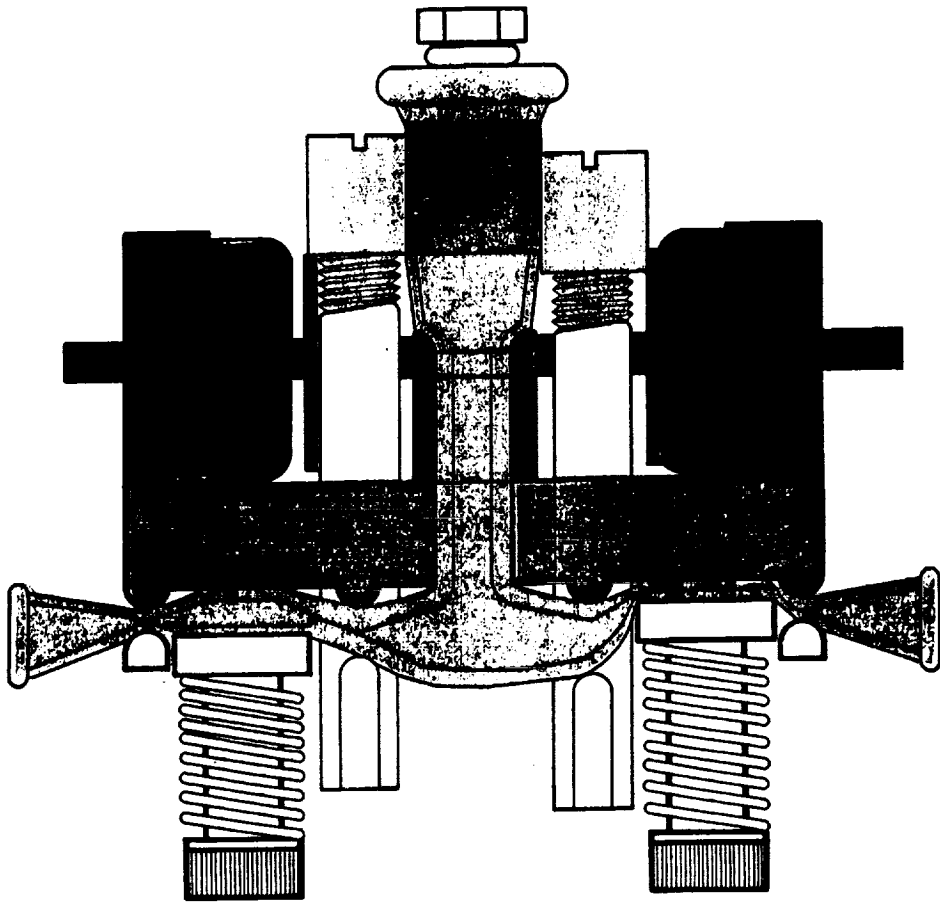
- GENENTECH, INC. AND CENTER FOR CELL RESEARCH
- SPACE SHUTTLE DISCOVERY OCTOBER 6, 1990
- COMMERCIAL GOAL: PROPRIETARY
- EXPERIMENT MEASURED THE EFFECT OF A NUMBER OF PROTEINS
- GENENTECH'S ASSESSMENT: "THE SYSTEM CAN WORK WITH PRIVATE ENTERPRISE"



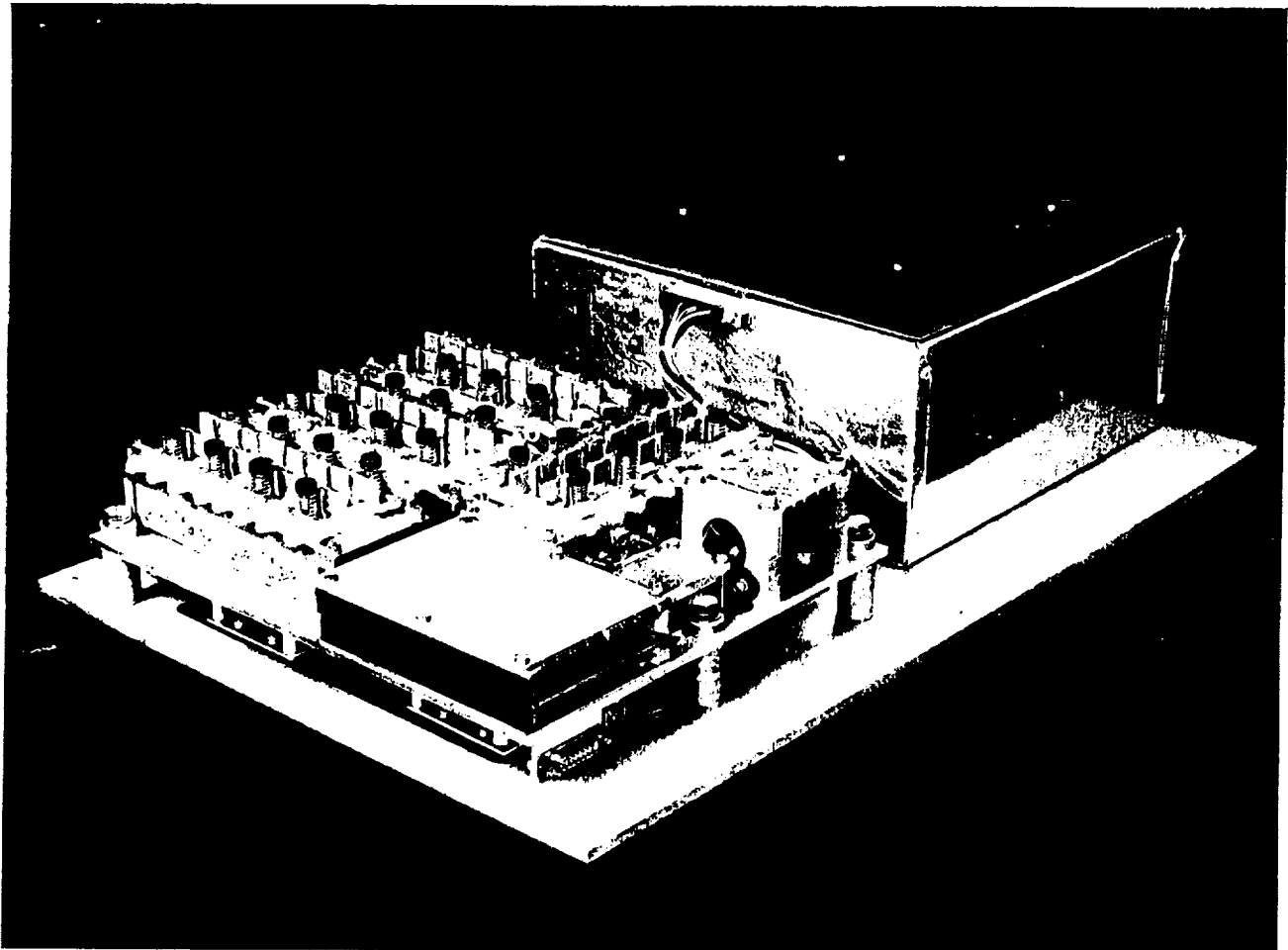
## CENTER FOR CELL RESEARCH

### HARDWARE



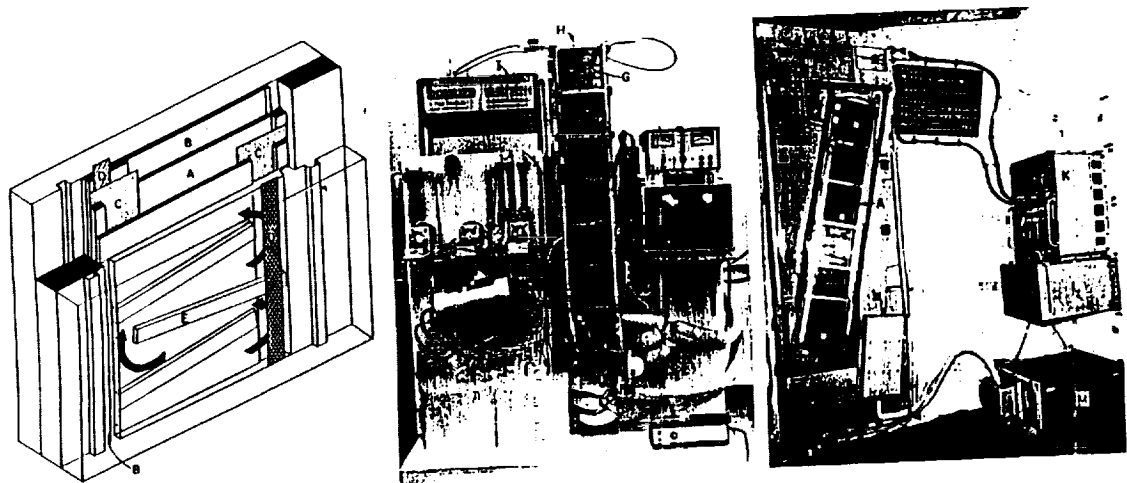


PENN STATE BIOMODULE SCHEMATIC



### CONSORT SOUNDING ROCKET MISSIONS DEMONSTRATE VERSATILITY OF BIOMODULE

ABOARD CONSORT 4, THE PENN STATE BIOMODULE WAS USED SUCCESSFULLY FOR THE FIRST TIME TO STUDY MICROGRAVITY EFFECTS ON MAMMALIAN CELLS, PLANT TISSUES AND PROTEIN CRYSTALS EXTENDING ITS UTILITY TO THREE MORE CLASSES OF BIOLOGICAL MATERIALS OF COMMERCIAL INTEREST.



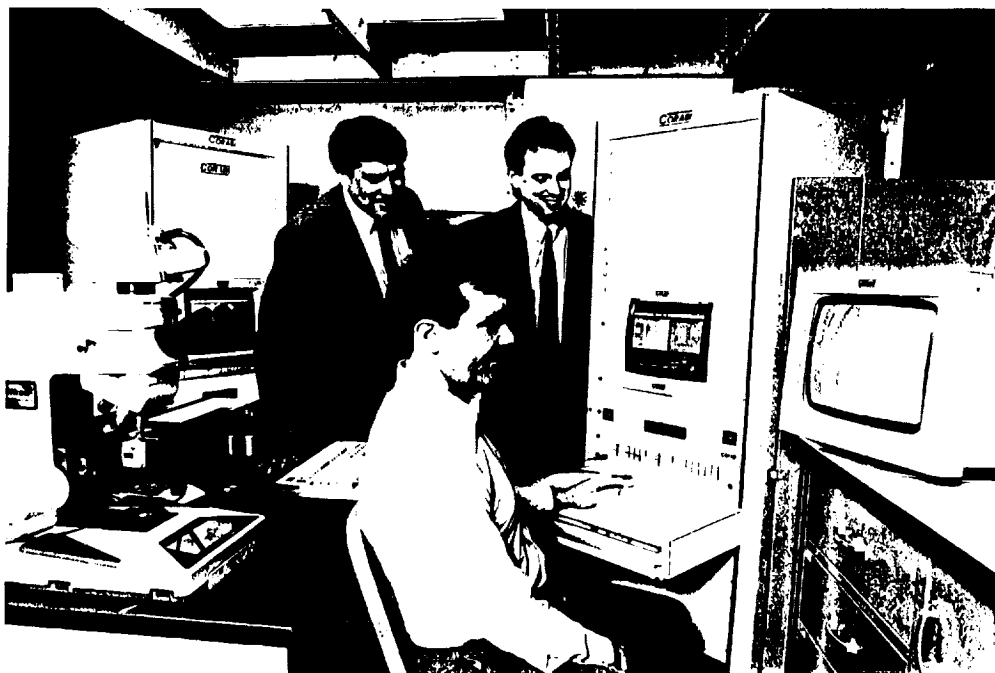


## TELEMICROSCOPY

THE CORABI/CCR TELEMICROSCOPY PROJECT WILL PROVIDE THE COMMERCIAL BIOMEDICAL/BIOTECHNOLOGY COMMUNITY WITH THE OPPORTUNITY TO STUDY MICROSCOPIC SPECIMENS ABOARD SPACE STATION FREEDOM FROM THE GROUND.

APPLICATIONS:      MONITOR PRODUCT PROCESSING, PRODUCTION,  
                                 TESTING COMMERCIAL DISCOVERY RESEARCH

ASTRONAUT HEALTH





## CONCLUSION

SPACE-BASED PRODUCT PROCESSING, TESTING, DEVELOPMENT AND DISCOVERY RESEARCH USING USCEPS AND CCR'S PHYSIOLOGICAL TESTING PROGRAM OFFER NEW ROUTES TO IMPROVED HEALTH ON EARTH.

THE CCR AND SSF WILL HELP AMERICAN INDUSTRY TO TAKE THOSE ROUTES AND TO USE MICROGRAVITY AS AN ENABLING FORCE TO ACHIEVE PRODUCT-ORIENTED GOALS.



## CONSORTIUM FOR MATERIALS DEVELOPMENT IN SPACE INTERACTION WITH SPACE STATION FREEDOM

Presented by Charles A. Lundquist and Valerie Seaquist  
Consortium for Materials Development in Space  
The University of Alabama in Huntsville

### ABSTRACT

The Consortium for Materials Development in Space (CMDS) is one of seventeen Centers for the Commercial Development of Space (CCDS) sponsored by the Office of Commercial Programs of NASA. The CMDS formed at the University of Alabama in Huntsville in the fall of 1985. The Consortium activities therefore will have progressed for over a decade by the time Space Station Freedom (SSF) begins operation. The topic to be addressed here is: What are the natural, mutually productive relationships between the CMDS and SSF? For management and planning purposes, the Consortium organizes its activities into a number of individual projects. Normally, each project has a team of personnel from industry, university and often government organizations. This is true for both product-oriented materials projects and for infrastructure projects. For various of these projects Space Station offers specific mutually productive relationships. First, SSF can provide a site for commercial operations that have evolved as a natural stage in the life cycle of individual projects. Efficiency and associated cost control lead to another important option. With SSF in place, there is the possibility to leave major parts of processing equipment in SSF, and only bring materials to SSF to be processed and return to earth the treated materials. This saves the transportation costs of repeatedly carrying heavy equipment to orbit and back to the ground. Another generic feature of commercial viability can be the general need to accomplish large through-put or large scale operations. The size of SSF lends itself to such needs. Also in addition to processing equipment, some of the other infrastructure capabilities developed in CCDS projects may be applied on SSF to support product activities. The larger SSF program may derive mutual benefits from these infrastructure abilities.



## Consortium for Materials Development in Space Interaction with Space Station Freedom

### 1. Background

The Consortium for Materials Development in Space (CMDS) is one of seventeen Centers for the Commercial Development of Space (CCDS) sponsored by the Office of Commercial Programs of NASA. In addition to NASA, the Consortium receives support from affiliated industries and from the State of Alabama. The CMDS formed at the University of Alabama in Huntsville in the fall of 1985.

The Consortium activities therefore will have progressed for over a decade by the time Space Station Freedom (SSF) begins operation. The topic to be addressed here is: What are the natural, mutually productive relationships between the CMDS and SSF? To answer that question, a basic understanding of the CMDS activities is needed; Section 2 sketches those activities. Section 3 then shows how natural interactions arise between CMDS and SSF.

### 2. Current Activities of the Consortium

When it formed, the Consortium adopted three fundamental concepts to characterize its scope.<sup>(1)</sup> These were:

- Commercial materials development that benefit from unique attributes of space
- Commercial applications of physical chemistry and materials transport
- Prompt and frequent experiments and operations in orbit

As intended here, "materials" is a broad term including inorganic, organic and living materials. These concepts have continued to be applicable to this day.

However, during its first years of operation, the Consortium recognized that it needed also to address infrastructure issues such as:

- Processing equipment for space use
- Rocket vehicles for access to space
- Environment measurements in spacecraft

The CMDS added such topics to its activities, as did other Centers for Commercial Development in Space.<sup>(2,3,4)</sup>

For management and planning purposes, the Consortium organizes its activities into a number of individual projects. Every project must have an appropriate space involvement. Normally, each project has a team of personnel from industry, university and often government organizations. This is true for both product-oriented materials projects and for infrastructure projects.

The materials projects, particularly, are expected to go through a life cycle beginning with exploratory tests of a concept, continuing through development operations, and finally reaching a state of maturity and independence. As individual projects reach a mature, independent status, they can be replaced by new projects starting with a concept to be explored. At each step in a project's life cycle, the project is evaluated for viability and is continued or terminated. The commercial prospects for the project and industrial interest are key factors in the evaluation process.

Equipment for use in space is an essential feature of each project. The Consortium has adopted an evolutionary equipment concept, in which equipment will evolve through several modest, periodic steps from a simple initial form.<sup>(4)</sup> This approach assures at any time that the subsequent operations are the next logical step<sup>(5)</sup> to be performed based on experience to date. It also enhances the probabilities of success because each step incorporates the positive features of its predecessors. Specifically, the equipment candidates for flight on SSF would be picked from the evolutionary flow at the time they are needed for flight.

The present Consortium projects and infrastructure services are listed in Table 1. The potential interactions with SSF can be examined on a project by project basis.

### 3. CMDS Relationship with SSF

Given the characteristics of the CMDS operations as sketched in Section 2, it is now possible to look for the natural mutually productive relationships between CMDS and SSF. The first option follows immediately from the last thoughts in Section 2; SSF can provide a site for commercial operations that have evolved as a natural stage in the life cycle of individual projects. Indeed, the examples offered below have this feature.

Efficiency and associated cost control lead to another important option. With SSF in place, there is the possibility to leave major parts of processing equipment in SSF, and only bring materials to SSF to be processed and return to earth the treated materials. This saves the transportation costs of repeatedly carrying heavy equipment to orbit and back to the ground.

Another generic feature of commercial viability can be the general need to accomplish large through-put or large scale operations. The size of SSF lends itself to such needs.

Also in addition to processing equipment, some of the other infrastructure capabilities developed in CCDS projects may be applied on SSF to support product activities. The larger SSF program may derive mutual benefits from these infrastructure abilities.

To illustrate these general relationships, specific examples can be drawn from the list of projects in Table 1. As a first example, the Organic Separation or the Materials Dispersion and Biodynamics Projects can illustrate the role of SSF as a site for commercial operations. Both of these projects envision eventual service operations on a carrier such as SSF. In such an operation, a service company provides a complement of basic equipment which is left in orbit and upgraded in a modular way from time-to-time. The company provides services to many customers using the equipment on SSF. The human involvement with such equipment and operations offered by SSF is valuable, particularly with living cells which need careful handling. The next speaker in this session will have much more to say about the promise of biodynamics activities on SSF.<sup>(6)</sup>

A related subject is the infrastructure problem of keeping living cells in a satisfactory environment from the time they are delivered for loading on the Shuttle for transportation to SSF until they are unloaded from the Shuttle upon return to earth. This infrastructure problem is being solved for the Organic Separation Project during its planned flights on Spacehab. Spacehab provides power for environment control to the Organic Separation equipment from delivery, through launch, orbital operations, return to earth and until unloading at the landing site. The same continuous service is needed for living cells on their way to and from SSF. One attractive solution is to use Spacehab as a logistic carrier to and from SSF, in which case the commercial Spacehab infrastructure provision for living cells also becomes the SSF solution. This option is illustrated in further detail in the Spacehab exhibit at this Conference.<sup>(7)</sup>

TABLE 1

CMDS COMMERCIAL POTENTIAL

PROJECT	INDUSTRY PARTNER	POTENTIAL PRODUCTS/ SERVICES
Electrodeposition	McDonnell Douglas Space Sys. Co.	Improved surface coatings
Physical vapor transport crystal growth	Boeing Aerospace	ZnSe electrooptical devices
Non-linear optical organic materials	Teledyne Brown Engineering	Electrooptical Devices
Materials preparation and longevity in hypothermal oxygen	Physical Sciences, Inc., AZ Technology	Spacecraft surface coatings Atomic oxygen measurement devices
Sintered and alloyed materials	Kennametal, Inc. Wyle Laboratories Teledyne Wah Chang Deere and Company	Composites and alloys of metals and refractory materials
High-temperature superconductors	Lockheed, GE, LANL (AI)	Improved superconducting materials
Materials dispersion and biodynamics	Instrumentation Technology Associates, Inc. RANTEK, Inc.	Materials dispersion and biodynamic services
Organic Separation by phase partitioning of immiscible polymers	Interfacial Dynamics, Corp. Space Hardware Optimization Technology, Inc.	Cell/heavy molecule separation service Partitioning apparatus
Polymer foam formation	Thiokol Corporation	Lightweight space structures

CMDS INFRASTRUCTURE SERVICES

INFRASTRUCTURE AREA	INDUSTRY PARTNER	SERVICE
Space Experiment Furnace (SEF)	Boeing Commercial Space Development Company McDonnell Douglas - Spacehab	In-space furnace service for multiple customers
Equipment for Controlled Liquid Phase Sintering Experiment (ECLIPSE)/ Universal Small Experiment Container (USEC)	Wyle Laboratories	In-space furnace service for multiple customers
Suborbital Launch Vehicles/Services	EER Systems, Inc. McDonnell Douglas Space Sys. Co. Orbital Sciences Corporation Teledyne Brown Engineering Wyle Laboratories	Access to 7-14 minutes microgravity for multiple customers
Accelerometers		Acceleration environment measurements to support investigations
Commercial Materials Dispersion/TTA Experiment (CMIX)	Instrumentation Technology Associates, Inc.	In-space biodynamic services for multiple customers

The Sintered and Alloyed Materials Project (Table 1) provides a further example of the efficiency of leaving equipment in orbit. Furnaces for processing sintered and alloyed materials by their very nature tend to be large or heavy, so it is inefficient to transport them to and from orbit repeatedly. Two furnace systems are candidates for use by this project on SSF: the Space Experiment Facility (SEF) and the Equipment for Controlled Liquid Phase Sintering Experiment (ECLiPSE). Another speaker in this conference will describe SEF, so it is unnecessary to discuss it further here.<sup>(8)</sup> The ECLiPSE is housed for safety considerations in a Universal Space Experiment Container (USEC) developed by Wyle Laboratories. USEC is explicitly designed to be compatible with Spacehab, SSF and other carriers.

The Polymer Foam Project (Table 1) is an example of a project that eventually will require a large scale operation that could be done outside SSF. An ultimate objective of the project is commercial production of large foamed structures for use in space. A demonstration of production of such a structure is appropriate for SSF sometime late in the 1990's.

Other CMDS developed capabilities of potential infrastructure interests to SSF include accelerometer systems and atomic oxygen flux measurements. An evolving accelerometer system began as a means to measure the low acceleration environment on suborbital rockets managed by the CMDS. It has developed further into a system that will be used on Spacehab and in other Shuttle circumstances. It could find use on SSF to perform similar support services for CMDS and other CCDS investigations.

One objective of the Atomic Oxygen Project is a commercially available instrument to measure the changing atomic oxygen flux that impacts the ram-facing surface of a low satellite. Such an instrument(s) could be mounted on SSF to demonstrate its long term operation and the associated data reduction capabilities.

#### 4. Conclusion

The projects of the Consortium for Materials Development in Space are ongoing activities that employ several means to attain access to space. For some of them, operations on Space Station Freedom offer an attractive option to meet project objectives. Further, some of the infrastructure capabilities developed for the Consortium may find applications on Freedom.

#### References

1. Charles A. Lundquist, "Projects of the Consortium for Materials Development in Space," Materials Processing in the Reduced Gravity Environment of Space, ed. Robert H. Doremus and Paul C. Nordine, Materials Research Society Symposia Proceedings, Volume 37, pg. 121. (Symposium, Dec. 1-3, 1986, Boston, MA).
2. Francis C. Wessling and Charles A. Lundquist, "Low Gravity Investigations on Suborbital Rockets," Proceedings of Twenty-Seventh Space Congress, pg. 3-41, Cocoa Beach, FL, April 24-27, 1990.
3. Charles A. Lundquist, "Transportation Requirements for Low Acceleration Conditions," Space Commerce, ed. John J. Egan, Proceeding of the Third International Conference on the Commercial and Industrial Uses of Outer Space, Montreux Switzerland, pg. 279, March 26-29, 1990, Gordon and Breach Science Publishers.
4. Charles A. Lundquist, "Evolution of Payload Equipment for Materials Development," AIAA Space Programs and Technologies Conference and Exhibit, Huntsville, AL, September 25-27, 1990.

5. CMDS Exhibit, NASA booth, Space Station Freedom Utilization Conference Exhibit.
6. Marian Lewis, "Materials Dispersion and Biodynamics Project Research," Space Station Freedom Utilization Conference, Huntsville, Alabama, August 3-6, 1992.
7. Spacehab exhibit, Space Station Freedom Utilization Conference Exhibit.
8. Barbara Heizer, "Crystals for Vapor Transport Experiment," Space Station Freedom Utilization Conference, Huntsville, Alabama, August 3-6, 1992.





## MATERIALS DISPERSION AND BIODYNAMICS PROJECT RESEARCH

Presented by Marian L. Lewis, Ph.D.  
Consortium for Materials Development in Space  
The University of Alabama in Huntsville

### ABSTRACT

The Materials Dispersion and Biodynamics Project (MDBP) focuses on dispersion and mixing of various biological materials and the dynamics of cell-to-cell communication and intracellular molecular trafficking in microgravity. Research activities encompass biomedical applications, basic cell biology, biotechnology (products from cells), protein crystal development, ecological life support systems (involving algae and bacteria), drug delivery (microencapsulation), biofilm deposition by living organisms and hardware development to support living cells on Space Station Freedom (SSF).

Project goals are to expand the existing microgravity science database through experiments on sounding rockets, the Shuttle and COMET program orbiters and to evolve, through current database acquisition and feasibility testing, to more mature and larger-scale commercial operations on SSF. Maximized utilization of SSF for these science applications will mean that service companies will have a role in providing equipment for use by a number of different customers. An example of a potential forerunner of such a service for SSF is the Materials Dispersion Apparatus (MDA) "minilab" of Instrumentation Technology Associates, Inc. (ITA) in use on the Shuttle for the Commercial MDAITA Experiments (CMIX) Project. The MDA wells provide the capability for a number of investigators to perform mixing and bioprocessing experiments in space. In the area of human adaptation to microgravity, a significant database has been obtained over the past three decades. Some low-g effects are similar to Earth-based disorders (anemia, osteoporosis, neuromuscular diseases and immune system disorders). Spending in the area of Earth-based biopharmaceuticals is increasing and is projected to be in the range of \$60 billion by the end of this decade, 50 times greater than it is now (Burill, G.S. and Lee, K.B. 1991. *Biotech 91: A Changing Environment*, Ernst and Young, San Francisco, CA). As new information targets potential profit-making processes, services and products from microgravity, commercial space ventures are expected to expand accordingly. Cooperative CCDS research in the above mentioned areas is essential for maturing SSF biotechnology and to ensure U.S. leadership in space technology.

Currently, the MDBP conducts collaborative research with investigators at the Rockefeller University, National Cancer Institute, and the Universities of California, Arizona and Alabama in Birmingham. The growing database from these collaborations provides fundamental information applicable to development of cell products, manipulation of immune cell response, bone cell growth and mineralization and other processes altered by low-gravity. Contacts with biotechnology and biopharmaceutical companies are being increased to reach uninformed potential SSF users, provide access through the CMDS to interested users for feasibility studies and to continue active involvement of current participants. We encourage and actively seek participation of private sector companies, and university and government researchers interested in biopharmaceuticals, hardware development and fundamental research in microgravity. The project has two industry participants at present. These are Instrumentation Technology Associates, Inc. (ITA), Exton PA (hardware provider) and RANTEK, a biomedical R & D company with headquarters in Florida and offices in Huntsville.

The challenge of new ventures such as SSF, man's presence on the Moon, Mars and beyond, can be met enthusiastically with the philosophy stated by Werher von Buaun: "The value of discovery becomes clear only in the wake of the discovery itself. No one can imagine what may accrue to mankind from the space program any more than Isabella could imagine what would come of Columbus' voyages." The development of bio-processes and biopharmaceuticals in space leading to enhanced quality of life on Earth, ameliorating undesirable space effects and contributing to US leadership in the world economy is a reasonable expectation.



## **SPACE STATION FREEDOM UTILIZATION CONFERENCE**

VON BRAUN CIVIC CENTER  
HUNTSVILLE, ALABAMA  
JULY 29-AUGUST 5, 1992

### **MATERIALS DISPERSION AND BIODYNAMICS PROJECT RESEARCH**

Presented by  
Marian L. Lewis, Ph.D.

Consortium for Materials Development in Space  
University of Alabama in Huntsville



### **MATERIALS DISPERSION AND BIODYNAMICS PROJECT FOCUS**

- 0 **Materials dispersion and mixing in microgravity**
  - o **Fluids and particles**
  - o **Liquid/liquid**
  
- 0 **Dynamics of biological systems**
  - o **Cell-to-cell communication**
  - o **Intracellular molecular trafficking**



## ACTIVITIES

### ACTIVITIES ENCOMPASS SEVERAL BROAD DISCIPLINES.

- o **Biomedical**
- o **Basic cell biology**
- o **Biotechnology (products from cells)**
- o **Protein crystal development**
- o **Life support (algae and bacteria)**
- o **Drug delivery (microencapsulation)**
- o **Hardware development for cellular life support**

## PROJECT OBJECTIVES

**To create private sector awareness of R & D potential in the space environment.**

**To facilitate private sector company growth in the areas of:**

**Services: hardware for low-g research**

**Products: (cells, cell products, crystals)**

**Processes: (ways to achieve products from low-g research)**





# CMIX Acronym Definition

**C**OMMERCIAL

**M**DA

**I**TA

**E**XPERIMENTS

CMDS/CMIX M.L. Lewis 2/5/92

## THE COMMERCIAL MDA ITA EXPERIMENTS (CMIX) PROGRAM

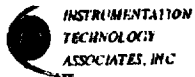
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### OVERVIEW

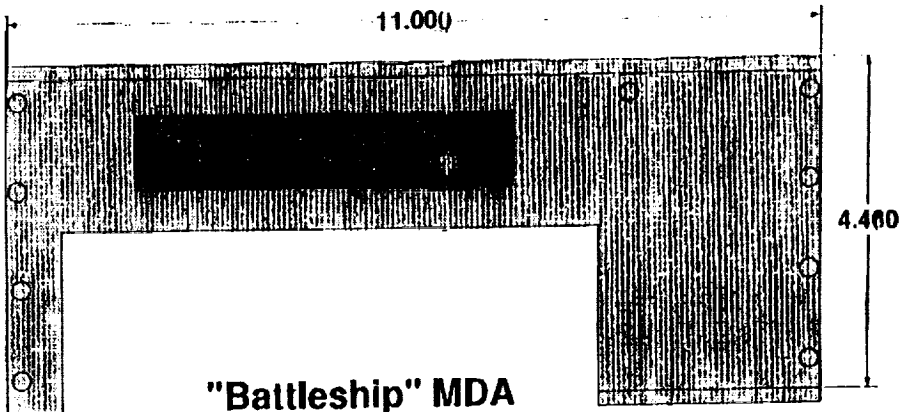
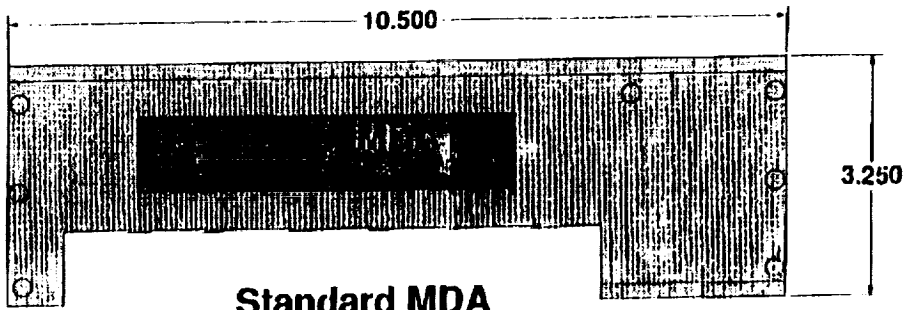
- 0 Created by - Agreement between NASA, Office of Commercial Programs and UAH.
- 0 Purpose - To provide additional research opportunities on the Space Shuttle for NASA's 17 CCDS's.
- 0 Program managed by the UAH CMDS
- 0 Duration of Agreement - 5-year period or until 5 flights are accomplished.
- 0 First flight scheduled for September 1992



# MDA HARDWARE DESCRIPTION

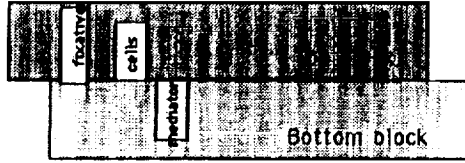


## MDA CONFIGURATION COMPARISON

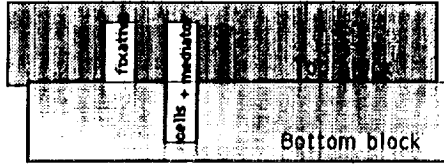


## THE MDA MINILAB HARDWARE

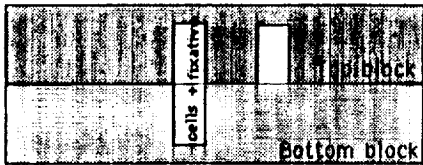
### MDA BLOCK CONFIGURATIONS FOR FLUIDS MIXING (Type 3 wells)



1  
Launch  
Position



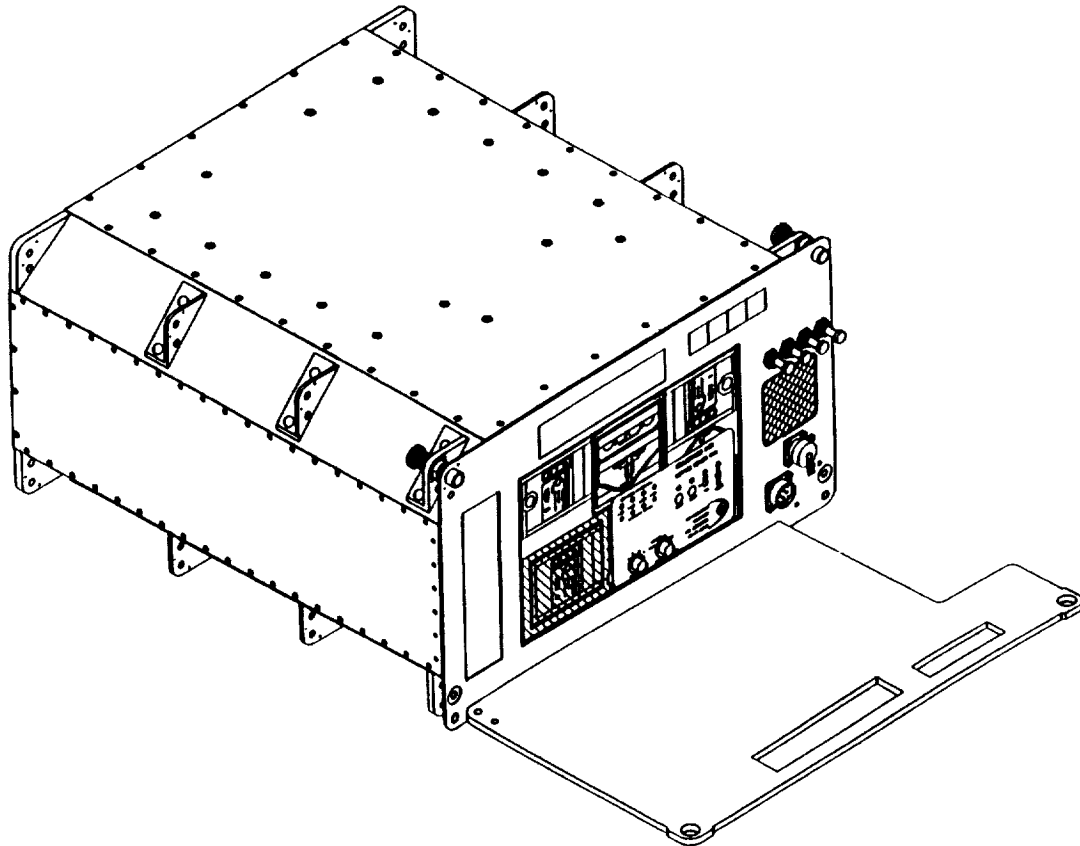
2  
Microgravity  
position



3  
Re-entry  
position

### PRINCIPLE OF OPERATION

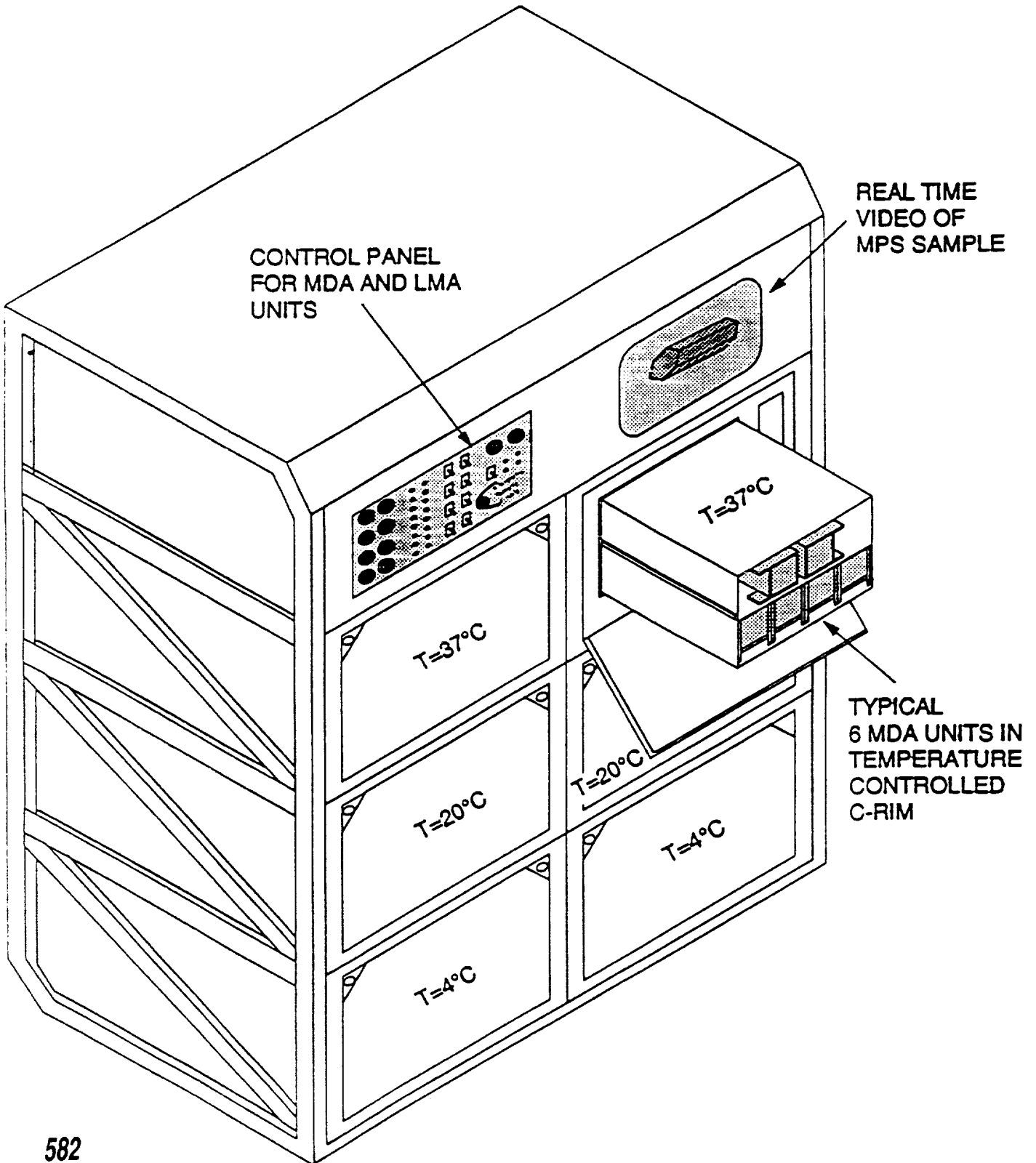
- o Two blocks of inert material
- o Compatible number of wells in upper and lower half
- o Held together in lightweight aluminum housing
- o Wells are misaligned prior to launch (materials are separate)
- o In microgravity, blocks aligned allowing materials to contact
- o In type 3 wells, blocks move again prior to re-entry





INSTRUMENTATION  
TECHNOLOGY  
ASSOCIATES, INC.

# ITA COMMERCIAL MPS RACK FOR SPACE STATION

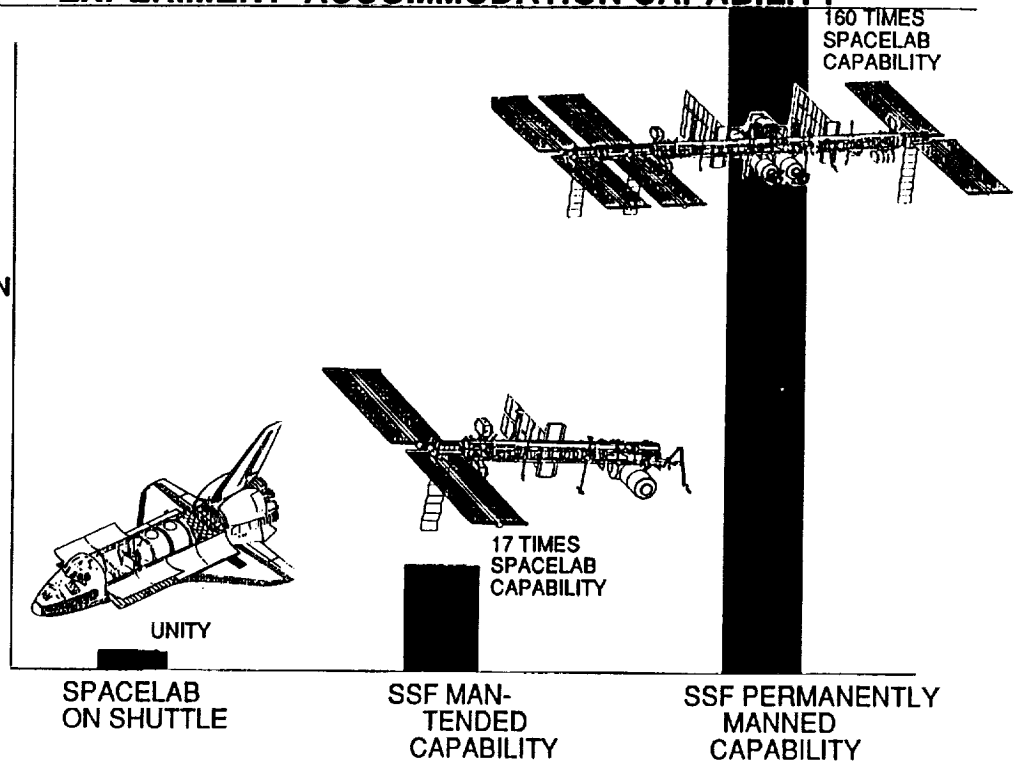




## SPACE STATION FREEDOM GREATLY INCREASES EXPERIMENT ACCOMMODATION CAPABILITY

### ACCOMMODATION CAPABILITY

(Product of:  
•power  
•mass  
•time in orbit)



## PROJECT GOALS

- 0 To expand the knowledge gained in the past three decades of microgravity research.
  - o Historic - effects of low-gravity on human physiology
  - o Recent and ongoing - low-gravity effects on single cells
- 0 To apply this information to develop SSF experiments and utilization in the areas of:
  - o Commercialization
  - o Basic science



# EFFECTS OF LOW-GRAVITY ON HUMAN PHYSIOLOGY



<u>SOME LOW-G EFFECTS</u>	<u>CORRESPONDING EARTH-BASED DISORDER</u>
Bone demineralization	Osteoporosis due to aging
Immune response blunted	Immune deficiency, leukemias
Cardiac deconditioning	Hypertension, heart failure
Muscle deconditioning	Muscle wasting diseases
Decreased red blood cell count	Anemia

**TO ENSURE SAFETY AND MAXIMIZE PRODUCTIVITY OF HUMANS IN SPACE, CONTINUOUS RESEARCH IS NEEDED IN THE FOLLOWING AREAS:**

**Cellular differentiation (i.e. stem cells to RBC's)**

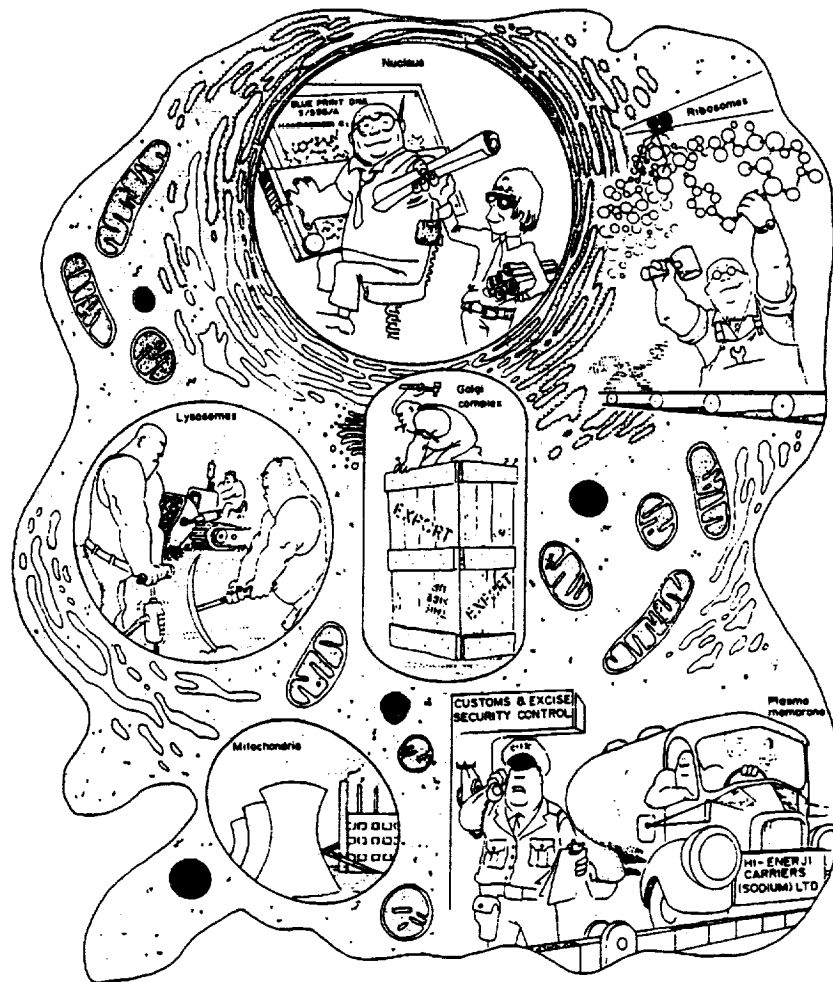
**Interactions of cells with drugs and medications in microgravity**

**Remediation of bone mineral loss and reduced bone cell growth**

**Mechanisms of reduced immune cell response and selective immunotherapy**

**Mechanisms of virus infectivity in microgravity (cell receptors/cell mediated immunity)**

**Nerve cell responses to stimuli (intracellular mechanisms)**



## MICROGRAVITY EFFECTS AT THE CELLULAR LEVEL

**PROCESS ALTERED**

**EFFECT OF SPACEFLIGHT**

**Gene expression**

**Suppression of some types**

**Cellular metabolism**

**Glucose use rate lowered**

**Secretory processes**

**Decreased or increased - cell type**

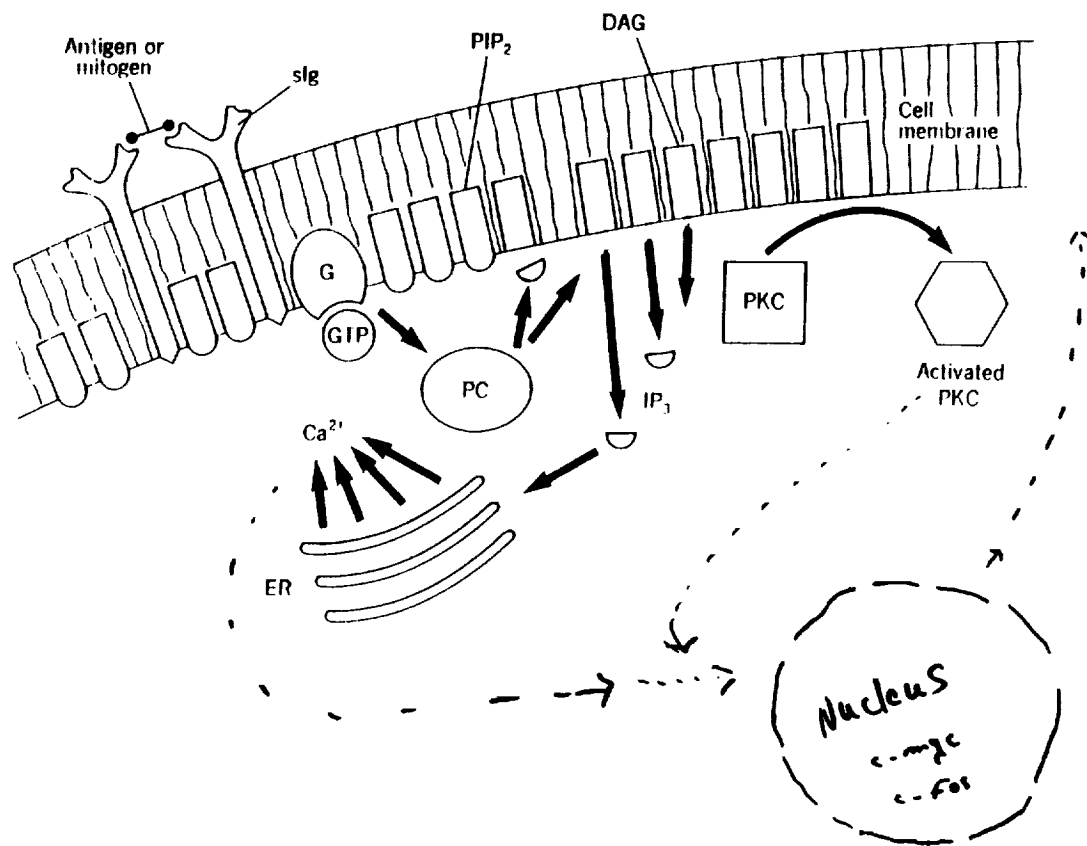
**T-lymphocytes**

**Reactivity suppressed**

**Plant cell metabolism**

**Fatty acid content shifts**





## MEDICAL/BIOLOGICAL UTILIZATION OF SSF

**O SSF long-term, continuous lwo-g environment can provide research capability to determine**

- o Cellular mechanisms
- o Develop remedies

**O Resulting in**

- o Spinning off new technologies
- o Development of new biopharmaceuticals
- o Advanced knowledge of fundamental biological processes.

## POTENTIAL AREAS OF MEDICAL COMMERCIAL APPLICATION

### Potential Markets

Companies producing natural cell products  
cancer

Institutions supplying cells

Biodynamic cell culture

Biodeposition (mammalian cells)

Pharmaceutical

Pharmaceutical

### Application

Infectious disease,

Transplantation

Cellular and tissue  
development

Osteoporosis/bone  
regeneration

Liposome and drug  
delivery technology

Protein crystals,  
drug design

## BENEFITS FROM SSF RESEARCH



IMPROVED QUALITY OF LIFE ON EARTH RESULTING FROM  
LONG-TERM RESEARCH CAPABILITY ON SSF

ENSURE SAFETY AND MAXIMIZE PRODUCTIVITY OF HUMANS IN  
SPACE

NON-TERRESTRIAL ENVIRONMENT REQUIRES DEVELOPMENT  
OF NEW MATERIALS AND TECHNOLOGIES TRANSFERABLE TO  
PRIVATE SECTOR INDUSTRIES

KNOWLEDGE GAINED ON FUNDAMENTAL PROCESSES AP-  
PLICABLE TO EARTH-BASED PROCESSING AND TECHNOLOGY

## **SOME STRATEGIES TO FACILITATE COMMERCIAL SPACE**

- o **Increase private sector awareness of potential areas for commercialization**
- o **Continued contact with private sector companies**
- o **Collaborative research with university researchers**
- o **Dissemination of knowledge gained to scientific community by publications, conferences, seminars, displays.**
  
- o **Education**
  - o **Involvement of students at the intermediate and high school and university levels**



## **PROSPECTS FOR THE FUTURE**

**Commercial space ventures are expected to increase as the database targets potential profit-making processes and products from microgravity technology development.**

- 0 **Spending in the area of biopharmaceuticals is increasing.**
  - o **Earth-based spending for biopharmaceuticals by the end of this decade is projected to be in the range of \$60 billion, 50 times greater than it is now.**
  
- 0 **Cooperative CCDS research in the above mentioned areas is essential for maturing SSF biotechnology**
  
- 0 **New technologies are expected to develop and to ensure U.S. leadership in space technology.**



**INTEGRATION AND USE OF A MICROGRAVITY RESEARCH  
FACILITY: LESSONS LEARNED BY THE CRYSTALS BY VAPOR  
TRANSPORT EXPERIMENT AND SPACE EXPERIMENTS  
FACILITY PROGRAMS**

Presented by Barbara L. Heizer  
Boeing Defense and Space Group

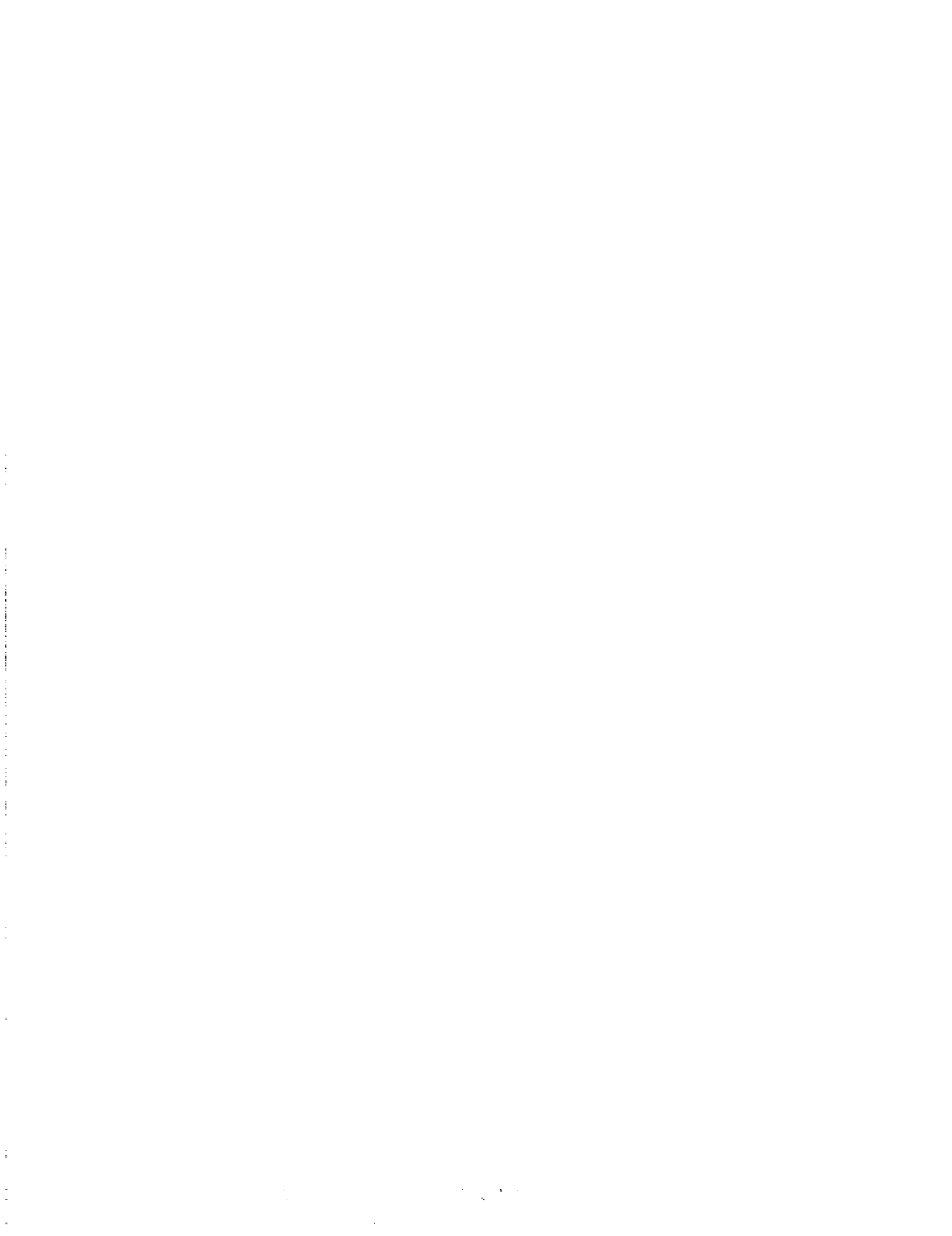
**ABSTRACT**

The Crystals by Vapor Transport Experiment (CVTE) and Space Experiments Facility (SEF) are materials processing facilities designed and built for use on the Space Shuttle middeck. The CVTE was built as a commercial facility owned by the Boeing Company. The SEF was built under contract to the UAH Center for Commercial Development of Space (CCDS). Both facilities include up to three furnaces capable of reaching 850°C minimum, stand-alone electronics and software, and independent cooling control. In addition, the CVTE includes a dedicated stowage locker for cameras, a laptop computer, and other ancillary equipment. Both systems are designed to fly in a Middeck Accommodations Rack (MAR), though the SEF is currently being integrated into a Spacehab rack. The CVTE hardware includes two transparent furnaces capable of achieving temperatures in the 850° to 870° C range. The transparent feature allows scientists/astronauts to directly observe and affect crystal growth both on the ground and in space. Cameras mounted to the rack provide photodocumentation of the crystal growth. The basic design of the furnace allows for modification to accommodate techniques other than vapor crystal growth.

Early in the CVTE program, the decision was made to assign a principal scientist to develop the experiment plan, affect the hardware/software design, run the ground and flight research effort, and interface with the scientific community. The principal scientist is responsible to the program manager and is a critical member of the engineering development team. As a result of this decision, the hardware/experiment requirements were established in such a way as to balance the engineering and science demands on the equipment. Program schedules for hardware development, experiment definition and material selection, flight operations development and crew training, both ground support and astronauts, were all planned and carried out with the understanding that the success of the program science was as important as the hardware functionality.

The CVTE payload has been delivered to the Kennedy Space Center and is undergoing final assembly and check-out prior to installation on the orbiter Columbia. It is manifested to fly on STS-S2. The SEF is undergoing assembly and checkout prior to environmental testing at the Boeing facility in Kent, WA. It will be delivered to the UAH in early October, 1992.

This presentation will be a discussion of how the CVTE payload was designed and what it is capable of, the philosophy of including the scientists in design and operations decisions, and the lessons learned during the integration process.





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**Integration and Use of a Microgravity  
Research Facility: Lessons Learned by the  
CVTE and SEF Programs**

Barbara Heizer  
August 5, 1992

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***BOEING***

**Crystals by Vapor Transport Experiment  
Outline**

***BOEING***

**Program Overview**

**Hardware Status**

**System Requirements**

**Integration Issues: Lessons Learned**

**Summary**

## Crystals by Vapor Transport Experiment Program Overview

**BOEING**

### Objectives:

Design, fabricate and assemble a microgravity materials processing facility for use on the Space Shuttle Middeck.

Develop the procedures, staff, experience, and facilities required to integrate complex payloads into a manned space system.

Develop a flexible, user friendly furnace facility capable of providing a stable, programmable thermal environment up to 850° C

August 9-1992, 2

## Crystals by Vapor Transport Experiment Program Overview

**BOEING**

### Approach:

Develop cooperative agreements with premier scientists and crystal growers

Select vapor transport crystal growth process

Identify candidate materials for space processing demonstration

Commercially viable

Potential for improved quality

Growth time: 8 min < GT < 2 days

August 9-1992, 2

## **Crystals by Vapor Transport Experiment Program Overview**

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**BOEING**

### **Approach (cont.):**

**Execute a Joint Endeavor Agreement (JEA) with  
NASA for microgravity experiments on shuttle flights**

**Design, develop, and fly hardware to perform these  
experiments**

**Expand capabilities to include advanced applications**

August 5, 1992 4

## **Crystals by Vapor Transport Experiment Program Overview**

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**BOEING**

### **Technology Application:**

**Space Systems are a major Boeing product area**

**Materials processing in space is a prime element of  
space commercialization**

**Potential markets exist for space materials processing  
facilities**

**Supports Space Station operation and growth**

August 5, 1992 5

# Crystals by Vapor Transport Experiment Program Overview

**BOEING**

## CVTE: Crystals by Vapor Transport Experiment

2-furnace facility with independent electronics and S/W  
Transparent furnaces, 2 samples/furnace  
Middeck payload

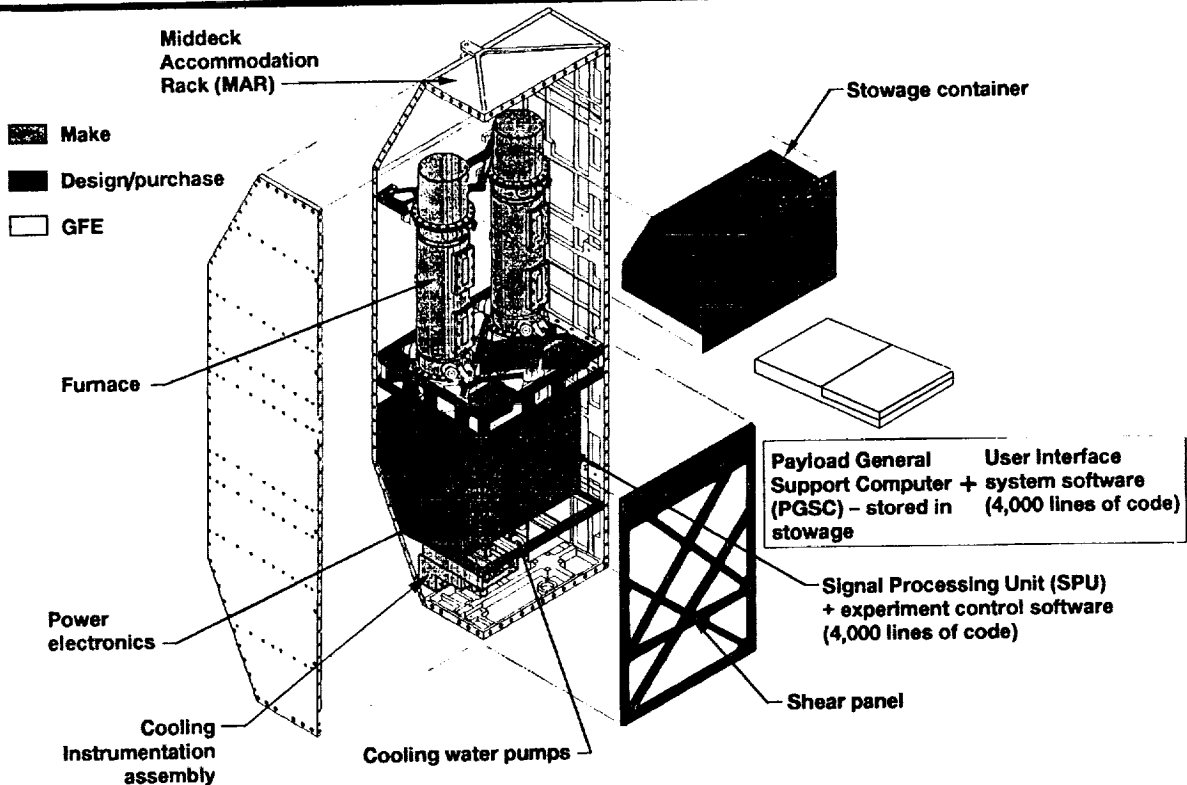
## SEF: Space Experiments Facility

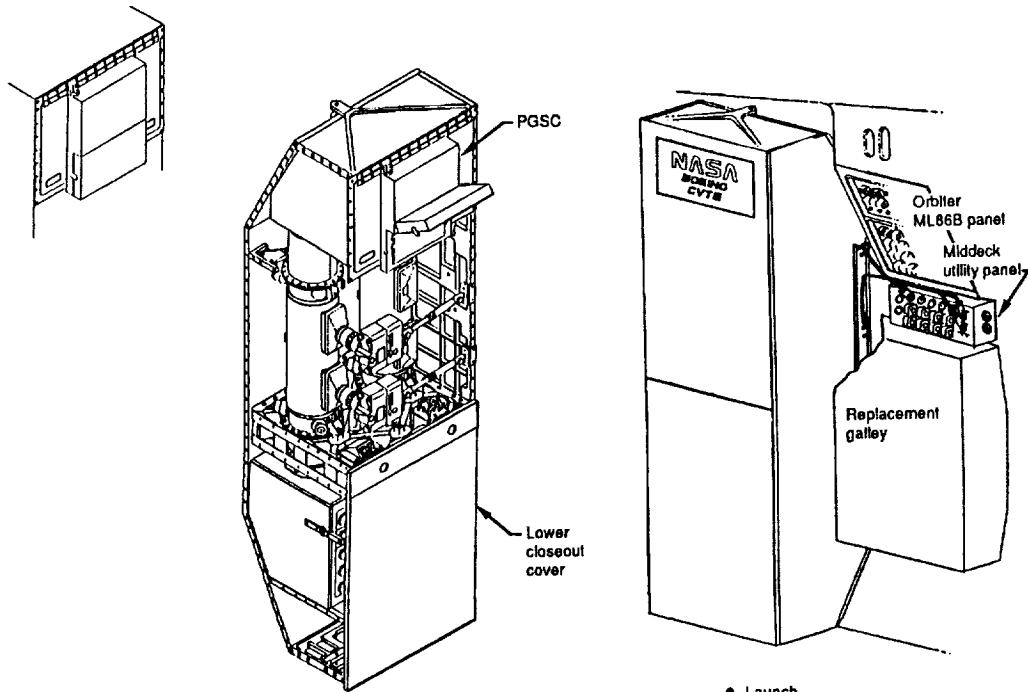
2nd CVTE facility being built for the UAH  
3-furnace facility; 2 transparent/1 opaque (1050 °C)  
Middeck payload

August 5, 1992 - 6

SD2-4243-R0

# Crystals by Vapor Transport Experiment Make, Buy, and GFE Hardware





On-orbit start up and operation (2 furnaces)  
(MAR aft panel removed)

- Launch
- Re-entry

*Operational Configuration*

## Crystals by Vapor Transport Experiment Hardware Status

**BOEING**

### **CVTE:**

**Undergoing final assembly and checkout at KSC  
Turnover to KSC personnel August 20  
STS-52 launch October 15**

### **SEF:**

**Environmental test program starts August 10  
Demonstration testing in September  
Delivery to UAH November 2**



## Crystals by Vapor Transport Experiment System Requirements

**BOEING**

### Transparent Furnace

#### Temperature repeatability

Furnace to Furnace  $\pm 5^{\circ}\text{C}$   
Coil Setpoint  $< \pm 1^{\circ}\text{C}$

Provide a suitable environment for growing large single crystals of CdTe

850°C centerline temperature  
Thermal gradient  $10^{\circ}\text{C}/\text{cm} < dt/dx < 50^{\circ}\text{C}/\text{cm}$   
Centerline temperature variation: Max  $< \pm 0.1^{\circ}\text{C}$   
RMS  $< \pm 0.025^{\circ}\text{C}$

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## Crystals by Vapor Transport Experiment System Requirements

**BOEING**

Pull rate:  $1 \text{ mm/day} < dl/dt < 25 \text{ mm/day}$

System set-up time not to exceed 30 minutes

Independent electronics, software, and cooling control

Safe operation

Must function in both ground research and flight operation environments

Must meet shuttle middeck environmental requirements

August 5, 1992 81

## **Crystals by Vapor Transport Experiment Integration: Lessons Learned**

**BOEING**

### **Chief Program Scientist Responsibilities:**

**Responsible to the Program Manager  
Not necessarily a PI for the flight  
Primary I/F with science and academic communities**

**Develop: Science requirements  
Ground and flight experiment plans**

**Provide inputs: Engineering design  
Software design**

**The Chief Scientist must have equal authority to the  
Chief Engineer.**

August 5, 1992 10

## **Crystals by Vapor Transport Experiment Integration: Lessons Learned**

**BOEING**

### **Principal Investigator Involvement:**

**Compatibility with ground and flight H/W required**

**Access to the ground and flight hardware prior to  
flight required**

**Time for confidence building between the resident  
science/engineering team and PI's essential**

**PI involvement in crew training, flight procedure  
development and mission support must be  
negotiated early in the program**

August 5, 1992 11

## Crystals by Vapor Transport Experiment Integration: Lessons Learned

**BOEING**

### Principal Investigator Involvement:

**Conflict between NASA, engineering and science requirements exists. Compromise is critical to program success**

**The experiment that is finally flown may not be the original concept due to incompatible requirements**

August 5, 1992 12

## Crystals by Vapor Transport Experiment Integration: Lessons Learned

**BOEING**

**Be prepared for the cost of flight integration**

**Critical integration requirements include:**

- Safety Reviews**
- Operation/Procedure Development**
- Analyses**
- Crew Training**
- Qualification Testing**

**Minimize Rework!**

August 5, 1992 13



## Crystals by Vapor Transport Experiment Integration: Lessons Learned

**BOEING**

### Understand who the players are:

**Boeing: Engineering and Science**

**NASA/HQ: Sponsor**

**NASA/JSC: Integration**

**NASA/MSFC: JEA Administration**

**NASA/KSC: Launch Site Support and H/W  
Installation**

**PI: Science**

August 6, 1992 - 14

## Crystals by Vapor Transport Experiment Integration: Lessons Learned

**BOEING**

### Joint Endeavor Agreement:

**JEA is a flawed document for use with a complex  
payload**

**No traditional "contractual coverage"**

**Program advocate or Mission Manger is needed  
to represent the payload through integration**

August 6, 1992 - 15

## **Crystals by Vapor Transport Experiment Integration: Lessons Learned**

**BOEING**

### **Flight Documentation Development:**

**Establish detailed interface requirements early**

**Establish controlling documentation early**

**Safety Reviews: Understand which system drives the requirement**

**Maintain communication and cooperation with the group responsible for hardware integration**

August 5, 1992 10

## **Crystals by Vapor Transport Experiment Integration: Lessons Learned**

**BOEING**

**In order to prepare experiments for use on the Space Station the following must be considered:**

**Chief Scientist with appropriate authority is key**

**Contractual instrument to define requirements is critical**

**Program advocate is a plus**

**Flexibility to react is essential**

**CVTE is a flight ready materials processing facility adaptable to Space Station Freedom.**

August 5, 1992 17

*SESSION 4:  
CLOSING PLENARY*

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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 6, 1992*

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## **A CONGRESSIONAL PERSPECTIVE ON THE SPACE STATION PROGRAM**

Presented by Richard M. Obermann  
Subcommittee on Space  
Committee on Science, Space and Technology  
U.S. House of Representatives

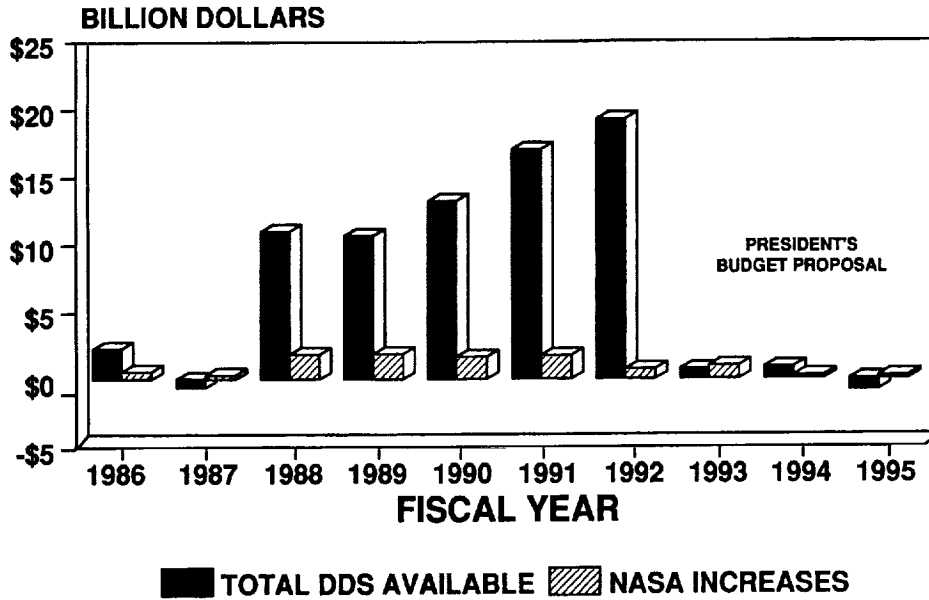
### **ABSTRACT**

While a number of factors enter into Congress' view of the Space Station program, the overall budgetary situation has had a major impact on determining the environment in which consideration of the Space Station program has taken place. The constrained budgetary outlook has driven much of the debate on spending and priorities in Congress this year, and the focus has been on which programs to cut rather than what new programs to start. Although NASA's overall budgetary request was relatively modest—an increase of less than 5 percent over Fiscal Year 1992—the Space Station Freedom program was the target of Representative's NASA Authorization bill and the VA/HUD/Independent Agencies appropriations bill. However, the amendments were defeated by comfortable margins on both occasions.

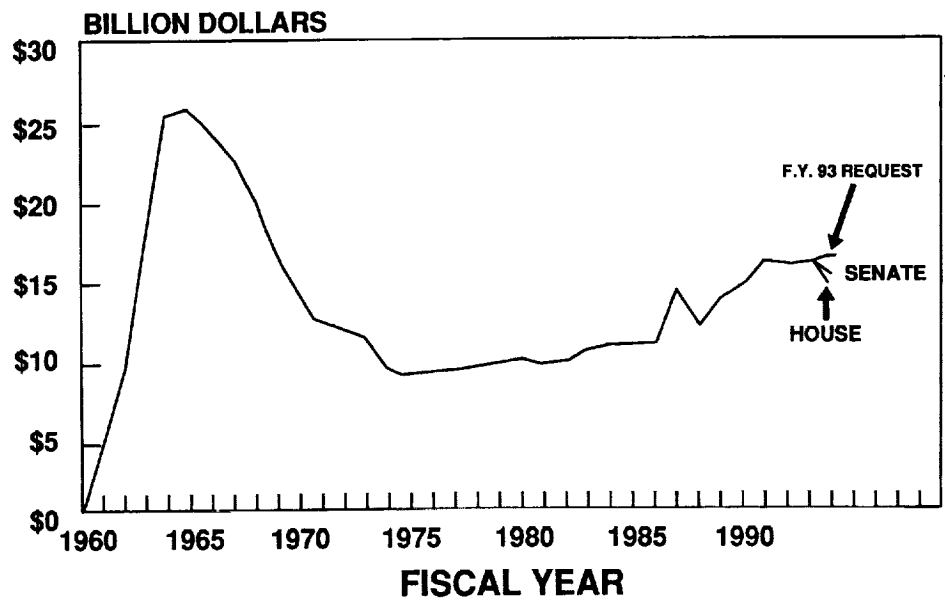
Over the near term, Space Station supporters in the Congress will attempt to achieve a final appropriation for the Space Station that is as close to the President's request as feasible. Over the longer term, it is vital to the success of the Station program and preservation of a balanced NASA program that the Space Station be affordable to operate and provide the most efficient and effective platform possible for its users. The House Committee on Science, Space and Technology has long been concerned with the potential annual operating costs of the Space Station and has urged NASA to investigate approaches to minimizing those costs.



## NASA INCREASES VS. TOTAL DDS AVAILABLE (DOMESTIC DISCRETIONARY SPENDING)



## NASA BUDGET (FISCAL YEAR 1993 DOLLARS)







## CREW EXPERIENCE IN SPACE RESEARCH

Presented by Bonnie J. Dunbar  
Astronaut Office  
NASA Johnson Space Center

### ABSTRACT

Space Shuttle crews train for 18 months per mission; they are assigned to science missions according to their background. Training encompasses preparations for troubleshooting. Astronauts often need to make judgement calls about how investigations will proceed in space; they want to work with investigators on preparing payloads and planning science operations so they will be as familiar as possible with the experiment.

The astronaut office at Johnson Space Center has organized an *ad hoc* science support group to keep abreast of the state of the art in science. The activities of this group support the work of the astronaut office's mission development group.

Astronauts are already testing space station precursor hardware on Space Shuttle missions, including two types of gloveboxes, and studying onboard vibration disturbances. Thus far, vibration caused by crew exercise has been indistinguishable from the background vibration of 5-10 micro-gs.



# *APPENDICES*

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*SPACE STATION FREEDOM UTILIZATION CONFERENCE*

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*AUGUST 3-6, 1992*

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UNIVERSITY OF WASHINGTON

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TELEDYNE BROWN ENGINEERING

DAMON SMITH  
LOCKHEED

SCOTT A. SMITH  
KRUG LIFE SCIENCES

WAYNE SMITH  
BOEING

DR. ROBERT S. SNYDER  
MARSHALL SPACE FLIGHT CENTER

DR. DENNIS G. SOCKER  
NAVAL RESEARCH LABORATORY

ROBERT J. SODANO  
GODDARD SPACE FLIGHT CENTER

SCOTT SPEARING  
TELEDYNE BROWN ENGINEERING

E. G. SPILGER  
MCDONNELL DOUGLAS

BOB STALLINGS  
TELEDYNE BROWN ENGINEERING

JERRY STEBBINS  
BOEING

KAREN L. STEPHENS  
MARSHALL SPACE FLIGHT CENTER

WILLIAM K. STEPHENSON  
NASA HEADQUARTERS

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GRUMMAN

ANDREW J STOFAN  
ANALEX CORPORATION

LOUISE STRUTZENBER  
MARSHALL SPACE FLIGHT CENTER

ARTHUR SULKIN  
ROCKWELL INTERNATIONAL

DEXTER SULLIVAN  
MARSHALL SPACE FLIGHT CENTER

KAY SUTHERLAND  
MARSHALL SPACE FLIGHT CENTER

FRANK SZOFRAM  
MARSHALL SPACE FLIGHT CENTER

ANN E. TAYLOR  
MARSHALL SPACE FLIGHT CENTER

KENNETH R. TAYLOR  
MARSHALL SPACE FLIGHT CENTER

GREG A. THOMAS  
TELEDYNE BROWN ENGINEERING

BOBBY J. THOMPSON  
MARSHALL SPACE FLIGHT CENTER

WALTER THOMPSON  
GENERAL DYNAMICS SPACE  
SYSTEMS

DAVID L. THRASHER  
BOEING

SUSAN TODD  
BOEING DEFENSE & SPACE GROUP

JEANETTE TOKAZ  
SVERDRUP CORPORATION

DR. LARRY P. TORRE  
BOEING

NEIL TOWNSEND  
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WANDA C. TOWRY  
MARSHALL SPACE FLIGHT CENTER

AL TRUESDALE  
LORAL AEROSYS

JERRY H. TUCKER  
LANGLEY RESEARCH CENTER

WALLACE B. TWICHELL  
TELEDYNE BROWN ENGINEERING

ANDREW P. TYGIELSKI  
TELEDYNE BROWN ENGINEERING

JAMES M. VAN ALSTINE  
USRA

WILLIAM K. VARDAMAN  
RANTEK INCORPORATED

CHUCK VEDANE  
TELEDYNE BROWN ENGINEERING

A. A. TONY VERRENGIA  
GE GOVERNMENT SERVICES

FELMINIO VILLELLA  
MARSHALL SPACE FLIGHT CENTER

FRANK L. VINZ  
LORAL

EDWARD C. VOETEN  
BRADFORD ENGINEERING

ROBERT M. VUOLO  
JET PROPULSION LABORATORY

# SPACE STATION FREEDOM UTILIZATION CONFERENCE

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JACK H. WAITE  
PACE & WAITE, INC.

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MARSHALL SPACE FLIGHT CENTER

TIMOTHY WALTON  
MARSHALL SPACE FLIGHT CENTER

TAYLOR H. WANG  
VANDERBILT UNIVERSITY

CARL WARD  
MCDONNELL DOUGLAS

CURTIS D. WARNICK  
INTERACTIVE SOLUTIONS, INC.

ALISON WATKINS  
THE EGAN GROUP, INC.

JIMMY R. WATKINS  
MARSHALL SPACE FLIGHT CENTER

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BIRMINGHAM

ALLAN WEBB  
NASA HEADQUARTERS

KENNETH WEBB  
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ROBERT K. WEISS  
I.S. - ROBOTICS

MARK E. WELLS  
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STANLEY H. WERLIN  
ARTHUR D. LITTLE, INC.

FRANCIS C. WESSLING  
UNIVERSITY OF ALABAMA IN  
HUNTVILLE

PERRY WESTMORELAND  
G E GOVERNMENT SERVICES

THOMAS WICKS  
MARSHALL SPACE FLIGHT CENTER

J. PHIL WILBOURN  
TEXACO SERVICES, INC.

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AZ TECHNOLOGY, INC.

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CHARLES R. WILLIAMS  
CINCINNATI ELECTRONICS  
CORPORATION

ED WILLIAMS

JOHN R. WILLIAMS  
CENTER FOR SPACE & ADVANCED  
TECHNOLOGY

RICHARD J. WILLIAMS  
NASA HEADQUARTERS

WENDY WILLIAMS  
MARSHALL SPACE FLIGHT CENTER

WILEY E. WILLIAMS  
BIONETICS CORPORATION

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TECHNOLOGY

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MARK WILSON  
BOOZ, ALLEN AND HAMILTON

ROSS L. WILSON  
BOEING

JOHN B. WINCH  
BOEING

DR. DWAYNE A. WISE  
MISSISSIPPI STATE UNIVERSITY

RICHARD J. WISNIEWSKI  
GENERAL RESEARCH CORPORATION

GERALD WITTENSTEIN  
INTERNATIONAL SPACE SYSTEMS

GORDAN WOOD  
MARSHALL SPACE FLIGHT CENTER

GARY WORKMAN  
UNIVERSITY OF ALABAMA IN  
HUNTSVILLE

JACOB YARBROUGH  
MARSHALL SPACE FLIGHT CENTER

I. C. YATES  
MARSHALL SPACE FLIGHT CENTER

JUDY YOUNG  
BOEING

MATTHEW B. YOUNG  
U.S. SPACE & ROCKET CENTER

JAMES R. YOUNGBLOOD  
LOCKHEED

RICHARD C. ZEECK  
SVERDRUP TECHNOLOGY, INC.

RICHARD ZWIERKO  
NASA HEADQUARTERS

# *LIST OF EXHIBITORS*

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## *SPACE STATION FREEDOM UTILIZATION CONFERENCE*

### ***Space Station Freedom Utilization Conference***

Boeing  
Canadian Space Agency  
Grumman  
McDonnell Douglas  
NASA Ames Research Center  
NASA Johnson Space Center  
NASA Marshall Space Flight Center  
NASA Headquarters Office of Aeronautics and Space Technology  
NASA Headquarters Office of Commercial Programs  
NASA Headquarters Office of Space Flight  
NASA Headquarters Office of Space Science and Applications  
National Space Development Agency of Japan  
Rockwell  
Rocketdyne  
Spacehab  
Teledyne Brown  
Wyle Laboratories

### ***Payload Data Services Workshop***

Avyx Incorporated  
Barrios Technology  
Boeing  
Gulton Data  
Harris Space Systems  
Honeywell  
IBM  
McDonnell Douglas  
NASA Kennedy Space Center  
NASA Marshall Space Flight Center  
NASA Headquarters Scientific and Technical Information Office  
NASA Headquarters Office of Aeronautics and Space Technology  
SBS Engineering  
Southwest Research Institute  
Speedring  
Texas Instruments





# *LIST OF EQUIPMENT*

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## *SPACE STATION FREEDOM UTILIZATION CONFERENCE*

### ***Laboratory Support Equipment (LSE)***

- Battery Charger
- Cameras and Locker
- Camera (video) and Lights (set)
- Cleaning Equipment
- Digital Recording Oscilloscope
- Digital Multimeter
- Digital Thermometer
- EM-shielded Locker
- Film Locker
- Fluid Handling Tools
- Freeze Dryer
- Freezer, -20°C
- Freezer, -70°C
- Freezer, Cryogenic Quick/Snap
- Freezer, Cryogenic Storage
- General Purpose Hand-tools
- Glovebox, Portable
- Macroscope, Stereo (includes video camera)
- Mass Measuring Device, Micro
- Mass Measuring Device, Small
- Microgravity Science Glovebox
- Passive Dosimeter, Reader/Annealer
- pH Meter
- Specimen Labels

### ***General Laboratory Support Facilities (GLSF)***

- Life Sciences Glovebox
- Materials Processing Glovebox



# PAYLOAD DATA SERVICES WORKSHOP

## SPACE STATION FREEDOM UTILIZATION CONFERENCE

### Summary

The Payload Data Services (PDS) Workshop was held on August 4-7, 1992 at the Von Braun Civic Center in Huntsville, Alabama. The workshop was sponsored by the Office of Space Systems Development to provide detailed engineering and operations information for Space Station Freedom (SSF) payload developers. Along with detailed hardware, software, and operations presentations, exhibits of commercially- and NASA-developed systems were displayed and demonstrated. The exhibits ranged from hardware and software systems to integration and information system services. The combination of presentations, demonstrations, and exhibits provided the payload community with current engineering details to enable them to effectively plan, develop, and implement their payload Data Management System (DMS) interfaces.

The Space Station Freedom Program Office initiated the workshop with a conceptual overview of SSF payloads and the DMS. Other introductory presentations addressed the major elements that play a role in supporting payload DMS activities, such as Communications and Tracking, the Space Station Control Center, the Payload Operations and Integration Center, and the Payload Data Services System. Additional presentations on payload operations and data flow concepts highlighted the contexts within which the payloads must operate. These operational scenarios provided payload developers with an understanding of how to interact with the DMS and what to expect from ground support equipment, data manipulations, and general operations.

An overview by McDonnell Douglas Space Systems Corporation (MDSSC) initiated the detailed baseline hardware presentations. This was followed by presentations from each hardware contractor (IBM, Honeywell, etc.) These presentations walked the payload developers through increasingly lower levels of detail covering all functional, mechanical, and electrical elements of DMS hardware. Included in the briefings were functional block diagrams, data flow concepts, schematics, and engineering drawings. The hardware presentations were followed by demonstrations on the various development kits

available through the SSF program. Also, an ad hoc presentation was given by a representative of the Johnson Space Center on the status of the Engineering Design Council activity and by the Marshall Space Flight Center on the status of the Payload Analytical Integration process.

The second day of the PDS Workshop started with an MDSSC overview of DMS software elements in each of the hardware components. These briefings addressed DMS interfaces, Object Model, and the general software architectures. Lower level, detailed briefings were given by IBM, Honeywell, and MDSSC that covered various aspects of the DMS software, including telemetry services, file services, and Runtime Object Data Bases. A presentation also was given on Timeliner by Draper Laboratories that addressed the automated operations capability of SSF.

The remainder of the second day's agenda addressed ancillary DMS activities. These included a discussion of the SSF's video architecture and capabilities, a Technical and Management Information System demonstration on how payloads can obtain engineering data, a presentation on the Office of Aeronautics and Space Technology's Data System Technology program and its relationship to the SSF, and a presentation on the Astronaut Science Advisor, which is an intelligent software application that optimizes payload operations.

Day three of the PDS Workshop focused on customized payload systems. The Payload Executive Software (PES) was presented by representatives of the Marshall Space Flight Center. They outlined the functions and operations of the PES and provided payload developers with insight into the implications of the various command and control connectivity options available to them. The following presentation addressed the specifications and designs for Freedom's onboard displays and controls. The Payload Data Services System was then presented. The manner in which it will link principal investigators, mission specialists, managers, local and remote facilities, the Space Station Control Center, and the SSF was described.

## SPACE STATION FREEDOM UTILIZATION CONFERENCE

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The final day's afternoon sessions involved presentations and demonstrations by Ames Research Center, Marshall Space Flight Center, and Honeywell representatives on various aspects of potential payload computers and development tools. Special presentations from Ames Research Center representatives addressing other payload-related data studies also were given.

The PDS Workshop concluded by generating action items addressing current and future payload DMS issues. Also, the participants overwhelmingly agreed the workshop should be repeated in the future to serve as a tool for educating the payload community and other user-oriented organizations, such as the Space Station Science and Applications Subcommittee.

# PAYLOAD DATA SERVICES WORKSHOP

## AGENDA

	August 4	August 5	August 6		
8:00	Registration	Payload Software DMS Interfaces	Payload Executive Software (PES)		
9:00			Opening Remarks DMS Overview Ground Operations Accommodations SSF Data Flow Operations Orientation	Displays and Controls	
10:00				Break	Break
11:00				Break	Payload Data Services System (PDSS)
12:00	Break	Portable Computer Commonality Study			
1:00	Lunch	Lunch	Lunch		
2:00	Payload Hardware DMS Interfaces	Payload Software DMS Interfaces (continued)	Payload Case Study		
3:00		Station Video Capabilities and Interface Definition	Payload Development System		
4:00		Technical and Management Information System	Break		
5:00		Break	Code R Data System Technology	Video Compression Study	
6:00	Dinner	Astronaut Science Advisor	Closing Session		
7:00		Display Walk Throughs			
8:00	Dinner	Dinner	Dinner		

Reception at  
Space Camp  
7:00 - 9:00 PM

