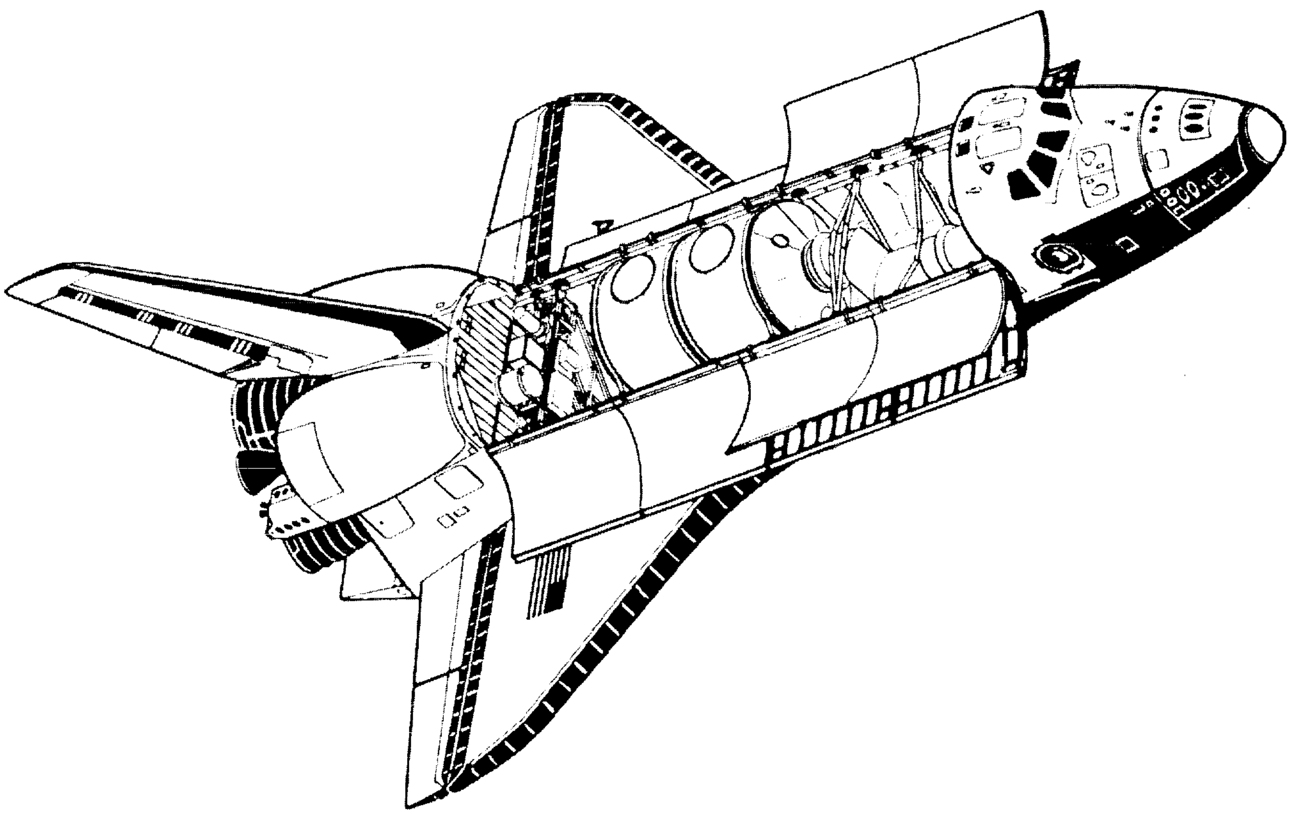
NASA

Microgravity Strategic Plan - 1988



This report has been prepared for use as an internal NASA document and will serve as the basis for NASA program planning in the future

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PREFACE

As part of its mandate to guide the United States' civil space program, the National Aeronautics and Space Administration (NASA) is committed to preserving U.S. preeminence in critical aspects of space science, applications, and technology. NASA's goals also include obtaining scientific, technological, and economic benefits through space-related activities, encouraging U.S. private sector investment in space, and improving the quality of life on Earth.

The space environment offers unique opportunities for research and development in the fundamental sciences, materials science, and the life sciences. The on-orbit microgravity environment, with reduced buoyancy forces, hydrostatic pressure, and sedimentation, is a particularly promising area to explore. Long exposure to a virtually zero-gravity environment is a unique situation that cannot be duplicated or even approximated for any length of time on Earth. In addition, the near-Earth orbit offers a unique contamination-free vacuum capability.

Of the research to be done in this environment, basic research would include the behavior of fluids and the study of transport phenomena in microgravity, as well as experiments that make use of the enhanced precision possible in microgravity to measure physical properties and to validate contemporary theories of relativity and condensed matter physics. Applied microgravity research both by NASA and its industrial partners could provide fundamental insights that would lead to better control strategies for Earth-based processes and also lead to the production of new benchmark materials with unique properties that cannot be produced on Earth.

Pioneering efforts such as these will challenge and motivate this Nation to new standards of excellence, and it will stimulate exciting developments in science, technology, and space commercialization that will be crucial to our economic growth and success in the 21st century. Successful exploration and development of the near-Earth space environment and the microgravity effects, requires a vision of the future, defined goals consistent with the national interest, and well-conceived strategic, development, and operational plans.

This document is NASA's agency-wide microgravity strategic plan, which addresses research, applications, and commercialization for the 1990's. The plan presents an analysis of the current situation, identifies critical factors, and defines goals, objectives, and strategies, which are intended to:

- provide a context for decision making;
- assure realism in long-range planning and direction for hardware development; and
- establish a framework for developing a National Microgravity Research Plan.

VISION OF THE FUTURE

Early in the 21st century, a permanently manned, on-orbit microgravity research, development, and pilot production facility is envisioned to be operated in many respects like a National Laboratory. The Space Station Freedom will be the centerpiece of this capability, however, private sector and foreign-developed carriers and platforms may be included. It may also incorporate space vacuum facilities for contamination free processing.

In the 1990's, NASA in conjunction with U.S. industry, other Federal agencies, and international partners will have qualified, developed, and begun to exploit the capabilities of the Space Station Freedom and other on-orbit facilities. The key elements of NASA's vision, *to develop near-Earth space as a national resource*, are:

- A multidisciplinary program of fundamental microgravity science in space that contributes to the peaceful, international use of space.

- A flow of practical benefits through utilization of a multi-capability infrastructure in space for microgravity research.

- Emergence of a viable, competitive U.S. microgravity-based industry capable of aggressive commercial application of microgravity research advancements.

- Strengthened U.S. competitiveness in international commerce through preeminence in materials science and processing technologies.

CURRENT STATUS

NASA's Office of Space Science and Applications (OSSA) conducts a program of enabling research in the space environment to explore the effects of microgravity on basic physical, chemical, and biological processes. In addition, OSSA pursues applied research on processing biomaterials; electronic and photonic materials; metals, alloys and composites; glasses and ceramics; and polymers. These NASA-funded, non-proprietary investigations are conducted by university, industry, and government researchers using both ground-based facilities and flight experimentation.

NASA's Office of Commercial Programs (OCP) sponsors industrial research and program initiatives that encourage the participation, funding of research, and commercial commitment of U.S. industry to space endeavors. Because many microgravity applications show commercial potential, it is imperative that a close partnership between government and industry be formed, analogous to that successfully demonstrated in NASA aeronautical research.

Joint government and industry programs are underway in Europe, Japan, and the Soviet Union. These programs are carefully planned and well funded. The U.S. can derive considerable value from international cooperation, particularly in basic microgravity research and hardware development. However, extending proprietary protection and a competitive edge to U.S. industry for applied research is an associated challenge that NASA accepts.

The 1986 Challenger disaster has significantly delayed NASA and the free world's flight program, and the lack of timely and predictable access to space has caused considerable concern and eroded confidence among academic, industrial, and international participants. However, during this time the recommendations of several, well-qualified NASA advisory bodies have been implemented. These include plans for a microgravity dedicated series of Spacelab flights (USML), a new generation of multiuser facility-class hardware, an extended-duration orbiter, and private sector developed carriers.

During the last two years, NASA's microgravity science and applications programs have matured significantly and are more realistic in scope and objectives. There is cooperation and coordination between OCP and OSSA reflecting their interdependence and a considerable potential for synergy. Congress, the Administration, and NASA continue to support and endorse an expanded microgravity research and development effort.

The goals and objectives of this NASA Microgravity Strategic Plan, are based on certain pivotal considerations:

1) The need for manned presence

Materials science and process research are experimental endeavors involving some empiricism and it is essential, in most cases, to have a manned presence to conduct interactive and iterative experiments. Only through this process of learning by doing can new materials and processing techniques be developed that take full advantage of the microgravity environment. Also, the experience of living and working in the microgravity environment will suggest new concepts for processing of materials that are not possible on Earth. The ability to explore and develop these concepts will evolve new processing techniques that may result in materials with unique and possibly superior properties.

Appropriate use will be made of automation, telescience operations, and expert systems particularly where processes are well defined. Many operations such as repair, refurbishment, or reconfiguring of experiments or production modules can be best performed through servicing on orbit by Space Shuttle or Space Station Freedom based astronauts.

2) The need for state-of-the-art hardware

Flight experience with the current hardware inventory has shown that a front-end investment in technology and equipment specific to microgravity research is essential. OSSA is currently involved in an extensive program of experiment hardware and facilities development to provide research capability necessary for scheduled USML flights and eventually the Space Station Freedom. The Space Shuttle, Spacelab, a Commercially Developed Space Facility (CDSF), and the manned Space Station Freedom will constitute an integrated carrier sequence that permits an evolutionary approach to microgravity research and hardware development. Experiment facilities can be developed on the ground, tested and refined aboard short-duration Spacelab flights and then deployed for longer duration on the Space Station Freedom for further manned experiments or a CDSF if the process can be automated. This sequence ensures maximum scientific return from planned investigations, encourages the growth of a vigorous microgravity research community and increases the early opportunity to identify and refine new techniques and processes of commercial value to ground-based U.S. industry.

The early availability of Spacehab or a CDSF used in the attached mode will accelerate both the science program and hardware development; however, only the Space Station Freedom can provide the necessary manned presence, power, and versatility required to explore and develop many of the most promising microgravity applications. Once Space Station Freedom is in operation the CDSF would continue to be utilized in the free-flyer mode, providing a long-duration microgravity environment for automated processes.

A free-flying, space vacuum facility is also contemplated. By virtue of its orbital velocity, such a facility can produce a contamination free vacuum behind a special shield. The ultra-low vacuum with near infinite pumping speed, and the ability to rapidly reject heat, enable numerous processing techniques and also complement the associated microgravity capabilities.

The eventual development of a free-flying, nano-g facility, which can compensate for residual atmospheric drag is envisioned. This facility would make it possible to conduct sophisticated experiments bearing on fundamental theories of condensed matter physics and relativity.

3) The need for cooperation and partnership

Various nations are now positioning to compete in materials and process research in space. To maintain scientific leadership it is imperative that NASA conduct an aggressive, high-quality microgravity research program and foster productive partnerships among the industry, academic, and government research communities. Research results demonstrating the benefits and limitations of the microgravity environment must be promptly and effectively reported. Increased and timely access to space, prompt and responsive review procedures, and reduced costs and time required for developing, integrating, and operating experiments in space must be provided to researchers. One measure of NASA's success in developing the space frontier will be the degree to which industry and other government agencies participate and invest in space research, development, and commercialization efforts.

GOALS OF THE NASA MICROGRAVITY PROGRAM

The following six goals were identified for the NASA Microgravity Program and reflect a merging of space science, applications, and commercialization objectives:

1. **Conduct a comprehensive research program in materials science, biotechnology, and fundamental physics, chemistry and biology through investigations in space.**

2. **Expand and facilitate an interdisciplinary research community, united by shared goals and resources, to conduct research in the space environment.**

3. **Establish a permanently manned, multi-facility national microgravity laboratory in low-Earth orbit to provide a long-duration, stable microgravity environment. In addition to its other functions, the Space Station Freedom would also be the centerpiece of this capability.**

4. **Develop and demonstrate new technologies, materials, and processes relevant to basic research and commercial applications through utilization of the space environment.**

5. **Transfer to industry the technology and "know-how" supporting new, commercially-viable products, services, and markets resulting from microgravity research.**

6. **Support, on a reimbursable basis, the launch and operation of private sector facilities and experiments. Continue to encourage the launch of microgravity research payloads by the private sector.**

PRIORITIES AND DECISION MAKING PROCESS

In order to take full advantage of microgravity research, it is essential to have a permanent laboratory in space with sufficient resources to allow scientists to experiment on a routine basis as they are able to do in their terrestrial laboratories. The U.S. Laboratory Module on the Space Station Freedom is being designed and equipped for this purpose and will serve as the centerpiece of a national microgravity laboratory which would be operated very much like any other National Laboratory. In such a laboratory it will be possible to carry out the reproducible and iterative experiments required to perfect a process without having to wait a year or more for the next flight opportunity to make an adjustment in the processing parameters.

To prepare for Space Station Freedom and to be ready to make effective use of its capabilities starting in the 1995 timeframe, a number of important steps must be taken in the next few years. Experiment facilities must be defined and developed. New technologies needed to assure that the facilities will remain state-of-the-art into the 21st century must be identified and pursued. Experiment modules that will be elements of the experiment facilities of the Space Station Freedom must be developed and tested on Shuttle flights using Spacelab, Spacehab, or a CDSF. The users community must be strengthened. Finally, and most important, a solid scientific rationale for use of microgravity must be established through high-quality experiments that clearly delineate the advantages of the microgravity environment.

To accomplish the objectives of the Flight Experiments Development Program funded under the Program Operating Plan (POP), the following tasks and decision rules have been established.

1. *Develop high-quality science experiments and modular multiuser apparatus for the USML/IML series of flights*

   This series of flights is crucial to the development of the Microgravity Science and Applications Division's (MSAD) program because it represents a continuity of microgravity-emphasis flight opportunities that will allow the development and testing of experiment modules that will eventually become elements of the Space Station Freedom experiment facilities. Also, these flights will generate an early scientific return from high-quality microgravity experiments performed in a well-characterized and controlled microgravity environment.

Factors to be considered in the determining the relative priorities of experiments to be conducted on USML missions are quality of science, pertinence to commercial interests, commitment to non-NASA supported experiments, and relative resource requirements.

2. *Development of Principal Investigator (PI)-specific apparatus for carrying out high-quality experiments which address fundamental physics and chemistry*

   Generally this apparatus is designed to carry out a specific experiment and is not suitable for multiple users. However, the potential scientific return would greatly elevate the program's status in the scientific community and would stimulate interest in other experiments of this nature. Also, several of these investigations can be expected to carry over into Space Station Freedom operation. Some of this apparatus may prove to be very expensive because of the high degree of sophistication required to challenge theories of contemporary science. The development of new or additional experiment apparatus will have to be phased into this level-of-effort program and may have to wait the completion of other projects unless the MSAD program receives additional funding. Generally, the priority within this category will be given to the projects that are nearest to being completed in order to reduce PI costs and to allow new projects to be started.

3. *Definition studies for Space Station Freedom facilities*

   It is important to begin such studies at this time, but major expenditures for the development of such facilities cannot be intelligently made until we have better understanding of the Space Station Freedom interfaces and have gained experience with the experiment modules being developed for the USML series. A systems engineering effort has been started to identify common subsystems, standardize reliability and quality assurance procedures, and to work with the developers of the various experiment modules to insure optimum interface compatibility with Space Station Freedom. Priority for funding of this category will increase next year, as the Space Station Freedom Critical Design Review (CDR) is approached.

4. *Development of science and apparatus for secondary payloads including Shuttle middeck and the Materials Science Lab (MSL) truss*

   The use of secondary flight opportunities can augment the number of flight opportunities available to the MSAD Program. However, there are a number of factors that make secondary flight opportunities less attractive; i.e., uncertainties in scheduling, unpredictable and perhaps unfavorable acceleration environment due to mission priorities, and generally fewer resources than can be provided on a dedicated mission. Nevertheless, effective use can be made of these opportunities if care is used in matching the experiment requirements to the mission capabilities.

5. *Advanced Technology Development*

   Such technology is essential to the development of facilities that will remain state-of-the-art during the operating life of the Space Station Freedom. These facilities will be designed using a modular approach so that new technology can be incorporated when it becomes available. However, since by definition, advanced technology is not on a critical path of developing any particular apparatus or facility, it must take a lower priority.

Tasks one and two have highest priority at this time. Other tasks will move up in priority with time. The order of listing does not imply that all resource requirements for early tasks must be met before any resources are made available to a later task since it is necessary to maintain a balance across the program. However, in the event of a funding short fall, some reallocation will be necessary to maintain resources for the higher priority tasks at the expense of the lower priority tasks.

The primary functions of microgravity ground-based research, funded through the Research and Analysis (R & A) program, are to develop concepts that will lead to flight experiments; to determine limitations of various terrestrial processing techniques in order to define what benefits may be expected from microgravity; or to provide support to the flight program by developing characterization techniques for analyzing results of flight experiments, modelling of processes in various acceleration environments, and determining various physical properties needed for such modelling.

Priorities in the R & A program are:

1. Support of institutional commitments such as the Discipline Working Groups, Visiting Scientist Program,Centers of Excellence, and other support functions.

2. Support of existing flight programs through process modelling or measurement of physical properties needed to design experiments.

3. Support of ground-based research needed to develop new flight experiments.

4. Support of investigations directed toward filling the gaps and addressing the "critical issues" identified in the directed research program.

5. Enhancement of ground-based and suborbital facilities such as the various drop facilities, aircraft, sounding rockets, and the Microgravity Materials Science Laboratory.

6. Ground-based research aimed at determining the limitations imposed by gravity in various processes in order to establish a rationale for future flight experiments.

Many of the research efforts sponsored by NASA's program, especially those required of a PI developing a potential flight experiment, suggest new and innovative methods for accomplishing the same result without resorting to microgravity. In such cases, especially if a process with commercial potential is involved, the PI is referred to the Office of Commercial Program's Technology Utilization Division to obtain funding to continue the development of that particular process.

IMPLEMENTATION STRATEGIES

The six major microgravity program goals and their objectives will be achieved through the following implementation strategies.

GOAL 1: ***Conduct a comprehensive research program in materials science, biotechnology, and fundamental physics, chemistry and biology through investigations in space.***

Objective: A. Develop a comprehensive knowledge base incorporating research results, advances in technology, and characteristics of the microgravity environment.

Strategies:

— Implement procedures that ensure maintaining and improving the quality of research.

— Maintain a vigorous program of ground-based and suborbital microgravity research to clarify requirements for, and optimize results from, spaceflight experiments.

— Exploit fully the range of capabilities of the Space Shuttle, Spacelab and other NASA and commercial carriers available for microgravity flight research centered around the dedicated USML microgravity missions to be initiated in 1992.

— Follow an incremental approach to research in which experiments are developed on the ground, tested and refined on Shuttle flights, and where appropriate, conducted on an orbiting national microgravity laboratory.

— Utilize expert advisory bodies (Discipline Working Groups) and the proposed National Microgravity Science, Applications and Commercialization Task Force, made up of representatives from NASA and other Federal agencies, to identify gaps in the current science program and other critical technical issues that need to be addressed.

— Develop and implement a microgravity communications plan to disseminate effectively research results and opportunities.

— Solicit and support research and applications proposals from industry, government, and the academic research community that extend the scope of current investigations or introduce new fields of study.

— Establish a database and network for research and engineering results and information on microgravity and related programs.

Objective B. Integrate industry-driven science requirements into the baseline research program.

Strategies:

— Expand a cooperative microgravity science and applications outreach program with industry, through the NASA Office of Commercial Programs and the Centers for the Commercial Development of Space.

— Establish and maintain new channels of communication among industry, academia, government, and scientific advisory groups.

Objective: C. Lead the development and implementation of a National Microgravity Research Plan that establishes and maintains coordination with, and contributions from, other Federal agencies.

Strategies:

— Conduct a survey of government agencies to document the level and type of interest in microgravity research.

— Develop a program of interagency cooperation, education, and commitment to foster a national perspective for microgravity research and applications.

— Provide a mechanism for Principal Investigators funded by industry or other government agencies to extend their research efforts to microgravity.

GOAL 2: ***Expand and facilitate an interdisciplinary research community, united by shared goals and resources, to conduct research in the space environment.***

Objective: A. Broaden participation in the microgravity program.

Strategies:

— Develop and fund new program initiatives.

— Intensify use of Discipline Working Groups (DWGs) and advisory committees to provide a proponency for high-priority work.

— Reach a wider spectrum of the research community through outreach activities and implementation of a communications plan.

— Increase the participation of industry and other government agencies.

Objective: B. Maximize the timely access to flight opportunities through consideration of all flight options including secondary payloads, military missions, sounding rockets, etc.

Objective: C. Foster the development of the next generation of scientists and engineers trained in microgravity and other space-related disciplines.

Strategies:

— Develop an interdisciplinary research capability in selected research institutions to foster wider understanding and interest in microgravity research.

— Emphasize microgravity research in NASA support programs for education.

Objective: D. Promote interdisciplinary communication of microgravity program goals, research opportunities, and results through affiliation with major scientific and professional associations.

GOAL 3: ***Establish a permanently manned, multi-facility national microgravity laboratory in low-Earth orbit to provide a long duration, stable microgravity environment. In addition to its other functions, the Space Station Freedom would also be the centerpiece of this capability.***

Objective: A. Define and develop state-of-the-art experiment hardware and facilities for the microgravity research.

Strategies:

— Pursue the evolutionary development of multiuser, facility-class hardware; refined on Spacelab for long duration deployment on the Space Station Freedom or a Commercially Developed Space Facility (CDSF).

— Identify and develop advanced technologies which significantly extend hardware capabilities.

— Develop experiment specific hardware for high-value experiments and emphasize adaptable or modular hardware for experiments with similar science requirements.

Objective: B. Utilize the U.S. Laboratory Module of the Space Station Freedom as the central component of a national microgravity laboratory.

Strategies:

— Maintain close coordination among the Office of Space Science and Applications, the Office of Commercial Programs, the Office of Aeronautical Science and Technology, and the Office of Space Station to ensure optimum microgravity research capabilities aboard the proposed Space Station Freedom.

— Initiate a systems engineering effort for Space Station Experiment Modules.

Objective: C. Encourage effective use of commercially-developed facilitie and carriers as additional components of a national microgravity laboratory.

Strategy:

— Advocate the private sector initiatives and proposals to provide commercially-developed facilities and carriers for microgravity research.

Objective: D. Provide for a national microgravity laboratory in space to be operated, to the extent technically feasible, like a National Laboratory.

Strategy:

— Collaborate with Office of Space Station (OSS) to develop a management plan and budget through consultation with other government agencies for a national microgravity laboratory in space.

GOAL 4: ***Develop and demonstrate new technologies, materials, and processes relevant to basic research and commercial application through utilization of the space environment.***

Objective: A. Increase the understanding of the influence of gravity on Earth-based processes and materials.

Strategies:

— Produce benchmark materials in space that yield key insights to materials and processes.

— Initiate a pilot manufacturing technology program to identify "high leverage" processing problems.

— Expand the Centers for the Commercial Development of Space program into promising new areas of research in the space environment.

Objective: B. Lay the foundations for space manufacturing.

Strategies:

— Initiate interaction with appropriate trade and professional associations to build an informed constituency.

— Conduct space-based production of small quantities of high-value materials.

— Develop new processes or processing techniques that are unique to microgravity.

— Explore modular processing for adaptable pilot scale production.

Objective: C Apply telescience, automation, and robotics to microgravity and materials processing in space.

Strategies:

— Support the Telescience Testbed Pilot Program (TTPP) within OSSA.

— Foster a program to develop and integrate advanced technologies that facilitate space processing.

GOAL 5: ***Transfer to industry the technology and "know-how" supporting new, commercially-viable products, services, and markets resulting from microgravity research.***

Objective: A. Provide effective dissemination of knowledge and technology derived from microgravity research to U.S. industry.

Strategies:

— Utilize the Technology Utilization Office within the NASA Office of Commercial Programs.

— Facilitate technology transfer by utilizing the most effective mechanisms developed by federal research laboratories.

— Expand opportunities for industrial personnel to participate in flight programs, which could include industrial payload specialists.

GOAL 6: ***Support, on a reimbursable basis, the launch and operation of private sector facilities and experiments. Continue to encourage the launch of microgravity research payloads by the private sector.***

Objective: A. Develop new models for NASA-industry partnerships in technology development and transfer, including commercialization.

Strategy:

— Select and employ the most effective mechanisms developed by Federal research laboratories and agencies to encourage commercialization of research results.