

# THE WORLD OF NASA MICROGRAVITY SCIENCE

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## Introduction

It has been said the the decade of the 1990's represents a second golden age of science. We are in the midst of one of the most exciting and interesting periods in the history of exploration - - a period which holds the potential for expanding our understanding of scientific phenomena ranging from intricacies of the universe to the subtleties of our own planet. The opportunities to study the effects of microgravity in space seem limitless during the next decade. Using the European Space Agency (ESA) built Spacelab, we will maximize opportunities for development of new microgravity facilities in order to obtain new information and increase our understanding of the effects of gravitational forces on phenomena in biological, chemical and physical systems. NASA intends to move aggressively, but sensibly, to develop additional space research facilities as we build toward the unique Space Station Freedom resources becoming available towards the end of this decade.

In the Space Studies Board's 1992 report, *Toward a Microgravity Research Strategy*, the Committee on Microgravity Research recommended that a long term research strategy be developed for microgravity sciences. The report defined the the overall goals of the field and summarized the current knowledge of its subdisciplines. In addition, the Committee concluded that this strategy should identify the fundamental questions that need to be addressed and the scientific community's ability to address them. For those of us involved in developing and supporting a growing microgravity science research program, this was yet another indicator that the field of low gravity research is beginning to prove its merit.

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## NASA's Microgravity Science Research Program

NASA funds a robust microgravity research program in a wide variety of microgravity related disciplines. Each research task is designed to yield a better understanding of phenomena within the areas of biotechnology, combustion, fluid dynamics and transport phenomena, and materials sciences. The knowledge gained from research in one field often has impacts in another. Investigations sponsored as part of the microgravity science program share one characteristic; they required reduced or very low gravity conditions in order to achieve their objectives.

The overall Microgravity Research Program is conducted through integrated ground-based and flight programs. The primary functions of the ground-based research program is to develop concepts that lead to flight experiments - - to determine limitations of various terrestrial processing techniques - - and to provide analysis and modeling support to the flight program. Although we support research that can be completed in the ground-based program, a successful ground-based research program is generally the first step in the process towards flight experimentation. At the start of 1992, the Microgravity Science and Applications Division was supporting a total of 115 microgravity research Principal Investigators; 73 in the ground-based program and 42 in the flight program.

### Ground-based Research

The ground-base research program has continued to perform the essential functions of providing theoretical and experimental background to support current flight experiments, and to nurture ideas and efforts that may later form the basis of future flight experiments. The program has used several types of unique facilities providing varying durations of reduced gravity environments such as drop tubes, drop towers, and aircraft. The most active of these ground facilities include two drop towers here at Lewis Research Center, wherein the sample and equipment can be protected from the drop environment and provide a low gravity environment for 2-5 seconds, and a drop tube at Marshall Space Flight Center. Aircraft in parabolic flight trajectories can provide reduced gravity durations of up to nearly 30 seconds; a KC-135 aircraft at the Johnson Space Center and a Learjet Model 25 here at the Lewis Research Center are available. In addition to the test facilities, the Microgravity Materials Science Laboratory here at Lewis Research Center provides an extensive computational and modeling capability.

In a continuing effort to expand the microgravity research community, we have supported several ground-based efforts in the academic community. The Graduate Student Researchers Program is one means where students, under the guidance of a faculty sponsor, can perform microgravity research using ground-based low gravity facilities. Secondly, government, industry, and university cooperation is encouraged through an active post-doctoral and Visiting Senior Scientist program. Recent Ph.D 's, tenured professors, and nationally known experts can spend one to two years conducting research at a NASA center or can participate in science planning and management at NASA Headquarters.

In addition, we disseminate results from both the ground-based and flight-based research programs to the scientific community-at-large through participation in conferences, forums, and workshops. These include such meetings as Gordon Research conferences, American Institute of Aeronautics and Astronautics science meetings, Committee on Space Research (COSPAR) conferences, International Astronautical Federation conferences, European Symposia on Materials and Fluid Sciences in Microgravity, and at workshops such as this Second International Workshop on Combustion Science in Microgravity. In this way we are expanding our base throughout the low-gravity research community.

#### The Flight Program: Research-in-Space

As our experience becomes more fine-tuned and as we more effectively use gravity as an experimental parameter, we will be able to realize the potential offered by this new age of low-gravity research. The sheer number of space science missions related to microgravity sciences in the years between 1991 and 1993 is dramatic. More microgravity research will have been conducted within these years than has been conducted over the preceding decade.

Significant effort is spent in preparation for a number of upcoming Space Shuttle missions. Multi-user and experiment-unique apparatus will be flown aboard the Shuttle periodically over the next six years in various payload configurations. The European developed Spacelab module is an important tool in supporting low gravity research. This year the International Microgravity Laboratory (IML), the United States Microgravity Laboratory (USML), and the Japanese/U.S. collaborative Spacelab-J mission utilized the pressurized Spacelab module. The U.S. Microgravity Payload (USMP), an unpressurized system in the Shuttle payload bay is to be first flown in October 1992. These Spacelab missions form a foundation for future microgravity research on space Station Freedom. This research will continue as Shuttle and

Spacelab flights are projected into 1998 as our basic research vehicle prior to access to Space Station. Another payload configuration is the commercial middeck accommodations module, Spacehab, scheduled to begin a series of flights in 1993.

Most of the recently launched and upcoming microgravity missions have an international component, fostering cooperation and an exchange of knowledge benefiting the entire science community. When combined with other international cooperative flight programs, such as the European Retrievable Carrier (EURECA) series, the German Spacelab-D2, the Japanese/ U.S. collaborative Spacelab-J mission, and the European Space Agency (ESA) proposed Spacelab-E1 and Spacelab-E2 missions, there should be frequent and routine access to space and its research opportunities during the remainder of the decade.

### Supporting Research & Technology

Flight experience has demonstrated that an early investment in technology specific to the microgravity program is essential. In order to achieve this, NASA funds research activities that seek to create or refine equipment that would enhance the scientific quality of future microgravity flight experiments. Technology development not specifically on the critical path of any particular flight project is funded through the Advanced Technology Development (ATD) program. The supporting technology development includes fundamental research that supports the goals and objectives of the overall microgravity science program. An example of this activity is the development of systems to characterize the reduced-gravity environment of space experiments.

### Space Station Freedom Utilization

Beginning as early as 1997, the Space Station will offer the environment, power, and duration necessary to pursue a wide range of scientific research. Extending on-orbit research time from the seconds and minutes of sounding rockets to the hours and days of the Shuttle and Spacelab program was a key element in the growth in research in which gravity is the experimental parameter. The Space Station extends the opportunity several orders of magnitude. Definition of several multi-user microgravity facilities for potential use on the Space Station began during the 1990-1991 time period. Hardware requirements necessary to support these facilities continue to be identified in order to influence Space Station design. The precursor payloads

flown on Shuttle missions and the research conducted provide experience for the operations and development of instrumentation and subsystems for use on the Space Station .

Space Station Freedom will provide a stable platform on which highly productive and flexible microgravity science experiment modules can be based. A key long term program goal is the development of several multi-user facilities specifically designed for long duration scientific research missions. We are studying several facility concepts to support the microgravity science research we expect will be conducted aboard the Space Station during the period 1997 and 2004. Some of this early hardware could be of Spacelab heritage - - consistent with our "go as you learn" strategy.

The Modular Combustion Facility, probably of most interest to this Workshop, could support a wide range of science experiments dealing with the study of combustion and its by-products. The facility is currently planned for flight aboard the Space Station as early as 1998. Advanced combustion experiment hardware is presently being defined for Spacelab missions in the mid 1990's as precursors to the Modular Combustion Facility experiments. It is likely that recommendations from this workshop will influence the research announcement leading to the selection of many of the early Space Station Freedom combustion Principal Investigators.

### The Future for Microgravity Science Research

Microgravity Research within the United States has an optimistic future. The President proposed a budget for Fiscal Year 1993 that represented a doubling of the funding for microgravity research over three years.

We have established four science Discipline Working Groups in the areas of Biotechnology, Combustion, Fluids and Transport Phenomena, and Materials Science. These groups are responsible for maintaining an overview of the efforts in the discipline areas and for providing an annual assessment of the program. They are to recommend refinements and science priorities within the discipline, and to identify the programs, strengths and weaknesses, as well as the most promising areas for investigation and the most advantageous approaches for experimentation.

We are using a series of NASA Research Announcements (NRA's), all open to the international science community, to select principal investigators for ground-based research, for flight experiment definition, and for space-based research. The NRA for combustion science issued in 1989 to solicit

ground-based and flight experiments produced 65 proposals, the NRA for Fluids and Materials Science Containerless Processing released in 1990 produced 69 proposals. Four NRA's were released in 1991 -- the fluid dynamics and transport phenomena NRA produced 205 proposals; the biotechnology NRA produced 94 proposals; the materials science NRA produced 141 proposals; and the NRA for fundamental science produced 51 proposals -- or a total of 491 proposals from NRA's released in 1991. In August 1992 we selected 122 Principal Investigators from these four NRA's - - a selection rate approximating 25%. This raises the number of Principal Investigators in the microgravity science program from 115 in 1992 to over 190 in 1993.

We are looking toward a 3-fold increase in funded Principal Investigators prior to Space Station Freedom Permanently Manned Capability in 1999. We plan to release research announcements in the coming years in order to continue to obtain high quality scientific investigations. Workshops such as this one will contribute to the content definition of future research announcements.

### Conclusions

The research in space we applaud in 1992 and 1993 is based upon plans laid in the mid to late 1980's. It has taken several years to develop and define a successful research plan. The present series of microgravity research missions is based upon work that was started almost a decade ago, and has evolved through successful international cooperation, planning and establishment of clearly defined research goals.

These are exciting times for those of us involved in microgravity research -- and we have only begun to define the work that needs to be done. So at the onset of this Second International Workshop on Combustion Science in Microgravity -- let us agree to start the cycle again, to plan for the research opportunities in the years ahead, using the Spacelab, free-flyers and, of course Space Station Freedom. Clearly, securing the promise of successful microgravity research for the late 1990's, both in the laboratory and in space, demands a science dialogue such as that supported by workshops like this one. I wish you well in your endeavors this week.