Plans and Future Directions of the German Life Sciences Program

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The German life sciences program covers three disciplines: 1) medicine, 2) biology, and 3) biological processing. The overall objectives are to acquire expertise in manned flight techniques and to enable scientists to conduct qualified scientific research by use of the specific space environment. To achieve these goals the German government provides the scientific community with experiment facilities and with national and international flight opportunities.

ADMINISTRATIVE STRUCTURE OF THE GERMAN LIFE SCIENCES PROGRAM

The German program "Research Under Weightlessness" is based on three major elements: 1) the scientific program covers both the fields of Materials Science and Life Sciences; 2) the program support element represents all kinds of activities related to program support, enabling the performance of qualified fundamental research related to microgravity on Earth and in space (e.g., establishment of scientific or user support centers, development of new flight hardware); 3) the flight program includes all national flight opportunities and those international missions open to German participation.

The German life sciences program is performed under the authority of the Federal Ministry of Research and Technology. DLR, the German Aerospace Research Establishment, supports the ministry by conducting program and budget planning, and program and budget execution; evaluating funding requests concerning scientific, technological, and legal aspects; preparing the final funding requests and recommendations to the ministry; and subsequently placing the contracts with the universities and industrial companies.

Program execution is controlled by the scientific advisory committee directly related to the ministry and involved in recommending program plans, setting priorities between single research areas and topics, and controlling the coherence of microgravity with terrestrial research activities. The scientists involved in the life sciences program are represented by planning groups. Together with DLR, these groups are responsible for the program plans of related research areas, the scientific evaluation of experiment proposals, and the recommendations for future hardware development.

SCIENTIFIC PROGRAM

During the previous two years, DLR and the Federal Ministry of Research and Technology have established the infrastructure needed for the verification of a highly qualified scientific program. The definition of this program with a perspective to the year 2000 has now been completed with the participation of all of the scientifically relevant groups involved in German space research activities. Three major research areas comprise the life sciences program:

- Biological Processing, including the main topics electrofusion, electrophoresis, and protein crystallization
- Biology, including gravitational biology, biological life support systems, radiation biology, and exobiology
- Medicine, including human physiology and operational space medicine.

Biological Processing

Biological Processing covers standard topics of biotechnological techniques such as free flow electrophoresis and electrocell fusion plus classical research in cell and microbiology, as well as fundamental research on crystallization of biological macromolecules. The following goals have been identified to be met by research in biological processing:

- achievement of a better understanding of the influence of gravity on cellular energetics and cell processes
- clarification within the next few years of the advantages of biotechnological separation techniques under microgravity, including aspects of applied research.

Biology

The goals defined for the research area of Biology include:

- elucidation of perception and transduction of gravitational stimuli in cells and whole organisms,
and understanding of the underlying biophysical and biochemical mechanisms
• understanding of long-term adaptation of plants and animals to spaceflight conditions
• understanding of the influence of gravity on the evolution of living organisms on Earth.

The main subtopic within the research area of Biology is represented by Gravitational Biology. In this area, research is performed on single cells, cell tissues, and on whole plants and animals.

The conception and development of special hardware for plant and animal habitats with emphasis on long-term and multigeneration experiments is performed within the subtopic Biological Life Support Systems. German activities on CELSS (Controlled Ecological Life Support System) research, especially the C.E.B.A.S.-AQUARACK project, compose most of the current activities.

Research on Radiation Biology has a successful tradition within German space research. Main activities are represented by investigations on the biological effects of cosmic radiation and its interference with microgravity. Special emphasis was brought to radiation dosimetry through the use of passive dosimeters, e.g., of the BIOSTACK type. In the future, however, passive dosimetry will be strongly supported by investigations with active dosimeters that are under development.

Exobiology covers investigations under extreme environmental conditions, including investigations on the survival of living organisms under cosmic conditions.

**Medicine**

German research in Medicine deals with four aspects of human physiology in order to guarantee the survival and health of humans in space:

• investigations on fluid shifts, including the understanding of transient regulation as well as the adaptation of the complete fluid system
• investigations on the underlying mechanism of graviperception in humans
• investigations on the mechanism of spatial orientation in microgravity and the causes of motion sickness
• investigations on bone and mineral metabolism.

Research in Medicine is performed within the subtopics Human Physiology and Operational Space Medicine. Research on human physiology has a successful tradition in Germany and especially at the DLR in Cologne. During prior spaceflights, progress has been made in investigations of the vestibulo-ocular system. Investigations on the cardiovascular and pulmonary system will be performed during the upcoming D-2 mission.

Operational Space Medicine will be a focus of the future activities of the newly established European Crew Training Center at the DLR in Cologne.

**PROGRAM VERIFICATION**

The establishment of up to five centers of excellence, e.g., Microgravity User Support Center, DLR, Cologne; AGRAVIS, University of Bonn; Controlled Ecological Biological Aquatic System (C.E.B.A.S.), University Bochum, is under consideration to support the German life sciences research program. These centers were envisioned to establish space-related research on a broad scale. They will concentrate on special focal points of science and establish collaborative projects with other universities in the field of emphasis.

Providing the German scientific community with adequate flight opportunities is mandatory for the verification of science in the life sciences program. To this end, all national available short-term flight opportunities, such as drop tower (4 sec, 10.4 g, 1990), parabolic flights and sounding rockets (TEXTUS, 6 min, 10.4 g; MAXUS, 18 min, 10.4 g, 1990), are currently used or under consideration.

The German sounding rocket program TEXTUS (Technologische Experimente unter Schwereelosigkeit) is especially useful, and has become the “work horse” of life sciences research during the last two years. Its main advantages for life sciences research are high flight frequencies (4 rockets per year), short turnaround time per experiment (4-6 months), low-cost flight opportunity, development of spacecab and reentry satellite-compatible hardware, late access (1 hr) and early retrieval (20 min), and on-line video observation and telescience capabilities. The TEXTUS program has been successfully used for investigations studying the mechanism of graviperception in higher plant cells and on gravitaxis in unicellular organisms.

Only a small part of the German life sciences program can use the short-term flight opportunities for scientific research. Therefore, it is obvious that there is a strong need for missions with durations from several days to at least a few months.

About 45 life sciences experiments will be performed during the shuttle Spacelab D-2 mission, scheduled for February 1992. Further participation on international manned spaceflights missions (International Microgravity Laboratory-1 and -2) will provide German scientists with a minimum of additional flight opportunities. Nevertheless, the intensification of international shared missions is needed for additional long-term unmanned missions, e.g., EURECA (European Retrievable Carrier) and BIOCOSMOS. Germany has considered the development of a reusable reentry satellite (Raumkuriert), and has also decided to participate in NASA’s international LifeSat program in order to close the obvious gap in long-term flight opportunities in preparation for the space station era.
Germany will participate on the international Space Station Freedom. Up to 38% of ESA's European module of the international space station is contributed by the German Federal Ministry of Research and Technology. Corresponding to this large financial contribution, Germany is developing a set of national experiment facilities for utilization on space station.

INTERNATIONAL COOPERATION

Future space research in the field of life sciences needs a strong international approach. This is especially true for optimization of the scientific output of space research, for solving outstanding problems in basic research and manned spaceflight missions, and for reduction of costs.

Germany has therefore established a variety of bilateral cooperations in the field of life sciences in addition to membership in ESA. Meetings are held once or twice a year with NASA (since 1985), CNES (Centre National d'Etudes Spatiales, France, since 1986), Science and Technology Agency of Japan (since 1987), and Chinese Academy of Space Technology (since 1987). Meetings to be held on a regular basis with the USSR are under negotiation.

Further attention will be given by Germany to accelerate cooperation with other space agencies on the following topics: sample and tissue sharing of flown material, data sharing in common flight experiments, development and use of common hardware, and performance of shared flight missions.

Intensification of collaboration in the international scientific community will facilitate and enhance the scientific output from space research and will benefit both the participating scientists and the involved agencies. The programmatic provisions described in this paper will prepare life sciences research in Germany for the next steps in space research to year 2000.