NASA

SPACE SHUTTLE

PROGRAMS AND PROJECTS, APRIL 1989

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NASA

Life Sciences Division
NASA Headquarters

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SPACE LIFE SCIENCES

Martian settlers watching the next apparition of Halley's comet in 2062. Reprinted courtesy of the artist, and Carl Sagan and Ann Druyan, Comet, Random House, N.Y., 1985. (above) The Great Orion Nebula M-42.

National Aeronautics and Space Administration
Office of Space Science and Applications — Life Sciences Division
Washington, D.C. 20546

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NASA Goals

National Space Policy Goals

- Maintain leadership in space.
- Improve the quality of life on Earth through space-related activities.
- Expand human presence and activity beyond Earth orbit into the solar system.
- Encourage U.S. private sector investment in space and space-related activities.

NASA Goals

- Advance scientific knowledge of the planet Earth, the solar system, and the universe beyond.
- Expand human presence and activity beyond Earth orbit into the solar system.

Life Sciences Goals

- Ensure the health, well-being, and performance of humans in space.
- Develop an understanding of the role of gravity on living systems.
- Expand understanding of the origin, evolution, and distribution of life in the universe.
- Promote the application of life sciences research to improve the quality of life on Earth.

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Michael Carroll

SCHEDULE OF LIFE SCIENCES SPACELAB MISSIONS

1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997

Mission	Date	Research areas
SLS-1	June 1990	Cardiovascular, Bone, Metabolism, Vestibular
IML-1	April 1991	Plant, Neurovestibular, Human Performance, Radiation, Cellular Differentiation
SL-J	July 1991	Gravitational Biology, Medicine
SL-D2	December 1991	Cardiovascular/Fluids, Radiation
SLS-2	July 1992	Medicine, Metabolism, Gravitational Biology
IML-2	October 1992	Rhesus Physiology
SLS-3	November 1993	
SL-D3	February 1994	
IML-3	June 1994	
SLS-4	May 1995	Artificial Gravity (1.8-M Centrifuge)
IML-4	August 1995	
SLS-5	January 1997	

SPACE STATION

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Space life science is the study of how microgravity affects living systems. It encompasses the study of how to keep people healthy and productive in space and how, where, and when life began, on Earth and in the universe. It is a multidisciplinary science performed at four NASA Field Centers, over 83 universities in 34 states, supported by engineering and technical capabilities of the aerospace industry and strong international cooperative activities.

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Through 27 years of space flight, we have learned that humans can survive and be productive in space, that they partially adapt to the microgravity environment and seem to readapt to Earth's gravitational field. We have identified major physiological changes that take place in space. The next step, and the focus of the forthcoming Life Sciences Spacelab missions and on Space Station Freedom, is to understand the mechanisms of these adaptive changes.

Over the last 4 years several NASA, NRC, and aerospace professional associations have presented the rationale for the need to establish a vigorous space life sciences program, which has slowly eroded since the end of the Skylab era through budgetary constraints. In 1988 the Report entitled, "Exploring the Living Universe - A Strategy for the Space Life Sciences" was adopted by NASA as a strategy for establishing a vigorous national leadership program in space life sciences. This strategy is intended to assure a gradual rebuilding of the Life Sciences infrastructure, with the aim of establishing the biomedical foundations for human exploration and developing the sizeable segment of the scientific community that so far has had no access to space-based laboratories. The four overarching recommendations are:

- Maintain and expand the Nation's life sciences research facilities located at the Agency's field centers, universities, and industrial centers by:
  - Establishing a mechanism for attracting promising young scientists to work on NASA projects and developing additional training programs at major universities and appropriate NASA installations
  - Establishing a program of NASA-supported professorships in space life sciences at selected universities
  - Encouraging industries to develop capabilities in space life sciences through technology research and development.
- Assure timely and sustained access to space flight, thereby facilitating the conduct of critical life sciences experiments. This should be accomplished through:
  - Accumulating state-of-the-art instrumentation
  - Flying an augmented series of Spacelab missions
  - Using a series of autonomous bioplatforms to study radiation and variable-gravity effects
  - Dedicating suitable facilities on the Phase 1 Space Station complex for life sciences research
  - Conducting a major augmentation of life sciences capabilities during the early Post-Phase 1 period.

(above left) A piloted Mars spacecraft could be assembled in Earth orbit. (above) Mars.

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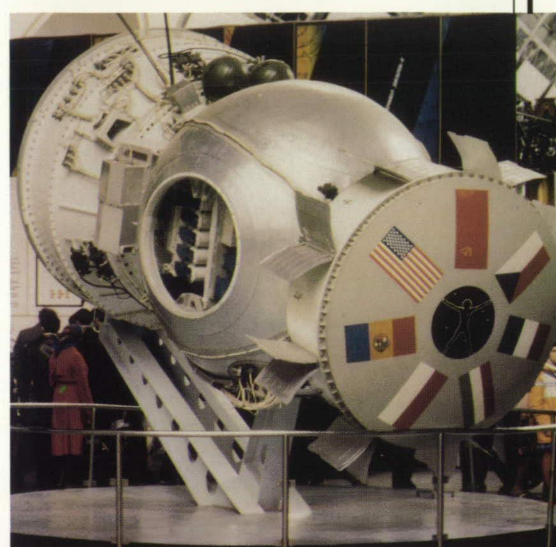
• Synergize the presently independent research activities of national and international organizations through the development of cooperative programs in the life sciences at NASA and university laboratories.

• Complete and consolidate the unique national data base consisting of basic life sciences information and the results of biomedical studies of astronauts conducted on a longitudinal basis. This data base should be expanded to incorporate information obtained by other spacefaring nations and be available to all participating partners.

We are now in the process of implementing these recommendations, and the projects described herein are responsive to the critical milestones outlined in this Report and do reflect the scientific needs expressed by other national agencies and university communities as expressed in the NAS report entitled, *A Strategy for Biomedical and Biological Sciences in the 1980's and 1990's.*

In this report, we will outline our programs and projects in operational medicine, biomedical research, space biology, closed loop life support, exobiology, and biospherics, and the projects that support these programs.



(above) NASA cooperates with the Soviet Union on Comos Biosatellite missions. (right) NASA life scientists talking with Soviet scientists about future space missions.

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Operational medicine program

The purpose of the Operational Medicine Program is to assure crew health, safety, and productivity. The program does so by the practice of preventive occupational and clinical medicine and establishing the effectiveness of appropriate medical countermeasures and life support systems in flight. Activities include preflight and postflight medical evaluations of space crews, inflight physical and environmental health monitoring and maintenance, emergency medical support, and maintenance of a database to identify long-term adaptive mechanisms to single and multiple exposures to space flight.

Operational medicine projects

Space Station Freedom will contain a **Health Maintenance Facility** (HMF) developed at the Johnson Space Center. Located in the habitation module, the HMF is a combination walk-in clinic and small emergency room. Subsystems consist of a life support unit; a digital radiographic imaging system; a respirator/ventilator; intravenous therapy equipment; and a clinical laboratory and pharmacy. Another of the major automation subsystems is a computer that provides access to medical data and detailed procedures for preventing, diagnosing, and treating various problems.

A prototype surgical work station for the HMF has been tested during short-duration weightlessness tests during KC-135 airplane parabolic flights; in-space verification tests of surgical techniques will be performed on Spacelab Life Sciences 1 (SLS-1) and Spacelab-J. The verification tests will cover emergency surgical and medical procedures, including restraint mechanisms and the ability to control, contain, and collect fluids. The HMF intravenous fluid administration system, clinical and chemistry analysis equipment, and microbiology and hematology diagnostic equipment will also be tested in subsequent space missions.

Biomedical research program

The Biomedical Research Program concentrates on investigating problems which could impact the health and well-being of space crews. Through ground-based research and flight experiments, we are studying the mechanisms of medical events occurrence and means to prevent them. Four major biomedical issues threaten to limit human stays in space unless they are solved and specific countermeasures are developed. These consist of: cardiovascular, bone, and muscle deconditioning and psychological difficulties inherent to long-duration flights, including stress related to isolation and confinement. In addition, new technologies need to be developed and tested to control the environmental effects of space and the spacecraft, such as protection from radiation, atmosphere revitalization, water and food production, contamination control, and habitability in order to assure long-

KC-135 payload crew for life science experiments on 1988 flights.

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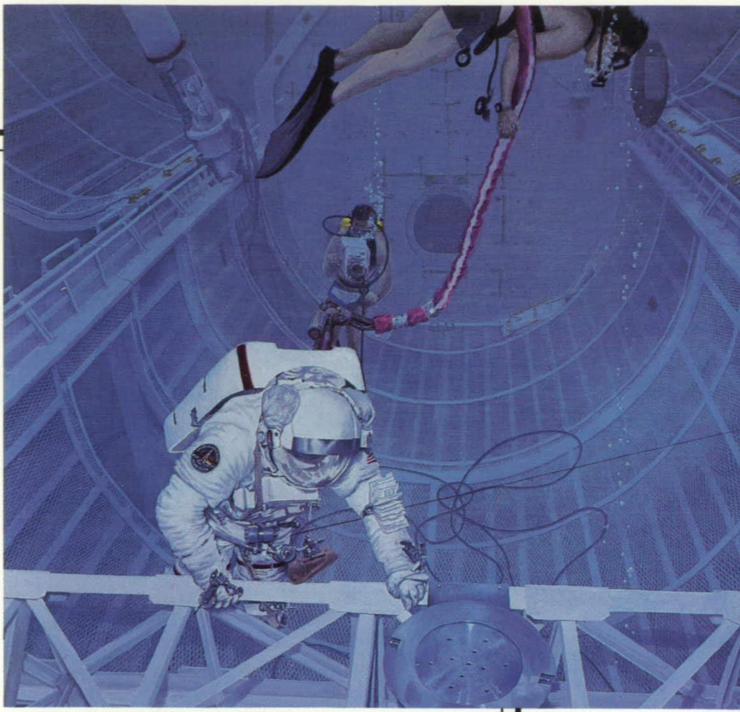
term presence in space. We are seeking to define more precisely the radiation risks facing humans in space, and to develop spacecraft standards for toxicology, microbiology, barophysiology, and vibroacoustics. We are also studying human factors such as social/psychological interactions and means to enhance microsociety performance and functions. We are exploring how to combat the psychological stresses of isolation and confinement, in individuals and in groups, including how the physical environment affects human productivity.



Jack Kroehnke for NASA

Weightless

Biomedical research projects

A comprehensive series of biomedical experiments will be conducted on the first three dedicated Spacelab Life Sciences (SLS) missions to be launched on the Space Shuttle in 1990, 1992, and 1993. The SLS missions are an integrated set of investigations designed to study physiological responses to microgravity and subsequent readaptation to one gravity in a variety of living organisms. All of the experiments to fly on **SLS-1** - scheduled for launching on STS 40 in 1990 - address problems facing crews relevant to short- and long-duration missions: neurovestibular disturbance, muscle atrophy and bone demineralization, alteration of red and white blood cell counts, fluid-electrolyte and endocrine regulation, and cardiovascular deconditioning. Six SLS-1 investigations focus on the cardiovascular/cardiopulmonary system, which interacts with every organ in the body; even small changes in this system may affect other body systems. The six investigations will measure physiological responses starting at insertion into orbit and continuing through the readaptation phase after return to Earth.

Most of the experiments to fly on **SLS-2,** scheduled for launch on STS 59 in 1992, will expand upon experiments flown on SLS-1. The SLS-3 mission will focus on the role gravity plays in biological processes. The Federal Republic of Germany's **Spacelab D2** mission scheduled for flight in late 1991 on STS 52 will continue experiments related to SLS studies of cardiovascular deconditioning and testing of countermeasures.

Spacelab-J, a Japanese mission manifested on STS 49 in 1991, will carry NASA life science experiments that are also related to the SLS investigations. One will be a test of lower body negative pressure as a countermeasure to cardiovascular changes that result in postflight inability to maintain upright positions due to changes in blood flow patterns. Another will be a cell-development study, examining how exposure to microgravity affects the development of living systems.

The **International Microgravity Laboratory (IML-1),** a Spacelab mission planned jointly with NASA's Microgravity Science and Applications Division, will fly on STS 47 in 1991 with cooperative experiments involving six national space agencies and investigators from many countries.

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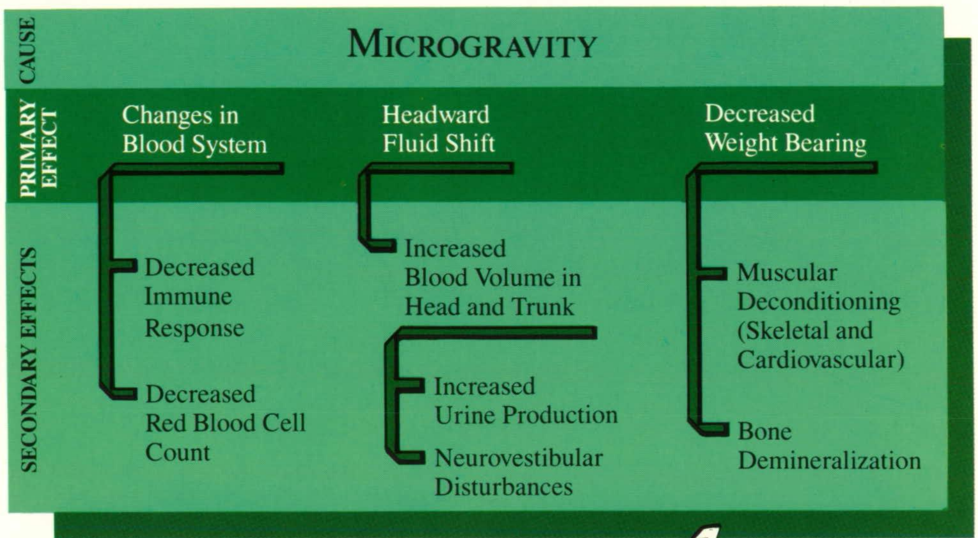
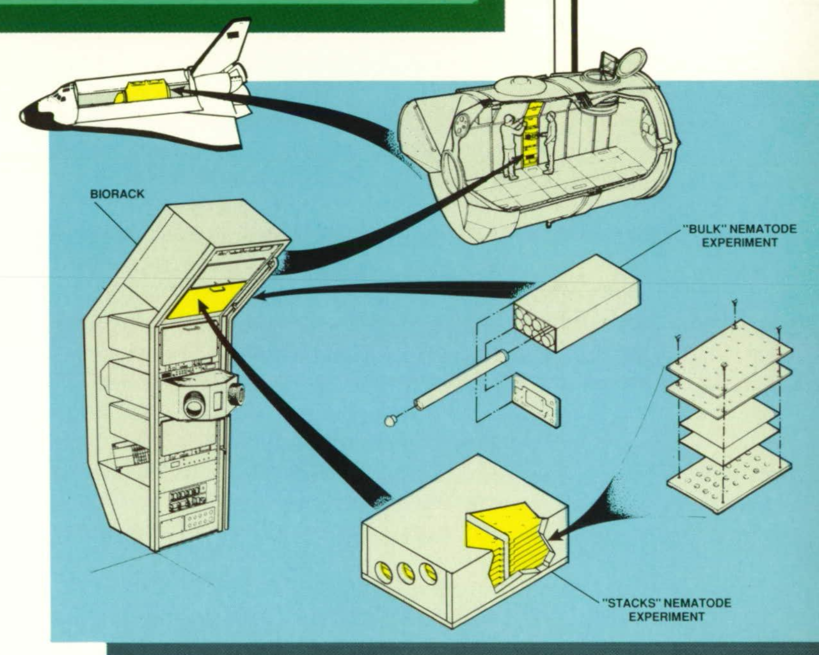


The major space life sciences investigation on this mission will study human neurovestibular responses to weightlessness. The Life Sciences Division will also fly investigations aimed at understanding the biological effects of cell development and growth in the European Space Agency's Biorack. Other NASA experiments on this mission will examine plant responses to light and gravity, human neurosensory responses, and the influence of space flight on general performance of tasks.

NASA plans to initiate Extended Duration Orbiter (EDO) flights on the STS, and the Life Sciences Division is implementing an **EDO Medical Project** in support of these missions. This project is intended to ensure crew health and safety during reentry after extended STS missions by conducting high priority medical investigations prior to the 1992 USML-1 mission to establish medical operational procedures for mission success. Development and testing of countermeasures to physiological deconditioning will be an important feature of this program. In addition, monitoring of occupational health factors such as radiation exposure, air and



Ames Research Center
IML-1 BIORACK RADIATION EXPERIMENT

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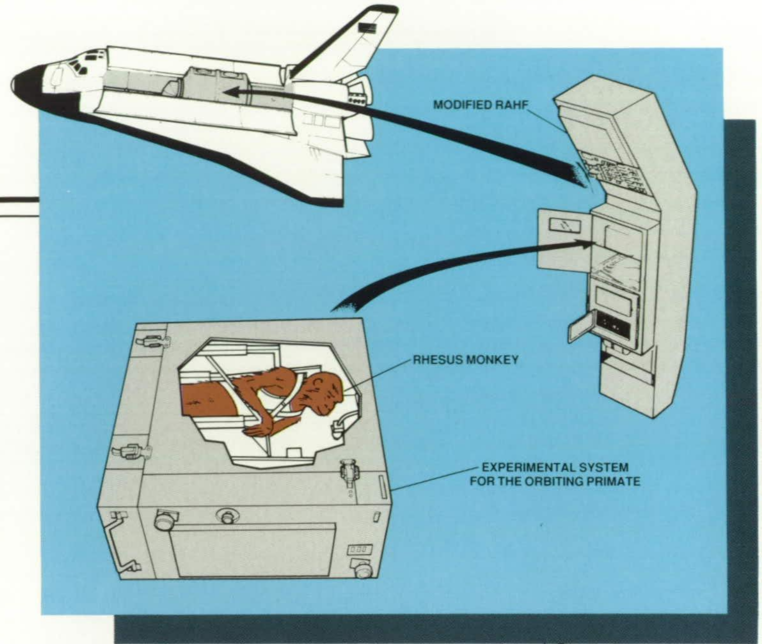
water quality, surface contamination, and waste management will be necessary to determine whether EDO missions will require enhanced personal hygiene and food systems.

The EDO will provide a valuable biomedical database that will be useful in planning and implementing another initiative to extend space flight crew tours of duty to 180 days on the Space Station Freedom. This project, called **Extended Duration Crew Operations** (EDCO) will be implemented in 1990. Through ground-based research and Shuttle experiments, we will develop, test, and further refine countermeasures to physical deconditioning in space. The aim is to demonstrate the effectiveness of medical protocols, technologies, and procedures that will assure the medical health and productivity of crew members in space and after return. Johnson Space Center is the lead center on both the EDO and EDCO projects.

U.S.-Soviet joint biomedical research in space encompasses cooperative investigations in space biology on Cosmos biosatellite and SLS missions, standardization of procedures and data acquisition in ground-based investigations and manned missions. Joint U.S.-Soviet experiments proposed for a Cosmos biosatellite flight in 1989 include analyses of neurovestibular and musculoskeletal physiology; a radiation experiment using detectors mounted inside and outside the spacecraft; and an analysis of rodent tissue biochemistry. Additional joint experiments are under consideration for a Cosmos biosatellite mission in 1991. Joint experiments will also be conducted on SLS-1/2/3 missions. With the French space agency CNES, the Life Sciences Division is planning a series of biomedical experiments for a new Spacelab **Rhesus Research Facility** that will be ready for flight in 1993. The experiments will focus



Ames Research Center
LARGE PRIMATE FACILITY

on how microgravity affects cardiovascular function, visual-motor function, bone and muscle metabolism, fluid balance, behavior, circadian rhythms, and the immune system in primates.

The biomedical program conducts human factors research in the laboratory and in isolated locations that simulate some characteristics of the space environment. We plan to participate in joint activities with the **National Science Foundation** at polar camps and with the **National Oceanic and Atmospheric Administration** in undersea habitats to study human responses to living during extended periods of time in isolation and confinement.

When the Agency moves to explore the solar system and beyond - first with unmanned spacecraft (*in situ* measurements and returned samples) and then with manned spacecraft in missions of long duration - an understanding of the complex environments that will be encountered will become of paramount importance. Without an understanding of the combined effects of other gravitational, temperature, lighting, radiation, geochemical, and atmospheric environments, long-term ventures would be extremely risky. Rela-

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tionships among these environments fall into the broad realm of ecosystem studies and will be crucial to successful understanding and exploration of the solar system. Programs in Space Biology, Life Support, Exobiology, and Biospherics have as their goal the study of ecosystems and the environmental variables within ecosystems, starting on the Earth and moving into the more unusual environments of spacecraft and other bodies in the solar system. These programs offer a unique synergism in establishing the foundations for future bold initiatives.

(right) Lower body negative pressure may combat cardiovascular deconditioning in space. (below) SLS-1 mission specialist Rhea Seddon training in Spacelab mockup.

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Space biology program

One of the major features of the physical environment on Earth is the constant presence of gravity. Microgravity encountered on spacecraft provides a unique laboratory which will permit us to unravel the mystery of the role gravity is playing in shaping life on Earth. Access to space provides an opportunity to manipulate gravity from one gravity (Earth gravity) down to almost zero, providing a broad-based gravitational research capability. The goals of the Space Biology Program are to answer basic scientific questions that can contribute to the resolution of biological enigmas of fundamental importance on Earth as well as in space. For example, understanding biomineralization and the mechanisms controlling the structural integrity of bone are important to understanding the problem of osteoporosis on Earth and bone deterioration in space.

Space biology projects

A central feature of space biology experiments in the 1990's will be the search for the presence of gravity sensors and to understand if gravity affects molecular forces in living systems. A **1.8-Meter Centrifuge** will be flown in the 1993 or 1994 time frame on Spacelab to permit a one gravity environment during flight. This, in turn, will enable us to distinguish the effects of the space environment, such as radiation, on living systems. By the late 1990's, an upgraded version of the Spacelab/Shuttle centrifuge will be installed on the Space Station Freedom for further experiments. Parallel microgravity and one-gravity ground-based studies will show what effects are independent of other space flight factors such as radiation and environmental contamination. The centrifuge is needed for long-term studies to determine gravity thresholds and the long-term effects of one-third g (Mars) and one-sixth g (Moon) on living organisms. Exposure to variable-gravity forces will reveal whether different physiological responses have different thresholds and sensitivity levels. The cen-

(above) Human expeditions to Mars. (right) Working with centrifuge mockup at Ames Research Center. (far right) Space Life Science Training Program students work on experiments at KSC.

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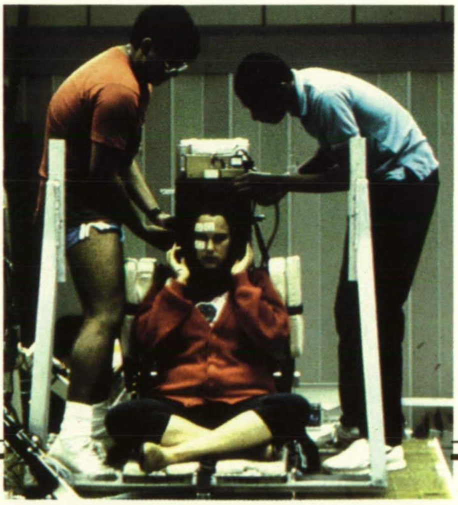
trifuge will also allow life scientists to conduct preliminary tests of the efficacy of artificial gravity as a countermeasure. A request for proposals for Phase B design studies for a Spacelab centrifuge was released in January 1989. NASA's Ames Research Center is managing the 1.8-Meter Centrifuge.

With time lines for human missions in space growing longer and destinations moving farther away from Earth, we need to learn more about the radiation environment of deep space and how it will affect living organisms. We also need to examine microgravity-induced changes that worsen or only become apparent during space missions longer than STS missions. We plan to study these phenomena by flying **LifeSat** missions on a regular basis starting in the early to mid-1990's. LifeSats are recoverable reentry biosatellites designed to carry plant and animal experiments for 30 to 60 days in orbits that the Space Shuttle cannot reach, such as polar orbits. They will be transported to orbit by the STS or expendable launch vehicles. Although NASA is planning the LifeSat program, five other space agencies are expected to participate: the European Space Agency, the National Space Development Agency of Japan, the German aerospace research organization (DLR), the French space agency (CNES), and National Research Council of Canada.

The **Space Biology Initiative** (SBI) will complete the suite of laboratory facilities to be used by life scientists on Space Station Freedom. Laboratory equipment will consist of support equipment and a centralized life sciences computer. It will also encompass facilities for biological sample management, bioinstrumentation and physiological monitoring, plant growth and development, and exobiology experiments. SBI experiments will focus on gravitational biology - in particular, how microgravity affects reproduction and development; physiological response mechanisms; and exobiology investigations of the origin and composition of biogenic compounds in the solar system. SBI hardware will be utilized and verified on Space Shuttle/Spacelab missions before it is installed on Space Station Freedom. Together with the Centrifuge Facility, it will provide a state-of-the-art laboratory to be used by NASA and other international space agencies.



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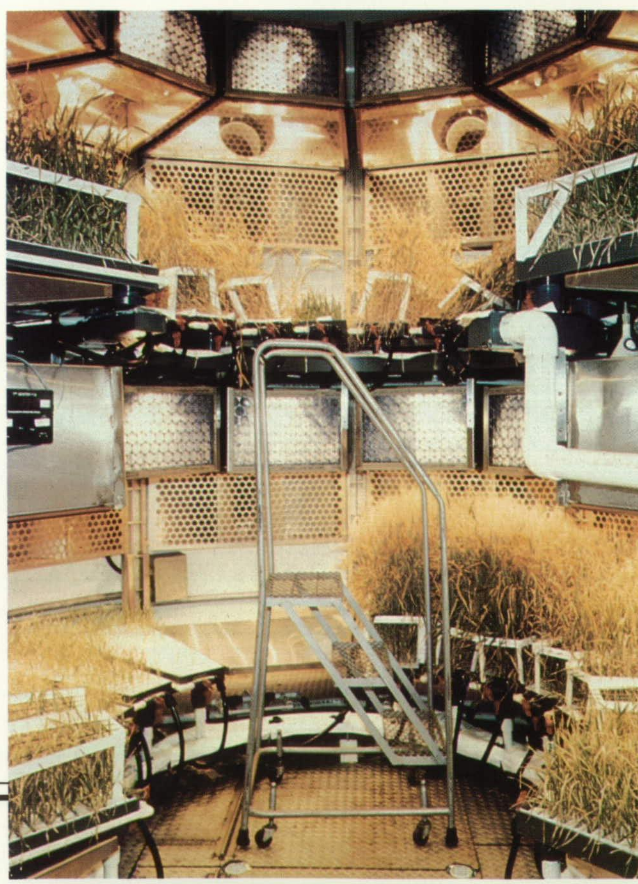

All photographs on this and the opposite page depict experiments in progress at the CELSS Breadboard Project.

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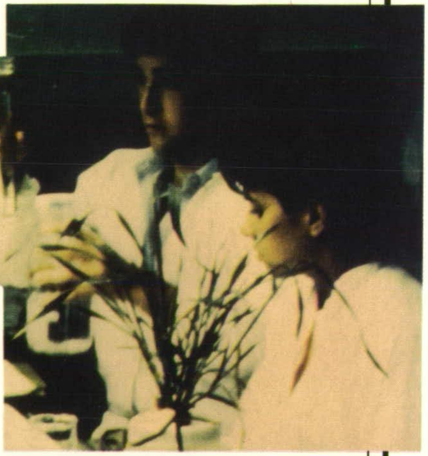
Closed loop life support program

As human missions in space grow longer, closed loop life support systems will be required. Regular resupply of air and food constitutes a major impact on the cost of operating early space stations. More advanced systems will be required during Phase II space station mature operations and long-duration solar system exploration missions and extraterrestrial outposts. We are developing subsystems for bioregenerative life support systems that can provide food, potable water, and breathable air without major and constant resupply from Earth. Advanced technologies for bioregenerative systems, including food crop production and processing, must be tested and demonstrated on Space Shuttle missions and on Space Station Freedom.

Life support projects

To support space station operations and other long-duration human missions in space, we are working on **Controlled Ecological Life Support Systems** that will provide food, water, and air without major replenishment of supplies. Toward this goal, Kennedy Space Center is operating an experimental facility known as the CELSS breadboard project - a 12'x26', sealed steel biomass production chamber to test plant growth techniques including environmental controls, water recycling, and hydroponic nutrient delivery techniques. A related CELSS project managed by Ames Research Center will culminate in a laboratory-scale research facility to study the properties of a life support system that includes crop plants. The Life Sciences Division is also sponsoring a number of smaller-scale research projects at different universities, focusing on such goals as increasing CELSS food crop yields by manipulating environmental variables and producing food from algae grown in a specially designed self-contained facility.

The Life Sciences Division is also planning a series of **CELSS flight experiments.** These experiments will support the development of a flight engineering design and test model that will prove the concept of a full-scale operational



CELSS. Areas such as power requirements, lighting, and plant environmental controls will be addressed early on in flight tests. CELSS flight experiments may be launched on LifeSat and Space Shuttle missions and ultimately on Space Station Freedom. Experiments are planned to control, monitor, and evaluate the growth and yield of candidate food plants. As part of this test, we are considering the development of a "CELSS Salad Machine," a small device capable of growing salad vegetables such as lettuce, radishes, tomatoes, and chives, to be used on Space Station Freedom. Further experiments are planned to study candidate crops and evaluate system reliability in gravity fields that will be experienced on the Moon and Mars. The knowledge gained from this program will have significant implications for agriculture.

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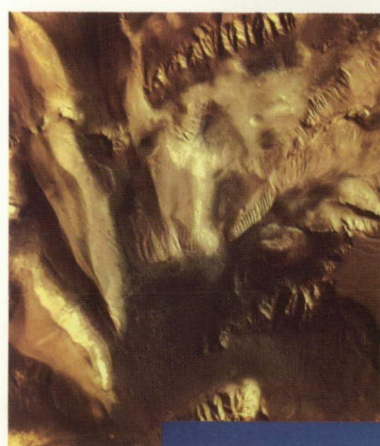
Exobiology program

The goal of the Exobiology Program is to understand the origin and evolution of life on Earth and the potential for life elsewhere in the universe. Research is focused on tracing the pathways taken by the biogenic elements, leading from the origin of the universe through the major epochs in the evolution of living systems and their precursors. We have come close to understanding how life began on Earth, but a definitive explanation continues to elude us. We have discovered that the biogenic elements, the building blocks of living things on Earth, are present throughout the universe. Some scientists now believe that planetary systems orbiting stars are the norm rather than the exception. A general theory of the origin and evolution of living systems within the context of the origin of the universe may eventually arise from knowledge gained through exobiology investigations.

USGS



USGS

Exobiology projects

The most accessible planet that we can search for signs of life is Mars. A ground-based analog of the martian surface - the dry valleys of Antarctica - is serving as a laboratory for **Mars exobiology precursor studies.** In these valleys, lichens and

(top) Mars may be the next target for human exploration. (middle) Candor Chasm in the Valles Marineris of Mars. (bottom) Antarctica's dry valleys may be similar to ancient Mars.

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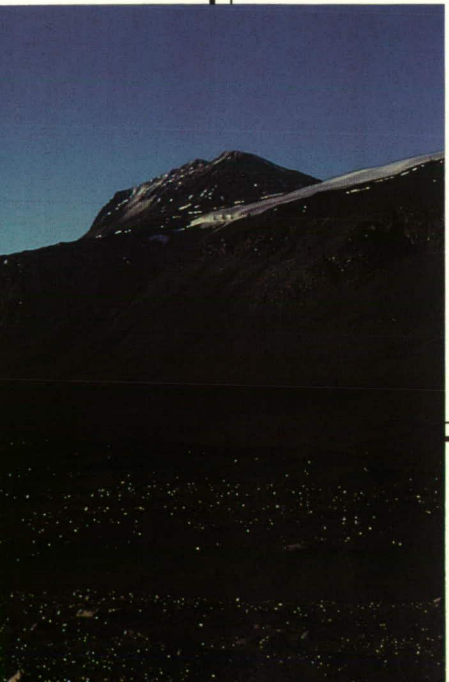
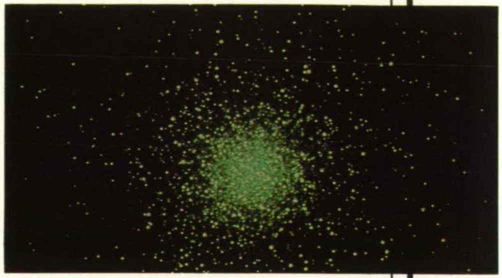
other simple organisms are able to live inside porous rocks, which also contain fossil records of such organisms. Living and fossil microbes, piled up in mats called stromatolites, are found at the bottom of dry-valley lakes that are perpetually covered with more than 15 feet of ice. Over the next few years, exobiologists will study these Antarctic lakes to determine how life thrives in them. This research will help scientists decide what to look for and where to look for it, especially on robotic expeditions to sites on Mars deemed likely to hold fossils.

Currently, our major ground-based exobiology initiative is the **Search for Extraterrestrial Intelligence Microwave Observing Project** (SETI MOP). Ames Research Center and the Jet Propulsion Laboratory in California are coordinating the project, which will probe our galaxy for radio signals of extraterrestrial intelligent origin. This search will be 10 billion times more comprehensive than all previous searches combined. Using existing telescopes in NASA's worldwide Deep Space Network and additional telescopes made available by other national and foreign organizations, we will conduct both a targeted search of about 800 solar-type stars within 100 light years of Earth in a limited frequency range and a sky survey of the entire celestial sphere for signals in a broader frequency range coming from anywhere in our galaxy. The SETI MOP will use off-the-shelf computers, coupled with a special multi-channel spectrum analyzer (MCSA) being developed by the SETI Institute, a nonprofit organization in Los Altos, California.



Dale Andersen



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The Orion Nebula

Tailor-made SETI software will be able to pick out and verify non-natural signals while rejecting radio frequency interference.

Exobiology flight projects in the works include a Cosmic Dust Collection Facility to fly as an attached payload on Space Station Freedom. This year, NASA will be reviewing proposals for **Intact Cosmic Dust Collection Experiments** (ICDCEs) that will collect interplanetary dust particles by nondestructive methods and measure the orbital elements of particles before capture. Also this year, we will begin conceptual studies for a **Gas/Grain Simulation Facility** (GGSF), a general purpose microgravity particle research facility, to fly on Space Station Freedom. The GGSF will be used to study nucleation of particles from gas, aggregation of small particles into larger ones, and low velocity collisions among particles, thereby learning more about how stars and planets form and how biogenic compounds evolve. An exobiology investigation is planned for the Cassini mission. It would be flown on the Cassini spacecraft to Saturn, which will include a Titan probe. Methane and other complex organic compounds have been detected on Titan; the exobiology investigation will analyze organic compounds on Titan to learn more about the prebiotic chemistry that led to life on Earth.

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Biospherics program

The goal of the Biospherics Program is to understand the interaction between biological processes and planetary properties and the effects of global-scale changes on life. The Biospherics Program conducts in-depth studies of the Earth's present biosphere, whereas the Exobiology Program studies the origin and evolution of biospheres. For the first time in our history, we have the capability to study our planet as a system, using satellites in Earth orbit to observe global phenomena; NASA life scientists are participating in assessments of the state of the Earth, its atmosphere, and its inhabitants. Through studies of the production and removal of atmospheric carbon dioxide, we have already documented the link between plant growth and atmospheric carbon dioxide concentration.

We are conducting research to study seasonal production of methane and other gases produced by biological processes that play important roles controlling ozone and climate. As greenhouse gases, methane and nitrogen oxides are ten times more effective than carbon dioxide. Our wetlands research is intended to study production of the same gases in different types of ecosystems. Our temperate forest research project is intended to study how soil and tree processes contribute to global cycling of chemical elements important to life, especially carbon and nitrogen. Studies of forest fires, using ground-based, aerial, and remote sensing techniques, contribute to the temperate forest research project by providing information on carbon cycling between forest ecosystems and the atmosphere. Global monitoring research focuses on integrating data on gas production in all types of ecosystems to produce a model of global gas production that may be used for predicting future conditions.

A focused biospherics research activity studies the underlying mechanisms in the transmission of malaria. Malaria kills millions of people a year and infects hundreds of millions more. In most parts of the world, the disease is not under control. Predicting the time and place of mosquito outbreaks is the key to the control of malaria epidemics, and the malaria project is intended to develop this capability. Our project began in 1985, when a NASA ER-2 aircraft collected data on rice fields in California. Researchers from the University of California at Davis used the data to define the type of environment - ground water, vegetation, and other features - where malaria-bearing mosquitos breed. Data collection and analysis will continue over the next few years. By the 1990's, sensors tailored to this application could be installed on a space station or polar-orbiting platform to collect global data.

(above) Mother Earth (right) Columbia Launch Fantasy (far right) Space Station

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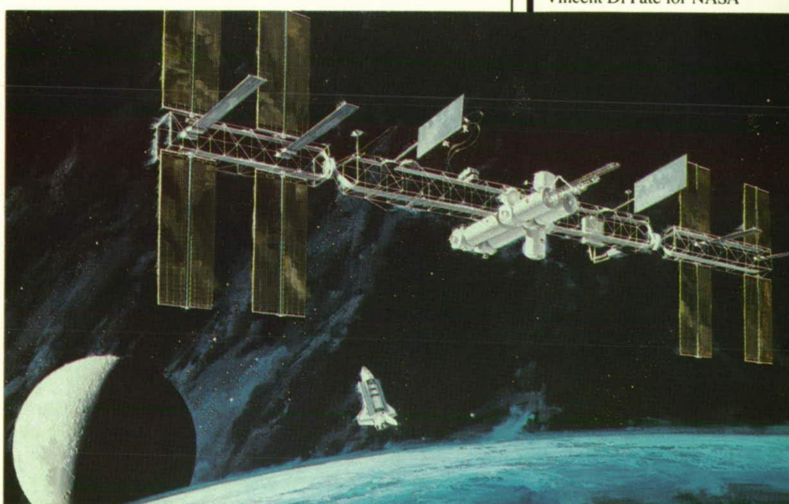
In the 40 years that we have been probing space, we have just begun to explore the possibilities for extending human presence beyond this planet and learning about ourselves, our world, and the universe. It is impossible to predict or quantify the benefits that will accrue to our society as a result of all of the life sciences research and technology development that we will undertake in the name of exploration. We can be sure, however, that they will be as significant in the future as they are today through the space life sciences contributions to human health and welfare back on Earth. Inventions and discoveries will be made, young people will be encouraged to pursue careers in space life sciences, and our educational institutions will be stimulated to expand.

Vincent Di Fate for NASA



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