OFFICE OF SPACE SCIENCE AND APPLICATIONS

STRATEGIC PLAN 1991

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A STRATEGY

FOR LEADERSHIP

IN SPACE

THROUGH EXCELLENCE

IN SPACE SCIENCE

AND APPLICATIONS

This report has been prepared as an internal OSSA document, and it will serve as the basis for OSSA program planning in the future.

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PREFACE

In 1988, the Office of Space Science and Applications (OSSA) developed and published a Strategic Plan for the United States' space science and applications program during the next 5 to 10 years. The Plan presented the proposed OSSA program for the next fiscal year and defined a flexible process that provides the basis for near-term decisions on the allocation of resources and the planning of future efforts. Based on the strategies that have been developed by the advisory committees both of the National Academy of Sciences and of NASA, the Plan balances major, moderate, and small mission initiatives, the utilization of Space Station Freedom, and the requirements for a vital research base. The Plan can be adjusted to accommodate varying budget levels, both those levels that provide opportunities for an expanded science and applications program, and those that constrain growth.

OSSA's strategic planning is constructed around five actions: (1) establish a set of programmatic themes; (2) establish a set of decision rules; (3) establish a set of priorities for missions and programs within each theme; (4) demonstrate that the strategy can yield a viable program; and (5) check the strategy for consistency with resource constraints. The outcome of this process is a clear, coherent strategy that meets both NASA's and OSSA's goals, that assures realism in long-range planning and advanced technology development, and that provides sufficient resiliency to respond and adapt to both known and unexpected internal and external realities.

The OSSA Strategic Plan is revised annually to reflect the approval of new programs, improved understanding of requirements and issues, and any major changes in the circumstances, both within NASA and external to NASA, in which OSSA initiatives are considered. Several noteworthy events occurred in 1990 that influence this year's Plan. For example, the Advisory Committee on the Future of the U.S. Space Program has made recommendations that are particularly relevant to OSSA: that science remain the cornerstone of NASA's program, that NASA pursue Mission to Planet Earth with the urgency that the program connotes and Mission from Planet Earth as resources become available, and that enhanced attention to technology and infrastructure be focused to serve those mission goals. Federal budget guidelines for NASA suggest a constrained environment for some time to come. The restructuring of Space Station Freedom has led to the revision of OSSA's near-term plans for utilization of Freedom Station.

This OSSA 1991 Strategic Plan reflects a transitional year in which we respond to these changes and focus on carrying out a vital space science program and strengthening our research base to reap the benefits of current and future missions. The Plan is built on interrelated, complementary strategies for the core space science program, for Mission to Planet Earth, and for Mission from Planet Earth. Each strategy has its own unique themes and mission priorities, but they share a common set of principles and a common goal — leadership through the achievement of excellence.

Calendar year 1990 was a period of high activity, with the launches of the Hubble Space Telescope, Pegsat, the Roentgen Satellite, the Combined Release and Radiation Effects Satellite, and Ulysses, and the flight of the Astro Spacelab mission. Missions launched in 1989 also successfully met major milestones in 1990, including Galileo's Venus and Earth flybys, the Cosmic Background Explorer sky survey, and the initiation of the Magellan mapping phase. An equally exciting year, 1991 will bring the launches of the Gamma Ray Observatory, the Upper Atmosphere Research Satellite, the Extreme Ultraviolet Explorer, and one Spacelab flight: the first Space Life Sciences mission. The challenge to which this 1991 Plan responds is to make certain that this level of activity is sustained and thus to ensure the realization of the space program envisioned by the Advisory Committee on the Future of the U.S. Space Program.

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April 6, 1991

INTRODUCTION

National Space Policy

The National Aeronautics and Space Act of 1958 established NASA's mandate to conduct activities in space that contribute substantially to the expansion of human knowledge and "to the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."

Three decades later, the Directive on National Space Policy, updated by the National Space Council and signed by President Bush on November 2, 1989, similarly states that "a fundamental objective guiding United States space activities has been, and continues to be, space leadership."

Leadership in space can only be maintained through the active, continuing development of a vital scientific research and applications program, and through the visible and significant achievement of the objectives of that program. Accordingly, the policy also states that some of the overall goals of the United States civilian space program are:

To obtain scientific, technological, and economic benefits for the general population

To improve the quality of life on Earth through space-related activities

To expand human presence and activity beyond Earth orbit into the solar system.

To achieve these goals, President Bush's 1989 space policy set forth the following objectives for civilian space activities:

To expand knowledge of the Earth, its environment, the solar system, and the universe

To create new opportunities for use of the space environment through the conduct of appropriate research and experimentation in advanced technology and systems

To develop space technology for civil applications and, wherever appropriate, make such technology available to the commercial sector

To preserve the United States preeminence in critical aspects of space science, applications, technology, and manned space flight

To establish a permanently manned presence in space

To engage in international cooperative efforts that further United States overall space goals.

Underscoring national space policy are the recommendations of the Advisory Committee on the Future of the U.S. Space Program. This Committee was appointed "to advise the NASA Administrator on overall approaches NASA management can use to implement the U.S. Space Program for the coming decades." The Committee's recommendations were made to the NASA Administrator, and with him, to the Vice President in his capacity as Chairman of the National Space Council. The Committee's report, published in December 1990, states that "the space science program warrants highest priority ... It is this endeavor in science that enables basic discovery and understanding, that uncovers the fundamental knowledge of our own planet to improve the quality of life for all people on Earth, and that stimulates the education of the scientists needed for the future. Science gives vision, imagination, and direction to the space program, and as such should be vigorously protected and permitted to grow, holding at or somewhat above its present fraction of NASA's budget even as the overall space budget grows." The report further recommends that, having established science as the central core, two mission-oriented objectives also should be supported: Mission <u>to</u> Planet Earth, and Mission <u>from</u> Planet Earth.

These recommendations reinforce traditional OSSA goals, and they affirm many both long-standing and evolving NASA goals. As its contribution to the President's U.S. Global Change Research Program, NASA has already initiated the international Mission to Planet Earth, a concept that uses space- and ground-based measurement systems to provide the scientific basis for understanding global change. An initiative of immediate urgency, Mission to Planet Earth begins with the launches of Earth science missions currently in development, including the Upper Atmosphere Research Satellite, the Ocean Topography Experiment, and instrumented Shuttle/Spacelab flights. The concept then builds on these missions to include three new program elements — Earth Probes, the Earth Observing System, and eventually Geostationary Platforms — to provide a constellation of satellites in a variety of orbits around Earth to study global changes within the Earth system.

NASA has also been examining alternative approaches to Mission from Planet Earth, which encompasses all elements of the previously named Space Exploration Initiative. The present role of space science and applications programs in Mission from Planet Earth is critical: to ensure the safety, well-being, and evolving self-sufficiency of human space travelers, to conduct scientific robotic missions to characterize the environments of the Moon and Mars, and to plan for scientific investigations on and from the Moon and Mars.

Through programs such as these, NASA has always endeavored to expand the frontiers of discovery, understanding, human experience, and technology to enrich our Nation, ensure a position of leadership, and capture the benefits of space for humankind. As space science and applications programs open new vistas of knowledge, the possibilities for human exploration and habitation of space expand. Using the unique characteristics and perspective of Earth orbit, space science increases our understanding of Earth and the way in which we humans are changing its environment. The knowledge gained through observing our own planet from space stimulates new capabilities to improve life on Earth. And the critical technologies that are developed to enhance the exploration and utilization of space can be transferred to the private sector to assure our economic competitiveness and contribute to the national defense. In all these ways, pushing the frontiers of knowledge and capability contributes to the realization of one of mankind's most compelling aspirations — to ever explore and understand.

OSSA Overview

The Office of Space Science and Applications (OSSA) is one of the program offices of the National Aeronautics and Space Administration (NASA). OSSA is responsible for planning, directing, executing, and evaluating that part of the overall NASA program that has the goal of using the unique characteristics of the space environment to conduct a scientific study of the universe, to understand how the Earth works as an integrated system, to solve practical problems on Earth, and to provide the scientific and technological research foundation for expanding human presence beyond Earth orbit into the solar system. OSSA guides its program toward leadership through its pursuit of excellence in space science and applications across the full spectrum of disciplines. The aspiration to excellence, combined with the active achievement of program goals, firmly positions U.S. space science and applications for an exciting, productive future.

The efforts of the OSSA program result in increased knowledge for all humanity. The scope of these efforts ranges from Earth's oceans and tectonic plates to the upper reaches of its atmosphere, and from our own solar system to the most distant galaxies. The pursuit of these objectives results in the development of tools, techniques, and procedures that can use the vantage point or characteristics of space to aid in the solution of major national and global problems and to contribute to the economic health and development of the United States.

OSSA pursues these goals through an integrated program of ground-based laboratory research and experimentation; suborbital flight of instruments on airplanes, balloons, and sounding rockets; flight of instruments and the conduct of life sciences and microgravity research on the Shuttle/Spacelab system and on Space Station Freedom; and development and flight of automated Earth-orbiting and interplanetary spacecraft. The program is conducted with the participation and support of all the NASA Centers, other Government agencies and facilities, universities throughout the United States, and the aerospace contractor community, with substantial international participation in many aspects of the program.

OSSA comprises eight Divisions. The Administration and Resources Management Division is responsible for OSSA fiscal and institutional management and for coordinating OSSA educational activities, public affairs, international relations, industry affairs, and Congressional relations. The Flight Systems Division is responsible for managing and integrating OSSA science and technology utilization of the Space Shuttle, Spacelab, and Space Station Freedom. In addition, the Flight Systems Division has been assigned the responsibility for serving OSSA-wide information systems needs in areas such as networking, supercomputers, and data management. The change was precipitated by the recent decision to reorganize the Communications and Information Systems

Division. This reorganization was initiated to enhance the efficiency of both communications and information systems activities, with the majority of communications efforts to eventually come under the auspices of the Office of Commercial Programs, and the technology research and development efforts to come under the Office of Aeronautics, Exploration and Technology.

The other six OSSA elements are program Divisions, each of which emphasizes and applies a different scientific discipline to successfully accomplish OSSA's goals. These Divisions and their roles are:

Astrophysics, which has the goals of understanding the origin and fate of the universe and the birth and evolution of the large variety of objects in the universe, from the most benign to the most exotic; and of probing the fundamental laws of physics by examining the effects of extreme physical conditions on matter. The strategy for accomplishing these goals is based on contemporaneous observations across the entire electromagnetic spectrum.

Solar System Exploration, which has the goals of understanding the origin, evolution, and current state of the solar system and the planets, moons, asteroids, and comets within it, including the search for planetary systems around other stars; of understanding Earth through comparative planetary studies; and of establishing the scientific and technical data base required to support major human activities on other planets.

Space Physics, which has the goals of understanding the Sun as a star, as an influence on Earth, and as the dominant source of energy, plasma, and energetic particles in the solar system; understanding the interactions between the solar wind and solar system bodies, including studies of the processes within and between the magnetospheres, ionospheres, mesospheres, and thermospheres of Earth and other solar system bodies; and understanding the nature of the heliosphere, in its steady state as well as dynamic configuration, and the origin, acceleration, and propagation of solar and galactic cosmic rays.

Earth Science and Applications, which has the goal of understanding planet Earth as an integrated system, including the interactive processes that maintain the global surface environmental balance that maintains life, and those processes — both natural and anthropogenic — that are acting to change that balance. The strategy to accomplish this goal involves basic research to understand the physics, chemistry, dynamics, and biology of interlinked Earth system processes, remote sensing from space for global-scale examination of Earth, and modeling and data analysis to provide a conceptual and predictive understanding of Earth as a system.

Life Sciences, which has the goals of ensuring the health, well-being, and productivity of humans in space; developing an understanding of the role of gravity on living systems; expanding our understanding of the origin, evolution, and distribution of life in the universe; and promoting the application of life sciences research to improve the quality of life on Earth.

Microgravity Science and Applications, which has the goals of utilizing the unique characteristics of the spaceflight environment to conduct basic research in physics and chemistry, with special emphasis on fundamental phenomena, materials science, and biotechnology; of understanding the behavior of materials in a reduced gravity environment; and, where possible, of demonstrating the production of improved materials that have high technological utility.

A more detailed discussion of OSSA's scientific disciplines and their individual strategies is provided in the Appendix.

OSSA Goals and Objectives

Advancing scientific knowledge of Earth, the solar system, and the universe beyond has traditionally been the focus of OSSA's activities. OSSA has always directed its energy toward using 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, and this pursuit remains a major component of OSSA's plans. OSSA is now undertaking Mission to Planet Earth, an integrated international satellite program for monitoring global change, coupled with a comprehensive data and information system. This program will generate high-precision, long-term data sets for modelling global change processes, such as increasing atmospheric greenhouse gases, atmospheric ozone depletion, and deforestation, which policy-makers and scientists can use in formulating strategies for managing human impacts on global processes. In addition, many current and future OSSA efforts will directly support the goal of expanding human presence beyond Earth. This goal will be supported by characterizing the environments and surfaces of the Moon and Mars, by determining the attributes of the space environment and establishing a scientific basis for understanding its long-term effects on human beings and their life-support requirements, by developing appropriate countermeasures to prevent or ameliorate any detrimental effects of human space travel, by conducting research in microgravity to support technology development, and by planning strategies for conducting science on and from the Moon and Mars.

OSSA has established a number of near-term objectives that will guide its programs and plans for the future. These now include (in no order of priority):

Observe the universe with high sensitivity and resolution across the entire electromagnetic spectrum by completing the Great Observatories and conducting selected complementary measurements.

Complete the detailed scientific characterization of virtually all of the solar system (including the terrestrial planets, typical primitive bodies (asteroids and comets), and at least the nearer parts of the outer solar system. Develop the scientific foundation to support the planning of human exploration beyond Earth by determining the nature of the environment and surfaces of the Moon and Mars.

Quantitatively describe the physical behavior of the Sun, the origins of solar variability, the geospace environment, and the effects of solar processes on the Earth, and extend these descriptions to Sun-planet interactions, to the edge of the heliosphere, and into the interstellar medium and galaxy beyond.

Establish a set of Earth-orbiting satellites and complementary instruments to study the Earth system on a global scale, examine the planet for evidence of global change, and eventually develop the capability to model the Earth system to predict changes that will occur either naturally or as a result of human activity. OSSA's efforts constitute a major contribution to the President's U.S. Global Change Research Program.

Conduct and coordinate all aerospace medicine, medical support, and life support activities within NASA. Determine human health, well-being, and performance needs, and conduct research, both on Earth and in space, to establish medical and life-support technology requirements for those needs for human flight missions.

Determine, develop, and exploit the unique capabilities provided by the Space Shuttle, Space Station Freedom, and other space-based facilities to study the nature of physical, chemical, and biological processes in a low gravity environment and apply these studies to advance science and applications in such fields as fluid physics, materials science, combustion science, space biology and medicine, and biotechnology.

OSSA Principles

In the coming years, OSSA will continue to nurture the principles that have served it well in the past, including:

Constant emphasis on excellence and the maintenance of U.S. scientific leadership

Basic scientific goals and strategies defined by the scientific community

Use of scientific peer review in all appropriate aspects of the program

Balance among the various scientific disciplines

Close communication with external scientific and applications communities, particularly in the advisory process

Strong support for universities to provide essential long-term research talents

Effective use of the NASA Centers in formulating and implementing the OSSA program

Choice of an appropriate mission approach determined by scientific and applications requirements

Emphasis on nurturing and enhancing educational opportunities, at all levels, to serve national needs.

Especially important is the need for an interdisciplinary approach to major scientific problems. The importance of such an approach becomes compelling as the pursuit of solutions to major space research problems evolves to transcend some of the narrow and artificial boundaries between disciplines. Such problems cannot be solved without applying data and insights from many different fields. The future will see a continuing application of multidisciplinary approaches in such areas as Earth system science; the origin of stars and solar systems; the origin, evolution, and distribution of life; the processes that cause all planets to form and change; and the information needed to conduct long-term human voyages beyond Earth.

The OSSA Vision

OSSA envisions that, at the dawn of the 21st Century, we will continue to exercise world leadership in space science through a balanced program of high-quality flight missions and ground-based research. We will have successfully implemented Mission to Planet Earth, and we will have initiated Mission from Planet Earth. We will be relying on a strong technological infrastructure that serves the needs of a variety of missions.

The international Mission to Planet Earth will have begun to build on the information gathered by earlier missions that studied Earth's global ozone changes, atmospheric dynamics, and ocean circulation. The nature and dynamics of the myriad components of the Earth system — core, mantle, crust, soils and land masses, global ecosystem, oceans, cloud cover, and the layers that compose the atmosphere — will have been observed and measured on a global scale for the first time. Scientists will have begun to make progress toward describing how these intimately connected component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.

The Earth Observing System and a complementary set of Earth Probes, major elements of the U.S. Global Change Research Program, will be obtaining long-term, continuous observations of our planet. Combined with ground-based measurements and observations, information received through these systems will be advancing our understanding of the Earth system on a global scale. These measurements will have been integrated into a comprehensive data and information system that scientists can access and use to understand and describe the global character of Earth. Earth system science will be on the way to developing the capability to predict those changes that will occur in the future, both naturally and in response to human activity. Earth itself will be understood as mankind's home, limited in resources and requiring attention and care to preserve its delicate global balance. Instead of carelessly or ignorantly exploiting Earth, humanity will have a growing sense of responsibility for managing the use of the planet's resources in a renewable, sustainable fashion.

Orbiting spacecraft will have traveled to every major solar system body that is accessible to us. One such orbiter will have visited Jupiter for a more detailed look, sending an instrumented probe through the gas giant's atmosphere and conducting an extraordinary 2-year tour of its Galilean satellites. The surface of Earth's sister planet Venus will have been mapped using radar that penetrates the dense Venusian clouds, substantially augmenting the information base necessary for the comparative study of Venus, Earth, Mars, and Earth's Moon. The history and future of our own planet will have become clearer through our increased understanding of our solar system neighbors.

A sophisticated spacecraft will be orbiting Saturn, closely observing its complex system of rings and moons and unveiling clues to the processes by which planets form. A probe will have descended through Titan's murky atmosphere, and a radar instrument will have revealed the nature of its invisible, possibly ocean-covered surface. In the atmosphere of this largest moon of Saturn, scientists believe that a chemical environment similar to that on early Earth exists. Studying this environment can teach us much, for it may be repeating some of the earliest steps in the processes that gave rise to life on our planet.

We will have peered back into the early history of the solar system by studying its most primitive, unaltered bodies — comets and asteroids. One spacecraft will have flown for 3 years in formation with a comet in its journey around the Sun and embarked upon a 50,000-kilometer excursion down its spectacular tail. En route to its final destination, the same spacecraft will have studied an asteroid at close range, adding to a growing body of scientific information about these relics of our solar system's origin. Using a variety of experiments, other missions will also have studied asteroids of different compositional types, in order to understand their puzzling diversity.

Mars, with its Earth-like mountains, canyons, and evidence of ancient flooding, will have been studied extensively to determine the planet's climate, global surface processes, and behavior of its volatiles. These studies will characterize the environment in which spacecraft and crew must function to help us identify the most promising locations for further scientific exploration and plan for human expeditions to Mars, journeys that will expand human presence ever farther beyond Earth's orbit.

Our own Moon's global surface mineral and elemental composition will have been determined. Its global topography, gravity, and magnetic fields will have been measured, and an initial assessment of its resources, including a search for frozen volatiles at the poles, will have been undertaken. Combined with what we have already learned from ground-based studies and from previous missions, this information will help us to understand the Moon as a unique terrestrial body. This knowledge will also help prepare for the return of human beings to the Moon to build an outpost that will be both a site for scientific research and a way station for further human exploration.

The Sun that gives us light and sustains life on our planet will have been studied both as a star and as the dominant source of energy, plasma, and energetic particles in the solar system. We will have begun to understand the Sun's interior and the origin of the solar wind, and to have the capability to predict the behavior of this star, which is central to the destiny of our solar system and of humanity. The results of Orbiting Solar Laboratory investigations will have increased our understanding of the Sun's variability and of solar particle eruptions. To extend that understanding and to provide early warning of solar events that might harm human explorers, orbital observatories will be in place at various locations to monitor all quadrants of the Sun's surface. A probe from Earth will be speeding toward the unexplored region between 3 and 60 radii from the Sun, where the solar wind first flows at supersonic speeds.

The nature of the interface between the interstellar medium and the interplanetary medium will have been determined, and the extent and three-dimensional structure of the heliosphere will have been mapped. Sources of galactic cosmic rays and the physics of their interactions with interstellar and solar system material will have been studied with the Advanced Composition Explorer. We will be well on our way to comprehending how the complex plasma phenomena in different regions of the solar system and the Milky Way Galaxy are related.

Multiple spacecraft will have flown in close coordination to measure the total energy budget of the plasma processes in Earth's magnetosphere. The quantitative study of the geospace environment that is created by the interplay of solar and terrestrial processes will be progressing toward a full-scale predictive stage. Comparative observations of plasma processes at other planets will be well under way.

Four Great Observatories — the Hubble Space Telescope, the Gamma Ray Observatory, the Advanced X-ray Astrophysics Facility, and the Space Infrared Telescope Facility — will have fulfilled the goal of observing the universe across the entire electromagnetic spectrum. Complementary measurements will be obtained by the Stratospheric Observatory For Infrared Astronomy, which will be routinely flown in a research aircraft. As we begin to use the information these observatories reveal to us, our Nation will be recognized as leading a worldwide effort to understand our place in the universe. The revolution that this understanding will cause in our thinking will rival the one that occurred when an earlier astronomer, Copernicus, showed that Earth was not the center of the universe. Many totally unexpected scientific discoveries will be made; nature, unfettered by the limitations of human imagination, will continue to surprise and inspire us.

The question of whether the universe is expanding indefinitely, or will at some time begin to contract, should have been answered. The distance scales and the rate of expansion will be known with much better precision. Theorists, by combining data from the Great Observatories with experiment results from Earth-based particle accelerators, will develop models for the origin and fate of the universe that include unification of physical laws. Scientists, from workstations at their universities, will browse through astronomical data from the Observatories, and vast data sets will be quickly and conveniently accessible. Orbiting experiments will have verified yet another prediction of General Relativity, or else they will have discovered the theory's first inconsistency while providing clues to alternative theories. Our understanding of the laws of physics will be revised to accommodate new insights gained from studies of relics of the creation of the universe and from observations of matter reacting to pressures and magnetic fields unimaginable in the vicinity of Earth, but common near compact objects such as neutron stars and black holes.

Our knowledge of the relationship of life to natural processes occurring in the cosmos will have been expanded, and a direct search for signs of life elsewhere will have been conducted. A sophisticated microwave observing project will have completed a comprehensive search for radio signals stemming from extraterrestrial technologies within a defined search space to extend our knowledge of life in the universe. We may, at last, know that life is not unique to planet Earth.

The effects of long-duration spaceflight on our most precious of resources, human life, will be known and understood. From Skylab, to the Space Shuttle, through extended-duration missions on Spacelab, to Space Station Freedom, and eventually on the Moon and Mars, we will have completed an evolutionary study of the response of biological systems, including human beings, animals, plants, and cells, to low gravity and space radiation. The results of the Lifesat/Radiation Biology Initiative will have defined the health hazards of space radiation from both solar flares and galactic cosmic rays. These programs will also have produced a shielding, warning, and countermeasure system to enable humans to venture safely beyond low Earth orbit. We will have determined and developed measures to provide medical care in space and to ameliorate or prevent the physiological and psychological effects of long-term exposure to the space environment and the relative isolation that space travel, of necessity, imposes on our explorers. The provision of closed-loop life-support systems based on integrated bioregenerative, physical, and chemical processes will enable extended human exploration missions to the Moon and Mars.

Gravity's role in a wide variety of fundamental biological processes of plants and animals will be understood through our ability to explore the mechanisms of gravitational detection and response at all levels of life, from single cells to complex multicellular organisms. The systematic exploration of a wide range of gravity levels, available only through the use of suitable on-orbit research facilities that use extended-duration Spacelab missions and Space Station Freedom, will help us understand the effects of microgravity on living systems and will provide some direct applications on Earth.

Hand in hand with U.S. industry, academia, other Federal agencies, and our international partners, we will have begun to build on our experience with Spacelab to use the unique capabilities for microgravity research offered by Space Station Freedom. In the on-orbit environment, where conditions such as buoyancy, sedimentation, and convection are dramatically reduced, we will be using these characteristics to conduct critical experiments to test fundamental physical concepts. This pioneering research will be applied to advance science and applications in such areas as fluid physics, materials science, combustion science, health science, and biotechnology. Space Station Freedom, an operational international laboratory, complemented by other space platforms such as man-tended free-flyers, will open a new frontier for microgravity science, a frontier that will stimulate exciting developments in science and technology and determine the scientific foundation for exploiting the commercial potential of space.

The success of our space program will be a source of great national pride, and it will attract our young people to develop the skills and knowledge that the Nation will need in the future. Exciting discoveries, widely disseminated through educational programs, will have kindled public interest so that the whole Nation follows, learns from, and shares in the space program. But perhaps the most fundamental reason for space science is that it expands the frontiers of discovery, understanding, human experience, and technology. The United States was founded by people determined to expand the frontier and to take advantage of that expansion to enrich our Nation and our lives. This determination forms a part of our national character, and we can and must apply our efforts to realize our visions of exploring space and making its riches part of our lives. With a strong and supportive national will, we can proceed.

The basic premise of strategic planning is to develop a clear vision of a desired future; this is OSSA's vision. The strategy for realizing this vision is necessarily ambitious, yet it is firmly tempered to be realistic enough to succeed. Our vision sees NASA and the United States enjoying an exciting and productive era in space science and applications, with leadership in space manifested by visible achievements that are second to none.

THE OSSA STRATEGY

To shape an enduring program to make its vision a reality, OSSA has formulated a strategy that is the culmination of extensive interaction and collaboration with the scientific and applications communities, careful consideration of resource guidelines, and interactive reviews of pertinent issues and challenges.

OSSA's strategic approach is constructed around five actions:

1. *Establish a set of programmatic themes.*
2. *Establish a set of decision rules.*
3. *Establish a set of priorities for missions and programs within each theme.*
4. *Demonstrate that the strategy can yield a viable program.*
5. *Check the strategy for technology readiness and for consistency with resource constraints, such as budget, manpower, facilities, and launch vehicle availability.*

Guided by OSSA's long-standing principles, these five actions define the process by which OSSA plans its activities and allocates its resources. The programmatic themes provide direction and balance, the decision rules guide us in choosing efforts among and within themes, and the priorities determine the order in which we pursue the missions and programs within each theme. By exercising these actions, various plans for an integrated OSSA program result, and these plans can be checked to determine whether they yield a viable program and are consistent with our resource constraints.

An important point to note is that exercising the above actions does not, nor is it intended to, result in a single plan. Rather, these actions define a realistic and flexible process that will provide the basis for making near-term decisions on the allocation of resources for the planning of future efforts. The least certain constraint on our planning is the budget level that will be available to OSSA. The process defined here allows us to adjust to varying budget levels, both those levels that provide opportunities for an expanding science and applications program and those that constrain growth.

In developing this strategy, we have assumed that the NASA budget will continue to experience modest growth to accommodate Agency plans for the core science program and Mission to Planet Earth and Mission from Planet Earth, the two mission-oriented objectives recommended by the Advisory Committee on the Future of the U.S. Space Program. We also assume that OSSA will receive the proportion of the overall budget that is consistent with its historical allocation and its expanded role in national initiatives. Further, we assume the continued implementation of current plans for a mixed fleet of launch vehicles, with the launch rates presently projected for the Space Shuttle and for expendable launch vehicles. (In general, expendable launch vehicles will be used for payloads that do not require crew intervention or other capabilities unique to the Space Shuttle.) The level of availability of the Agency work force is assumed to be consistent with current NASA projections, as augmented by needs associated with national initiatives.

As a result of the President's initiatives in Global Change Research and the human exploration of the Moon and Mars, the OSSA strategy is now composed of three interrelated, complementary parts. The first part is the core science strategy that OSSA introduced in 1988. The second reflects OSSA's lead role in the multinational Mission to Planet Earth, a key element of the U.S. Global Change Research Program. The third encompasses a strategy to fulfill OSSA's role in Mission from Planet Earth. As NASA's plans for Mission from Planet Earth are refined to reflect the recommendations of the Advisory Committee on the Future of the U.S. Space Program, OSSA's strategy will be refined accordingly.

The core strategy defines a space science program that OSSA should pursue even in the absence of overarching national and Agency initiatives. When such initiatives are undertaken, the appropriate resources must be added over and above the baseline. It is particularly important to note that the initiation of Mission to Planet Earth represents more than the beginning of a traditional OSSA science program. It also reflects NASA's role in a Presidential-level commitment to aggressively seek the understanding of global change needed to develop the predictive capability on which to base major policy decisions. Because the pace of Mission to Planet Earth is driven by this policy imperative, it will require a long-term commitment of resources to support that pace while preserving the vigor of the ongoing core space science and applications program.

OSSA's participation in Mission from Planet Earth will be scaled to match the level and pace of the program for the Agency as a whole, and the character of OSSA's role will be shaped to complement the role of the new Office of Exploration. The magnitude of each element of OSSA's contribution will be driven primarily by the pace at which the Nation proceeds and by the total institutional capability to pursue those activities in a way that adheres to the principles of excellence, balance, and appropriateness of approach.

Finally, in developing the strategy, no explicit assumptions are made about the level of international participation. Instead, we define our strategy and then move forward to seek opportunities for international cooperation to fit our plans. The strategy also preserves the flexibility to respond meaningfully to new international opportunities or initiatives. For example, in the event of a national decision to embark on a major new international collaborative program, the strategy will serve as the starting point from which we will shape the OSSA program to integrate new initiatives into the total science and applications effort.

THE CORE SCIENCE STRATEGY

Within the guidelines and assumptions discussed above, five basic themes drive the development of OSSA's core science strategy.

Programmatic Themes

1. The Ongoing Program.
First and foremost, for missions in the ongoing program, the scheduling, resource allocations, and manifested slots on the Space Shuttle or an expendable launch vehicle must be protected and assured. The same high level of priority applies to ongoing research programs and mission operations and data analysis activities.

2. Leadership through Major and Moderate Missions.
OSSA plans to move boldly forward to make fundamental and visible advances in key areas of space science to ensure that our world leadership is preserved in the future. Our pursuit of leadership is most conspicuous through major and moderate missions, because they provide the largest quantum leaps in the advancement of scientific knowledge and technological ability.

3. Increased Opportunity with Small Missions.
Small missions are vital to the program because they can be accomplished relatively quickly and inexpensively, allowing continuing opportunity for consideration of innovative ideas for focused scientific objectives. The small missions are particularly important for training the next generation of scientists and engineers, since the missions are of a size that universities can develop, and the development and flight of small missions can occur in the same amount of time as that required to earn a graduate degree. These types of opportunities also build the experience and qualify the technology for major and moderate missions.

4. The Transition to Space Station Freedom.
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 capabilities for microgravity science and life sciences research in pressurized laboratories.

5. The Research Base.
The research and analysis program provides base support for a vigorous and productive research community, and it presents a special opportunity for students to develop the skills that will enable them to conduct the programs of the future. The program consists of ground-based laboratory and suborbital research, data analysis, theory and modeling, and advanced technology development.

Decision Rules

The first step in the process of determining mission priorities and sequence is the establishment of a realistic budget level. Then, the five themes described earlier provide the template on which the OSSA core science program is built. Ideally, at least one new initiative for each theme, except the ongoing program, would be included each year, and we would systematically pursue each item under each theme, in sequence by priority. However, in the event that the budget or other aspects of the external environment do not accommodate simultaneous enhancements in all four areas, certain rules have been formulated to determine the mix of program elements.

1. Complete the ongoing program.
Completing the ongoing program always has the highest priority; resources allocated to those programs already under way will not be sacrificed or postponed in order to pursue new starts.

2. Initiate a major or moderate mission each year.
Major missions preserve and enhance U.S. leadership in key areas of space science and applications, and we will pursue major missions whenever available resources allow us to do so. If an assessment of foreseeable expenditures for candidate missions, over both the near term and the lifetime of the program, indicates that our resources do not permit a major mission, we will seek to pursue a moderate mission.

3. Initiate small missions in addition to major or moderate missions.
We endeavor to start a small mission or a small mission program every year, in conjunction with either a major or moderate mission.

4. Move aggressively, but sensibly, to build science instruments for Space Station Freedom.
S.S. Freedom initiatives are determined by the pace and balance of the scientific disciplines involved, relevance to and compatibility with Freedom Station capabilities and schedule, and technological maturity of the initiative. We will move forward systematically to provide a complete set of fully developed facilities and instrumentation for Space Station Freedom.

5. Research base augmentations will be sought whenever they are warranted.
They are determined by the impact of both the external environment and other elements of the OSSA program on discipline stability, progress, and future needs. Provisions for meeting the long-term requirements for an adequate scientific work force and assuring access to the scientific data base from past missions are particularly critical.

STRATEGY FOR MISSION TO PLANET EARTH

In 1990, the OSSA core science program strategy was enhanced to accommodate NASA's participation in the U.S. Global Change Research Program. Concerns about global environmental change have reached the highest levels of many governments throughout the world. Irrefutable evidence exists to show that human activity has altered Earth's nature by changing its landscape and the composition of its global atmosphere. As never before, the public, the Government, the private sector, and the media are being exposed to scientific evidence that suggests changes, such as potential global warming, changing sea levels, declining upper atmosphere ozone levels, and massive deforestation, can affect their lives and their economic status. However, although the potential for these changes has been recognized, researchers have not yet reached consensus on the causes, the long-term extent, or the consequences of many of them.

To reduce the scientific uncertainties associated with global change, President Bush has proposed a multi-agency U.S. Global Change Research Program. The goal of this program is "To establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system." Contributions will be made by the National Oceanic and Atmospheric Administration, the Department of Energy, the Department of the Interior, the Environmental Protection Agency, NASA, the National Science Foundation, and the United States Department of Agriculture.

OSSA plays a particularly important role in the U.S. Global Change Research Program. We are to apply our expertise in remote sensing to use the global perspective that is available from space to understand how the Earth works as a system. To this end, an integrated, comprehensive program, including space- and ground-based measurements, research, and data and information systems, has been developed. This program, Mission to Planet Earth, is unlike any other NASA space science program. It is not intended to increase incrementally our knowledge of Earth. Rather, it is intended to increase with all due haste our knowledge of the Earth system to a sufficient level of understanding to make sound policy decisions. This will require aggressive and sustained funding, and will dwarf any past space science activity.

OSSA's strategy for Mission to Planet Earth follows three progressive phases: near-term monitoring and focused studies; comprehensive long-term studies; and intensive studies. The pursuit of these phases is structured around four of the five traditional OSSA core science themes: the ongoing program, major and moderate missions, small missions, and research base enhancements.

1. Near-Term Monitoring and Focused Studies.
The first phase of Mission to Planet Earth consists of several missions and research activities already part of the core science program. During the next few years, our knowledge of Earth should increase substantially, as NASA will participate in more than 20 Earth science missions to study various aspects of how the Earth works. The Upper Atmosphere Research Satellite to be launched in 1991 will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. The Ocean Topography Experiment (TOPEX)/POSEIDON will reveal more about the circulation of the world's oceans than all the ships in history. Shuttle flights of the Atmospheric Laboratory for Applications and Science (ATLAS) and the Shuttle Solar Backscatter UltraViolet (SSBUV) instrument will study the atmosphere, and the Space Radar Laboratory will observe the structure of the land. In addition, the Ocean Color Data Mission, to be launched in 1993, will measure changes in ocean color.

Small missions of this phase include the Earth Probes, which were approved in FY 1991 as a series of smaller satellites with specialized instrumentation and orbits for investigations that cannot be accomplished otherwise. The Total Ozone Mapping Spectrometer, the NASA Scatterometer, and the Tropical Rainfall Measurement Mission make up the near-term complement of small missions in the Mission to Planet Earth strategy.

Research base enhancements are an integral part of this phase. To make optimum use of the data from ongoing and upcoming missions, we intend to improve computational capabilities in Earth science, and to enhance the access of researchers to these data through networks and archiving facilities. The Earth Observing System (EOS) program includes an EOS Data and Information System (EOSDIS), essential elements of which will be brought online in the early 1990s in advance of the launch of the EOS spacecraft. EOSDIS will be used to derive maximum information from existing and upcoming missions, and, in turn, the data from these missions will be used to test and perfect EOSDIS in advance of the larger data flows from the EOS spacecraft.

Data alone, of course, do not yield understanding. That will require scientists interpreting the data, developing concepts for the processes that control Earth, and building predictive models of its future. EOS will effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to ensure the future continuity of this research base.

2. Comprehensive Long-Term Studies.

The main element of this phase of study is the Earth Observing System (EOS), approved in FY 1991 as a major new start. EOS is composed of a series of well-instrumented spacecraft in polar orbit designed to observe concurrently the behavior of the atmosphere, the oceans, the land, and life on Earth. The spacecraft are sized to accommodate instruments that need to observe the Earth simultaneously, through the same column of air. Our international partners, the European Space Agency (ESA) and Japan, are planning to build complementary spacecraft that include accommodations for U.S. scientific instruments.

The EOS-A spacecraft series, planned for launch in 1998, is devoted to measurements of Earth's surface and the conditions of the lower atmosphere needed to understand global change. In 1991, OSSA selected the 11-instrument payload for the first spacecraft in the EOS-A series. The final determination of the instrument manifest on subsequent satellites will be made after development is under way on the initial set. This approach is intended to allow for the continuing evolution in mission planning that is expected to result from the development of new technology, improved understanding of measurement requirements, and the availability of alternative sources of data and new space missions being planned by other nations.

The second spacecraft series, EOS-B, which will begin to fly $2\frac{1}{2}$ years later, is devoted to measurements of the chemistry and dynamics of the atmosphere, the circulation of the oceans, and the behavior of the solid Earth. In contrast to the initial EOS-A spacecraft, which carries a full suite of instruments on a single spacecraft, the EOS-B series may be conducted using multiple smaller spacecraft with smaller numbers of instruments. OSSA is currently studying this approach to assess its merit and feasibility.

The EOS Synthetic Aperture Radar, which will provide complementary land surface information not accessible with passive instruments on the EOS spacecraft, will be initiated later this decade. The Earth Probes series will continue with follow-on missions, and the research base will be enhanced to begin preliminary global climate modeling.

3. Intensive Studies.

In the major and moderate mission area, this final phase of Mission to Planet Earth will include geostationary platforms to be initiated in the 1990s. The geostationary platforms will provide continuous monitoring of highly transient events on a global basis. Follow-on Earth Probes will continue, and research will address the development of comprehensive global climate models.

STRATEGY FOR MISSION FROM PLANET EARTH

OSSA has also developed a third strategy for fulfilling OSSA's role in the national initiative for human exploration of the Moon and Mars. As defined by the President, Mission from Planet Earth follows a progressive timeline beginning with Space Station Freedom in the 1990s, a return to the Moon in the next century, and then a human mission to Mars. In broad terms, NASA plans to meet these objectives by performing life sciences research and technology development on Space Shuttle and Freedom, conducting scientific robotic missions to support site selection, and developing and supporting permanent human outposts on the Moon and Mars.

Although the specific pace and implementation plans are not yet defined, NASA's preliminary approach to the development of outposts on the Moon and Mars consists of four phases. The first, robotic exploration, obtains data to assist in the design and development of subsequent human exploration missions and systems, demonstrates technology and long communications time operation concepts, and dramatically advances scientific knowledge of the Moon and Mars. The second phase, outpost emplacement, emphasizes accommodating basic human habitation needs, establishing surface equipment and science instruments, and laying the foundation for future, more complex instrument networks and surface operations by testing prototypes of later systems. The third phase, consolidation, further expands these capabilities, and the fourth phase, operation, entails a steady-state mode with the maximum possible degree of self-sufficiency.

The current OSSA strategy for Mission from Planet Earth is built around Space Station Freedom and the four development phases to encompass three themes.

1. Meeting Human Needs.
We will commit humans to long-term space activities only when we have developed an adequate understanding of the physiological and psychological effects of and countermeasures to space travel and habitation of nonterrestrial bodies. Currently planned life sciences research in the areas of medical and life support systems conducted aboard extended-duration Spacelabs, Lifesat, and Space Station Freedom will help to develop that understanding. Other missions will be flown to characterize and provide warning systems for in-space radiation hazards. Later, life sciences research preparatory for Mars missions will be conducted at the lunar outpost. Significant technology development of systems to protect and support human space travelers must also be conducted. Areas of concern include radiation protection, reduced gravity countermeasures (including artificial gravity), medical care, life support, and resolution of behavioral and human factors issues. Additional research is also required in areas of fluid flows, low-gravity combustion and fire safety, and the mechanics of granular materials in low gravity to support other technology needs in advance of long-term spaceflight to and operations on the Moon and Mars.

2. Robotic Exploration.
In addition to their inherent scientific objectives, robotic exploration missions will develop global information on the Moon and Mars to prepare for human missions and aid in spacecraft landing and outpost site selection. Robotic exploration will proceed in synergy with human exploration, and robotic missions will be pursued with appropriate emphasis on the parallel objectives of continuing to conduct fundamental science and preparing for human exploration. The collection of critical data to support planning of human exploration missions constitutes an activity that

extends beyond OSSA's traditional role of conducting basic research from the perspective of scientific value alone. Therefore, OSSA recognizes an added responsibility to develop and implement these missions to serve other parts of the NASA program, in concert with their extension of the pursuit of OSSA's basic scientific objectives.

3. In Situ Science.
Science conducted on and from the Moon and Mars can take the form of local human geologic and exobiological exploration, more distant rover traverses, return of samples to Earth, the installation of scientific instrument networks for long-term observations in several discipline areas, and scientific research in pressurized laboratories. OSSA's selection of science activities will be based on merit and intrinsic scientific value. Choices will be made between available alternatives on the basis of value, cost-effectiveness, or specific advantages. In addition, in planning for science on the Moon and Mars, choices between human and robotic approaches will be made on the basis of appropriateness of approach to the particular objective.

DECISION RULES FOR INTEGRATING OVERARCHING INITIATIVES

The first step in the process of determining mission priorities and sequence for integrating Mission to Planet Earth and Mission from Planet Earth into the core science program is the establishment of a realistic budget level. Our ability to preserve the strength of the core science program will require a continuing level of resources comparable to the historical fraction allocated to the program; both Mission to Planet Earth and Mission from Planet Earth require resources beyond that level. Then, OSSA will approach the incorporation of new missions into the program by assessing how these overarching national initiatives also contribute to the objectives of the OSSA core science program and meet established OSSA principles. In many cases, components of Mission to Planet Earth and Mission from Planet Earth originated in the core science program. In fact, the two initial elements of Mission to Planet Earth — the Earth Observing System and Earth Probes — had their roots as part of the core science program. The pace of incorporating the EOS Synthetic Aperture Radar and the geostationary platforms, the only two remaining components of the Mission to Planet Earth strategy, will be driven by national policy, but constrained by the state of technological readiness to pursue them.

The strategy for Mission from Planet Earth is somewhat less mature, and it will be driven by a philosophy that matches the schedule to the funding. Lifesat and the Biomedical Monitoring and Countermeasures program are missions that originated as part of the OSSA core strategy; they have also been identified as part of the Mission from Planet Earth strategy. However, for the longer term, incorporating elements of Mission from Planet Earth into the OSSA program will be an important strategic activity.

In an unconstrained resource environment, at least one new initiative for each Mission from Planet Earth theme described earlier would be included each year, and we would systematically pursue each item under each theme in sequence by priority. However, when the budget or other aspects of the external environment do not accommodate simultaneous enhancements in all three areas, certain rules have been formulated to determine the mix of program elements for the

Mission from Planet Earth. These rules would also guide the timing of the initiation of later elements of Mission to Planet Earth.

1. **Match the pace of the OSSA program for overarching initiatives to the pace at which NASA and the Nation proceed as a whole.**
   The Advisory Committee on the Future of the U.S. Space Program has stated that Mission to Planet Earth "connotes some degree of urgency," and OSSA's planning reflects this urgency. For Mission from Planet Earth, the Committee recommends an approach in which schedule is a function of availability of resources. These two guidelines will form the basis for the pace at which OSSA pursues these programs.

2. **Establish a feasible pace and scale.**
   The pace and scale of the total program will always be matched to the capability of the NASA institutional infrastructure and of the scientific and industrial communities to accomplish these missions.

3. **Preserve program balance.**
   OSSA will always adhere to the principle of scientific balance among the disciplines within the core science program; the core science program must proceed in parallel with overarching national initiatives. Mission sequence and priority will, therefore, depend on how various alternatives affect the balance of the overall OSSA program and on how those alternatives protect the central position of the core science program recommended by the Advisory Committee on the Future of the U.S. Space Program.

THE PLAN FOR 1992

The Core Science Program

Fiscal year 1992 will be a transition year for OSSA. Following the successful initiation of three major mission programs, two small mission programs, and the development of Space Station Freedom laboratory facilities over the past 3 years, 1992 occurs in a period of explicitly constrained resources, tied into the new Federal budgeting environment. It also marks the introduction of steps taken by NASA in response to recommendations of the Advisory Committee on the Future of the U.S. Space Program, and some of those steps will be reflected in the OSSA program. The five programmatic themes and the rules for decision-making were followed in the construction of our fiscal year 1992 core science program plan.

ONGOING PROGRAM

The FY 1992 plan includes sufficient resources to operate and use the fleet of more than a dozen currently flying U.S. research spacecraft and to keep each ongoing flight project development program on schedule for launch in its manifested slot on the Space Shuttle or an expendable launch vehicle.

Major events in space science and applications for calendar years 1991 through 1997, summarized on the inside back cover, indicate a vital and productive ongoing program. The year 1990 saw OSSA's fleet of operating spacecraft expanded by the launches of the Hubble Space Telescope, Pegsat, the Roentgen Satellite, the Combined Release and Radiation Effects Satellite, and Ulysses. The Astro Spacelab flight made extraordinary progress in exploration into the far ultraviolet and X-ray bands. In 1991, this pace will continue with the launches of the Gamma Ray Observatory, the Upper Atmosphere Research Satellite, the Extreme UltraViolet Explorer, one flight of the Shuttle Solar Backscatter UltraViolet instrument, and one Spacelab flight: the first Space Life Sciences mission.

Development continues on the impressive array of major, moderate, and small missions to be launched from 1992 through 1998. Initiatives and programs approved in FY 1991 are now underway as part of the ongoing program. The Earth Observing System and Earth Probes are in development. A major communications mission, the Advanced Communications Technology Satellite, is being developed on schedule for a 1992 launch. The Mars Observer also is on schedule for launch in 1992. Two major solar system exploration missions are in development: Cassini will begin its journey to Saturn in 1995, and the Comet Rendezvous Asteroid Flyby (CRAF) will be launched in 1996. The Advanced X-ray Astrophysics Facility is being developed for a 1998 launch. The Explorer program continues and has been expanded to include the preparation of three small missions to begin launching in 1992. The SETI Microwave Observing Project continues instrument development for the 1992 initiation of observations.

The ongoing program also includes preparations for research missions on the Space Shuttle to encompass additional Space Life Sciences flights; a series of International Microgravity Laboratory, U.S. Microgravity Laboratory, and U.S. Microgravity Payload missions; several Atmospheric Laboratories for Applications and Science; and several flights of the Shuttle Solar Backscatter UltraViolet instrument and the Space Radar Laboratory. The Extended Duration Orbiter Medical Program has been defined and is operationally collecting data and refining protocols to certify the capability of the flight crew to safely pilot the return of the Shuttle and leave the spacecraft following extended-duration flights of 16 days. Under the theme of Space Station Freedom Utilization, we are developing a major life sciences focus on the unprecedented extravehicular activity associated with Freedom assembly, as well as a centrifuge facility for life sciences research and several facilities in preparation for microgravity research on Freedom.

In considering the implementation of the ongoing program for this and any other year, our strategy must retain the flexibility to address alternatives for recovering from catastrophic loss (i.e., the loss of the spacecraft during launch or very early in its lifetime). The recovery process would strongly depend on the nature of the mission that suffered the loss; approaches to reliability and redundancy would be tailored to suit specific programs. Generally, consistent with the high priority that is placed on the ongoing program, we would assess the alternatives for recovering the lost mission before pursuing any new projects or adding any new missions to the program. Several factors contribute to this assessment. We must consider the relationship of the mission to the discipline involved and determine the impact of the loss on the discipline's health. The urgency and relevancy of the science to be conducted are assessed; if the mission is a precursor to a future mission, that is also an important factor. The current state of technology would be compared to the technology used in the original design; near-term projects already in development might more than compensate for the loss.

The related international implications of the loss and recovery would also need to be determined. In any case, cost will be a critical consideration, particularly because the OSSA budget does not carry the financial reserves to provide the contingency to cope with catastrophic mission loss.

LEADERSHIP: MAJOR AND MODERATE MISSIONS

As noted earlier, the Advanced X-ray Astrophysics Facility, CRAF/Cassini, and the Earth Observing System major mission programs are all in development for launches in the second half of the 1990s. Major development milestones will occur for all three programs in 1991 and 1992. As a consequence of expected budget constraints in fiscal years 1992 and 1993, no new major or moderate mission initiatives are proposed for 1992.

SMALL MISSIONS

To maintain program continuity and vigor through frequent flight opportunities, three missions were added to the Explorer program during 1989. These missions are to be launched on small-class expendable launch vehicles to achieve first-class scientific objectives in physics and astronomy. Launches will begin in 1992, and we plan to approve additional small missions in 1992.

A new small mission series initiated in 1991 is the Earth Probes, a line of Explorer-class spacecraft that complement the Earth Observing System and provide for Earth science missions with highly focused scientific objectives that do not require a large set of simultaneous observations, or that do require specialized spacecraft or unique orbits. These include the Ocean Color Data Sets to be obtained commercially, several Total Ozone Mapping Spectrometer flights in 1991 through 1995, the Tropical Rainfall Measurement Mission, and the NASA Scatterometer planned for flight in 1995 on the Japanese Advanced Earth Observations Satellite. In addition, the Tropical Rainfall Measurement Mission has been refined to include payloads crucial to maintaining ongoing long-time-series data sets needed for global climate change research in advance of the EOS missions. For FY 1992, we propose an augmentation to the Earth Probes series to enhance our pursuit of knowledge of the Earth system.

We are also proposing for FY 1992 the initiation of development of Lifesat, a small mission program that plays a critical role in both the core science program and the Mission from Planet Earth strategy. Lifesat is a small, recoverable, reusable orbiting biosatellite that can be used as an inexpensive platform for conducting life sciences experiments. Lifesat in polar orbit will support critical radiation biological experiments — studies that will not be addressed in any other area of the U.S. space program. The Lifesat spacecraft can be launched on a variety of expendable launch vehicles and can provide up to 60 days of microgravity environment. NASA has had discussions with a number of potential partners in Europe, Canada, and Japan, who have expressed an interest in collaborating in such a series of missions.

SPACE STATION FREEDOM UTILIZATION

The fourth theme of our 1992 plan concerns Space Station Freedom. In its FY 1991 appropriation legislation for NASA, Congress directed NASA to develop a plan for restructuring Space Station Freedom to reflect a simplified design that can be developed in an evolutionary manner, beginning with man-tended capability for microgravity research and later progressing to permanently manned utilization for life sciences research. The Advisory Committee on the Future of the U.S. Space Program made similar recommendations that Freedom Station be reconfigured with "only two missions in mind: first, life sciences experimentation (including the accrual of operational experience on very long duration human activities in space) and, second, microgravity research and applications." OSSA has represented the scientific community during NASA's study of a restructured program.

One consequence of the restructuring has been the deletion of early provisions for Space Station Freedom attached payloads. This capability is a significant element of the overall science potential offered by the baseline Freedom Station, particularly in the early years. OSSA supports the consideration of an architecture that enables the capability for meaningful scientific use of attached payloads after the permanently manned utilization phase begins. In the meantime, we will pursue opportunities in a small and rapid-response payload program and seek full use of international partners' contribution to Space Station Freedom in supporting OSSA science objectives. OSSA's Space Station Freedom priorities will remain focused on the use of the pressurized laboratories for microgravity and life sciences research. No new laboratory facilities beyond those already in development are proposed for 1992.

RESEARCH BASE

The fifth and final theme of our core science program concerns the supporting Research and Technology program, which is the vital foundation for a vigorous and productive research community. The research base program constitutes an important mechanism for sustaining a healthy balance between investment in space science via large-scale projects and research teams (primarily through major and moderate missions) and via small-scale projects and support to individual investigators. It provides for the acquisition of essential laboratory, ground-based, and suborbital measurements to complement spaceflight investigations, and it supports retrospective spaceflight data analysis activities and theoretical studies that maximize the scientific return of data obtained from flight projects. In addition, the research base program provides for the advanced instrument technology development and mission planning that are essential to assure the viability of future space science missions. Most important perhaps, the research base elements of OSSA's core science program lend a stability and continuity to the individual discipline programs that flight projects alone cannot provide.

Research base initiatives proposed for FY 1992 will address three particularly important areas: the development of an adequate community of researchers to meet the work force requirements for future space science programs, the revitalization and use of data holdings from prior flight missions, and the initiation of focused research efforts in unique scientific problem areas.

The ability of the research base program to nurture the health of the research community has been identified by OSSA's advisory bodies as an issue of highest priority. As we look toward the late 1990s, demographic studies project a wave of retirements of senior investigators that can lead to a serious shortfall in the space science community unless adequate numbers of new researchers are recruited and trained. Therefore, one element of OSSA's FY 1992 research and analysis initiative will focus on providing resources for graduate student assistantships, initiating grants for new researchers, and augmenting support for individual researchers, especially at universities. Certain discipline areas are especially stressed due to the aging of the current investigator population, structural vulnerability caused by repeated external pressures on the research and analysis budget, and/or mismatches between present investigator community size and future program needs. These areas, including planetary science, microgravity science, and space physics, will receive particular attention.

The OSSA data revitalization initiative will ensure that current space science data holdings are preserved, migrated to modern storage media, and managed in archives that enhance the availability of the data to all investigators. More attention will also be devoted to augmenting the capabilities and use of discipline-specific data systems in fields such as astrophysics, planetary science, and space physics. One new research thrust will begin in FY 1992 — a program of studies of the mesosphere and lower thermosphere. A region long neglected compared to other subjects of space science, the mesosphere/lower thermosphere region constitutes the interface between Earth's atmosphere, where processes critical to global climate change occur, and Earth's ionosphere and magnetosphere, where space plasma processes and fields and particles of solar origin predominate. To address this gap in our program, OSSA will begin a modest suborbital research program and an advanced technology effort to support multidisciplinary studies of important dynamical processes in the mesosphere/lower thermosphere region.

The Mission to Planet Earth Program

The four Mission to Planet Earth themes and the integrating decision rules were followed in the construction of our fiscal year 1992 plan for Mission to Planet Earth.

ONGOING PROGRAM

The 1992 ongoing program will provide for the continued development and operation of near-term missions, including the Upper Atmosphere Research Satellite to be launched in 1991 and the Ocean Topography Experiment (TOPEX)/POSEIDON to be launched in 1992. Flights of the Atmospheric Laboratory for Applications and Science, the Shuttle Solar Backscatter UltraViolet instrument, and the Space Radar Laboratory complete the Mission to Planet Earth ongoing program for FY 1992.

LEADERSHIP: MAJOR AND MODERATE MISSIONS

The Earth Observing System (EOS) was approved for initiation in FY 1991. During FY 1992, the EOS-A spacecraft series will be in the final design stage, and EOS-B instrument selection will begin. Concept definition studies for the EOS Synthetic Aperture Radar will continue. No new major or moderate mission is proposed.

SMALL MISSIONS

Small missions in the 1992 program include the NASA Scatterometer, and the first in the line of Earth Probes, the Total Ozone Mapping Spectrometer scheduled for its first flight on a Soviet meteorological satellite in 1991. The Tropical Rainfall Measurement Mission Earth Probe will be entering its final design phase in preparation for a 1997 launch. In FY 1992, an augmentation to the Earth Probes series has been requested to further refine our data set in advance of EOS.

RESEARCH BASE

Research base enhancements for FY 1992 enable the evolution of an interdisciplinary Earth system science program augmented by about 30 interdisciplinary investigations in the second year of research. The EOS Data and Information System (EOSDIS) will nearly complete its pathfinder data program, making available to the international science community long-term, high-precision data sets from prior Earth science missions crucial to global change research.

The Mission from Planet Earth Program

The three Mission from Planet Earth themes and the integrating decision rules were followed in the construction of our fiscal year 1992 plan for Mission from Planet Earth.

MEETING HUMAN NEEDS

Life sciences research planned as part of the OSSA core science program will also play a key role in supporting Mission from Planet Earth. The Space Biology Initiative, which provides flight hardware for conducting research on Space Station Freedom in space physiology, gravitational biology, controlled ecological life support systems, and exobiology, continues definition studies. Planning for a Biomedical Monitoring and Countermeasures program has also been initiated to determine ways to maintain optimum crew health and performance and to medically certify repeated extended-duration tours of duty. These two activities combine to begin the strategy for conducting life sciences research on Space Station Freedom. In 1992, we also propose a development start to complete definition studies to permit the first launch as early as 1996 of Lifesat, a reusable biosatellite that will support critical experiments needed to quantify the effects of space radiation and microgravity on biological systems.

ROBOTIC EXPLORATION

Development of the Mars Observer will be continued to prepare for a 1992 launch. Missions beyond Mars Observer will also be studied, both to continue the scientific exploration of Mars and to prepare for human landings. These missions may include a network of small landers to study Martian seismology, meteorology, and geochemistry; rovers to explore regions of scientific interest and to survey potential human landing sites; and the return of samples of Martian soil and rock. The application of micro-technologies to these missions will be studied to determine the most effective approach to continuing Mars exploration. Several approaches to implementing Lunar Observer will also be examined.

IN SITU SCIENCE

The Exploration Science Working Group and discipline subcommittees of the Space Science and Applications Advisory Committee will complete initial analyses of recommended science strategies and identify critical advanced technology development priorities to support science on and from the Moon and Mars.

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With a clear eye toward the next 5 years, this plan for fiscal year 1992 allows us to make significant progress toward achieving our goals. The U.S. space science and applications program has historically produced an outstanding scientific return on America's investment, and we expect this return to continue and grow through the implementation of our 5-year strategy, described next.

FIVE-YEAR STRATEGY

Beginning with the overarching goals of NASA as articulated by National Space Policy and focused by the Advisory Committee on the Future of the U.S. Space Program, and working through OSSA's goals and objectives, the themes and principles cited earlier form the basis for our current strategy for fiscal years 1993 through 1997. We applied the decision rules with appropriate consideration of budgetary availability, institutional capability, and the pace of both Mission to Planet Earth and Mission from Planet Earth.

The Core Science Program

ONGOING PROGRAM

Through each succeeding year, the flight projects and research programs started the previous years combine with those already under way to form the ongoing program. In all cases, the highest priority of OSSA's strategy is to carry out the ongoing program.

LEADERSHIP: MAJOR AND MODERATE MISSIONS

All the major flight projects in the 1992 ongoing core science program will be launched by 1998; a new major flight project requires 4 to 7 years to develop. Therefore, to pursue leadership in key areas, the next step is to select the successors to the ongoing program. Our approach to adding new major and moderate initiatives to the queue is to incorporate several missions at the same time, rather than one every year. In future strategic plans, we will add the next group of major and moderate missions in a series of steps.

Each OSSA Division Advisory Subcommittee of the Space Science and Applications Advisory Committee is assessing candidate missions and initiatives for each strategic plan theme. This assessment is guided by the overall science strategy guidelines formulated by the National Academy of Sciences. The subcommittees maintain close coordination with the relevant committees and boards of the National Academy of Sciences, particularly the Space Studies Board.

Candidate missions of the highest priority will be placed in the subcommittee's long-term mission queue reflecting that subcommittee's priority in implementation of the missions. In order to avoid excessive oversubscription, consideration will be restricted to missions judged to be within no more than about 10 years of technological readiness. Major and moderate missions in the long-term queue will be the focus of studies and advanced technology development funding by the discipline. Missions that slip in priority may be removed from the queue. On a triennial basis, the Space Science and Applications Advisory Committee will review each Division strategy and its long-term mission queue for scientific validity and consistency with the overall OSSA Strategic Plan. When OSSA augments its 5-year queue of major and moderate missions, the Space Science and Applications Advisory Committee will evaluate the missions proposed by the subcommittees and assist OSSA in preparing an integrated queue.

The Space Science and Applications Advisory Committee will hold the first triennial review of Division strategies and proposed queues in the summer of 1991, and make its recommendation by fall 1991 in time for inclusion in the 1992 OSSA Strategic Plan. In view of the changing character of space science and applications, with the launches of many missions and the addition of Mission to Planet Earth and Mission from Planet Earth, the Committee may also reevaluate the decision rules during this time frame. The Space Science and Applications Advisory Committee will review the Division Subcommittee positions on small missions, Space Station Freedom utilization, and the research base on a continuing basis and make recommendations annually at the annual May-June Space Science and Applications Advisory Committee meeting. The Aerospace Medicine Advisory Committee will recommend a strategy to address the human needs theme of Mission from Planet Earth, in addition to other aerospace medicine and life support research areas.

The OSSA Strategic Plan seeks to provide for starting one major or moderate new mission per year. Although we recognize the fact that circumstances may present occasions where no new start is possible, and others where more than one core science program new start is possible, an average pace of one per year is necessary to meet the goals of leadership in key areas and to assure vigor and continuity. On the other hand, given a realistic estimate of resource constraints, more than one core science program new start per year cannot ordinarily be expected, because available resources for small missions and for research and analysis must be preserved.

The major and moderate missions in the current core science program strategy are described below.

ORBITING SOLAR LABORATORY

The Orbiting Solar Laboratory, the highest priority for initiation as a new start, is an ensemble of instruments in Sun-synchronous orbit designed to probe the Sun's fine-scale magnetic structures and to investigate the transfer of mass and energy across the photosphere and into the corona. The mission's objective is to study the fundamental magnetohydrodynamic processes of the Sun's atmosphere in visible and ultraviolet light at the limits of the spatial and temporal resolutions at which they occur. The Orbiting Solar Laboratory will provide the means with which to study the origin and evolution of features leading to solar flares and solar variability, which have profound effects on Earth's upper atmosphere, and which may affect aspects of global change measured by EOS. These same fundamental processes are thought to occur in other stellar and astrophysical systems, and, therefore, this mission provides important quantitative measurements with which to better understand the results from the Great Observatories. The understanding gained from these observations will also make an important contribution to our ultimate ability to predict the occurrence of energetic solar particle events that will pose health hazards to astronauts en route to and from or at the Moon and Mars. The Orbiting Solar Laboratory, therefore, will serve as a critical first step in determining the observations to be made by a network of solar monitoring stations that can provide early warning of solar events.

SPACE INFRARED TELESCOPE FACILITY

Fourth in the series of Great Observatories, the Space InfraRed Telescope Facility (SIRTF), an 85-centimeter, free-flying telescope in high-Earth orbit, will be ready for initiation in 1994. Cooled to the extremely low temperatures required to obtain high-sensitivity infrared data, SIRTF will probe the distant and ancient universe with a sensitivity that will exceed that of current ground-based and airborne facilities by factors of one to ten thousand. Among its prime observational targets will be protogalaxies near the edge of the observable universe, colliding galaxies, planetary systems beyond our solar system, brown dwarf stars, and bodies within our solar system.

SIRTF's timely development will allow essential coordinated observations with the Hubble Space Telescope and the Advanced X-ray Astrophysics Facility as they operate for their planned 15-year lifetimes. Because the Gamma Ray Observatory instruments have large fields of view, and the mission will mainly operate in "survey" modes, the correlative analysis of gamma-ray data with infrared data can be accomplished with the Gamma Ray Observatory data archives. Conversely, the Hubble Space Telescope and the Advanced X-ray Astrophysics Facility have very small fields of view, and these missions must be directed at unusual or interesting targets observed by SIRTF.

SIRTF will operate in a complementary and synergistic manner with the Stratospheric Observatory for Infrared Astronomy (SOFIA). SIRTF, with its profound sensitivity, will probe the deepest reaches of the universe, where the "red shift" places the primary emission of many objects in the infrared regime. SOFIA will provide extremely high-resolution spectroscopy of relatively bright and nearby sources.

LUNAR OBSERVER

The Lunar Observer, an element of both the core science program and the Mission from Planet Earth strategy, will provide an essential global scientific data base for the Moon by carrying out a 1-year mapping mission in lunar polar orbit. The Lunar Observer will globally measure the chemical and mineral composition of the Moon's surface, determine the surface topography and landforms, and measure the Moon's magnetic and gravitational fields. These data will produce a new understanding of the Moon as an individual terrestrial body. The mission will provide key support to future human activities on the Moon by determining critical surface characteristics and by providing an assessment of potential resources, including possible frozen volatiles at the lunar poles.

GRAVITY PROBE-B

Gravity Probe-B is designed to be a cornerstone test of general relativity. Einstein's universally accepted theory of special relativity ties together the structure of time and space. His theory of general relativity, which is far less thoroughly tested, ties together space, time, and gravity. This theory is on a much less secure experimental footing than the special theory, and alternative hypotheses exist. Gravity Probe-B will measure both the distortion of the "fabric of space time," imposed by the Earth's presence, and the subtle dragging of this fabric, predicted to result from the Earth's rotation. The influence of these effects will be seen in subtle precessional changes affecting the behavior of a set of four ultra-precision gyroscopes operating in a drag-free, superconducting environment. The required technology for this demanding undertaking has been under development since 1965. The key elements will be tested using a functioning prototype to be flown on a Space Shuttle flight prior to the science mission.

SOLAR PROBE

The Solar Probe will be humanity's first direct exploratory venture to the near vicinity of the Sun. The mission will study the unexplored region inward from 60 solar radii to within 3 solar radii of the surface of the Sun. With the objectives of understanding the mechanisms of coronal heating and solar wind acceleration, the Solar Probe will make in-situ measurements of the electromagnetic fields, plasma, and energetic particle populations in the region close to the Sun. The Solar Probe offers a unique opportunity for leadership in exploration of the heliosphere, and it has been cited by the scientific research community as a high-priority objective.

SMALL MISSIONS

Missions in this category are essential to sustaining the vigor of our scientific community because of their frequent opportunity for launch, perhaps as often as every 2 years per discipline. The small missions provide opportunities comparable to the continuing series of classical Explorers, which emphasize focused scientific objectives in astrophysics, space physics, and upper atmospheric physics. The small mission currently identified for the 5-year plan is described below.

MICROGRAVITY FUNDAMENTAL SCIENCE

A number of fundamental physical and chemical laws can be investigated through access to the low-gravity environment of spaceflight. The strategy to be pursued is to give much-needed flight opportunities to these investigations. The experiments will focus on challenging or developing experimental data for a large number of contemporary theories. This experimental program will include several low temperature investigations examining parameters involved in Renormalization Group Theory, as well as investigations involving general relativity and mechanics of granular materials. In the mid-1990s, an augmentation is needed to develop flight instrumentation to accommodate these investigations and pursue the use of dedicated Explorer-class payloads to facilitate these investigations. Where applicable, the Space Shuttle, Space Station Freedom, available commercial platforms, and dedicated free-flyers will be used as vehicles on which to conduct research. The scientific merit and desirability of developing opportunities in this area are cited by the Space Science Board in *Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015 - Fundamental Physics and Chemistry*.

SPACE STATION FREEDOM UTILIZATION

For this segment of our 5-year plan, we wish to continue developing an initial suite of Space Station Freedom facilities that will be capable of supporting basic research in the space sciences. Such research requires a "core facility" that can be optimally instituted using the unique resources of Space Station Freedom.

A key factor in OSSA's preparation for Space Station Freedom will be the continued use of Spacelab, Space Shuttle mid-deck lockers, and other appropriate carriers to develop, test, and verify new improved instrumentation for subsequent use on S.S. Freedom. OSSA-sponsored studies will further refine U.S. instrument requirements through evaluating coordinated, multinational hardware development programs.

RESEARCH BASE

Earlier sections of this Plan have outlined the principal objectives of the research base segment of the OSSA core science program — namely, maximizing the ultimate science return from OSSA's flight projects, providing a foundation for future programs, assuring stability and continuity in discipline programs and research communities, and sustaining a healthy component of small projects by individual investigators. The Plan has also noted that the principal activities by which we expect to achieve these objectives are retrospective data analyses and theoretical studies, supporting ground-based and suborbital investigations, and advanced capability development.

Our strategy for implementing a vigorous research base program is guided by the following principles:

High-quality science will continue to be the foremost criterion for establishing research program content.

The program should always preserve the short-term flexibility to respond to unforeseen opportunities without compromising the ability to provide the foundation for future spaceflight programs.

The level of the research base effort in each discipline should be appropriate to the level and complementary to the pace of the discipline's current and planned flight program.

The content of the research base effort in a particular discipline should maintain proper balance with and complement the content of the discipline flight program.

OSSA's approach to meeting the objectives of the research base program includes the following actions:

Protecting reasonable reserves and establishing cost containment plans so that research base funds are insulated from flight project problems.

Ensuring significant science funding in new flight project budgets to complement research base science funding levels.

Continuing to assess long-term science work force requirements and the ability of the research base program to respond to those requirements.

Developing explicit advanced technology plans and priorities that reflect realistic mission priorities and queues.

Considering consolidation of research proposal solicitations, protection of viable funding levels for research grants, selective use of long-term (i.e., 3- to 5-year) grants, and simplification of proposal requirements in order to reduce proposal preparation and evaluation workloads.

Using discipline Management Operations Working Groups and advisory subcommittees to assess mix, balance, and priorities in a discipline's research base program.

Reviewing research base program content, balance, and programmatic health at both a discipline level and OSSA-wide on an annual basis.

Augmentations to the research base program approved in 1989 and 1990 and proposed for 1992 will revitalize science programs to more vigorous levels of activity and will strengthen the ability of the program to sustain that vigor in the future. In subsequent years, we will focus primarily on new elements of the OSSA program, addressing specific activities such as the facility described below.

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

SOFIA is designed to fly a 2.5-meter telescope above 99% of the Earth's atmosphere in the fuselage of a Boeing 747 aircraft to provide high angular and spectral resolution for infrared astronomy. The SOFIA program is a collaboration with the Federal Republic of Germany, who will provide the telescope system. SOFIA is the ideal system for studies of the near universe with the clarity of view and spectral resolution essential for correlative analysis with data from orbiting observatories.

The SOFIA is planned to fly by the mid-1990s; this facility will allow astronomers to observe, with good angular resolution at infrared wavelengths inaccessible from the ground, the fascinating infrared sources discovered by the Infrared Astronomical Satellite launched in 1983. This continuity will ensure that the U.S. community (the pioneers and developers of the field of infrared astronomy) will maintain a major role until SIRTF flies and the complement for infrared astronomy is completed.

As a suborbital program, the SOFIA has several unique and important characteristics. SOFIA can provide frequent flight opportunities — more than 100 missions (or flights) per year. Instruments developed by the university research community can be changed for every flight. This capability allows the latest technology to be continuously incorporated and provides the essential test-bed for the development of sub-millimeter wavelength instruments to be flown in the space observatories of the next century. SOFIA will accommodate a large "guest observer" community, which also involves the training and development of space scientists for the next century.

Mission to Planet Earth Program

OSSA's 5-year plan for Mission to Planet Earth has basically been laid out, with the Earth Observing System (EOS), approved in FY 1991, as the centerpiece of the plan. With the initiation of the EOS Synthetic Aperture Radar and the Geostationary Platforms later this decade, major and moderate missions for the strategy will be essentially complete.

The EOS Synthetic Aperture Radar is planned for flight on a dedicated spacecraft to be launched by a Delta-class vehicle concurrent with the EOS spacecraft. The Synthetic Aperture Radar's primary scientific objectives are to monitor (1) global deforestation and its impact on global warming; (2) soil, snow, and plant canopy moisture and flood inundation and their relationship to the global hydrologic cycle; and (3) sea ice properties and their impact on polar heat flux.

The Geostationary Platforms are focused on measuring Earth system processes that cannot be adequately observed from polar or low-inclination orbits. Geostationary orbits permit observations during the complete diurnal cycle, so that rapidly developing phenomena can be viewed at any time and on a continuous basis. Continuous observations are crucial for understanding short-term processes essential for refinement of global Earth system models. Examples of processes to be monitored include precipitation and evaporation, atmospheric water vapor and wind, and land, ocean, and atmosphere energy fluxes. Current plans call for an array of five satellites supplied by NASA, ESA, and Japan, which permits concurrent monitoring from multiple observation points. Instrument payloads are planned to parallel as much as possible certain key instruments on EOS polar spacecraft in order to allow direct intercomparisons of data from the two systems.

Follow-on Earth Probes will complement the data obtained by the major missions described above. Earth Probes currently under study include a multistage mission to simultaneously measure Earth's magnetic and gravitational fields and a mission to provide high-resolution topographical data.

Research base enhancements will address the integration and analysis of mission data toward the ultimate goal of developing comprehensive global climate models.

Mission from Planet Earth Program

The themes and integrating decision rules cited earlier form the basis for OSSA's preliminary 5-year plan for Mission from Planet Earth. Although the schedule for Mission from Planet Earth has not been determined, OSSA will support each progressive phase with the appropriate activities in the three themes described below.

In the theme of human needs, life sciences research to support human exploration will progress incrementally as the program proceeds. In the early stages, Space Station Freedom will serve as a controlled test-bed for studying extended-duration human habitation of space and for developing and validating systems and elements, such as habitation and laboratory modules and life support systems, to be used later on the Moon and Mars. In the area of radiation protection, the Orbiting Solar Laboratory, a mission in the OSSA core science program, will serve as a critical first step in learning how to predict the occurrence of energetic solar particle events. The Advanced Composition Explorer will provide crucial data on the intensities of both the solar and galactic cosmic rays that are the primary source of the radiation. An additional element of the OSSA strategy for understanding space radiation risks will be the continued use of ground accelerators to study heavy ion physics and radiobiology to complement the spaceflight data from the Lifesat series.

Upon the initiation of the emplacement phase of the lunar outpost, an additional focus for life sciences research will be on systems developed on the Moon itself. Early systems will be used to establish prototypes for long-term habitation, and later habitats will provide additional space for increased biomedical and life sciences research. The facilities will be used to simulate the eventual long-term stays anticipated for Mars missions. Research on Space Station Freedom will continue to address issues associated with travel to and from Mars. Also during this time, a global system of solar monitors will begin to provide an early warning system for solar particle events.

The microgravity science research to support Mission from Planet Earth will initially focus on analyzing results of the ongoing space experiments to quantify to the maximum extent possible the effects of gravity on various physical phenomena in the areas of fluid flows, combustion, fire safety, and the mechanics of granular materials. Out of these analyses will come more detailed experiments for later development.

In the theme of robotic exploration, the Lunar Observer, which is also an element of the core science program, would be the next lunar robotic mission of the Mission from Planet Earth strategy. Then, preparation for human missions to Mars will require a series of robotic missions after Mars Observer to support and verify landing site selection, identify hazards to human explorers, and prepare for science experiments conducted by crew. For example, a Mars Environmental Survey mission involving multiple landers can provide high-resolution surface data and extended-duration seismological and meteorological measurements. Then a mission to return samples of Mars to Earth for scientific analysis and hazard evaluation and determination of the potential for back-contamination is appropriate. Next, a Mars site reconnaissance orbiter would provide detailed imaging to characterize landing sites, assess landing site hazards, and provide a data base for subsequent rover traverses and piloted surface operations. Finally, several Mars rover missions could certify sites with the greatest potential for piloted vehicle landing and outpost establishment.

As with all elements of Mission from Planet Earth, in situ science will become progressively more sophisticated as the program proceeds. At both the Moon and Mars, science capabilities should begin with local human exploration complemented by unmanned rover traverses and be followed by the emplacement of initial science instruments. Later, more advanced scientific instrument facilities can be built to broaden the range of observations, and pressurized laboratories can be used to conduct research in a variety of areas. For example, the characteristics of the Moon make it a unique site for astronomical observatories, in particular for arrays of optical interferometers. The establishment of ultraviolet, visible, and infrared telescopes on the Moon will substantially contribute to studies of the terrestrial planets and the atmospheres and surfaces of the outer planets and their satellites. In addition, science from the Moon offers unique opportunities to conduct high-priority cosmic-ray physics research.

On Mars, exploration will address questions of geoscience, climatology, exobiology, and life sciences. In early stages, the mobility of human explorers will be limited, but dependable and versatile long-range robotic rovers will have been deployed.

Strategy Summary

The strategy for OSSA's core science program is illustrated in Figure 1. Figure 2 illustrates OSSA's specific strategy for Mission to Planet Earth, and Figure 3 illustrates the strategy for OSSA's role in Mission from Planet Earth. As stated in the previous pages and illustrated by the figures, some areas and missions are common or complementary among the strategies. The specific timing and phasing of OSSA's Mission from Planet Earth strategy will match the pace determined by national priorities and capabilities. In future strategic plans, more explicit definition of the program will be developed.

Fiscal Year	Ongoing Program	Major & Moderate Missions	Small Missions	Space Station Freedom Utilization	Research Base Enhancements
1991	Research and Analysis	Earth Observing System†	Earth Probes†	Space Biology Initiative* Biomedical Monitoring and Countermeasures*	
1992	Mission Operations and Data Analysis Aerospace Medicine		Lifesat* Earth Probes Augmentation†		Resources to Augment Research Community Data Revitalization Initiative Studies of Mesosphere and Lower Thermosphere
1993 THROUGH 1997	Flight Projects Spacelabs and Other Carriers	Orbiting Solar Laboratory* Space InfraRed Telescope Facility Lunar Observer* Gravity Probe-B Solar Probe	Microgravity Fundamental Science	Small and Rapid-Response Payloads	Stratospheric Observatory For Infrared Astronomy Focused Research and Analysis, Suborbital, Advanced Technology Development, Data Systems Enhancements

* Also see Mission from Planet Earth Strategy
† Also see Mission to Planet Earth Strategy

Figure 1. **OSSA Core Science Program Strategy**

Phase	Ongoing Program	Major & Moderate Missions	Small Missions	Research Base Enhancements
Near-Term Monitoring and Focused Studies	Research and Analysis Mission Operations and Data Analysis Upper Atmosphere Research Satellite Ocean Topography Experiment Atmospheric Laboratory for Applications and Science/Shuttle Solar Backscatter UltraViolet Instrument Flights Global Ocean Color Measurements Space Radar Laboratory		Total Ozone Mapping Spectrometer NASA Scatterometer Tropical Rainfall Measurement Mission	EOS Interdisciplinary Investigations EOS Data and Information System
Comprehensive Long-Term Studies		Earth Observing System: "A" Spacecraft Series "B" Spacecraft Series EOS Synthetic Aperture Radar	Follow-On Earth Probe Missions	Preliminary Global Climate Modeling
Intensive Studies		Geostationary Platforms		Comprehensive Global Climate Models

Figure 2. **Mission to Planet Earth Strategy**

Phase	Meeting Human Needs	Robotic Exploration	In Situ Science
Robotics and Space Station Freedom	Space Biology Initiative*† Biomedical Monitoring and Countermeasures*† Lifesat**† Orbiting Solar Laboratory† Advanced Technology Development Life Sciences Test-Beds for Lunar Outpost	Mars Observer† Lunar Observer† Mars Environmental Survey	Opportunities Definition Advanced Technology Development
Lunar Emplacement and Mars Robotics	Lunar Mission Systems	Mars Sample Return with Local Rover Mars Site Reconnaissance Orbiter	Teleoperated Rover Lunar Transit Telescope Lunar Geology and Exobiology
Lunar Consolidation	Global Solar Monitors	Mars Rovers	Pressurized Rover Pressurized Laboratories
Lunar Operation and Mars Emplacement	Mars Life Sciences Test-Beds Mars Mission Systems	Additional Mars Rovers	Advanced Lunar Astronomical Facilities Mars Geology and Exobiology Meteorological Stations Unpressurized Rover Mars Science Network

* 1991 initiative
** 1992 development start
† Also part of core science program

Figure 3. **Mission from Planet Earth Strategy**

IMPLICATIONS OF THE OSSA STRATEGY

Although the OSSA strategy is carefully constructed to provide a balanced program in space science and applications, it also results in an annual sequence in which specific disciplines are highlighted in an orderly progression. In FY 1989, special emphasis was placed on astrophysics (new start for the Advanced X-ray Astrophysics Facility) and on microgravity science and applications (new start for facilities evolving to use on Space Station Freedom). In FY 1990, we highlighted solar system exploration (CRAF/Cassini new start and "Origins of Solar Systems") and life sciences (Space Biology Initiative and Biomedical Monitoring and Countermeasures planning, plus a research base augmentation for Specialized Centers of Research and Training). Similarly, FY 1991 was the "year of Earth," with new starts for the Earth Observing System and Earth Probes. In FY 1992, we will begin to reap the benefits of and build on new initiatives of previous years. Accordingly, FY 1992 will be a transition year in which we place priority on critical needs in the research base and adjust the pace of the program to respond to national budget constraints. This approach systematically infuses strength into each of our scientific disciplines, building strength and vitality across the entire OSSA program.

OSSA also interacts with and relies upon other NASA and other agency (domestic and international) programs by creating requirements and opportunities in a variety of areas. Within NASA, the appropriate allocation of Agency resources among the various program elements will, therefore, be essential to the success of the OSSA program.

This section of the OSSA strategic plan provides a summary assessment of the implications of the strategy on other segments of national and international space activities. This section will be updated each year, based on continuing activities to refine our understanding of the implications in each area.

Budget

Using the decision rules described earlier, OSSA has constructed a number of alternative plans that serve to demonstrate that the strategic process will permit most programs discussed in the previous section to be accomplished. However, in times of continued budgetary constraint, the pace at which these programs are developed will be affected strongly by the Nation's ability to control the deficit and by the way in which NASA's overall budget fares in the context of broad national priorities.

The strategic process does provide the decision mechanisms for determining the composition of the OSSA program, consistent with the realities of the budget. For example, with a growth in the total NASA budget of more than 10 percent per year, and with OSSA receiving a portion of that budget consistent with its historical allocation and its role in major national initiatives, carrying out the ongoing program and initiating major missions at a rate of nearly one per year would be possible. In some years, however, the initiation of moderate missions would be dictated. In a more constrained budgetary environment that provides for little growth, the development phase of major or moderate missions will be delayed or stretched out over a longer period of time. In most years, a steady sequence of small missions, appropriate Space Station Freedom initiatives, and selective augmentations to the research base can also be accomplished.

In order to protect other elements of the OSSA program from budget overruns in major and moderate missions, we have instituted a policy of developing cost-containment plans for each mission. These plans address four main areas of project management and control: (1) a clear definition of mission requirements and corresponding costs at the outset of a program, (2) formal documentation of requirements and controls, (3) assignment of experienced program managers and staff, and (4) proper levels of program review. If these steps do not adequately control cost, OSSA will also have in place a descope plan to adjust science content and mission complexity to contain cost. This descope plan describes a prioritized list of actions to be taken in the event of cost growth. In this way, costs will be contained within the mission budget without impacting other elements of the ongoing program.

Complementary strategies developed for OSSA's core science, Mission to Planet Earth, and Mission from Planet Earth programs permit the initiation of a mission in more than one area in the same year, provided sufficient budgetary and institutional resources are available. However, if there were pressure to accelerate the pace of either Mission to Planet Earth or Mission from Planet Earth while constraining OSSA to only one new start in a particular year, then maintaining a balanced overall program could become impossible.

Critical to all new initiatives in the budget is reliable access to space through a robust fleet of launch vehicles. In the past, the cost of maintaining spacecraft and Spacelab instruments on the ground, awaiting launch opportunities, has severely hampered our ability to manage program costs and to progress with new initiatives.

Transportation

The OSSA strategy assumes the implementation of NASA plans for a mixed launch vehicle fleet, including the current Space Shuttle system (with the fourth orbiter Endeavour becoming available for flight in 1992) and the full range of existing expendable launch vehicles. A maximum permitted downweight of 230,000 pounds enables Spacelab missions with a fifth energy kit to fly on either Orbiter Vehicle 102 (Columbia) or, beginning in 1992, Orbiter Vehicle 105 (Endeavour), for up to 10 days. With the Extended Duration Orbiter kit now under development, on-orbit stay time could be extended to up to 28 days. Space Shuttle launch rates for Spacelab module missions continue to be one to two per year and for pallet missions two to three per year.

As the result of NASA's response to the Congressionally mandated restructuring of Space Station Freedom, the period between initial man-tended capability and the point at which a four-person crew permanently staffs Space Station Freedom will span 3 years. As a result, OSSA will divert some Spacelab flights during 1997 to 1999 to be used as Space Station Freedom Utilization Flights. The scheduling of these flights will depend on Freedom Station availability and an enhanced capability of the operational manned base relative to science missions with the Shuttle. In addition, we will continue to use one to two Shuttle flights per year to conduct science and applications research that does not require the very long-duration opportunities provided by Freedom, to test new experiment hardware planned for Space Station Freedom, to service free-flyers, or to conduct unique observational science missions with attached payloads.

The OSSA strategy also requires the availability of "small" (Scout-and Pegasus-class), "medium and intermediate" (Delta-, Atlas/Centaur-, Titan III-class), and "large" (Titan IV-class) expendable launch vehicles. Launch rates for expendable vehicles will average approximately two small and one to two medium or intermediate expendable launch vehicles per year, with large expendable vehicles required in 1995, 1996, and beyond.

The rate at which the overall OSSA science strategy is achieved could be substantially enhanced with improvements to the Orbiter and its support systems. For example, significant increases to upmass capability could increase the payloads delivered to the Freedom Station manned base during the assembly phase. Any decrease in the projected launch rate of 10 to 12 flights per year would significantly delay delivery of equipment to Space Station Freedom.

A current deficiency in transportation capability for planetary missions is the absence of a high-performance transfer stage that is equivalent to the cryogenic Shuttle/Centaur upper stage cancelled in 1986. The use of the lower-performance Inertial Upper Stage for Galileo necessitated multiple gravity-assist swingbys at Earth and Venus, requiring costly design changes and increasing the travel time to Jupiter. OSSA currently intends to use the Titan IV or equivalent launch vehicles to support solar system exploration. However, until either a heavy-lift launch vehicle equipped with a high-performance cryogenic upper stage, or some version of an orbital transfer vehicle (combined with a capability for space-based assembly) becomes available, planetary orbiters will not be able to achieve efficient direct transfers between Earth and the outer solar system.

In addition to those capabilities presently available or planned within the Office of Space Flight (OSF) in support of OSSA, our strategy includes substantial utilization of sounding rockets, balloons, and aircraft in carrying out the science and applications programs. OSSA, in conjunction with OSF, is engaged in a continuing assessment of civil space transportation needs as part of a larger national effort focused on space transportation architecture studies. Each year, the OSSA strategy will form a basis for inputs to these assessments.

In-Orbit Infrastructure

Previous assessments of Space Station Freedom indicated that OSSA could fully utilize the baselined accommodations and resources of Space Station Freedom envisioned prior to the 1989 Configuration Budget Review. Subsequent configuration changes, coupled with assembly and schedule modifications, have raised many issues concerning the ability of the currently rephased Freedom Station to accommodate an aggressive science program. Some shortfalls, such as development of selected laboratory support equipment and experiment interface and support equipment, will now need to be provided by users.

The restructuring of Space Station Freedom resulting from the FY 1991 Congressional appropriation has reduced projected early capabilities, but it should not affect the long-term science program achievable on Freedom. For example, the deferral of permanent crew occupation delays some primary space physiology and gravitational biology research until the end of the 1990s. On the other hand, Freedom's assembly sequence will provide an unparalleled opportunity for focused studies of human space physiology associated with extravehicular activity (EVA). In 3 years, these assembly activities will involve the performance of more EVAs than all previous U.S. and Soviet experience combined. In the tended mode, Freedom Station will be a large free-flyer providing a continuous microgravity environment unmatched in the U.S. program. OSSA intends to operate up to 30 percent of its on-orbit Space Station Freedom experiment hardware during periods between Shuttle visits, and following establishment of a full permanent crew complement, OSSA plans an aggressive science program in all areas of low-gravity research. Therefore, with the capability offered by Freedom to conduct meaningful science research on EVA space physiology during assembly flights, and low-gravity research between Shuttle utilization flights, fundamental microgravity sciences will pursue research goals during the 3 years of man-tended activities prior to routine permanently manned science operations. OSSA endorses a restructured Freedom Station that accommodates effective microgravity research between Shuttle visits, provides for early life sciences research prior to the year 2000, and has an architecture supportive of the development of an attached payload program, including the early capability to support small and rapid-response research objectives.

OSSA has extended its planning for Freedom Station utilization to include U.S. science communities external to NASA. A Space Station Science and Applications User Board and an associated Working Group have been established to coordinate Federally funded U.S. science planning for and utilization of Freedom. To enhance the high quality of the international science programs performed on Space Station Freedom, international user groups regularly address the evolving plans of the partners for Freedom. OSSA has initiated cooperative studies with its science counterparts in Canada, Western Europe, and Japan. This cooperation has already shown significant promise of enhanced accommodation and resource utilization through international science collaboration. This continuing multilateral science activity is expected to lead to increasingly close cooperation at the science discipline level.

Research Operations and Information Systems

As OSSA moves into the data-intensive era of the 1990s, timely and responsive data and information systems support increases in importance as a crucial element of overall success in achieving science mission objectives. Data volume alone represents a significant challenge, with the flow of science data into archives expected to increase by several orders of magnitude over the next decade. Furthermore, new trends in the character of space research will drive the evolution of data and information systems. Broad scientific questions to be addressed will be increasingly multidisciplinary in nature, will involve widely dispersed investigator teams, and will require the combination and analysis of data from many different sources. The importance of data products will extend well beyond a particular flight mission, and researchers will increasingly use data sets to address scientific questions and study phenomena not anticipated during initial mission planning.

The effective management and utilization of our rapidly growing data assets call for new approaches and significant modifications to the infrastructure for accomplishing quality research. Ultimate success in meeting this challenge will be measured in terms of responsiveness to science user needs for convenient access both to data and to the tools and capabilities to convert data into meaningful information and use the information for improved scientific insight.

As guided by the advice and direction of the National Research Council and the NASA Advisory Council, key elements of OSSA's approach to meeting this data management challenge include:

Discipline Data Systems: Science discipline divisions will provide the primary focus for discipline-specific data management approaches, guided by the advice and counsel of their respective science communities. Data management and archiving issues will be afforded appropriate emphasis and priority from the onset of mission planning. Projects will address these issues and document them in Project Data Management Plans, which will be reviewed by discipline divisions as part of the new start approval process. Disciplines will integrate project data plans with ongoing research needs to evolve to a total research capability for that community. Discipline data systems will emphasize wide availability of information about data holdings, easier access to those data by all researchers, and improved connectivity between researchers for the interchange of data, information, knowledge, and ideas.

OSSA-Wide Integration: OSSA-wide integration functions will be planned and managed under the oversight of a coordination board reporting to the Office of the OSSA Associate Administrator. This board will assess overall OSSA architecture, policies, and implementation guidelines to ensure that data and information systems achieve the needed level of connectivity between major disciplines, and will provide for resource sharing where advantageous. A high-level Master Directory will ensure open and uniform access to information about space research data, regardless of discipline or location. Communications and network services will be expanded to support the full range of mission operations and scientific data exchange and analysis. The OSSA infrastructure also oversees major institutional facilities that transcend individual missions and disciplines, including high-performance supercomputers and a central long-term archive facility.

Coordination with Office of Space Operations: OSSA will make effective use of the space- and ground-based operations and data handling expertise, capabilities, and resources developed and managed by the Office of Space Operations (OSO) and other NASA offices. Requirements will be coordinated through the OSSA management oversight board and will include priority conflict resolution for OSSA-required services and assessment of budget implications as funding constraints necessitate a consensus OSSA position to OSO.

Information Systems Research and Technology and Systems Evolution: OSSA will work with the Office of Aeronautics, Exploration and Technology and other groups to stimulate and help bring about technological developments needed for the future. OSSA will sponsor test-bed projects and other applied research efforts to infuse new technologies and advanced capabilities as they become available and are appropriate to enhance operational effectiveness.

Over the next 5 years, discipline-oriented data systems such as the Astrophysics Data System, the Planetary Data System, and EOSDIS will further the process of integrating individual mission data plans into a complete research capability for each major discipline community. The OSSA-wide infrastructure, including networking connectivity, access to supercomputers, long-term archives, and Master Directory services will be maintained at an institutional readiness appropriate to support all discipline requirements. The information systems research program initiated in FY 1991 to apply advanced computer and information systems technology to improve the effectiveness of science data management, analysis, and visualization will also continue.

A new OSSA-wide data management initiative will begin in FY 1992 to work in conjunction with the science disciplines to revitalize and preserve data holdings from past missions, and to provide for more systematic flow of science data into discipline-oriented archives for future missions.

Another new OSSA initiative for FY 1992 will be participation in the NASA portion of the Federal High Performance Computing and Communication Program. This program is being established to maintain and extend U.S. leadership in high performance computing, and to increase its assimilation into the U.S. science and engineering communities. OSSA scientists and researchers will join with academia and industry in the application of high-performance computing technologies to modeling, simulation, and data analysis challenges in Earth and space science, as well as remote exploration and experimentation.

Technology

In developing our strategy, we assume the availability of technology that is currently the state of the art or near that level. In addition to depending upon continued efforts by the Office of Aeronautics, Exploration and Technology (OAET) in a wide range of spacecraft and instrument subsystems, OSSA currently is conducting Advanced Technology Development programs for the next major OSSA initiatives — the Orbiting Solar Laboratory, the Space Infrared Telescope Facility, and Gravity Probe-B. The Solar Probe mission will present significant new challenges, especially in the areas of thermal protection and communication systems; therefore, advanced technology studies in support of this candidate major mission will also be needed. Advanced development assures the timely availability of proven critical technologies well before they are needed for full-scale development. This approach to risk and cost reduction is an important element of the OSSA strategy.

Future OSSA programs will benefit substantially from technologies associated with cryogenically cooled infrared and submillimeter wave detectors, optical interferometers, sensors, space-qualified lasers, space data and information systems, vibration isolation, automation and robotics, and artificial intelligence. Applications include ultrahigh density data storage on Earth-orbital and solar system exploration missions, autonomous experiment systems operations, telescience, telerobotic servicing, and orbital assembly. In addition, a number of technology areas have heightened relevance and impact in connection with OSSA's role in Mission from Planet Earth. These areas include bioregenerative life support systems, autonomous sample collection and analysis, spacecraft aerobraking and aerocapture, and lunar-based assembly of scientific instruments.

OSSA is actively involved with OAET to develop an OSSA-endorsed set of advanced technology requirements and priorities that can be confidently acted upon by NASA installations, industry, and universities through OAET technology programs. To foster this process, an OAET liaison has been assigned to OSSA to assist the science divisions in assembling, articulating, and prioritizing OSSA technology requirements for advanced instrument observation, information, spacecraft, and operations technologies. The outcome of this process is expected to have a significant impact on how technology is coordinated and transferred into science instrument projects and missions. Currently, OAET programs in advanced sensor systems, cryogenics, advanced propulsion, autonomous rendezvous and docking, large space structures, and advanced communications continue to establish the technological foundation for OSSA missions in Earth orbit and deep space and on the Moon and Mars. The two offices have established joint technology working groups in the areas of sensors (especially for astronomy and Earth remote sensing at infrared wavelengths) and spacecraft data systems. OSSA and OAET have also initiated regular coordination activities to pursue development of critical technologies that will be needed for future OSSA programs in such areas as long-term Earth remote sensing from geosynchronous orbit, robotic exploration of planetary surfaces, and precision pointing and stationkeeping from orbiting platforms. In each case, OSSA defines science requirements, whereas OAET develops generic technologies and advanced devices that OSSA can later integrate into operating systems to meet its specific needs.

Establishing permanent human outposts on the Moon and Mars for research, development, and exploration will require a comprehensive understanding of processes in extraterrestrial environments where different gravity levels are encountered. Processes must be understood in the areas of fluid mechanics, combustion science, the mechanics of granular media, and materials processing. In fluid mechanics, the studies of multiphase flow and phase change are essential to understanding heat transfer processes under varying gravity levels. An understanding of capillary phenomena is necessary for fluids management. The study of mechanics of granular materials is important to understanding the properties of unconsolidated soils in reduced gravity. An understanding of combustion science is necessary for fire prevention and control in the extraterrestrial environment. Finally, the study of materials processing in different gravity levels is necessary for the production of commodities to support human presence.

Aerospace Medicine and Life Support

A key OSSA objective is to accommodate immediate life sciences requirements by conducting and coordinating all aerospace medicine, medical support, and life support activities within

NASA. OSSA also establishes future requirements by determining human health, well-being, and productivity needs, and by conducting research, both on Earth and in space, to establish medical and technology requirements to meet those needs for human flight missions. The character of studies conducted to provide for future requirements is in many ways distinctly different from the larger ensemble of research roles within OSSA.

During the last 20 years, space life sciences research has evolved from simply providing operational medical support and enabling human survival in space to seeking an understanding of the causative mechanisms underlying space adaptation, predicting related health-threatening issues, and developing more effective procedures and countermeasures. As a result, the life sciences program now covers a truly interdisciplinary field, both advancing scientific and technical knowledge in biomedicine and optimizing life support for human spaceflight, exploration, and safe return to Earth.

Traditionally, life sciences research has included an Aerospace Medicine Program providing a unique preventive and clinical medicine organization charged with ensuring crew health, safety, and performance. This Aerospace Medicine Program encompasses crew medical selection and retention standards, clinical medicine programs for human flight missions, certification of crews for spaceflight duties, longitudinal studies of astronauts, and an environmental health monitoring and intervention program. Support is provided to the Office of Space Flight for health care and crew equipment development and testing (including life support systems) and escape systems development. The Aerospace Medicine Program provides requirements to the Life Support Program in life sciences for research and development of countermeasures to mitigate changes due to spaceflight, and maintains the health data base to identify long-term adaptation mechanisms. In turn, life support research activities establish the scientific foundation for improving crew selection, medical care, and monitoring, and for enhancing crew productivity and protection in space. Life support research supports the Aerospace Medicine Program by providing environmental requirements and countermeasures, and medical knowledge for the practice of clinical and preventive medicine.

Human exploration of the Moon and Mars presents crucial new challenges for life sciences research and technology development in the areas of medical and life support systems. Fundamental differences between space and Earth — the lack of gravity, inadequate atmospheres, deep cold, and radiation — challenge space life scientists and mission designers to provide solutions and strategies to protect the health of crew members and sustain their lives in space. To this end, OSSA, in collaboration with OAET, is formulating a comprehensive program to provide the range of medical and life support capabilities and technologies necessary for the dynamic space missions envisioned for the next few decades.

Institutions

The successful accomplishment of the OSSA strategy depends on support from the NASA Centers, other Federal laboratories, U.S. universities, and the private sector. External to the Agency, the ongoing contributions of scientists and engineers at U.S. universities, at other Federal laboratories, and in industry are critical to the success of all OSSA programs. Internal to the Agency, OSSA has specific institutional management responsibilities for the Goddard Space

Flight Center and the Jet Propulsion Laboratory; however, every NASA center is a direct participant in OSSA's science and technology programs, and the continuation of this support is essential. NASA Center scientists are expected to win support for their part in the OSSA research program through the same competitive review process required for their extramural counterparts.

NASA CENTERS

The NASA Centers are a national resource. The Centers themselves provide unique scientific research facilities, and the NASA civil service work force includes some of the Nation's and the world's finest scientists and engineers. Unfortunately, the facilities are aging, and the civil service work force has decreased substantially since the Apollo era. In order for OSSA to conduct a world-class program and meet the goals of this Strategic Plan, the Nation's investment in the NASA institution must be protected.

In the area of facilities, the NASA Centers need substantial maintenance, repair, renovation, and modernization. There is also a requirement for so-called "New Capability"; that is, new facilities that will enable the development, test, and operation of the more sophisticated and sensitive instruments envisioned in this plan. Examples of this type of capability are the enhancement of the LeRC low-gravity drop tube and the X-ray Calibration Facility now under construction at the Marshall Space Flight Center, which will provide the sophisticated capability essential for testing the Advanced X-ray Astrophysics Facility mirrors. In 1992, development will continue on the EOS Data and Information System facility at the Goddard Space Flight Center. This facility will house the critical data processing, archiving, and distribution functions for the EOS program, and it will accommodate members of the science community working with EOS data.

The availability and capability of NASA's civil service work force is a critical element to the success of the OSSA program. NASA has been successful in partially recovering from the work force decreases that have occurred since the Apollo era. For example, the new start package for the Mission to Planet Earth program included provisions for additional civil service strength to provide effective program management. NASA is now focusing on ensuring that the quality of the NASA work force remains high. In response to this focus and to a recommendation from the Advisory Committee on the Future of the U.S. Space Program, the NASA Administrator has announced the establishment of a NASA Office of Human Resources. This Office will be responsible for the establishment of policies that will ensure that NASA is a valid competitor in the recruitment and retention of high-quality science, engineering, and administrative personnel, using hiring and salary flexibilities allowed by the recently passed Civil Service Pay Reform Act.

The following descriptions of the roles of the NASA Centers in the OSSA program are intended to identify the nature of the predominant activities of each center. The descriptions are not intended to be exhaustive.

Goddard Space Flight Center – GSFC is involved in virtually all scientific disciplines within OSSA, with the exception of microgravity and life sciences. Personnel at Goddard have extensive experience in the management of science and applications satellite projects and instruments, including the Explorer program. GSFC is responsible for many critical support functions in the research base, including the operation of the NASA Center for Computational Sciences, the Wallops Test Range, the National Space Science Data Center, and the sounding rocket and balloon program at the Wallops Flight Facility. GSFC has management responsibility for EOS, including the polar spacecraft and most initial Earth Probes.

Goddard is also responsible for the scientific management and operation of the Hubble Space Telescope, as well as the Space Telescope Science Institute, where Hubble Space Telescope scientific data and operations planning take place. Goddard is responsible for managing the development and operation of the Gamma Ray Observatory, and is expected to serve the same function for the Orbiting Solar Laboratory. Mission operations for a number of science and applications satellites are also conducted by Goddard. Under the management of the Office of Space Operations, GSFC runs the Tracking and Data Relay Satellite system and the near-Earth tracking and data acquisition network, which are essential to the operation of all U.S. Earth-orbiting spacecraft, balloons, and sounding rocket activities.

Jet Propulsion Laboratory – JPL is most often associated with the OSSA solar system exploration program, and indeed, the laboratory is a unique national resource in the development and scientific operation of deep space flight missions, including Galileo, Magellan, Mars Observer, CRAF/Cassini, and Lunar Observer. JPL will also play a critical role in the development of the future robotic missions of the Mission from Planet Earth. However, JPL plays a key role in most other areas of observational science and in the development of unique computational capabilities. The laboratory's development of synthetic aperture radar systems, as well as other instruments, is central to the OSSA Earth science strategy. JPL will also be responsible for developing the Space InfraRed Telescope Facility and plays an important role in the microgravity science program, specifically in the area of developing Spacelab and Space Station Freedom hardware for containerless processing experiments. JPL also plays a key role in the SETI Microwave Observing Project.

Under the management of the Office of Space Operations, JPL operates the Deep Space Network, the worldwide tracking stations for planetary spacecraft.

Marshall Space Flight Center – MSFC has vast experience as a major system development center and, accordingly, develops and integrates major flight facilities for OSSA. Current examples include management of the development of the Advanced X-ray Astrophysics Facility, as well as mission management and instrument development for the U.S. Microgravity Laboratory and most other Spacelab and Shuttle-attached payload missions. Continuation of Marshall's mission management role is critical to OSSA's effective utilization of the manned base of the Space Station Freedom complex. Less widely known, but very important, is MSFC's participation in the OSSA science and applications programs, particularly in certain aspects of space physics, astrophysics, Earth science, and microgravity science.

Ames Research Center – ARC is a major participant in the OSSA life sciences program in space physiology, life support, human factors, artificial gravity, space biology, and exobiology. Ames has special roles in infrared astronomy, planetary sciences, and Earth sciences, in terms of both scientific research and the operation of the airborne science program (including the Kuiper Airborne Observatory, the ER-2s, the DC-8, and the C-130) and will build upon the successful operation of the Kuiper Airborne Observatory with the development and operation of SOFIA. In addition, ARC supports OSSA efforts in information systems and in telescience for Space Station Freedom. Ames is the focal point in the Agency for exobiology research and for the SETI Microwave Observing Project.

Johnson Space Center – JSC plays a critical role in the OSSA life sciences activity, particularly in operational and space medicine and research on the effects of spaceflight on humans. JSC also participates in the solar system exploration program and manages the Planetary Materials Facility that preserves and distributes lunar samples, Antarctic meteorites, and cosmic dust. In microgravity science and applications, JSC has an ongoing program in biotechnology, as well as in the operation of the KC-135 aircraft, which is used for both life sciences and microgravity experimentation. JSC is also the mission management center for life sciences Spacelab missions and some Earth science and applications activity, including the flight of imaging radar on the Shuttle. In addition, JSC supports OSSA efforts in analytical integration of life sciences pressurized volume payloads and of small and rapid-response payloads for Space Station Freedom.

Kennedy Space Center – Because of KSC's operational character, the center's participation in the research program is limited to life sciences, particularly to playing a key role in developing controlled ecological life support systems. In keeping with its operational expertise, KSC is a major support center for Spacelab payload integration and maintenance of reusable Spacelab flight hardware; a similar role for KSC is expected to evolve in the Space Station Freedom era. The Kennedy Space Center processes the majority of spacecraft prior to launch on both the Shuttle and unmanned launch vehicles and is responsible for coordinating NASA launch activities at the Vandenberg Air Force Base in California. KSC also supports OSSA efforts in developing a management plan for science payload physical integration for Space Station Freedom.

Langley Research Center – Langley plays a substantial role in the Earth science and applications research program, particularly in the development of satellite experiments in the modelling of atmospheric chemistry, and in the analysis of climatic and other observations. LaRC also supports the materials science program for Spacelab and Space Station Freedom facility systems engineering, and provides fundamental research expertise in space radiation physics.

Lewis Research Center – LeRC is a key participant in the microgravity materials science and applications program, particularly in the disciplines of fluids, combustion, and metals and alloys. Lewis not only participates in the ground-based program by conducting research and operating a Lear Jet and drop facilities for microgravity simulation, but also contributes to the flight program by developing flight facilities and apparatus. LeRC has the lead role in the OSSA communications program and is responsible for the development of the Advanced Communications Technology Satellite.

Stennis Space Center – The Stennis Space Center is an important participant in the life sciences and the Earth science and applications programs, including operation of the Earth Resources Laboratory, which is involved in research in land/sea interactions and forest ecosystems.

U.S. ACADEMIC INSTITUTIONS

OSSA has traditionally considered the U.S. universities part of its institutional base and will continue to do so. NASA depends heavily on academia, not only as scientific investigators, but also as educators of the next generation of space scientists and technologists. The participation of

U.S. universities is essential to maintaining a broad base of capability in areas vital to the future of space science and applications. In its 1986 report, entitled "The Crisis in Space and Earth Science," the NASA Space and Earth Science Advisory Committee cited a number of issues that are acutely important to the health of universities as key elements of the OSSA program. Among these issues are the need for a spectrum of small and large research opportunities, reliable and frequent access to space, attention to training and development of graduate students, and the stabilizing role of research and analysis. The OSSA strategy explicitly addresses those issues. OSSA intends to continue to work with its advisory bodies to assess the needs of the university community and to devise approaches to ensure that the unique long-term contributions that the community makes to space science and applications continue in the future.

Realizing the OSSA vision will require a trained and experienced academic community to analyze the vast amounts of data that will result from the accomplishment of the Plan. This need will be especially critical in the 1990s, when the launch of many missions will result in an unprecedented increase in data on significant science problems, at a time when many current members of the research community will be approaching retirement age. The science community may find itself inadequately prepared, both in technical capability and number of personnel, to deal with this onslaught of data. When combined with the projected decrease in science, mathematics, and engineering students over the next decade, these factors strongly stress the need for enhancing recruitment and training at the pre-college and undergraduate levels and for maintaining and increasing support for graduate students and postdoctoral researchers.

To respond to the growing concern over both NASA's and the Nation's needs for scientific and technical manpower at the turn of the century, OSSA is involved in a variety of programs that focus on education ranging from pre-high school to post-graduate levels. Examples include special educational programs tied to specific flight missions (e.g., the Astro and Space Life Sciences Spacelab flights), specialized residential summer courses (e.g., in life sciences, Earth science, and planetary science), graduate student fellowships (e.g., the Graduate Student Research Program and a new program in global change research), NASA Specialized Centers of Research and Training in the life sciences, and special outreach programs to bring new colleges and universities into the space science and applications research arena (e.g., via the Joint Venture in Education or "JOVE" program administered through MSFC and the Historically Black College and University Program).

International Cooperation

In developing the OSSA strategy for leadership in space science and applications, no explicit assumptions were made about the level of international participation to achieve OSSA goals and objectives. Indeed, international space cooperation is not an end in itself, but a means of enhancing programmatic capabilities. We intend to exercise international leadership first and foremost through a strong commitment to the national vitality of our own ongoing program, major and moderate missions, small missions, use of Spacelab and Space Station Freedom, and maintenance of a vigorous research base. Through an ambitious and broadly based national program in science and applications, we will continue to attract the best scientific and technical talent from abroad to work with us, and to gain the most attractive opportunities for cooperation abroad.

Past experience has shown that considerable benefit can frequently be gained from international cooperation. Nearly all ongoing and planned OSSA space science and applications missions involve some form of international participation. In keeping with long-standing NASA policy, international cooperation takes place on a "no-exchange-of-funds" basis, whereby each side agrees in advance to cover the costs associated with its contribution to the cooperative activity. Such participation is generally enabled through the OSSA "Announcement of Opportunity" (AO) process, under which the international scientific community is routinely invited to submit proposals to NASA to fly foreign experiments on U.S. spacecraft, to participate in U.S.-led experiment teams, and to take part in post-flight data analysis activities. Foreign proposals compete on an equal footing with U.S. scientific proposals and are evaluated under the peer review process along with their U.S. counterparts. In turn, U.S. scientific proposals are entertained by many of our foreign partners for missions that they are planning, under comparable peer review procedures, thereby extending the criterion of scientific merit and adding to the opportunities available to the U.S. scientific community.

Foreign space capabilities will continue to improve in the future. A number of Western nations now have indigenous spacecraft and launch capabilities; this number is likely to increase over the next 5 years. As a result, NASA maintains a regular dialogue with space agencies abroad to exchange information on our respective plans and to identify potential areas for cooperation. We will continue to seek opportunities for inviting foreign participation in NASA missions where there is mutual programmatic benefit, as well as to seek opportunities for participation in the missions of other nations, when those opportunities are consistent with our programmatic objectives and resources.

International cooperation plays a role in each of the principal programmatic themes of the core science strategy. In terms of the ongoing program, a number of significant foreign contributions to NASA science missions are now underway. For example, the Hubble Space Telescope involves major scientific hardware contributions from the European Space Agency (ESA); the Gamma Ray Observatory carries a European instrument as an important contribution to its four-instrument payload; and the Advanced X-ray Astrophysics Facility to be launched in the latter portion of this decade will carry a Dutch instrument. Other major ongoing missions with significant foreign contributions include: the Ocean Topography Experiment/POSEIDON, the Upper Atmosphere Research Satellite, Galileo, the International Solar-Terrestrial Physics Program, the CRAF/Cassini Program, the Earth Observing System, and several planned Spacelab missions (the International Microgravity Laboratory, the Space Radar Laboratory, the Atmospheric Laboratory for Applications and Science, and the Space Life Sciences series).

The first in the International Microgravity Laboratory series of missions is to be launched in early 1992. The mission will include 42 science investigations, 13 in microgravity science and 29 in life sciences, and it will include experiments in a wide assortment of areas such as fluids, organic and inorganic crystal growth, biotechnology, casting technology, critical phenomena, plant physiology, and human space physiology. Twenty-eight of these investigations will involve international participation with five foreign space agencies and eleven foreign countries. Eight of the 15 payload elements are supplied by our foreign partners.

As in the case of the ongoing program, leadership through major and moderate missions can be enhanced through mutually beneficial international cooperation. Planned programs such as the Orbiting Solar Laboratory and the Space InfraRed Telescope Facility each anticipate high-quality foreign contributions of scientific instruments, mission-related hardware, or both. Our pursuit of leadership is most conspicuous through major and moderate missions, since they provide the bases for the largest quantum leaps in scientific knowledge and technological ability; by the same token, they can offer the richest programmatic benefits from international cooperation.

International cooperation has also been important to the development of increased opportunity for small missions, notably in the development of level-of-effort programs, such as Earth Probes and the Explorer series. NASA has had discussions with a number of our foreign partners in Europe, Canada, and Japan regarding their interest in participating in the Lifesat program, a small, recoverable orbiting biosatellite. In addition, missions such as the Tropical Rainfall Measurement Mission and the multiple flight opportunities for the NASA Total Ozone Mapping Spectrometer instrument for measurement of stratospheric ozone are greatly facilitated and accelerated by the contributions of foreign partners, such as major instrument elements (Tropical Rainfall Measurement Mission) or the provision of flight opportunities on foreign platforms (flight of the Total Ozone Mapping Spectrometer and the NASA Scatterometer on the Japanese Advanced Earth Observation Spacecraft). In each case, given the level-of-effort nature of the funding for these projects, lack of foreign participation would have substantially delayed our ability to mount these important Earth observation missions.

To support the transition to Space Station Freedom, we are engaged with our partners (ESA, Japan, and Canada) in planning for the utilization of Freedom Station, as well as in development of precursor experiments that can be flown on the Spacelab between now and the availability of Space Station Freedom. Experiments carried on the International Microgravity Laboratory and on reimbursable Spacelab missions provided by our European and Japanese partners will be realistic opportunities to develop techniques and procedures to optimize the utility of Space Station Freedom.

The research base program serves as the foundation for a vigorous and productive research community in the U.S. International cooperation affords additional opportunities for flight and analysis, often working in concert with leading experts overseas. For example, the Stratospheric Observatory For Infrared Astronomy, a high-priority future initiative in the research base, will involve substantial collaboration with Germany. We also rely on international cooperation to conduct suborbital flight campaigns requiring launches outside the U.S.

Growth in opportunities for cooperation with the Soviet Union has been of particular interest in recent years. NASA has worked with the Soviets in space science activities since the early 1960s, but the trend toward improved relations in the past 2 to 3 years offers the chance for broader cooperation. Although the development of these relationships has required some unique arrangements, OSSA has been working toward a more traditional relationship with the Soviets, under which the same principles of open competition and scientific peer review are used with the Soviets as with our other partners in determining cooperative opportunities.

Based on the principles of the 1987 Space Cooperation Agreement between the U.S. and the U.S.S.R., as well as on the results of the 1988 Moscow Summit, OSSA is engaged in regular discussions with Soviet experts on potential areas of cooperation in each of the five Joint Working Groups (space biology and medicine; solar system exploration; solar-terrestrial physics; astronomy and astrophysics; and Earth science). Contributions to the ongoing program, such as the 1991 flight of a Total Ozone Mapping Spectrometer instrument on the Soviet METEOR-3 satellite, the flight of a Soviet gamma-ray burst detector on the U.S. Wind spacecraft in 1992, and U.S. participation in Mir biomedical research and the 1992 COSMOS biosatellite mission are tangible evidence of the fruitfulness of these discussions.

Future planned missions include flight of two U.S. astrophysics instruments on the Soviet 1993 Spectrum-X Gamma mission; the flight of a Soviet receiver on the Mars Observer spacecraft, to relay data from French balloons on the surface of Mars in 1994; U.S. participation in the Soviet Radioastron mission and the Japanese Very Long Baseline Interferometry Space Observatory Program, in which NASA will provide crucial time synchronization and ground-based tracking and communications support and participate in the science program; and medical investigations with Mir cosmonauts in all flight phases, leading to joint biomedical studies of flight crews from Mir and from the Space Shuttle. As the broader national relationship between the Soviet Union and the U.S. improves over the next 5 years, and as resources are made available, the opportunities for fruitful cooperation in space science can also be expected to improve.

APPENDIX: THE OSSA SCIENTIFIC DISCIPLINES—INDIVIDUAL STRATEGIES

Developing a strategy for the future program of OSSA and its discipline divisions begins in the scientific research community, where active collaboration between OSSA and the community translates goals into strategies for scientific discipline programs. A number of panels of the National Academy of Sciences and the NASA Advisory Council advise OSSA about broad issues of the overall OSSA program. These panels include the Space Studies Board, the Space Science and Applications Advisory Committee, and the Aerospace Medicine Advisory Committee. These and other special advisory bodies, such as the Committee on Global Change, the Space Station Science and Applications Advisory Subcommittee, and the Exploration Science Working Group, also specifically address the composition and direction of each of the scientific disciplines that fall under OSSA's umbrella. Focused groups, such as project definition teams and scientific working groups, provide more specific recommendations regarding particular project strategies. These advisory bodies, and the publications in which their recommendations are elucidated, are listed at the end of each discipline description.

With the recommendations of these advisory groups as detailed objectives, and with the overall goals for space science and applications providing the framework, each scientific discipline formulates specific program plans designed to focus on a particular aspect of the OSSA program. Each division strives to complement the other five, and each formulates a strategy that can then be integrated into a comprehensive, cohesive plan, which provides a context for decision-making within OSSA.

In the pages that follow, we summarize for each discipline its goals and objectives, its current situation, relevant factors of the external environment, and the strategy that will guide its activities for the next 5 to 10 years. The integration of these individual plans is the basis of OSSA's overall strategy.

Astrophysics

The astrophysics program uses space missions in Earth orbit and, perhaps, ultimately on the Moon, to observe the universe and develop physical models of the phenomena observed. The program is implemented in close coordination with the astronomical community, especially through the cognizant committees of the National Academy of Sciences.

The goals of the program relate to three key themes—cosmology, astronomy, and physics—to address the questions:

What was the origin of the universe? What is its large-scale structure? What will be its fate?

What is the origin of galaxies, stars, planets, and life, and how do they evolve?

What is the physics of matter under the extreme conditions found in astrophysical objects?

The program is optimized around a methodology that includes contemporaneous observations across the entire electromagnetic spectrum. The "Great Observatories" cover the four major wavelength bands: infrared, ultraviolet/visible, X-ray, and gamma-ray. Explorer, Spacelab, moderate, and suborbital missions bridge the gaps in the measurements made by the Great Observatories.

Data are provided to the science community through an infrastructure that includes the Astrophysics Data System and several data archival programs. Grants are used for data analysis, theory, laboratory astrophysics, ground-based telescope data, and education initiatives. Long-term viability is ensured through an advanced technologies program and a continuing series of short-time-scale flight opportunities using aircraft, rockets, balloons, and moderate and small-sized Explorer satellites.

CURRENT SITUATION

Launch of the Hubble Space Telescope ushered in the decade of the Great Observatories. Although technical problems have delayed achievement of some important science objectives until after the 1993 servicing mission to install a second-generation Wide Field/Planetary Camera and new solar arrays, many observations have been made during early operations. These include the highest resolution images ever taken of the Wilber Spot on Saturn, the Einstein Cross gravitational lens, and the SN1987A supernova remnant.

The other Great Observatories are in various stages of development. The Gamma Ray Observatory is prepared for a 1991 launch. The Advanced X-ray Astrophysics Facility is continuing development with primary emphasis on fabrication of the largest in its set of six mirror assemblies. The Space InfraRed Telescope Facility is proceeding with definition and technology development activities leading to a planned development start in 1994.

The Cosmic Background Explorer has largely completed its mission. The Roentgen Satellite, a collaboration with the Federal Republic of Germany, was launched in 1990 and has completed its initial survey. In December 1990, the Astro-1 mission performed more than 150 successful far ultraviolet and X-ray observations from the Shuttle cargo bay. The data on distant and nearby galactic gases have already given scientists new clues on how galaxies form and evolve. The International Ultraviolet Explorer entered its fourteenth year of operations, supporting observations by more than 1,000 astronomers.

Explorer missions scheduled for launch in 1991 are Solar-A, a solar physics program collaboration with the Japanese, and the Extreme UltraViolet Explorer, which is the first mission attached to the Explorer Platform, a reusable and serviceable spacecraft.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The Great Observatories will continue to probe the universe in unprecedented ways. Top priority is given to operation of the Hubble Space Telescope, which will be restored to its original specifications with a Shuttle servicing mission in 1993. A later servicing mission will install advanced instruments to provide further ultraviolet and near-infrared observation capabilities. This period will also see operation of the 1991 Gamma Ray Observatory and the Advanced X-ray Astrophysics Facility, scheduled for a 1998 launch. The Space Infrared Telescope Facility is planned for development and launch by the end of the century.

In 1993, we plan to begin development on the Stratospheric Observatory For Infrared Astronomy (SOFIA), a 2.4-meter diameter telescope carried in a modified Boeing 747. An international collaboration with the Federal Republic of Germany, SOFIA will study the near universe with very high spatial and spectral resolution to complement the Space Infrared Telescope Facility. With more than 100 flights planned per year, SOFIA will also provide essential opportunities for training new scientists and developing instruments.

Explorer program plans include increased flight opportunities to at least one mission per year and the use of expendable launch vehicles. Explorer missions planned for launch during this decade are the X-ray Timing Explorer, the Advanced Composition Explorer (a Space Physics mission), and the Far Ultraviolet Spectroscopy Explorer. The Nuclear Astrophysics Explorer, designed to provide the first high spectral resolution survey of gamma ray emission line sources in the energy range of 0.05 to 10 MeV, is beginning feasibility study. Three small-sized Explorer missions, the Solar, Anomalous, and Magnetospheric Particle Explorer, the Fast Auroral Snapshot Explorer, and the Submillimeter Wave Astronomy Satellite, are planned for completion and launch by the mid-1990s.

Three moderate missions are in varying stages of definition. Gravity Probe-B will test previously unverified General Relativity predictions with enough precision to begin differentiating between alternative theories. The Submillimeter Mission will observe 100 to 200 sources for a complete spectral line survey at high spectral resolution in a largely unexplored region of the electromagnetic spectrum. The third mission may be an optical interferometer that will provide ultra-high angular resolution measurements that could resolve the cores of active galaxies and may achieve the goal of calibrating the extragalactic distance scale.

International collaborations allow the U.S. to use its unique instrument development capabilities to achieve a significant U.S. science community participation for a modest investment. U.S. instruments will be flown aboard the Japanese Astro-D mission scheduled for launch in 1993. Two U.S. instruments will be flown on the Soviet Spectrum-X-Gamma mission, a unique X-ray polarimeter and an X-ray all sky monitor. The U.S. will supply crucial timing and tracking support for the Soviet Radioastron and the Japanese Very Long Baseline Interferometry Space Orbiting Program. The U.S. will also supply hardware for two of the three instruments on the European Space Agency's X-Ray Multi-mirror Mission, to be launched by the end of the decade. NASA is also considering support of the Italian Space Agency mission, LAGEOS-III, the first test of the General Relativity Lense-Thirring effect.

A robust Advanced Technology Development program will continue to identify critical technologies and prepare for future astrophysical missions. Current mission plans envision "second generation" orbiting observatories and lunar telescopes. Lunar missions may evolve from the Lunar Transit Telescope, a robotic mission that would perform a deep-sky survey in the ultraviolet, visible, and infrared. A series of missions could culminate with an optical interferometer capable of detecting planets orbiting nearby stars.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Space Astronomy and Astrophysics of the Space Science Board, National Academy of Sciences, National Research Council

The Explorer Program for Astronomy and Astrophysics (1986).

Long-Lived Space Observatories for Astronomy and Astrophysics (1987).

Astronomy and Astrophysics Survey Committee, National Academy of Sciences, National Research Council

Astronomy and Astrophysics for the 1990s (1991).

Solar System Exploration

The fundamental goals and approaches of the solar system exploration program are those recommended by the Committee on Planetary and Lunar Exploration of the National Academy of Sciences and the Solar System Exploration Committee of the NASA Advisory Council. Briefly stated, the goals are:

***Origin and Evolution:** To determine the present nature of the solar system, its planets, moons, and primitive bodies, and to search for other planetary systems in various stages of formation, in order to understand how the solar system and its objects formed, evolved, and (in at least one case) produced environments that could sustain life.*

***Comparative Planetology:** To better understand the planet Earth by determining the general processes that govern all planetary development and by understanding why the "terrestrial" planets of the solar system are so different from each other.*

***Pathfinders to Space:** To establish the scientific and technical data base required for undertaking major human endeavors in space, including the survey of near-Earth resources and the characterization of planetary surfaces.*

Solar system exploration is conducted in three distinct stages: (1) reconnaissance, involving flyby missions; (2) exploration, generally conducted with orbiting spacecraft and atmospheric probes; and (3) intensive study, involving soft landers, sample returns, and human exploration. The essential part of this exploration is a core science program of balanced missions and research that stresses continuity, commonality, cost-effectiveness, and the use of existing technology. This program consists of: (1) moderate-scale Planetary Observer missions to the inner planets, using previously developed spacecraft equipment; (2) Mariner Mark II missions to the outer planets, using common spacecraft and evolving technology; (3) development of a multimission spaceflight operations and data analysis capability; and (4) a strong program of ground-based research and analysis and related activities. Future programs envision completing the reconnaissance phase for all planets, completing the exploration phase of the inner solar system and small bodies, advancing the exploration phase of the outer planets, and conducting in-depth studies of Mars and a comet with surface landers and sample returns.

CURRENT SITUATION

The successful 1989 Voyager 2 encounter with Neptune completed the initial flybys of Jupiter, Saturn, Uranus, and Neptune. The reconnaissance phase of solar system exploration is now almost complete; only Pluto remains to be visited by planetary spacecraft. The launch of the Galileo mission to Jupiter in October 1989 began the exploration phase of the outer planets. Galileo will be the first spacecraft to orbit an outer planet, and it will inject a probe into Jupiter's atmosphere. Also in 1989, NASA started the development of the Cassini and Comet Rendezvous Asteroid Flyby (CRAF) missions, the first missions to use the advanced capabilities of the Mariner Mark II series of spacecraft.

In September 1990, NASA extended the exploration phase of the inner solar system as high-resolution mapping through the optically opaque cloud layer of Venus was initiated by means of a synthetic aperture radar instrument on the Magellan spacecraft in orbit around the planet. This mission is providing unparalleled scientific data on the surface morphology of Venus, and is proving the radar mapping technique that will be used to image the surface of Titan on the Cassini mission. Mars exploration will continue with the 1992 launch of Mars Observer, a mission that will orbit the planet for at least 1 Martian year to complete a global scientific assessment of Mars.

Space agencies of other nations, including the European Space Agency, the Soviet Union, Germany, France, and Japan, have now established programs in solar system exploration and have expressed specific interest in collaborative efforts with the United States. Such efforts are underway in the Galileo, Mars Observer, CRAF, and Cassini programs, and we expect further such activities in the future.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The highest priority for solar system exploration is to complete those missions now launched (Galileo, Magellan) or under development (Mars Observer, Cassini, and CRAF). Beyond these missions, the Solar System Exploration Division, in close cooperation with the science community, is developing a flexible, dual-path strategy for the exploration of the solar system in the 1990s and beyond. The first path continues the evolving, step-by-step scientific program. The second path pursues robotic exploration for Mission from Planet Earth. In the near-term, the "traditional" path is identical to the one for Mission from Planet Earth. However, the second path would carry out additional detailed exploration and characterization of Mars in preparation for human landings by means of landed networks, sample returns, imaging orbiters, and surface rovers. Planning is also under way for a "Discovery" program of small, highly focused missions in planetary science, as well as an initiative designed to search for and unambiguously detect planets around other stars.

Solar system exploration must remain at the cutting edge of space science and space technology. Toward that end, the research and analysis base is being enhanced to support crucial advanced technology development, advanced mission studies, and related science initiatives. Two enhancements to the research base, one for instrument and laboratory upgrading, and the other for an interdisciplinary study of the origins of solar system, were begun in FY 1990. In FY 1992, research and analysis initiatives will focus on resources for graduate student assistantships, initiation grants for new researchers, and augmented support for individual researchers. Additional initiatives are under consideration for implementation during the 1990s. Among these are a program to ensure the preservation of all planetary data in digital formats that are easily accessible by scientists; a research program affiliated with a broadly scoped initiative that would employ ground-based and spacecraft-borne instrumentation to detect and study other planetary systems; a "Comparative Planetology" initiative that would take advantage of new data returned by planetary missions in order to deepen our understanding of planet Earth and the differences between and similarities among the planets; and finally, an Advanced Technology Development program that would support the development of technologies critical for enabling new missions.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Planetary and Lunar Exploration, Space Science Board, National Academy of Sciences, National Research Council

Strategy for Exploration of Primitive Solar-System Bodies — Asteroids, Comets and Meteoroids: 1980-1990 (1980).

A Strategy for Exploration of the Outer Planets, 1986-1996 (1986).

1990 Update to Strategy for Exploration of the Inner Planets (1990).

A Strategy for the Detection and Study of Other Planetary Systems and Extrasolar Planetary Materials 1990-2000 (1990).

Committee on Cooperative Mars Exploration and Sample Return, Space Science Board, National Academy of Sciences, National Research Council

International Cooperation for Mars Exploration and Sample Return (1990).

Joint Working Group of the National Academy of Sciences and the European Science Foundation, National Research Council

Report of the NAS/ESF Joint Working Group: A Strategy for U.S./European Cooperation in Planetary Exploration (1986).

Solar System Exploration Committee of the NASA Advisory Council

Planetary Exploration through Year 2000: Part One: A Core Program (1983).

Planetary Exploration through Year 2000: Part Two: An Augmented Program (1986).

Planetary Exploration through Year 2000: Scientific Rationale (1988).

The Planetary Astronomy Committee of the Solar System Exploration Division

Other Worlds from Earth: The Future of Planetary Astronomy (1989).

Space Physics

The space physics program investigates the origin, evolution, and interactions of space plasmas in the heliosphere and the cosmos. The goals of the discipline, endorsed by the Committee on Solar and Space Physics of the National Academy of Sciences, are to understand:

The Sun as a star, as an influence on Earth, and as the dominant source of energy, plasma, and energetic particles in the solar system

The interactions between the solar wind and solar system bodies, including studies of the processes within and interactions between the ionospheres, mesospheres, and thermospheres of Earth and other solar system bodies

The structure and dynamics of the magnetospheres of planets, especially that of our own Earth

The nature of the heliosphere in its steady state as well as its dynamic configuration, and the origin, acceleration, and propagation of solar and galactic cosmic rays.

Data are obtained by sensors situated directly within regions of interest, as well as by remote sensing for inaccessible regions or regions requiring a global view. Cosmic rays provide samples of matter that results from energetic processes occurring outside our solar system. Measurements are obtained by instruments mounted on free-flying satellites, the Space Shuttle, sounding rockets, and balloons. Researchers use theory, models, and computer simulations to synthesize these measurements into a general understanding of space physics phenomena.

CURRENT SITUATION

Reconnaissance of most solar system ionospheres and magnetospheres, of the heliosphere, and of the outer layers of the Sun's atmosphere has been completed. Basic characteristics of solar and galactic cosmic rays have been measured. The process of explaining, interpreting, and formulating theoretical descriptions of many phenomena has begun, and some understanding of cause-and-effect relationships has been established.

The International Cometary Explorer and the Interplanetary Monitoring Platform continue to collect scientific information. The Division has science purview of Ulysses, Pioneers 10 and 11, and Voyagers 1 and 2, and conducts a robust data analysis program for its completed flight missions through a newly established guest investigator program. The 1990 DoD/NASA Combined Release and Radiation Effects Satellite has begun mapping Earth's radiation belts and studying ionosphere/magnetosphere interactions. This mission studies space plasma processes initiated by chemical releases from the satellite. Releases were performed in September 1990 and in January and February 1991, with additional releases planned during August 1991 with concurrent chemical releases by sounding rockets launched from Puerto Rico.

Measurements of the Sun throughout the current peak of the solar activity cycle will be made by the 1991 Japanese/U.S. Solar-A mission. In 1992, the U.S./Italian Tethered Satellite System will deploy a diagnostic satellite tethered to the Space Shuttle by a 20-kilometer conducting wire for investigations of electrodynamic plasma effects.

The next major flight program is the International Solar Terrestrial Physics program, consisting of the Global Geospace Science program and the ESA Solar-Terrestrial Science Programme. The Global Geospace Science program is designed to study geospace as an interconnected, interactive system using a fleet of spacecraft, including the NASA Wind and Polar satellites, the Japanese/NASA Geotail mission, and the Combined Release and Radiation Effects Satellite extended mission. In addition, the Sun's corona will be studied with the Spartan 201 mission, to be launched and retrieved during a single Shuttle flight. The Solar-Terrestrial Science Programme includes the Solar and Heliospheric Observatory and Cluster missions. Both carry NASA-contributed instruments, and both will be launched in 1995.

Two small Explorers, the 1992 Solar, Anomalous, and Magnetospheric Particle Explorer and the 1994 Fast Auroral Snapshot Explorer, are in development. Approved as a standard Explorer is the Advanced Composition Explorer.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The health of the space physics discipline depends on maintaining a mix of major, moderate, and small missions, the suborbital program, a Guest Investigator Program, and significant increases in supporting research and technology. The highest priority mission, ready for immediate new start, is the Orbiting Solar Laboratory, which is fundamental to understanding the most basic processes of both steady-state and energetic stellar astrophysics. This mission should also make advances in observing solar flares, and hence the ability to predict solar particle radiation events that directly affect Earth and pose a threat to human exploration of the Moon or Mars. The desired 1999 launch date of the Orbiting Solar Laboratory is ideal since the next maximum of solar flare activity will be starting about the same year.

A small spacecraft, multi-agency mission to provide equatorial plasma and energetic particle and field measurements is being considered for a 1993 or early 1994 launch in order to overlap with the Wind and Polar missions. An Explorer-type mission using chemical releases to study ionospheric chemical and electrodynamic processes in conjunction with the Combined Release and Radiation Effects Satellite extended mission is also a high-priority small mission. Astromag, an array of detector systems clustered around a superconducting magnet to study ultra-high energy galactic cosmic rays and search for primordial antimatter, was originally selected for Space Station Freedom, but it is now being studied in conjunction with the Italian space agency for launch on an expendable vehicle at the end of the decade.

Additional missions undergoing definition studies include: (1) the Solar Probe; (2) a Mercury orbiter; (3) a Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics mission; (4) a High Energy Solar Physics mission; (5) an Inner Magnetospheric Imager mission; and (6) a Grand Tour Cluster of satellites.

The Coordinated Heliosphere Observations program, expected to start in 1992, will study the heliosphere and the coupled geospace systems through coordination of data from ongoing missions. This will be accomplished through a vigorous Guest Investigator program using the Space Physics Data System, a network of data centers united under the common theme of heliospheric science. An unprecedented level of cooperation for solar-terrestrial science in the 1990s includes U.S. collaborations with European and Japanese space agencies as well as joint studies under the auspices of the U.S./U.S.S.R. Joint Working Group on Solar Terrestrial Physics.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Solar and Space Physics of the Space Science Board, National Academy of Sciences, National Research Council

Solar-System Space Physics in the 1980s: A Research Strategy (1980).
Solar-Terrestrial Research in the 1980s (1981).
An International Discussion on Research in Solar and Space Physics (1983).
A Strategy for the Explorer Program for Solar and Space Physics (1984).
Solar-Terrestrial Data Access, Distribution, and Archiving (1984).
The Physics of the Sun (1985).
An Implementation Plan for Priorities in Solar-System Space Physics (1985).

Committee on Solar-Terrestrial Research of the Space Science Board, National Academy of Sciences, National Research Council

National Solar-Terrestrial Research Program (1984).
Long-Term Solar-Terrestrial Observations (1988).

Physics Survey Committee, National Academy of Sciences, National Research Council

Physics through the 1990s: Plasma and Fluids (1986).

Astronomy and Astrophysics Survey Committee, National Academy of Sciences, National Research Council

Astronomy and Astrophysics for the 1990s (1991).

Space Physics Subcommittee, Space Science and Applications Advisory Committee

Space Physics Strategy-Implementation Study (1990).

Earth Science and Applications

The overarching goal of Earth science and applications as formulated by the Earth System Sciences Committee of the NASA Advisory Council is to:

Obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.

Study of phenomena in Earth's atmosphere, oceans, on land, and within the biosphere must be directed at understanding the responsible physical, chemical, and biological processes that operate to unify the Earth environment as a system. These processes must then be cast in the form of algorithms for assimilation into global models. Finally, these models must be tested against comprehensive, long-term, global-scale data sets in order to validate their accuracy as descriptive and predictive tools.

CURRENT SITUATION

The Division is currently developing EOS, an FY 1991 major new start, which will provide the core elements of Mission to Planet Earth: two polar spacecraft series and their science instruments and the EOS Data and Information System. Together with the Earth Probes, also approved in 1991, EOS will provide the long-term, global-scale, self-consistent data sets required for monitoring, understanding, and predicting global change.

Current flight programs include the Nimbus-7 research satellite now returning global ozone data; the Earth Radiation Budget Experiment to measure the global energy balance that is important to climate and global change; the Upper Atmosphere Research Satellite, which will be launched in 1991 to study the chemistry and dynamics of the stratosphere and mesosphere important for the ozone layer; the Ocean Topography Experiment (TOPEX/POSEIDON), a joint project with France that will map the global circulation of the oceans; the NASA Scatterometer and a Total Ozone Mapping Spectrometer to fly on the Japanese Advanced Earth Observations Satellite for measurement of the wind stress that drives ocean currents and couples the atmosphere to the sea; the LAGEOS II laser geodynamics satellite joint project with Italy for measuring crustal motions; RadarSat, a joint project with Canada in which the U.S. will launch a Canadian radar satellite for polar ice and snow studies; and the Total Ozone Mapping Spectrometer, to fly on a Soviet meteorological satellite in 1991 and a small free-flyer in 1993.

The Total Ozone Mapping Spectrometer is also the first in the line of Earth Probes, an Explorer-class line of missions, which will carry out observations to complement EOS with measurements that cannot be carried out from polar orbit. Current plans include additional flights of the Total Ozone Mapping Spectrometer instrument on U.S., Japanese, and Soviet spacecraft, the Tropical Rainfall Measurement Mission, and other small missions currently under initial study.

Several Shuttle payload missions are planned, including the Shuttle Solar Backscatter UltraViolet instrument for atmospheric ozone sounding, the Atmospheric Laboratory for Applications and Science for measuring the solar output and the chemistry and dynamics of the atmosphere, and the Space Radar Laboratory for Earth remote-sensing and imaging. The foundation for Earth science space-borne instruments is the Division's aircraft and Shuttle payloads development program. The aircraft observation program is used to support field experiments on Earth system process studies and for instrument development. The Division continues to develop and launch NOAA's polar-orbiting and geostationary operational environmental satellites, and it is responsible for the development, launch, on-orbit checkout, and achievement of on-orbit operations of the Advanced Communications Technology Satellite. In addition, the Division recently assumed responsibility for COSPAS-SARSAT, a satellite-based search and rescue program.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The long-term strategy for the Earth Science and Applications Division has been defined by the Earth System Science Committee and the subsequent definition of the U.S. Global Change Research Program by the interagency Committee on Earth and Environmental Science to focus on three objectives: (1) establish an integrated, comprehensive monitoring program for Earth system measurements on a global scale; (2) conduct a program of focused studies to improve our understanding of the physical, chemical, and biological processes that influence Earth system changes and trends on global and regional scales; and (3) develop integrated conceptual and predictive Earth system models.

To achieve the first goal, the Division has devised the concept of Mission to Planet Earth: the Earth Observing System of polar orbiting spacecraft, a series of Earth probes, and a set of geostationary orbiting platforms. The second and third goals required the reorganization of the Division into interdisciplinary elements in Earth system process studies for understanding of global change. More focused efforts in constructing models of the Earth as a global system, and the construction of a data and information system for easy access to global space-based Earth remote-sensing data have also been established.

The first steps in carrying out this strategy have been taken. First, the Division has been reorganized along interdisciplinary research lines and into four main elements to match the stated objectives: two Flight Program elements (EOS is treated as a single program element) to provide for global-scale Earth observations and monitoring, a Modeling and Data Analysis element to provide for the construction of Earth system models and EOSDIS as the principal element of a data and information system for global scale Earth observation data, and an Earth System Process Studies element for basic research to understand how Earth functions as a global system. The second major step is the initiation of the core elements of Mission to Planet Earth as a new start in FY 1991.

One essential element of EOS that was not started in FY 1991, the EOS Synthetic Aperture Radar (EOS SAR), will require new funding in the future. The SAR is required for surface geological studies and for understanding the global carbon cycle. Planning is underway for the EOS SAR and for the final element of Mission to Planet Earth: the Geostationary Platforms. Geostationary Platforms are required for observation of processes that have large diurnal variation, and others, such as precipitation, volcanoes, and severe storms, which occur only during short periods of time, and therefore cannot be properly sampled from polar orbiting spacecraft that see specific ground targets only twice a day. New funding for this final component of Mission to Planet Earth will be needed in the second half of the 1990s.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Global Change, National Academy of Sciences

Toward an Understanding of Global Change: Initial Priorities for the U.S. Contribution to the International Geosphere/Biosphere Program (1988).

Committee on Earth Sciences, Federal Coordinating Committee on Science, Engineering and Technology, Office of Science and Technology Policy

Our Changing Planet: The FY 1990 Research Plan (1989).

Our Changing Planet: The FY 1991 U.S. Global Change Research Program (1990).

Our Changing Planet: The FY 1992 U.S. Global Change Research Program (1991).

Earth System Sciences Committee of the NASA Advisory Council

Earth System Science: A Program for Global Change (1986).

Committee on Earth Sciences of the Space Science Board, National Academy of Sciences, National Research Council

A Strategy for Earth Science from Space in the 1980s, Part I: Solid Earth and Oceans (1982).

A Strategy for Earth Science from Space in the 1980s, Part II: Atmosphere and Interactions with the Solid Earth, Oceans, and Biota (1985).

Strategy for Earth Explorers in Global Earth Sciences (1988).

U.S. Global Change Research Program, an Assessment of the FY 1991 Plans (1990).

Life Sciences

The life sciences program has four major goals:

Ensure the health, well-being, and productivity of humans in space.

Develop an understanding of the role of gravity on living systems.

Expand our 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.

The life sciences program extends from fundamental biological research using the spaceflight environment to applied clinical medical practice with two principal themes: (1) basic scientific research in biomedical physiology, space biology, biospherics, and exobiology; and (2) enabling technology definition, development, and operational implementation of medical support and life support systems for human spaceflight.

Earth-based research, conducted in NASA laboratories and in extramural programs centered on university-based individual Principal Investigators and Specialized Centers of Research and Training, is combined with on-orbit research to study basic processes on a variety of animal and plant species, as well as human beings. The exobiology and biospheric elements of the program use planetary exploration spacecraft, ground- and space-based astronomical observatories, and Earth observing systems, in addition to ground-based laboratory and field studies, to understand the processes that led to the origin of life and to study the continuing interplay between planetary environments and living processes.

The Division provides the requirements, practices, and procedures for medical, environmental, and operational life support, medical support, and extravehicular activity systems for the Space Shuttle, Space Station Freedom, and Mission from Planet Earth. The Division also develops specific medical and life support systems, defines planetary protection requirements, establishes operational protocols and procedures, and performs implementation monitoring.

CURRENT SITUATION

Efforts have been initiated to expand the access to space required by Division science programs, to upgrade the ground-based research infrastructure as recommended by several advisory panels, and to develop program elements that require long lead times. These efforts continue to be constrained by limited resources.

Space Life Sciences missions, scheduled to commence in 1991 and to continue at the approximate rate of one dedicated mission every 2 years, represent the first opportunity since Skylab to collect systematic experimental data on primary physiological systems. This series of missions is augmented by cooperative Spacelab missions, including International Microgravity Laboratory missions and Shuttle middeck secondary payload experiments. In addition, the Division is conducting joint scientific studies utilizing the Soviet COSMOS biosatellite flights every 2 years, and is expanding its program of collaborative biomedical studies utilizing the Soviet Mir space station.

The Division has been conducting the Extended Duration Orbiter Medical Program for 13- to 16-day missions. The program monitors cardiovascular and neuromuscular performance capacities under optimized countermeasures to ensure that crew capability remains within established performance limits. The goal of medically certifying the extended duration operations by the time of the first U.S. Microgravity Laboratory flight remains dependent upon the accumulation of sufficient experience with extended flight subjects.

Three NASA Specialized Centers of Research and Training have been established to mobilize university-based talent to concurrently advance basic knowledge and generate effective strategies to solve specific problems in gravitational biology, environmental health, and bioregenerative life support. Additional Centers in radiation biology and exobiology are planned.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

Life sciences experimentation requires exposures of statistically significant numbers of appropriate specimens under controlled conditions for periods of time that are meaningful to living systems. The Division will increase its access to regular spaceflight opportunities of lengthier duration with a continuation of the extended-duration Spacelab series throughout the decade and a major augmentation of collaborative research activities with our Soviet colleagues on Mir. The proposed Lifesat series will enable space-based quantitative studies of biological effects of the unique spectrum of space radiation as well as basic microgravity research on plants and animals.

Although a functional Space Station Freedom offers a unique opportunity for international leadership in space life sciences research, we must guarantee our scientific community continuity in the utilization of pressurized manned laboratories. Since life sciences participation on Freedom is early in the planning phase, we plan continuation of the dedicated Spacelab series through at least flight five. Also planned is a further laboratory devoted to brain and behavioral research that will provide unique neurological information critical to support the Nation's commitment to the Decade of the Brain. Experiment hardware developed for the Spacelabs of the late 1990s will be transitional in design and function so that it can be largely employed on Freedom Station, when needed. Extension of the Spacelab era also permits us to fly unique payloads that might not be compatible with early Space Station Freedom phases. These would include the Rhesus facility, which is planned for three flights.

The Biospheric Research Terra Initiative will be proposed to enhance the use of EOS data. The Biospheric Research Program is also contributing to the coordination and planning of multiagency research in the area of fresh water systems. By integrating data provided by orbiting satellites with ground-truth research, the initiative would develop a predictive understanding of freshwater ecosystems and the management alternatives to mitigate adverse environmental impacts on this resource. The Search for Extraterrestrial Intelligence Microwave Observing Project will commence operations in October 1992, providing search capabilities that far exceed the sum of all earlier searches. The multidimensional search of the microwave universe, as viewed through the terrestrial window, will finish at the turn of the century.

Future human exploration activities will be supported by augmented ground-based research efforts in advanced medical care, radiation health, advanced countermeasures including artificial gravity, closed-loop life support, and human factors. This research, much of which will involve studies within suitable analog environments, will establish a firm foundation for the planning of future human missions.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Space Biology and Medicine of the Space Sciences Board, National Academy of Sciences, National Research Council

Life Beyond the Earth's Environment - The Biology of Living Organisms in Space (1979).

A Strategy for Space Biology and Medical Science for the 1980s and 1990s (1987).

Committee on Planetary Biology and Chemical Evolution of the Space Sciences Board, National Academy of Sciences, National Research Council

Origin and Evolution of Life - Implication for the Planets: A Scientific Strategy for the 1980s (1981).

The Search for Life's Origins: Progress and Future Directions in Planetary Biology and Chemical Evolution (1990).

Committee on Planetary Biology of the Space Sciences Board, National Academy of Sciences, National Research Council

Remote Sensing of the Biosphere (1986).

Life Sciences Strategic Planning Study Committee of the NASA Advisory Council

Exploring the Living Universe: A Strategy for Space Life Sciences (1988).

Microgravity Science and Applications

The microgravity science and applications program uses the unique attributes of the space environment to conduct research in three primary areas: (1) fundamental science, which includes the study of the behavior of fluids, transport phenomena, condensed matter physics, and combustion science; (2) materials science, which includes electronic and photonic materials, metals, alloys, glasses, and ceramics; and (3) biotechnology, which focuses on macromolecular crystal growth and cell science. The major goal of the program is to:

Develop a comprehensive research program in fundamental sciences, materials science, and biotechnology, to attain a more structured understanding of those physical phenomena made obscure by the effects of gravity.

This goal is accomplished by defining and conducting a broad-based microgravity research program in the physical, chemical, and biological sciences, supported by the development of flight instrumentation. The growth of an interdisciplinary research community is fostered, and international cooperation and coordination in conducting space research are encouraged. The program uses the future capabilities of Space Station Freedom, together with free-flying platforms and Extended Duration Orbiter missions. Research in the space environment should result in the promotion of industrial applications for the development of new, commercially viable products, services, and markets.

CURRENT SITUATION

The microgravity program uses an evolutionary approach that starts with new ideas arising from individuals or teams of investigators. Proposals are peer-reviewed and, if accepted, are approved for ground-based or flight development, depending on concept maturity. New ideas undergo a ground-based definition stage to allow progress in supporting theory and experimental data and the development of sharply focused flight objectives. Some hypotheses may be refined or confirmed and their associated flight apparatus validated using ground-based reduced-gravity facilities where test environments of varying durations are available: up to 5 seconds in drop towers and drop tubes, 30 seconds in aircraft, and up to 15 minutes in suborbital rockets. To cost-effectively support those investigations requiring longer periods of reduced gravity, the microgravity flight program uses a broad base of available carriers and carrier resources, including the Space Shuttle Orbiter with its middeck, cargo pallet, Spacelab, and Get Away Special canisters. The additional resources necessary to maintain the level of experimental effort to produce the high-quality flight experiments of the future is the subject of an augmentation that has been proposed for FY 1992.

The microgravity effort is now entering a phase of high flight experiment activity. Two additional protein crystal growth experiment flights and the flight of the first microgravity combustion experiment were highly successful. In 1992, the first International Microgravity Laboratory will be launched. It will carry multiple flight experiment apparatus built by investigators both from the United States and our international partners, made available to the U.S. science community through a cooperative science program. Microgravity experiments will also fly on several other Shuttle missions in the coming year. Additional near-term opportunities are the United States Microgravity Laboratory and the United States Microgravity Payload series of flights, both scheduled to begin in 1992. A NASA Research Announcement (NRA) was issued in 1990 to solicit ground-based and flight combustion experiments. Approximately 65 proposals were received, of which six were funded for flight experimentation and 12 for ground-based experimentation. An NRA for Containerless Processing was released late in 1990, and proposals will be received and evaluated in the coming year.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

The microgravity science and applications discipline will continue to utilize the ground-based research program, which is necessary in the development of high-quality flight investigations. The program will also attempt to obtain additional resources to augment the research efforts to the level necessary to continue to initiate and produce high-quality flight experiments for the future.

The Division is currently developing plans for the release of additional Announcements of Opportunity and NRAs that will be used to continue to obtain high-quality science investigations. Upon acceptance for the ground-based program, a Principal Investigator can pursue a 3-year project that is reviewed annually. In the flight program, an Investigator is funded for definition or flight development depending on the experiment's initial level of maturity. Transition from experiment definition to flight development is accomplished via a structured review process that examines the scientific and technical progress of the investigation.

The flight program will continue to pursue the development and flight of scientifically worthy experiments. To this end, the program will utilize the opportunities offered by the International Microgravity Laboratory, U.S. Microgravity Laboratory, and U.S. Microgravity Payload series of missions, as well as other possibilities on the Space Shuttle as independent cargo bay or middeck experiments. Initial studies of the requirements and feasibility of utilizing the capabilities of free-flyers are being initiated. Also, the development of methodology and processes for analyzing, documenting, and archiving the flight data is being addressed.

As a further adjunct to the flight program, a new initiative is under consideration to support several significant fundamental science experiments that are now ready to proceed to flight development. Numerous peer reviews have determined that the scientific merit of the experiments warrants flight opportunities. However, these flight experiments generally lie outside the current and planned microgravity flight hardware capabilities. The Division is also currently exploring options for the use of suborbital rockets and free-flyers in order to most efficiently match investigation needs with carrier capabilities.

In the latter part of the 1990s, Space Station Freedom will provide additional capabilities, particularly greater experiment duration and flexibility. Several multiuser microgravity facilities are now being defined for potential use on Space Station Freedom. Hardware requirements to support the facilities are also being identified in order to influence Space Station Freedom design. Precursor apparatus flown on the Shuttle will provide experience with operations and development of instrumentation and subsystems for use in these Freedom Station facilities. Additional emphasis will be placed on development of telescience and automation in order to effectively use the Space Station Freedom facilities.

In a further attempt to maximize the early use of Space Station Freedom, a study is also presently underway to examine the feasibility of using selected hardware originally built for Spacelab on Space Station Freedom. This study will define the scientific plausibility of performing the experiment on Space Station Freedom as well as the hardware modifications required and their cost and schedule implications.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Subcommittee on Microgravity Science, Applications, and Commercialization, Space Applications Advisory Committee of the NASA Advisory Council
General Program Review and Recommendations Regarding the Microgravity Centers (1987).

Microgravity Materials Science Assessment Task Force, NASA Headquarters
Microgravity Materials Science Assessment Task Force Final Report (1987).

Microgravity Science and Applications Review Committee, Universities Space Research Association
Review of Microgravity Science and Applications Programs, January-March 1987 (1987).

Task Group on Fundamental Physics and Chemistry, Space Science Board, National Research Council
Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015 - Fundamental Physics and Chemistry (1988).

Space Station Science and Applications Advisory Subcommittee of the Space Science and Applications Advisory Committee, NASA Advisory Council
Summary Minutes, Summer Study, Woods Hole, MA (1990).

Acronym List

ACE .... Advanced Composition Explorer
ACTS .... Advanced Communications Technology Satellite
ATLAS .... Atmospheric Laboratory for Applications and Science

CRAF .... Comet Rendezvous Asteroid Flyby
CRISTA .... Cryogenic Infrared Spectrometer Telescope for Atmosphere

DXS .... Diffuse X-ray Spectrometer

EUVE .... Extreme UltraViolet Explorer
EUVE RETR .... Extreme UltraViolet Explorer Retrieval

FAST .... Fast Auroral Snapshot Explorer

GRO .... Gamma Ray Observatory

HST REV .... Hubble Space Telescope Revisit

IML .... International Microgravity Laboratory

LAGEOS .... Laser Geodynamics Satellite
LITE .... Lidar In-space Technology Experiment

MSAT .... Mobile Satellite

OAET-FLYER .... Office of Aeronautics, Exploration and Technology-Flyer
ORFEUS .... Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer

SAMPEX .... Solar, Anomalous, and Magnetospheric Particle Explorer
SL .... Spacelab
SL-D .... Spacelab, German dedicated mission
SL-E .... Spacelab, ESA sponsored mission
SL-J .... Spacelab, combined NASA/Japanese mission
SLS .... Space Life Sciences laboratory
SOHO .... Solar and Heliospheric Observatory
SPAS .... Shuttle Pallet Satellite
SPTN .... Shuttle Pointed Autonomous Research Tool for Astronomy
SRL .... Space Radar Laboratory
SSBUV .... Shuttle Solar Backscatter UltraViolet instrument
SSF-UF .... Space Station Freedom-Utilization Flight
SWAS .... Submillimeter Wave Astronomy Satellite

TOMS .... Total Ozone Mapping Spectrometer
TOPEX .... Ocean Topography Experiment
TRMM .... Tropical Rainfall Measurement Mission
TSS .... Tethered Satellite System

UARS .... Upper Atmosphere Research Satellite
USML .... United States Microgravity Laboratory
USMP .... United States Microgravity Payload

WISP .... Waves In Space Plasma

XTE .... X-ray Timing Explorer

■ Space Shuttle Launch ● Expendable Launch Vehicle Launch ▲ Other Major Events

Major Events in Space Science and Applications

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
1991		■ GRO; ■ SLS-1	■ SSBUV-3	▲ Galileo Gaspra Flyby; ■ UARS; ● EUVE
1992	■ IML-1; ▲ Ulysses Jupiter Flyby	■ ATLAS-1/ SSBUV-4; ● TOPEX/ POSEIDON; ● SAMPEX; ■ USML-1	● Geotail; ■ TSS-1; ■ LAGEOS II / USMP-1; ■ SL-J; ● Mars Observer	■ ACTS/DXS; ● Wind
1993	■ ORFEUS-SPAS; ■ SL-D2	■ ATLAS-2/ SPTN-2/ SSBUV-A-01; ■ SLS-2; ● Polar	■ USMP-2/ SPTN-3; ● TOMS; ▲ Mars Observer Arrival at Mars; ▲ Galileo Ida Flyby	■ LITE/SPAS-3; ■ SRL-1; ■ HST REV
1994	■ ATLAS-3/ CRISTA-SPAS/ SSBUV-A-02; ■ SPTN-4	■ IML-2; ■ USMP-3/ OAET-FLYER (SPTN)	▲ Ulysses Over Sun's South Pole; ● FAST; ● MSAT	■ SRL-2; ■ XTE/EUVE RETR
1995	■ ATLAS-4/WISP/ SSBUV-A-03; ■ USML-2	■ SL-D3/E1; ▲ Ulysses Over Sun's North Pole; ● SWAS	● SOHO; ■ USMP-4	■ SPTN-5; ▲ Galileo Arrival at Jupiter; ● Cassini
1996	● Small Explorer-4; ● CRAF; ■ SLS-3; ■ SRL-3	■ USMP-5; ● Lifesat-1	■ ATLAS-5/SSBUV-A-04	● ACE
997	● Small Explorer-5	● TOMS; ■ SSF/UF-1; ● Lifesat-2; ■ ATLAS-6/ SSBUV-A-05	■ USMP-6; ■ SL-E2; ● Small Explorer-6; ● TRMM	■ SLS-4; ■ SSF/UF-2

Notes: Launch readiness dates (in calendar years) for OSSA planning purposes.
Dates based on March 21 revision to February 1991 manifest.
FY 1997 and beyond reflects OSSA Civil Needs Data Base.

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