OFFICE OF

SPACE

SCIENCE AND

APPLICATIONS

STRATEGIC PLAN 1990

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. This OSSA 1990 Strategic Plan refines the 1989 Plan and presents OSSA's initial plans for fulfilling its responsibilities in two major national initiatives. The Plan is now built on interrelated, complementary strategies for the core space science and applications program, for the U.S. Global Change Research Program, and for the Space Exploration Initiative. 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 1989 heralded the beginning of a second golden age in space science. Like the first crisp notes in a symphony, the launches of Magellan, Galileo, and the Cosmic Background Explorer are to be followed in 1990 with a crescendo of activity to include the launches of Hubble Space Telescope, Gamma Ray Observatory, the Roentgen Satellite, the Combined Release and Radiation Effects Satellite, and Ulysses, and the flights of the Astro, Space Life Sciences, and International Microgravity Laboratory Spacelab missions. The challenge is to make certain that this level of activity is sustained through the end of this century and into the next. The 1990 Plan presents OSSA's strategy to meet that challenge.

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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 is President Bush's speech on July 20, 1989, commemorating the 20th anniversary of the Apollo 11 lunar landing. In that speech, the President shared his vision of NASA's future: Earth, the Moon, and Mars beckon as targets for understanding and future exploration. To safeguard the future of our own planet, he said: "A major national and international initiative is needed to seek new solutions for ozone depletion, and global warming, and acid rain. And this initiative—'Mission to Planet Earth'—is a critical part of our space program." To move beyond Earth's boundaries into the solar system, the President proposed to the Nation "a long-range, continuing commitment. First, for the coming decade—for the 1990s—Space Station Freedom—our critical next step in all our space endeavors. And next—for the new century—back to the Moon. Back to the future. And this time, back to stay. And then—a journey into tomorrow—a journey to another planet—a manned mission to Mars."

National space policy reinforces traditional OSSA goals, and it affirms the fact that the United States embraces and supports both long-standing and evolving NASA goals. As its contribution to the President's U.S. Global Change Research Program, NASA has 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 particular urgency, Mission to Planet Earth builds on current OSSA Earth science missions to include three program elements—the Earth Observing System, Earth Probes, and Geostationary Platforms—to provide a constellation of satellites in a variety of orbits around Earth.

NASA has also been studying alternative approaches to human exploration of the solar system; most recently, a preliminary plan for a Space Exploration Initiative was developed in response to the President's speech. The role of space science and applications programs 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 science 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.

OSSA Overview

The Office of Space Science and Applications is one of the program offices of the National Aeronautics and Space Administration. 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 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 nine Divisions. The Administration and Resources Management Division is responsible for OSSA fiscal and institutional management and for coordinating OSSA educational activities, public 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. The other seven 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 sources and interactions of particles and electromagnetic fields in the space environments of Earth and other solar system bodies; understanding the Sun as a star and as a source of interplanetary mass and energy; understanding the solar-terrestrial connection; and understanding the origin, transport, and interactions of energetic particles and plasmas, both within the solar system and throughout the galaxy.

Earth Science and Applications, which has the goal of understanding Earth as a system, including the interactive processes that maintain the global surface environmental balance, 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, 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 performance of humans in space; developing an understanding of the role of gravity in 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.

Communications and Information Systems, which has the goals of developing technologies to assure that the United States is in a position to make optimum use of the unique advantages of space-based communications systems; and of identifying and applying advanced communications and information systems technologies to meet the unique needs of the space science and applications program, the satellite communications industry, and the public sector.

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 long-term data sets for modelling global change processes, which policy-makers and scientists can use in formulating strategies for managing human impacts on global processes, such as greenhouse gases, ozone depletion, and deforestation. In addition, many current and future OSSA efforts will directly support the national goal of expanding human presence beyond Earth into the solar system by providing the scientific and technical research foundation that is essential for planning and implementing the President's Space Exploration Initiative. This foundation will be built 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 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 observing platforms 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, a multi-agency activity aimed at gaining an understanding of global change.

Conduct and coordinate all operational 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 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, plant and animal physiology, and biotechnology.

Develop and operationally verify advanced communications and information system concepts to meet future needs in space exploration, the U.S. satellite communications industry, and the public sector.

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

Strong research foundation for space applications

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

Especially important is the need for an increasingly interdisciplinary approach to major scientific problems. The importance of such an approach becomes progressively more 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 have successfully pushed back the frontiers of science and technology to further understand the past and to look into the future of our own planet, the solar system, and the universe.

Men and women will have travelled beyond the confines of their home planet, and will have begun to explore the Moon and Mars as they did the New World five centuries ago. 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.

Led by the U.S., 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. 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.

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.

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, deposited a sampling instrument into the comet's frozen crust, 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.

Traveling farther into the outer solar system, 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.

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.

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.

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 orbiting the Sun, and with the Astromag facility on Space Station Freedom, which will have provided unprecedented information about nucleosynthesis, cosmic ray origin, acceleration regions, and modes of propagation, in addition to searching for antimatter. 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 Boeing 747 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. 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 reaction of biological systems, including human beings, animals, and plants, to low gravity and space radiation. 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 research facilities on extended-duration Spacelab missions and on Space Station Freedom, will be providing major 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, will open a new frontier for microgravity science, a frontier that will challenge and motivate us, stimulate exciting developments in science and technology, and establish the scientific foundation for exploiting the commercial potential of space.

Advanced communications and information management technologies and computational facilities will be operating to support the transmission, acquisition, archiving, and analysis of the tremendous volume of data returning from all these instruments in space. The demand for communicating vast quantities of data will be met by commercially available communications satellite systems that have incorporated technologies derived from the Advanced Communications Technology Satellite. Globally separated research sites will be connected by high-data-rate channels operating over optical intersatellite links on Earth-orbiting satellites. New high technological risk components and subsystems provided by NASA will be significantly shortening the adoption time for advanced technologies and continuing the improvement of commercially available satellite communication systems.

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. 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. 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 grow to accommodate Agency plans, including Mission to Planet Earth and the Space Exploration Initiative, and 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 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 strategy that OSSA introduced in 1988. The second, an enhancement to the core strategy, 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 the Space Exploration Initiative.

The core strategy defines a 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 the Space Exploration Initiative will be scaled to match the level and pace of the program for the Agency as a whole. 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 STRATEGY

Within the guidelines and assumptions discussed above, five basic themes drive the development of OSSA's core 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 opportunities, such as pressurized laboratories for microgravity science and life sciences research and the multidisciplinary use of attached payloads.

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 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 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, 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 the other elements of the program on discipline stability, progress, and future needs. Provisions for improving the productivity of the ground-based and suborbital facilities are particularly critical.

STRATEGY FOR U.S. GLOBAL CHANGE RESEARCH PROGRAM

The OSSA core program strategy has been 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 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 all aspects 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.

The Mission to Planet Earth is composed of four interrelated elements, each of which builds on or complements the others. The first element consists of near-term missions already part of the core program. During the next several years, our knowledge of Earth should increase substantially, as NASA will participate in 19 Earth science missions to study various aspects of how the Earth works. The Upper Atmosphere Research Satellite will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. TOPEX/POSEIDON will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and the Shuttle Radar Laboratory will observe the topology of the land. Our international partners, the Japanese and the Europeans, will also launch seven missions, some of which will carry U.S. payloads, and many of which we will help track in return for access to their data. And the National Oceanic and Atmospheric Administration will continue to operate meteorological satellites.

The second element of Mission to Planet Earth, the Earth Observing System (EOS), is composed of a series of well-instrumented platforms in polar orbit designed to observe concurrently the behavior of the atmosphere, the oceans, the land, and life on Earth. The platforms are sized to accommodate instruments that need to observe the Earth simultaneously, through the same column of air. The first platform, which will launch in late 1997, is devoted to measurements of Earth's surface and the conditions of the lower atmosphere. The second platform, which will fly 2½ years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulation of the oceans, and the behavior of the solid Earth. Our international partners, the European Space Agency (ESA) and Japan, are planning to build platforms that include accommodations for U.S. scientific instruments. Some duplicate EOS instruments will be attached to Space Station Freedom to take advantage of its location in low Earth orbit. Supplementing these core components will be the third element, a series of smaller Earth Probe satellites with specialized instrumentation and orbits for investigations that cannot be accomplished otherwise. The EOS Synthetic Aperture Radar, which will provide complementary land surface information not accessible with passive instruments on the EOS platforms, and the fourth element of Mission to Planet Earth, large geostationary platforms that will provide continuous monitoring on a global basis, will be initiated at a later time.

To make optimum use of the data from these 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 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 platforms. 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 platforms.

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 also 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.

The strategy for implementing Mission to Planet Earth is quite straightforward. The first element, the evolutionary precursors, consists of missions that have been approved or are already flying. The second and third elements, the Earth Observing System and Earth Probes, are proposed for FY 1991. Current preparatory studies for geostationary platforms are laying the foundation for the future initiation of the final element of Mission to Planet Earth.

STRATEGY FOR SPACE EXPLORATION INITIATIVE

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, the Space Exploration Initiative 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 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 OSSA strategy for the Space Exploration Initiative 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, polar-orbiting biosatellites, 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, medical care, life support, and resolution of behavioral and human factors elements. 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 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 outpost site selection. Robotic exploration will proceed in synergy with human exploration, and robotic missions will be pursued with equal 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 the Space Exploration Initiative into the core program is the establishment of a realistic budget 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 program and meet established OSSA principles. In many cases, components of Mission to Planet Earth and the Space Exploration Initiative are also part of the core program. In fact, two of three new elements of Mission to Planet Earth—the Earth Observing System and Earth Probes—

stem from the OSSA FY 1991 core program. The EOS Synthetic Aperture Radar, which is deferred to a later start, and the geostationary platforms, which will be initiated when feasible, are the only two remaining elements of the U.S. Global Change Research Program strategy. The pace of incorporating these two elements will be driven by national policy, but constrained by the state of technological readiness to pursue them.

The strategy for the Space Exploration Initiative is somewhat less mature. The Lunar Observer, Lifesat, and the Biomedical Monitoring and Countermeasures program are missions of both the OSSA core strategy and the Space Exploration Initiative strategy. However, for the longer term, incorporating elements of the Space Exploration Initiative into the program will be an important strategic activity.

Ideally, at least one new initiative for each Space Exploration Initiative theme described earlier 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 three areas, certain rules have been formulated to determine the mix of program elements for the Space Exploration Initiative. These rules would also guide the timing of the initiation of the EOS Synthetic Aperture Radar and the geostationary platforms into the U.S. Global Change Research Program strategy.

1. **Match the pace of the OSSA program for overarching initiatives to the pace at which NASA and the Nation proceed as a whole.**
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; the core program must proceed in parallel with overarching national initiatives. Mission sequence and priority will, therefore, depend to the extent possible on how various alternatives affect the balance of the overall OSSA program.

THE PLAN FOR 1991

The Core Program

The five programmatic themes and the rules for decision-making were followed in the construction of our fiscal year 1991 core program plan, as enhanced by the U.S. Global Change Research Program strategy.

ONGOING PROGRAM

The FY 1991 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 1990 through 1996, summarized on the inside back cover, indicate a vital and productive ongoing program. The year 1989 began a new era in space science and applications, as the Magellan mission to Venus, the Galileo mission to Jupiter, and the Cosmic Background Explorer were launched successfully. The program's momentum will continue to increase in 1990 in a full range of scientific disciplines with the launches of Pegsat, the Hubble Space Telescope, the Roentgen Satellite, the Gamma Ray Observatory, the Combined Release and Radiation Effects Satellite, Ulysses, and three Spacelab flights: Astro/ BBXRT, the first Space Life Sciences mission, and the first International Microgravity Laboratory.

Development continues on the impressive array of major, moderate, and small missions to be launched from 1991 through 1997. Initiatives and programs approved in FY 1990 are now underway as part of the ongoing program. A major communications mission, the Advanced Communications Technology Satellite, is being developed on schedule for a 1992 launch. Two major solar system exploration missions are now beginning development: the Comet Rendezvous Asteroid Flyby will be launched in 1995, and Cassini will begin its journey to Saturn in 1996. The Advanced X-ray Astrophysics Facility is being developed for a 1997 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; several flights of the Shuttle Solar Backscatter UltraViolet instrument; and three flights of 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 centrifuge and six facilities in preparation for microgravity research on Freedom. The definition of first-generation attached payloads continues.

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.

Redundancy may, in some cases, be an integral element of the program. For example, the Mariner Mark II program is based on the use of a new generation of cost-effective, modular spacecraft that can be easily modified to accomplish a variety of missions to outer solar system targets. This approach has already been initiated with the approval of two missions: the Comet Rendezvous Asteroid Flyby (CRAF) and the Cassini mission to Saturn. Each spacecraft is designed to carry and use the instruments for either mission; therefore, in the event of an early loss of the CRAF spacecraft, the mission could be flown on the spare reserved for Cassini. A similar approach can be used for Mars Observer and Lunar Observer. For missions in near-Earth orbit, on-orbit refurbishment or repair is a possibility.

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

OSSA's leadership program for FY 1991 is the Earth Observing System, the centerpiece of Mission to Planet Earth and an essential component of the President's U.S. Global Change Research Program. This major Agency initiative builds on evolutionary precursor Earth science missions to respond to the ground swell of public and Government concern about potential change in our global environment. The U.S. Global Change Research Program requires a comprehensive Earth monitoring system. Mission to Planet Earth meets this requirement, with the goals of understanding Earth as a global system, providing comprehensive, long-term, and continuous global Earth observations, providing an information system for access to these data, and building accurate, quantitative models to predict global change—and the consequences of such change—on both regional and global scales.

The Earth Observing System (EOS) includes two series of polar sun-synchronous orbiting platforms, payloads attached to Space Station Freedom, and the EOS Data and Information System, which will provide for the reception, processing, archiving, and distribution of EOS data, with interfaces to interagency and international networks that link it to the entire Global Change community. The information resulting from the EOS global remote-sensing observations is an important element in advancing knowledge of the fundamental processes that determine Earth's global environmental balance, including:

The hydrological cycle, involving interactions of land, sea, atmosphere, vegetation, and topography

Biogeochemical cycles, concerning global distribution and variation of biomass and the fluxes of tropospheric gases and aerosols

Climatological role of variables such as wind, pressure, temperature, cloudiness, and precipitation

Geophysical processes, such as the interaction of physical and biological functions in the ocean and the land that modify Earth's surface.

EOS will establish an international Earth observing and data system capability to operate for at least 15 years. In addition to two series of U.S. platforms, the European Space Agency (ESA) plans to provide two series of platforms, and the Japanese are planning one series. At least one

ESA and one Japanese instrument will fly on the U.S. platforms, and U.S. instruments will fly on the ESA and Japanese platforms.

In 1989, NASA selected eight facility instrument complements and their associated team leaders and members, 23 research instruments and investigator teams to be provided by principal investigators from various U.S. universities and research institutions, duplicates of three EOS instruments to fly on Space Station Freedom, and 28 teams of researchers for interdisciplinary EOS studies. These investigations include studies of climate modeling, biosphere-atmosphere interactions, the terrestrial carbon budget, deforestation, desertification, the global water cycle, global biogeochemistry, and the global radiant energy budget.

The global remote-sensing observations planned from EOS are extensive and comprehensive. The first observatory series includes instruments to investigate the land surface biogeochemistry and ecology, ocean productivity, geology, polar ice, and lower atmospheric dynamics and climatic processes. The second series concentrates on upper atmospheric chemistry and physics to continue the investigations begun by the Upper Atmosphere Research Satellite. In addition, the second series will build on the investigation of the ocēan surface, circulation, wind fields, and air-sea interaction begun by TOPEX/POSEIDON and the NASA Scatterometer on the Japanese Advanced Earth Observations Satellite, and it will examine plate tectonics and glacier dynamics.

A third platform, a dedicated spacecraft for the Synthetic Aperture Radar, is not part of the FY 1991 plan; it is deferred to a later start. The Synthetic Aperture Radar will contribute to several EOS mission requirements, including the physical and biological structure, state, composition, and dynamics of the land surface, including terrestrial and inland water ecosystems; the circulation, wind stress, and sea state of the oceans; and the extent, type, state, roughness, and dynamics of glaciers, ice sheets, snow, and sea ice in the global cryosphere. The Synthetic Aperture Radar provides penetration of vegetation cover and volumetric information not accessible with passive instruments in other regions of the electromagnetic spectrum, is independent of cloud cover, and provides data for both day and night.

The EOS platforms will be launched from the Western Test Range on Titan IV vehicles into polar sun-synchronous orbit, which provides for simultaneous global coverage every 3 days. The first platform series will begin with a launch as early as late 1997, and the second series will begin with a launch in 2000. Each platform, which will carry from 3,000 to 3,500 kilograms of scientific payload, will be designed for a lifetime of 5 years, and will be replaced twice to achieve a minimum mission life of 15 years.

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 more small missions in time to sustain a steady series of flights. In addition, the Total Ozone Mapping Spectrometer is being prepared for launch on a Soviet Meteor-3 satellite in 1991 and on a Scout-class launch vehicle in 1993.

A new small mission series in the FY 1991 plan is the Earth Probes, a line of Explorer-class spacecraft in Earth science 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.

Some science objectives of Mission to Planet Earth cannot be accomplished from EOS. These include observation and monitoring of processes, such as rainfall, which operate on diurnal time scales. Thus, the Tropical Rainfall Measurement Mission has been defined as one of the early missions in the Earth Probe series to examine the cycle of evaporation, evapotranspiration, and rainfall in the tropical regions; this cycle forms the heat engine of our global atmospheric circulation patterns.

The Earth Probes series, together with the Upper Atmosphere Research Satellite and TOPEX/POSEIDON missions now in development, provides for the additional capability to obtain vital global Earth observations in advance of EOS. Examples of such observations include the global ozone measurements currently being made by the Total Ozone Mapping Spectrometer on the Nimbus-7 satellite launched in 1978, and ocean productivity measurements interrupted in 1985 by the failure of the Coastal Zone Color Scanner on Nimbus-7. The global ozone measurements will be continued via the Earth Probes line with the launches of three Total Ozone Mapping Spectrometer instruments: on a Soviet Meteor-3 satellite in 1991, on a U.S. small-class vehicle in 1993, and on a Japanese Advanced Earth Observations Satellite (ADEOS) in 1995. The near-term Earth Probes will also support the flight of the Proteus Ocean Productivity Experiment. The NASA Scatterometer is also planned for flight in 1995 on ADEOS.

SPACE STATION FREEDOM UTILIZATION

The fourth theme of our 1991 plan concerns Space Station Freedom. In the coming year, the Space Biology Initiative, which provides flight hardware for conducting in-space research in space physiology, gravitational biology, controlled ecological life support systems, and exobiology using gas/grain simulation studies, will come into full development. The facilities provided by this initiative establish a core capability to support basic life sciences research requiring multiple specimen samples over extended periods of exposure to reduced gravity loading. The facilities also provide monitoring and analytical capabilities to support provocative challenges to a variety of living specimens over the complete lower range of the gravity variable.

In addition to the life sciences basic research program, a Biomedical Monitoring and Countermeasures program will be initiated to determine methods to maintain optimum crew health and performance and to medically certify repeated extended-duration tours of duty. The program is being designed to document specific factors limiting crew stay time on orbit, establish acceptable risk ranges of physiological adaptation that can be reasonably maintained on orbit, and design and validate countermeasures to maintain crew adaptation within levels acceptable to optimized mission operations. This program is an essential prerequisite to routine Freedom operations and is critical to the implementation of human exploration activities in space.

The 1988 EOS Announcement of Opportunity led to the selection of several flight projects and concept studies for attached payloads on the manned base, which are included in the EOS program to be initiated in 1991. Duplicates of selected polar platform instruments will be placed on Space Station Freedom to provide for additional coverage of low latitudes at all times of day and night. The duplicate instruments selected for the initial capability on Freedom Station are the Stratospheric Aerosol and Gas Experiment III for obtaining global profiles of aerosols and clouds, the Lightning Imaging Sensor for studying lightning and energetic atmospheric processes at low latitudes, and Clouds and the Earth's Radiant Energy System for measuring diurnal cycles in Earth's radiation budget at low latitudes.

Eleven attached payloads in astrophysics, space physics, solar system exploration, life sciences, and communications technology selected from the OSSA 1988 Attached Payload Announcement of Opportunity will be nearing completion of their definition phases, leading to decisions on actual development and manifesting for flight on the early Freedom Station. These flight projects, along with the concept studies also selected, will provide critical requirements both for the early Freedom Station configuration and for its evolution as a research platform.

Planning for the integration, transport, accommodation, and operations of these experiments will culminate in 1991 in an initiative for 1992 to develop necessary space and ground facilities to support internal and external Space Station Freedom utilization.

RESEARCH BASE

The fifth and final theme of our core program plan concerns the Supporting Research and Technology program, which is the vital foundation for a vigorous and productive research community. In the approved 1990 program, we are beginning augmentations to alleviate known funding problems to provide for a healthy research base, not only in 1990, but also over the long term. Key areas to be addressed are: maintenance of a stable suborbital flight rate, space physics research and analysis, ground-based instruments for solar system exploration, and mission operations and data analysis for astrophysics and Earth science and applications. Two new research base efforts will be initiated: the Life Sciences Specialized Centers of Research and Training and the multidisciplinary Origins of Solar Systems programs. The enhancements approved in each of these areas in FY 1990 will continue in FY 1991, but no new augmentations are proposed.

The Space Exploration Initiative Program

The three Space Exploration Initiative themes and the integrating decision rules were followed in the construction of our fiscal year 1991 plan for human exploration of the Moon and Mars, described below.

MEETING HUMAN NEEDS

Life sciences research planned as part of the OSSA core program will also play a key role in supporting the Space Exploration Initiative. 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, will come into full development. Planning for a Biomedical Monitoring and Countermeasures program will also be 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 1991, we will also complete definition studies to permit the first launch as early as 1994 of Lifesat, a recoverable biosatellite that will support critical experiments needed to quantify the effects of space radiation on biological systems.

ROBOTIC EXPLORATION

Development of the Mars Observer will be continued to prepare for a 1992 launch. The ground data and software systems will be enhanced to enable higher-resolution imagery to assist in the landing-site selection process for future robotic and human missions to Mars.

The Lunar Observer, OSSA's highest priority new robotic mission of the Space Exploration Initiative strategy and an element of the core program, will provide an essential global scientific data base for the Moon by carrying out a 1-year mapping mission in lunar polar orbit. In FY 1991, definition studies will identify modifications to the Mars Observer design to meet Lunar Observer requirements. In addition, long-lead-time parts procurement will be initiated to preserve the opportunity for a 1996 launch. 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. The Lunar Observer will use spare instrument and spacecraft components from the Mars Observer mission.

IN SITU SCIENCE

In FY 1991, 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 will identify critical advanced technology development priorities to support science on and from the Moon and Mars.

With a clear eye toward the next 5 years, this plan for fiscal year 1991 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 working through OSSA's goals and objectives, the themes and principles cited earlier form the basis for our strategy for fiscal years 1992 through 1996. When we apply the decision rules with appropriate consideration of budgetary availability, institutional capability, and the pace of both the U.S. Global Change Research Program and the Space Exploration Initiative, the queue for the OSSA program is nearly defined. Major missions were begun in FY 1989 and 1990 and proposed for FY

1991; therefore, budgetary considerations dictate that the new start for FY 1992 will be a moderate mission: the Orbiting Solar Laboratory. The next highest priority core program new start will be the Space Infrared Telescope Facility. This strategy, then, steps through most of the currently defined major and moderate missions.

The Core 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 1991 ongoing core program will be launched by 1997; a new major flight project requires 4 to 7 years to develop. Thus, 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 will assess candidate missions and initiatives for each strategic plan theme. This assessment will be guided by the overall science strategy guidelines formulated by the National Academy of Sciences. The subcommittees will 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 the Space Exploration Initiative, 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 the Space Exploration Initiative, in addition to other life sciences research areas.

One major or moderate new mission should be started per year. Although we recognize the fact that circumstances may present occasions where more than one core program new start is possible, and others where no 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 program new start per year cannot ordinarily be expected, because available resources for small missions and for research and analysis must be preserved. Depending on the pace of national initiatives, two new starts in some years may be necessary in order to maintain program balance.

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

ORBITING SOLAR LABORATORY

The Orbiting Solar Laboratory, the highest priority mission for initiation as early as 1992, 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.

THE SPACE INFRARED TELESCOPE FACILITY

Fourth and last 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 1993. 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 near-infrared sources.

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.

THE 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.

Currently identified small missions of the 5-year plan include:

LIFESAT

Lifesat, a key element of both the core strategy and the space exploration strategy, is a small, recoverable, reusable orbiting biosatellite that can be used as an inexpensive platform for conducting life sciences (and possibly other) 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.

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 a broad range of contemporary theories, including those in condensed matter physics and general relativity. 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 research 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.

Two special facilities are planned for external attachment to Space Station Freedom. The Cosmic Dust Collection Facility is proposed for research in exobiology and planetary science. The purpose of the Cosmic Dust Collection Facility is to determine the orbital elements of individual cosmic dust particles (including meteorite and cometary debris and possible interstellar particles), to trap each particle in the least degraded manner, and to provide for the return of the collected particles to Earth, together with the orbital information required for detailed analysis. Studies of pristine particles of known origin can provide unique clues about the formation of the solar system and the fate of the elements and compounds that led to planetary bodies and the origin of life.

Astromag (Particle Astrophysics Magnet Facility) is being studied as a joint NASA-Italian Space Agency facility for the early Space Station Freedom. The core of the facility is a magnetic spectrometer based on a set of superconducting coils that produce an intense magnetic field. The facility is designed to accommodate at least two experiments operating simultaneously, and the experiments can be changed or serviced as required. The three investigations selected for first-generation observations will provide unprecedented information about nucleosynthesis, cosmic ray origin, acceleration regions, and modes of propagation, in addition to conducting searches for antimatter at unprecedented levels of sensitivity.

The study and selection of candidate second-generation attached payloads will also continue over the 5-year period.

RESEARCH BASE

The highest priority in this area is to enhance the research and analysis base that is essential to OSSA's program. The augmentations to the base approved in FY 1990 constitute critical fixes during the next 5 years to revitalize science programs to vigorous levels of activity and to provide adequate mission operations and data analysis support. In the future, we will not seek generic augmentations to the base, but only those that support new elements of the OSSA program, addressing very specific areas of focused activity to be added to the research base, 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.

Space Exploration Initiative Program

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

MEETING 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 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. Lifesat, a reusable biosatellite, will support critical radiation biological experiments.

Upon the initiation of the emplacement phase of the lunar outpost, the focus for life sciences research will shift to 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. Also during this time, a global system of solar monitors will begin to provide an early warning system for solar particle events.

ROBOTIC EXPLORATION

Preparation for human missions to Mars will require a series of robotic missions after Mars Observer to support and verify landing site selection. For example, a Mars Global Network mission involving an orbiter and 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 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.

IN SITU SCIENCE

As with all elements of the Space Exploration Initiative, 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 program, including initial elements of the strategy for the U.S. Global Change Research Program, is illustrated in Figure 1. Figure 2 illustrates the preliminary strategy for OSSA's role in the Space Exploration Initiative. As stated in the previous pages and illustrated by the figures, many areas and missions are common or complementary among the strategies. The specific timing and phasing of OSSA's Space Exploration Initiative strategy will match the pace determined by national priorities and capabilities. In future strategic plans, a more explicit phasing between the schedules of the two strategies will be developed.

Year	Ongoing Program	Major & Moderate Missions	Small Missions	Space Station Freedom Utilization	Research Base Enhancements
1990	Research and Analysis Mission Operations and Data Analysis	CRAF/Cassini	Total Ozone Mapping Spectrometer	Space Biology Initiative Definition Earth Observing System Payload Definition	Research and Analysis and Mission Operations and Data Analysis Corrections
1991	Operational Medicine	Earth Observing System†	Earth Probes††	Space Biology Initiative Biomedical Monitoring and Countermeasures*	
1992 THROUGH 1996	Flight Projects Spacelabs and Other Carriers	Orbiting Solar Laboratory Lunar Observer* Space Infrared Telescope Facility Gravity Probe-B Solar Probe	Lifesat* Microgravity Fundamental Science	Cosmic Dust Collection Facility Astromag Second-Generation Attached Payloads	Stratospheric Observatory For Infrared Astronomy Focused Research and Analysis, Suborbital, Advanced Technology Development, Data Systems Enhancements

* Also see Space Exploration Initiative Strategy
† NASA contribution to the U.S. Global Change Research Program; will require the later addition of the Synthetic Aperture Radar
††NASA contribution to the U.S. Global Change Research Program

Figure 1. **OSSA Core Program Strategy, Including Initial Elements of Strategy for U.S. Global Change Research Program**

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 (with ground system enhancements*) Lunar Observer*** Mars Global Network	Opportunities Definition Advanced Technology Development
Lunar Emplacement and Mars Robotics	Lunar Mission Systems Mars Life Sciences Test-Beds	Mars Sample Return with Local Rover Mars Site Reconnaissance Orbiter	Teleoperated Rover Initial Astronomical Facility Lunar Geology
Lunar ·Consolidation	Global Solar Monitors	Mars Rovers	Pressurized Rover Pressurized Laboratories
Lunar Operation and Mars Emplacement	Mars Mission Systems	Additional Mars Rovers	Advanced Lunar Astronomical Facilities Mars Geology and Exobiology Meteorological Stations Unpressurized Rover Mars Science Network

* 1991 initiatives
** 1991 definition activities to preserve launch opportunity as early as 1994
*** 1991 definition activities to preserve 1996 launch opportunity

Figure 2. **Space Exploration Initiative 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 is the "year of Earth," with proposed new starts for the Earth Observing System and Earth Probes. This approach systematically infuses strength into each of our scientific disciplines one by one, thus 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, if we assume that the growth in the total NASA budget continues over the next several years at its currently planned rate and that OSSA receives a portion of that budget consistent with its historical allocation and its role in major national initiatives, then carrying out the ongoing program and initiating major missions at a rate of nearly one per year will be possible. In some years, however, the initiation of moderate missions may be dictated, as is likely to be the case in FY 1992. 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 a more constrained budgetary environment that provides for little growth, the development phase of major missions would be delayed or stretched out over a longer period of time. In this case, moderate missions may be initiated at a rate of one per year.

In order to protect other elements of the OSSA program from budget overruns in major and moderate missions, we have instituted a policy whereby a "descope plan" is instituted for each mission. This 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.

The complementary strategies developed for OSSA's core, global change, and space exploration 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 the Space Exploration Initiative 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 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. An Extended Duration Orbiter kit now under development will extend the potential on-orbit stay time to up to 28 days. Space Shuttle launch rates for Spacelab module missions continue to be two to three per year and for pallet missions one to two per year. During the period between initial man-tended capability and the point at which an eight-person crew permanently staffs Space Station Freedom, OSSA is considering converting some of these Spacelab flights to Science Utilization Flights tied to the availability and capability of the operational manned base. Following the establishment of a full permanent crew complement on Freedom Station, OSSA plans to continue to use on the order of one to two Shuttle flights per year to test new experiment hardware planned for Space Station Freedom, to conduct science and applications research that does not require the very long-duration opportunities provided by Freedom, or to service free-flyers.

Regarding expendable launch vehicles, implementing the OSSA strategy requires the availability of "small" (Scout- and Pegasus-class), "medium and intermediate" (Delta-, Atlas/Centaur-, Titan III-class), and "large" (Titan IV-class) 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 and 1996.

The rate at which the strategy can be achieved can be substantially enhanced with the Advanced Solid Rocket Motor, which would allow significant increases for payloads delivered to the Freedom Station manned base during the assembly phase. Without this new capability, delivery of user equipment to Space Station Freedom would be delayed, or additional Shuttle flights would be required. Even with additional Shuttle flights, significant time and effort would be necessary to install, test, and check out the piecemeal delivery of user equipment transported to Freedom—an effort that can be largely avoided with an Advanced Solid Rocket Motor capability.

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 Intermediate 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 (such as the Shuttle-C) 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

The Earth Observing System will be launched from the Western Test Range using NASA's Polar Orbiting Platform. Although the Polar Orbiting Platform was initially designed as part of the Space Station Freedom program, the use of the polar platforms for EOS has resulted in a plan to transition the full development and management responsibility of the platforms to OSSA. The EOS payload and its platforms are designed to be launched on a Titan IV expendable launch vehicle and to be replaced in-kind every 5 years.

The early and mid-1990s will be devoted to developing instruments and testing concepts on Spacelab in preparation for utilization of Space Station Freedom. Prior to completing and outfitting on-orbit Freedom Station laboratory facilities, human space operations will continue to rely on the Space Shuttle and its associated Spacelab systems. Spacelab module missions of up to 10 days can be flown three times in a 12-month period on Space Shuttle Columbia and, beginning in 1992, on Endeavour as well. The Extended Duration Orbiter kit could also extend Spacelab missions to as many as 28 days. In order to assure crew safety and performance on extended-duration flights, an Extended Duration Orbiter Medical Program has been established.

During the transition from Spacelab science operations to Space Station Freedom operations, early utilization of Freedom Station is being considered. OSSA expects to operate approximately three Spacelab flights per year. It may be appropriate to use some of these flight opportunities for utilization flights to Space Station Freedom. This approach would provide early scientific return during the extended Freedom assembly period now under consideration.

Regarding Space Station Freedom itself, previous assessments indicated that OSSA could fully utilize the baselined accommodations and resources anticipated for the fully operational Space Station Freedom prior to the 1989 Configuration Budget Review. Subsequent proposed changes to and deferrals of some capabilities and the corresponding assembly schedule modifications have raised many issues concerning the ability of the rephased Freedom Station to accommodate and operate OSSA payloads. Some shortfalls, such as upmass and power, only the Space Station Freedom Program can remedy. Others, however, such as development of laboratory support equipment and payload-unique attachment equipment, could be provided by users, although adequate funds would need to be incorporated in OSSA budgets beginning in FY 1992. In particular, the ability to support small attached and rapid-response payloads is critical to OSSA's goal of supporting small science missions and frequent flight opportunities. Future OSSA programs will require power and external attachment accommodations in addition to those currently projected for the baseline Freedom Station.

The inclusion of a Freedom-based Orbital Maneuvering Vehicle for retrieving co-orbiting spacecraft, along with some limited capability at the manned base for changing out orbital replacement units on free-flyers and for replenishing cooling cryogens and fuel on free-flyers or attached payloads, could significantly enhance planned utilization of Freedom Station. Until the Orbital Maneuvering Vehicle becomes an element of Space Station Freedom, OSSA will use the Orbital Maneuvering Vehicle in the Shuttle-based mode to support on-orbit servicing of large free-flyers.

OSSA has extended its planning for Freedom Station utilization to include two science communities external to NASA. A Space Station Science and Applications User Board and an associated working group have been created to coordinate Federally funded U.S. science planning and utilization of Freedom. Starting at the level of Discipline Working Groups, these U.S. agencies develop integrated research plans in life sciences, materials sciences, astrophysics, Earth science, space physics, solar system exploration, and communications. In its leadership role, OSSA will make its on-orbit and ground infrastructure available to assist these agencies. In addition, 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

Because the primary purpose of OSSA data and information systems is to obtain and provide easy access to research data, trends in the character of space research drive the evolution of these systems. For research in an early exploratory phase, the instruments tend to be relatively simple, the investigations are focused, and the flight operations and data handling are fairly straightforward. That environment will continue for some classes of investigation, especially principal investigator-class experiments, which tend to use the suborbital, Small Explorer, Earth Probe, and Space Station Freedom attached payload platforms.

However, many of the missions highlighted in this Strategic Plan are far more complex. The broad scientific questions addressed by these missions are multidisciplinary, involve widely dispersed investigator teams, and require the combination and analysis of data from many different sources. They involve coordinated and often simultaneous observations in many wavelength bands with high spectral, spatial, and temporal resolution over long periods of time. Such investigations cannot be conducted without substantial advances in the approach to research flight operations and data handling. In addition, the sheer volume of data to be acquired, transmitted to the ground, processed, distributed to investigators, analyzed, and archived for future use will increase several thousand-fold by the late 1990s. This factor also calls for new approaches to maintain research effectiveness.

OSSA planning for research data and information systems embraces the complete life cycle, beginning with instrument development and ending with data dissemination, analysis, and archiving. A broader multi-mission and multi-discipline thrust is being added to the traditional mission-by-mission approach. This new emphasis will provide better connectivity between the distributed resources, extend the range of technological capabilities, and broaden the spectrum of shared facilities. New project definition and progress reviews will address data handling resources and the use of existing capabilities, and will help assure budgets adequate to meet their needs.

A multi-tiered strategy has been adopted to meet the OSSA operations and data analysis challenge in this changing environment.

1. Provide robust basic systems to meet the specific objectives of the individual missions: The discipline program offices will continue to carry the primary responsibility for ensuring that specific mission research objectives are met.

2. Enhance the capability for scientific research that encompasses multiple missions within major disciplines: The discipline divisions will continue to plan and implement discipline-specific data management approaches. 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. Scientists will be explicitly involved in defining, planning, and implementing the operations and data analysis systems in both an advisory and working group capacity.

3. Provide for a meaningful level of OSSA-wide interoperability, planning, and resource sharing: The coordination of broad provisions for interoperability, research data standards and guidelines, and the management of specified common capabilities will be conducted as an OSSA-wide function under the oversight of an OSSA director-level board. OSSA will ensure that data and information systems achieve the needed level of connectivity between major disciplines, and will provide for resource sharing where advantageous. Data and information systems will be designed for maximum direct interaction by investigators in mission science operations and analysis consistent with safety, security, and resource constraints. A high-level master directory will ensure open and uniform access to information about space research data, regardless of discipline or location. Communication services are being expanded to support the full range of mission operations and scientific data exchange. This OSSA infrastructure also oversees major institutional facilities that transcend individual missions and disciplines, including the long-term archives.

4. Build upon operations and data analysis capabilities existing outside OSSA: OSSA will make more effective use of the space- and ground-based operations and data handling expertise, capabilities, and resources managed by the Office of Space Operations and other NASA offices. Working relationships with universities, other agencies within the United States, and other nations will be expanded to achieve greater access to valuable data holdings and to otherwise enhance the national and global research programs in which OSSA is involved. International collaboration will be integrated into the overall information systems infrastructure as defined through the science discipline requirements.

5. Foster system evolution: OSSA will work with the Office of Aeronautics, Exploration and Technology and other groups to stimulate and help bring about new technological developments needed for the future. The operations and analysis systems will be designed to facilitate the introduction of new technologies as they become ready for use.

Two key themes emerge in the evolution of the OSSA strategy for research operations and information systems. The first is the trend toward discipline-oriented data management systems that further the process of integrating the traditional mission data systems into more complete research capabilities for each major research community. The Astrophysics and Planetary Data Systems are good examples of this trend. The second theme recognizes the need for a systematic approach to meeting the need for certain common capabilities, which involves coordinated planning across NASA offices and with the broader national and international research and technological communities.

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 Earth Observing System, the Orbiting Solar Laboratory, and the Space Infrared Telescope Facility. 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 generally 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 the Space Exploration Initiative. 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 currently involved with OAET in planning the scope and content of activities within the OAET program that are of direct interest to OSSA. 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 when 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.

Operational Medicine and Life Support

A key OSSA objective is to accommodate immediate life sciences requirements by conducting and coordinating all operational medicine, medical support, and life support activities within NASA, and to provide for future requirements by determining human health, well-being, and performance needs, and 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 for 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 Operational Medicine Program providing a unique preventive and clinical medicine organization charged with ensuring crew health, safety, and performance. This Operational Medicine Program encompasses crew medical selection and retention standards, clinical medicine programs for each manned flight mission, certification of crews for spaceflight duties, longitudinal studies of active and retired astronauts, and an operational environmental real-time 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 Operational Medicine Program provides requirements to the Biomedical 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, the Biomedical Research Program establishes the scientific foundation for improving crew selection, medical care, training, and monitoring, and for enhancing crew productivity and protection in space. Biomedical research supports the Operational Medicine Program by providing environmental requirements and countermeasures, and medical knowledge for practice of the 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. 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. 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.

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 1991, development will begin 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. Also included in the FY 1991 budget is funding for the Jet Propulsion Laboratory's Observational Instruments Laboratory, which will provide unique capability for developing large instruments for EOS and CRAF/Cassini.

NASA's civil service work force has decreased by more than 33 percent since the Apollo era. This decrease impedes our ability to manage major programs and limits our support to the science community. Particularly critical is the availability of qualified technical managers; NASA has successfully negotiated with the Office of Management and Budget for increases to this portion of the NASA work force. In addition, NASA will supplement its administrative staff, especially procurement personnel, so that the contract and grant interface with the scientific community and industry will be handled more effectively. The FY 1991 budget also contains a significant increase in the personnel needed for the EOS program.

In concert with the Centers and Agency management, OSSA will assess the current state and future needs of the NASA institutional base. A key first step was the "Center Science Assessment Team" activity conducted in 1987. This study identified strengths and weaknesses in the in-house space science and science-related technology program. NASA has begun to address the recommendations of the study report.

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 and are not meant to imply any limitations on participation.

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 Space and Earth Sciences Computing Center, 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 platforms and most initial Earth Probes. Goddard is the Flight Telerobotic Servicer development center and supports OSSA integrated Freedom utilization efforts in the areas of platforms and small attached payloads.

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 will take place. Goddard also is responsible for managing the development and operation of the Gamma Ray Observatory, and in all likelihood will 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 Space Exploration Initiative. 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 a limited, but important, role in the microgravity science program, specifically in the area of containerless processing. In addition, JPL supports OSSA efforts in studying evolutionary payload and on-orbit data handling requirements for Space Station Freedom.

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 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. MSFC provides overall management and integration of OSSA's science utilization management activities for Space Station Freedom. Less widely known, but very important, is MSFC's participation in the OSSA science and applications programs, particularly in 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, artificial gravity, space biology, and exobiology. Ames has an active role 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 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, small and rapid-response payloads, and selected attached 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 were 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), 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

Nearly all OSSA's ongoing and planned space science and applications missions involve some form of international participation. One of the principal means by which such participation is made possible is through OSSA's "Announcement of Opportunity" (AO) process, in which the international scientific community is routinely invited to submit proposals to NASA to fly foreign experiments on U.S. spacecraft, participate in U.S.-led experiment teams, and take part in post-flight data analysis activities. Foreign proposals compete on an equal basis with U.S. scientific proposals and undergo the standard peer review process prior to the final selection of participants. In keeping with long-established NASA policy, international cooperation in OSSA programs takes place on a "no-exchange of funds" basis, wherein each side agrees in advance to cover the costs associated with its own contribution to the activity.

In developing this 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 priorities. We intend to exercise international leadership first and foremost through a strong commitment to national vitality in our own ongoing program, major and moderate missions, small missions, use of Spacelab and Space Station Freedom, and maintenance of a vigorous research base. Only through an ambitious and broadly based national program in space science and applications will we continue to attract the best scientific and technical personnel from foreign nations to work with us to enhance the overall scientific return from our programs.

Other nations no longer must depend on the United States for access to space. A number of Western nations now have indigenous spacecraft and/or launch capabilities. As a result, NASA maintains an active dialogue with space agencies abroad to exchange information on our respective plans and to identify potential areas for cooperation. We will not only continue our past practice of inviting foreign participation in NASA missions, but we will also seek opportunities to participate in the missions of other nations and to jointly define missions of mutual interest. In addition to working with developed nations that have well-established space capabilities, NASA also conducts cooperative projects with developing nations. An area that is particularly attractive for participation by developing nations is Earth observations, especially the provision of ground-truth data.

OSSA is strongly committed to fulfilling existing international cooperative agreements with traditional major space partners in Western Europe, Canada, and Japan. In many cases, foreign contributions to NASA space science missions currently under development are quite significant. For example, the Hubble Space Telescope to be launched in 1990 involves major scientific hardware contributions by the European Space Agency (ESA); the Gamma Ray Observatory will carry one European instrument in its four-instrument payload; and the Advanced X-ray Astrophysics Facility will carry a Dutch instrument. The Ocean Topography Experiment (TOPEX/POSEIDON) is being carried out as a joint development effort with France, and the Upper Atmosphere Research Satellite involves investigators from Canada, the United Kingdom, France, and the Federal Republic of Germany, in addition to U.S. investigators. The Galileo mission currently en route to Jupiter uses a Federal Republic of Germany retro propulsion system on the U.S.-developed orbiter spacecraft. The Tropical Rainfall Measurement Mission is planned as a cooperative effort with Japan.

The NASA Scatterometer and the Total Ozone Mapping Spectrometer are planned to fly on the Japanese Advanced Earth Observations Satellite. The International Solar-Terrestrial Physics program, a multilateral coordinated program to study interactions in the Sun-Earth system, will involve contributions of spacecraft from Japan (the Geotail mission) and ESA (the SOHO and Cluster missions), in addition to the two-spacecraft contribution of NASA (the Wind and Polar missions). The multilateral "Inter-Agency Consultative Group on Space Science," composed of space agencies of Europe (ESA), Japan (ISAS), the Soviet Union (Intercosmos), and the U.S. (NASA), serves to coordinate the various International Solar-Terrestrial Physics missions with planned Soviet missions *in this area of scientific inquiry. The International Microgravity Laboratory is an example of a major* NASA Spacelab mission series in which the U.S. and its international partners play cooperative roles.

The Earth Observations International Coordination Working Group is the forum within which the U.S., Europe, Japan, and Canada discuss, plan, and negotiate international cooperation on the Earth Observing System. The delegations are led by the Earth observations offices of these nations' respective space agencies and also include operational environmental monitoring agencies. The group meets three to four times annually to address a full range of technical and policy issues that include payload, operations, data management and policy, and instrument interfaces.

The intent of the small-class Explorer program of focused-science missions using Scout-class expendable launch vehicles is to eventually achieve two launches per year, including launches designated for U.S. scientific missions and others for foreign missions. In exchange for the U.S.-provided launch, opportunities for U.S. scientists to fly experiments on foreign spacecraft will be made available. The small Explorer program should ultimately provide new opportunities for those nations with space science programs that are more modest in scale.

OSSA's upcoming missions in planetary science—the CRAF/Cassini missions—entail substantial participation from the Federal Republic of Germany (CRAF) and ESA (Cassini). In 1989, NASA and ESA issued simultaneous coordinated AOs for the Cassini Saturn Orbiter and the Huygens Probe. The OSSA initiative proposed for FY 1991—EOS—is being planned as a major cooperative venture between the U.S., ESA, and Japan, with additional participation by other Western nations. Discussions are also in progress regarding possible Federal Republic of Germany and Italian collaboration on the Orbiting Solar Laboratory and Federal Republic of Germany collaboration on SOFIA. Opportunities for cooperation involving the flight of U.S. investigations on foreign missions will also continue to arise, and OSSA will seek to provide adequate resources to retain the flexibility to take advantage of these opportunities.

NASA has worked with the Soviet Union in space science activities since the early 1960s. With the signing of the most recent U.S./U.S.S.R. Space Cooperation Agreement in 1987, a new era of bilateral space science cooperation has been initiated. OSSA is engaged in implementing an increasingly active and ambitious program of joint activities with the Soviet Union; those activities are carried out on the basis of scientific merit, mutual benefit, and reciprocity. To that end, five Joint Working Groups have been established and meet annually to review the progress of ongoing projects and to propose new science activities: space biology and medicine, solar system exploration, solar-terrestrial physics, astronomy and astrophysics, and Earth science. Joint activities under this agreement initially included exchanges of data, scientific personnel, and mission coordination/

optimization. For example, U.S. scientists were jointly selected as "participating scientists" in the Soviet Phobos mission. Soviet scientists participated in the Voyager Neptune encounter in August 1989, and they will participate in the Magellan mission as well. Looking to the future, we intend to jointly select another group of U.S. scientists to be "participating scientists" in the U.S.S.R.'s Mars '94 mission, and to select a group of U.S.S.R. participating scientists on the 1992 Mars Observer mission.

During the May-June 1988 Moscow Summit, the U.S./U.S.S.R. space agreement was expanded to include two new project areas: (1) the exchange of opportunities for flight of scientific instruments on one another's spacecraft, and (2) the exchange of results of independent national studies of future robotic solar system exploration missions as a means for assessing the prospects for future U.S./U.S.S.R. cooperation on such missions. Both nations also agreed at that time to increase the level of exchange of scientific personnel and scientific data within the framework of the U.S./U.S.S.R. space agreement.

We are currently engaged in implementing a project involving a 1991 flight of the U.S. Total Ozone Mapping Spectrometer instrument on a U.S.S.R. Meteor-3 satellite, and the Soviets are preparing a gamma ray burst detector to fly on the Wind spacecraft in 1992. In addition, we are preparing two high-energy astrophysics instruments for flight on the U.S.S.R.'s 1993 Spectrum-X Gamma mission: an X-ray polarimeter and an all-sky monitor. The U.S. is now planning to participate in the Soviet Radioastron mission; NASA will provide ground-based communications support to the spacecraft. We are also in the midst of modifying our 1992 U.S. Mars Observer spacecraft to receive a Soviet-provided receiver (built by the French) to serve as a communications relay for the Soviet Mars '94 balloon mission. Exchanges of study results have taken place on the following proposed missions: Solar Probe, Mercury Orbiter, and Mars Rover/Sample Return.

In space biology, OSSA will play a major role in the Soviet 1992 COSMOS Biosatellite mission. The United States will also conduct medical pre-, in-, and post-flight investigations with cosmonauts on the MIR space station. These studies will be initiated in 1990 and will expand over the next few years as both nations collaborate on joint biomedical studies of flight crews on both MIR and Space Shuttle missions.

In all our interactions with the Soviets, OSSA is making a transition to a traditional working relationship in which principles of open competition and scientific peer review are being used to respond to Soviet invitations for flight opportunities or joint data analysis activities. Although we are pleased with the progress being made in developing our cooperative relationship in space science with the Soviet Union, the pace at which these efforts proceed in the future will depend, in part, on the availability of resources to support an expanding cooperative program.

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 Space Station Science and Applications Advisory Subcommittee, the Committee on Global Change, 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 scientific working groups and project definition teams, 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 six, 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 first includes contemporaneous observations across the entire electromagnetic spectrum. The "Great Observatories" are major missions covering the four major wavelength bands—infrared, ultraviolet/visible, X-ray, and gamma-ray. Explorer, Spacelab, Space Station Freedom, and suborbital missions bridge the gaps in the measurements made by the Great Observatories.

Second is the provision of data to, and data analysis by, the science community through an infrastructure including the Astrophysics Data System, Directory Service, workstations, and software; and grants for data analysis, supported by theory, laboratory astrophysics, ground-based telescope data, and education initiatives. The third element is investment in long-term viability via a continuing series of short time scale flight opportunities using aircraft, rockets, balloons, and moderate and small-sized Explorer satellites.

CURRENT SITUATION

The Great Observatories program is progressing well. The Hubble Space Telescope and the Gamma Ray Observatory will be launched in 1990. The Advanced X-ray Astrophysics Facility is moving forward with primary emphasis on the fabrication of its flight mirrors. The Space Infrared Telescope Facility is entering development and planning for a new start in 1993. Each of these missions is an enormous advance over its predecessor, and together they promise a revolution in our understanding of the beauty and complexity of the universe.

Explorer and Spacelab activities are highlighted by the launch and successful early operations of the Cosmic Background Explorer. The International Ultraviolet Explorer will enter its thirteenth operational year. More than 1,000 astronomers have made observations with this instrument. Among the Spacelab activities, exploration into the far ultraviolet and X-ray bands will occur with the launch of the Astro mission within the Shuttle cargo bay.

The Roentgen Satellite, in cooperation with the Federal Republic of Germany, will be launched in 1990 on a Delta-II rocket. The Extreme Ultraviolet Explorer remains on track for a 1991 launch, and work is underway on the X-ray Timing Explorer. Both these missions will use the Explorer Platform.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The Hubble Space Telescope and the Gamma Ray Observatory will continue operations after their 1990 launches. Starting in 1996, the original instruments on the Hubble Space Telescope will be replaced by an infrared array camera and a "two-dimensional" ultraviolet spectrograph. The Advanced X-ray Astrophysics Facility is planned for a 1997 launch. The Space Infrared Telescope Facility is planned for development and launch by the end of the century.

In addition to the Great Observatories, both moderate and small Explorer missions are under development or in planning. The Far Ultraviolet Spectroscopy Explorer, the third payload for the Explorer Platform, is planned for installation by the Space Shuttle during 1997. A small-sized Explorer mission, the Submillimeter Wave Astronomy Satellite, will begin development in FY 1991, with plans for completion and launch during the summer of 1993.

Planning is underway for an Explorer mission to study nuclear emission line sources in the galaxy and beyond. The Nuclear Astrophysics Explorer would provide the first high spectral resolution survey of gamma ray sources in the energy range of 0.05 to 10 MeV. Planning is also underway for a moderate mission, the Submillimeter Infrared Line Survey Mission, which will target about 100 to 200 sources for a complete spectral line survey, at high spectral resolution, in the 100 to 1,000 micron region.

Work continues on international collaborations as part of the Explorer Program. U.S. instruments will be flown aboard the Japanese Solar-A and Astro-D missions scheduled to be launched during 1991 and 1993 respectively. In 1994, Japan will launch the Infrared Telescope in Space as part of the instrument complement on the Space Flyer Unit mission. One of the four focal plane instruments on this telescope is being developed by the U.S., and a second instrument is being developed jointly by the U.S. and Japan. U.S. X-ray astronomy instruments will also be part of the Soviet Spectrum-X-Gamma Mission and the European Space Agency's X-Ray Multi-Mirror Mission.

Another international collaboration is the Stratospheric Observatory For Infrared Astronomy (SOFIA) project with the Federal Republic of Germany. The SOFIA project will mount an advanced infrared/submillimeter telescope on a modified Boeing 747 aircraft to significantly enhance our current suborbital observing capabilities to complement the Great Observatories and offer essential opportunities for training new scientists and instrumentalists.

Two international cooperative space Very Long Baseline Interferometry missions are being planned with the Soviets and the Japanese. Both missions will use satellites with 10-meter diameter radio telescopes to obtain orbital radio astronomical signals. Correlation with ground observations will produce angular resolution of tens of microarcseconds.

Development of an active astrophysics element of the Space Exploration Initiative is currently under way. Low gravity, lack of atmosphere, seismic stability, large dimensions, and the availability of virtually unlimited amounts of lunar rock for radiation shielding make the Moon a most promising site for an astronomical observatory. The selection of potential astrophysical instruments is based on scientific merit, relevance of the Moon as a site, and cost-effectiveness. Current plans envision an evolutionary progression of instruments. For example, the progression could begin with a 1- to 2-meter ultraviolet/visible/near infrared lunar transit telescope. This could be followed by the installation of various wavelength interferometers. The series could culminate with the installation of a 16-meter filled aperture segmented optical telescope. These and other instruments will be studied in the future for their potential application to the lunar outpost.

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 (target availability 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 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. An Augmented Program includes more complex and sophisticated candidate missions: robotic sample returns from a comet and from the surface of Mars, and the beginning of the search for planetary systems around other stars.

CURRENT SITUATION

The successful Voyager 2 encounter with Neptune in August 1989 virtually completed the reconnaissance phase of solar system exploration. With the exception of Pluto, all the planets and most of the larger moons have been studied by spacecraft at close range. Also in 1989, the exploration phase advanced with the launches of the Magellan radar mission to map Venus and the Galileo orbiter/probe mission to Jupiter. Exploration will continue with the 1992 launch of the Mars Observer to complete a global scientific assessment of Mars and with the launch of two newly approved missions in the mid-1990s: CRAF to an asteroid and comet and Cassini to the planet Saturn.

Other nations—particularly the U.S.S.R., Western Europe, and Japan—have now established robust and ambitious programs of solar system exploration. The presence of these other programs has already generated specific cooperative and collaborative efforts involving Galileo, Mars Observer, CRAF, and Cassini, and we expect that such cooperative activities will expand 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 or under development, which will preserve U.S. preeminence in the exploration of both the inner and outer solar system and will, in particular, initiate a program of excellence in the study of comets and asteroids. Beyond these missions, the Solar System Exploration Division, in close cooperation with the science community, is now developing a flexible, dual-path strategy for the exploration of the solar system in the 1990s and beyond. The first path continues and expands the traditional scientific program; the second path responds to a national commitment for human exploration of the

Moon and Mars. In the traditional path, the Lunar Observer would be the next mission, followed by such missions as a Mars surface network and orbiter/probe missions to the outer planets beyond Saturn. This dual program has the advantage of flexibility because, in the near term, the "traditional" path is identical to the one for human exploration. However, the second path would, after the Lunar Observer, carry out additional detailed exploration and characterization of Mars by means of landed networks, imaging orbiters, sample returns, and rovers. Planning is also under way for a "Discovery" program of small missions in planetary science.

In any active program of solar system exploration, Space Station Freedom will play a significant role. Two candidate attached payloads are under active consideration: a Cosmic Dust Collection Facility, which would collect particles of cosmic dust for analysis back on Earth, and a possible telescope facility for detecting and characterizing planetary systems around other stars.

Current plans for solar system exploration place a high priority on launch and mission risk reduction. A policy has been established with the Mars Observer and CRAF/Cassini missions to acquire spare key subsystem components in order to enable rapid changeout during development testing. This approach will protect the development schedule and the launch windows; if the spares are not needed, they can provide a cost-effective nucleus for a subsequent mission. Future mission planning will also provide for backup in case of major mission failure.

Solar system exploration must remain at the cutting edge of space science and space technology, and 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—for instrument and laboratory upgrading and for an interdisciplinary "Origins of Solar Systems" initiative—were provided in FY 1990. A potential science initiative now being studied—"Comparative Planetology"—would take advantage of the data from new missions to the inner solar system (Magellan, Mars Observer, Lunar Observer, and the partially successful U.S.S.R. Phobos mission) and from the planned Earth Observing System to deepen our understanding of planet Earth by studying the detailed differences between the inner planets.

ADVISORY COMMITTEES AND RELEVANT REPORTS

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

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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 a wide variety of astrophysical settings. The goal of the discipline, endorsed by the Committee on Solar and Space Physics of the National Academy of Sciences, is to understand:

The Sun, both as a star 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 ionospheres and magnetospheres of the Earth and other solar system bodies,

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.

Data are obtained by probes situated within plasma systems, such as a magnetosphere or the heliosphere. Remote sensing is used for inaccessible regions, such as the solar surface, and regions requiring a global view, such as Earth's auroral zone. Cosmic rays provide a means of studying phenomena outside our solar system. These 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

Initial reconnaissance of a variety of solar system magnetospheres and ionospheres, of the heliosphere itself, and of the layers of the solar atmosphere has nearly been completed, and solar and galactic cosmic rays have been characterized. Many phenomena have been identified and classified, and some understanding of cause-and-effect relationships has been established.

Three U.S. spacecraft continue to collect scientific information: the International Cometary Explorer, Interplanetary Monitoring Platform, and Dynamics Explorer. Coordinated plasma physics studies are being conducted jointly among Japan (Akebono), the Soviet Union (ACTIVE), and the U.S. (Dynamics Explorer).

The DoD/NASA Combined Release and Radiation Effects Satellite, to be launched in 1990, will map the radiation belts during the solar maximum and conduct further studies of ionosphere/magnetosphere interactions through the analysis of chemical releases. Augmenting these investigations is analysis of chemical releases from Pegsat. Also to be launched in 1990, the ESA/NASA Ulysses mission will study the heliosphere out of the ecliptic plane. The U.S./Italian Tethered Satellite System (1991), which will carry a diagnostic satellite tethered to the Space Shuttle by a 20-kilometer conducting wire, will investigate electrodynamic plasma effects. Further measurements of the Sun will be made with the Spartan-201 white light coronagraph and UV coronal spectrometer and with X-ray instruments planned for the Japanese/U.S. Solar-A mission.

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, which will investigate geospace as an interconnected interactive system, includes the NASA Wind and Polar satellites, the Japanese/NASA Geotail mission, and the Combined Release and Radiation Effects Satellite extended mission phase. The Solar-Terrestrial Science Programme includes the Solar and Heliospheric Observatory and Cluster missions, both of which will feature NASA-contributed instruments.

Two small-class Explorers, the Solar, Anomalous, and Magnetospheric Particle Explorer and the Fast Auroral Snapshot Explorer, are in development for launches in 1992 and 1993. Also approved for addition to the Delta-class Explorer program 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, and modest increases in support of the research base. The highest priority major mission is the Solar Probe, which will make humanity's first in situ measurements in the near vicinity of the Sun. The highest priority moderate mission is the Orbiting Solar Laboratory. Its unique ability to investigate the Sun's fine-scale magnetic structure will contribute to important scientific objectives, and it may lead to the capability to predict solar particle events, which pose a threat to human travelers occupied in exploring the Moon or Mars. The planned 1997 launch of the Orbiting Solar Laboratory makes it an ideal prelude to a system of monitoring stations to form a warning network in support of human exploration missions.

A small-class payload using chemical releases to study ionospheric chemical and electrodynamical processes in conjunction with the Combined Release and Radiation Effects Satellite is the highest priority small mission. Many objectives can be fulfilled through other small programs, such as Explorers, sounding rockets and balloons, and Space Shuttle-attached payloads. Small payloads attached to spacecraft with other primary missions can be utilized to study space plasma processes. Future small and rapid-response Space Station Freedom opportunities also can provide important focused science results and essential training opportunities for graduate students. An important candidate Space Station Freedom attached payload facility is the superconducting Astromag system, which can study galactic cosmic rays of GeV to TeV energies. A significant opportunity for the study of the dynamics and structure of the heliosphere is offered by the coordination of the ongoing International Cometary Explorer, Interplanetary Monitoring Platform, Pioneers 10 and 11, and Voyagers 1 and 2, as well as by the upcoming Ulysses, Mars Observer, and Galileo missions.

A feasibility study is nearing completion for a Mercury orbiter mission to provide measurements of the solar wind interaction with the magnetized planet and to complete the mapping of the planet's surface.

The international space physics community is moving toward an unprecedented level of cooperation in solar-terrestrial science in the 1990s that will include major U.S. collaborations with European, Japanese, and other allies, and a number of projects and joint studies that are going forward 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).

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 planning for a major new start in FY 1991 on EOS, which will provide the core elements of Mission to Planet Earth: two polar platform series and their science instruments, the EOS Data and Information System, and duplicate EOS payloads attached to Space Station Freedom. Together with the Earth Probes new start for FY 1991, EOS will provide the long-term, global-scale, self-consistent data sets required for understanding and predicting global change.

Current flight programs include the Nimbus-7 research satellite currently returning global ozone data; the Earth Radiation Budget Experiment to measure the global energy balance that is so important to climate and global change; the Upper Atmosphere Research Satellite, which will 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.

The Total Ozone Mapping Spectrometer is also the first in the proposed 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; a Tropical Rainfall Measurement Mission; the Proteus Ocean Productivity Experiment; a Magnetic Field Explorer; and a Solid Earth Mission.

In addition, 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 environmental satellites.

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 in combination with the recent definition of the U.S. Global Change

Research Program by the Committee on Earth 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, an architecture for global Earth observations involving four elements: the Earth Observing System of polar orbiting platforms, payloads attached to Space Station Freedom, a series of Earth probes, and a set of geostationary orbiting platforms. The second and third goals require the reorganization of the Division into interdisciplinary elements in Earth system process studies for understanding of the Earth, more focused effort on 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.

The first steps in this strategy have been taken in this past year. 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 observations and monitoring, Modeling and Data Analysis 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 Earth System Process Studies for basic research to understand how the Earth functions as a global system. The second major step is the proposal of the core elements of Mission to Planet Earth as a new start in the FY 1991 budget.

One essential element of EOS was not proposed for an FY 1991 new start, the EOS Synthetic Aperture Radar (EOS SAR) spacecraft, and will require a new start in the FY 1994-1995 time frame. The EOS mission is not complete without the SAR, which 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, which occur only during short periods of time, and therefore cannot be properly sampled from polar orbiting platforms.

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).

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).

Life Sciences

The life sciences discipline is involved in all aspects of NASA's activities in space exploration. The 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 in space.

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 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 laboratory 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 basic and applied research that utilizes the spaceflight environment as an experimental tool to study basic processes on a variety of animal and plant species, as well as human beings. The exobiology and biospherics elements of the program use planetary exploration spacecraft and Earth observing systems, in addition to ground-based 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 Life Sciences Division is responsible for providing 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 Space Exploration Initiative missions. The Division also defines the specific mission requirements for medical support and life support, conducts ground-based and flight research necessary to specify design criteria and establish operational protocols and procedures, and performs implementation monitoring to ensure that mission designs meet human life support requirements.

CURRENT SITUATION

Efforts have been initiated to implement the recommendations of advisory panels to upgrade the ground-based research infrastructure, provide life support technology for the Agency, and expand the flight capabilities required by the disciplines, but these efforts continue to be constrained by limited fiscal and manpower resources.

Since much research depends heavily upon access to the spaceflight environment, the Division has implemented major flight programs that will come to fruition in the near term. A series of dedicated Spacelab missions, commencing with Spacelab Life Sciences 1 in August 1990 and continuing at the rate of one dedicated mission every 2 years, represents the first opportunity since Skylab to collect systematic experimental data on primary physiological systems. This series of missions is augmented with cooperative Spacelab missions with our foreign partners, and with International Microgravity Laboratory missions. In addition, the Division has an ongoing program in joint scientific studies on the Space Shuttle and utilizing the Soviet COSMOS biosatellite flights every 2 years. An active program of biomedical studies utilizing the Soviet MIR space station and U.S. Spacelab Life Sciences missions is under way.

The Division is conducting the Extended-Duration Orbiter Medical Program to ensure that Space Shuttle crews are capable of safely landing and leaving the Shuttle after 13- to 16-day missions. The program monitors cardiovascular and neuromuscular performance capabilities and provides appropriate countermeasures to maintain crew capability within established limits, with the goal of medically certifying the extended duration operations by the time of the first U.S. Microgravity Laboratory flight.

NASA Specialized Centers of Research and Training are being established to mobilize university-based talent to concurrently advance basic knowledge and generate effective strategies to solve specific problems in focused life science areas. The three initial areas are gravitational biology, environmental health, and bioregenerative life support, and will draw together research and training expertise in these selected areas, providing a stable base upon which problem-solving strategies can be built. In addition, the ground-based SETI Microwave Observing Project has been implemented to search for radio signals from distant technologies, and the observation phase should last from 1992 to 1999.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

The Division will continue to increase its access to spaceflight with extended exposure durations. Dedicated 13-day Spacelabs are scheduled for 1992 with potential mission operations of up to 16 days by 1994. Both dedicated Spacelab and International Microgravity Laboratory missions are planned to continue in extended duration mode until Space Station Freedom capabilities permit significant on-orbit research. The Lifesat biosatellite has been defined to enable space-based quantitative studies of biological effects of the unique spectrum of space radiation and to provide additional flight opportunities in basic biological research. Lifesat can enter orbits chosen to meet the scientific requirements, including the polar orbits of interest to radiation biology, and can provide autonomous return from flights of up to 60 days. Current plans call for two flight opportunities per year.

Space Station Freedom offers another unique opportunity for the development of international leadership in life sciences research. The on-orbit Space Station Freedom facilities will focus on basic biomedical research to understand the various mechanisms responsible for adaptation to weightlessness and the physiological problems encountered upon return to Earth. To meet Freedom operational requirements, a Biomedical Monitoring and Countermeasures program is being established to optimize physiological countermeasures. On-orbit centrifuges will provide artificial gravity to enable controlled studies with animal and plant subjects and the initiation of variable-gravity studies utilizing the unique capabilities of spaceflight research. Space Station Freedom facilities will also serve to confirm the feasibility of establishing a fully regenerative life-support system for use on future human exploration missions.

ADVISORY COMMITTEES AND RELEVANT REPORTS

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

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

Planetary Biology and Chemical Evolution: Progress and Future Directions (target availability, 1990).

Committee on Planetary Biology of the Space Science 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 goals of the program are to:

Develop a comprehensive research program in fundamental sciences, materials science, and biotechnology, for the purpose of attaining a structured understanding of gravity-dependent physical phenomena in both Earth and non-Earth environments.

Foster the growth of an interdisciplinary research community, united by shared goals and resources, to conduct research in the space environment.

Encourage international cooperation for the purpose of conducting research in the space environment.

Utilize a permanently manned, multi-facility national microgravity laboratory in low Earth orbit to provide a long-duration, stable microgravity environment.

Promote industrial application of space research for the development of new, commercially viable products, services, and markets resulting from research in the space environment.

CURRENT SITUATION

The microgravity program uses an evolutionary approach to conducting research in the environment of space. The process starts with new ideas arising from university, NASA, other Federal agencies, or industry research. These new ideas undergo a concept feasibility stage and detailed laboratory investigations to mature the hypotheses and ensure their worthiness for low-gravity flight investigations. Hypotheses are confirmed, and the flight apparatus is validated using ground-based reduced-gravity facilities. Reduced-gravity test environments of varying durations are available: up to 5 seconds in drop towers and tubes, 30 seconds in aircraft, and up to 15 minutes in sounding 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 mid-deck, cargo pallet, Spacelab, and Get Away Special Canisters.

Microgravity payloads are scheduled for flight as mid-deck experiments on a number of Shuttle missions in 1990. The major near-term opportunities for microgravity science and applications payloads are the International Microgravity Laboratory (IML) flights, the U.S. Microgravity Laboratory (USML) flights, and the U.S. Microgravity Payload (USMP) flights. Space Station Freedom represents a significant advance in the capability to conduct microgravity research, particularly with respect to experiment duration and flexibility. Six multi-user microgravity facilities are being defined for use on Space Station Freedom. Precursor apparatus flown on the Space Shuttle will provide experience with operations and development of instrumentation and subsystems for use in the space facilities.

An Announcement of Opportunity (AO) issued in 1988 invited investigators to propose experiments using the Space Shuttle. Selection of investigations on USML-1 and IML-2 occurred in 1989. In the future, invitations such as the AO and NASA Research Announcement will be used extensively to continue to obtain high-quality science investigations.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

The microgravity science and applications program supports ground-based research to prepare for flight investigations. Many ground-based efforts have matured to the point where Shuttle flights are warranted. Four flights each of USML, IML, and USMP are planned over the next 5 years. Given this substantial number of flight opportunities, renewed program focus on expansion of the ground-based research program, including the addition of sounding rocket investigations and enhanced advanced technology development is crucial, as is the development of flight hardware. Also, the development of methodology and processes for analyzing, documenting, and archiving the flight data is essential to the accomplishment of the overall program goals. The following steps will be taken to ensure optimum use of flight opportunities:

Identify and pursue high quality science investigations requiring the reduced gravity of the space environment.

Expand and facilitate an interdisciplinary research community.

Define and develop cost-effective instrument systems to conduct flight research.

Identify and pursue advanced developments to enable and enhance scientific investigations.

Develop a knowledge base of gravity dependent physical phenomena, such as fluid transfer, fire safety, and the behavior of granular media, to support human exploration of the solar system.

Develop methodology for analyzing, documenting, and archiving the flight data.

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

Final Report, 1988 Summer Workshop (1988).

Communications and Information Systems*

The communications research program focuses on developing the high-risk satellite and ground segment communications systems and subsystems needed to enable new services and to increase the capacity, flexibility, and interconnectivity of present and future telecommunications resources. The goals of the program are to:

Maintain U.S. leadership in space communications

Enable new and innovative services

Enhance efficient utilization of the orbital arc and electromagnetic spectrum through technology innovations

Support U.S. and NASA interests in domestic and international regulatory forums.

CURRENT SITUATION

The U.S.' s position of preeminence in space communications is being challenged by the Western European and Japanese satellite development programs, which are committed to multiple satellite developments and are used as test-beds for near- and long-term system concepts and advanced technology evaluation and demonstration. Consequently, these foreign programs will more than likely accelerate the introduction of advanced technologies into the global telecommunications market, and they may open many new and innovative services that may not be available from U.S. industry. NASA has responded to this challenge with a vigorous program that would curtail further deterioration of these assets.

The Advanced Communications Technology Satellite (ACTS) program has been the centerpiece of activities in support of U.S. industry. Scheduled for an April 1992 Shuttle deployment, ACTS technology will provide capabilities qualitatively different from those of current satellite and fiber optic systems, such as on-demand assignment, frequency reuse, and the flexible targeting of spotbeams directly to customer premises. The 2-year demonstration period will provide an opportunity for NASA to take the lead in carrying out a wide-ranging set of experiments and demonstrations to meet future commercial telecommunications needs.

COSPAS-SARSAT, a satellite-based search and rescue program, has been credited with saving more than 1,400 lives by locating distress beacons from crashed aircraft and marine vessels in distress. SARSAT evolved from NASA's research and development to become a joint venture of the U.S., Canada, and France in 1979, joined by the Soviet Union a year later. In the U.S., the program is a joint effort of the National Oceanic and Atmospheric Administration, Coast Guard, Air Force, and NASA. The constellation consists of two operational SARSAT satellites and two operational COSPAS satellites. The current ground system includes stations in ten countries, with more becoming operational in the near future. NASA is responsible for research and development activities, and will focus on development of the next spaceborne system, which will offer new services and improve system response time.

The Optical Communications program focuses on flight testing systems to support future NASA missions as well as the space demonstration of this technology to reduce its adoptive risk by the American space communications industry. This technology will both enhance and enable new science through increased data gathering, transceiving, and processing capability.

Mobile Satellite Program activities have progressed to the point where the L-band technologies have been successfully tested in true land aeronautical mobile applications. NASA's lead role in regulatory activities has significantly contributed to the securing of the L-band frequency allocation. Close cooperation between the U.S. and Canadian service providers will enable a North American mobile service by mid-1993. To meet future growth, higher frequency bands, such as Ka, are being investigated to alleviate spectrum congestion and to provide an order of magnitude increase in the user base.

*The discussion of Information Systems may be found earlier in this document; only communications research is discussed here.

Radio science experiments provide the technical basis for standards development and regulatory decisions for space services at the national and international levels. Propagation studies and measurements fill the voids in data needed for design of new satellite applications for fixed communications, mobile communications, sound broadcasting, and high definition television broadcasting. In the coming year, emphasis will be placed on the detailed characterization of Ka-band for both low and high bit rate data communications. This will be performed, in part, as a cooperative effort with the ESA Olympus I Experimenters Group as a percursor to experiments on ACTS.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

Through its close partnership with industry, NASA will continue to look for opportunities to contribute to new U.S. markets and services. Emphasis will be placed on the high-risk microwave, optical, and digital subsystems needed to increase the capacity, flexibility, and interconnectivity of future systems. These developments, building on ACTS and mobile satellite technologies, will enable future satellite communication systems to provide services at lower costs to smaller terminals for both fixed and mobile commercial and scientific applications. We also plan to expand optical link developments that have the potential to greatly increase the rate of information return from deep space missions and to interconnect commercial satellite systems.

Personal access communications is a future market candidate. This system concept elevates mobile communications to its ultimate form; i.e., direct to the person two-way data and voice communications. By exploiting the advantage of high frequency bands, greater freedom of access, larger user bases, and wider diversity of services can be achieved. Key enabling technologies include: directive-tracking user antennas, multi-beam satellite antennas, MMIC/VLSI-based user terminal, rain-compensation techniques, and efficient networking technologies.

One major thrust of the communications program will be the evaluation and implementation of techniques addressing health and safely related to public sector needs. Direct support will be provided in areas in which NASA has a unique communications technology development role to address a specific, well-defined, public sector need. The Search and Rescue Satellite (SARSAT) program is such as effort. Spin-off support will be provided when public sector needs for advanced communications technology can be satisfied by technology already developed by or for NASA. or for NASA.

NASA's research and technology program will continue to be assessed with the participation of the U.S. space communications industry, so that selected high-risk enabling technologies will be identified for flight validation. Beginning in 1992, specific government and commercial flight opportunities will be identified for inclusion of these technologies on a recurring basis. These flight validation opportunities will constitute a suite of small missions consistent with the OSSA programmatic themes.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Communications Subcommittee of the Space Applications Advisory Committee of the NASA Advisory Council

Communications Satellites: Guidelines for a Strategic Plan (1987).

Committee on Data Management and Computation of the Space Science Board, National Academy of Sciences, National Research Council

Data Management and Computation—Volume I: Issues and Recommendations (1982).

Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences (1986).

Space Applications Board of the National Research Council

NASA Space Communications Research and Development: Issues, Derived Benefits, and Future Programs (1989).

OSSA Major Events Acronym List

ACTS . . . . Advanced Communications Technology Satellite
Astro . . . . Astronomy Laboratory
ATLAS . . . . Atmospheric Laboratory for Applications and Science

BBXRT . . . . Broad Band X-Ray Telescope

COBE . . . . Cosmic Background Explorer
CRAF . . . . *Comet Rendezvous Asteroid Flyby*
CRISTA . . . . Cryogenic Infrared Spectrometer Telescope for Atmosphere
CRRES . . . . Combined Release and Radiation Effects Satellite

EUVE . . . . Extreme Ultraviolet Explorer

FAST . . . . *Fast Auroral Snapshot Explorer*

GRO . . . . Gamma Ray Observatory

HST . . . . Hubble Space Telescope
HST-REV . . . . . . Hubble Space Telescope Revisited

IML . . . . International Microgravity Laboratory

LAGEOS . . . . Laser Geodynamics Satellite

MSAT . . . . Mobile Satellite

OMV . . . . *Orbital Maneuvering Vehicle*

ROSAT . . . . Roentgen Satellite

SAMPEX . . . . . . Solar, Anomalous, and Magnetospheric Particle Explorer
SL . . . . Spacelab
SLS . . . . *Space Life Sciences laboratory*
SOHO . . . . Solar and Heliospheric Observatory
SPAS . . . . *Shuttle Pallet Satellite*
SRL . . . . Space Radar Laboratory
SSBUV . . . . Shuttle Solar Backscatter UltraViolet instrument
STORE . . . . Shuttle Test Of Relativity Experiment
SWAS . . . . Submillimeter Wave Astronomy Satellite

TOMS . . . . Total Ozone Mapping Spectrometer
TOPEX . . . . Ocean Topography Experiment
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

Note: Launch dates for OSSA planning purposes.

Major Events in Space Science and Applications: 1990 Planning Manifest

	January	February	March	April	May	June	July	August	September	October	November	December
1990		▲ Galileo Venus Flyby ▲ Voyager Lookback		■ HST	■ Astro/BBXRT ● ROSAT	▲ COBE completes first sky survey ● CRRES		▲ Magellan Arrival at Venus ■ SLS-1		■ Ulysses/ SSBUV-2	■ GRO	■ IML-1 ▲ Galileo at Earth
1991				■ ATLAS-1	■ SSBUV-3	■ SL-J		■ UARS ● EUVE	■ TSS-1	▲ Galileo Gaspra Flyby		■ LAGEOS II
1992		▲ Ulysses Jupiter Flyby ■ USMP-1	■ USML-1	■ ACTS	■ SL-D2	■ ATLAS-2 ● TOPEX/ POSEIDON ● SAMPEX	● Geotail		■ SLS-2 ● Mars Observer			● Wind
1993	■ IML-2		■ USMP-2	■ ATLAS-3/ SPAS/ CRISTA/ SSBUV-4		■ HST REV ● Polar ● TOMS ● SWAS		▲ Mars Observer Arrival at Mars ▲ Galileo Ida Flyby	■ SRL-1	● MSAT	■ USMP-3/ STORE	● FAST
1994			■ ATLAS-4/ SSBUV-5	■ USML-2		■ USMP-4/ STORE	■ XTE	▲ Ulysses Over Sun's South Pole	● Small Explorer-4	■ SSBUV-6		■ SRL-2 ● Lifesat-1
1995	■ OMV/WISP	■ SLS-3	● SOHO			▲ Ulysses Over Sun's North Pole ■ IML-3 ● Small Explorer-5 ● Lifesat-2		● CRAF	■ ATLAS-5/ SSBUV-7			▲ Galileo Arrival at Jupiter ● Small Explorer-6 ● Lifesat-3
1996	■ SSBUV-8			● Cassini	■ USML-3 ■ SRL-3	● Lifesat-4 ● Small Explorer-7	■ USMP-5	■ ATLAS-6/ SSBUV-9		● Lunar Observer		

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