



## Toward a New Era in Space: Realigning Policies to New Realities (1988)

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**NATIONAL ACADEMY OF SCIENCES  
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**2101 CONSTITUTION AVENUE  
WASHINGTON, D.C. 20418**

**The Honorable George Bush  
The President-Elect of the United States  
Office of the President-elect  
1825 Connecticut Avenue, N.W.  
Washington, D.C. 20270**

**Dear Mr. President-Elect:**

**Early in your Administration, you will be called on to balance the pace and direction of the civil space program with many other claims on the federal budget. The most immediate decisions concern the Space Station. We believe a permanently manned space station is needed to maintain a viable manned space flight capability for the United States. However, its primary justification is to establish the feasibility of human exploration beyond Earth's orbit. For this reason decisions regarding its final configuration, pace of deployment, and place among competing budgetary priorities are best made in the context of your long-term goals for space. Goals that emphasize human exploration, for example, would require that the station be optimized for research on human biology in the space environment.**

***Building Consensus on Goals***

**The post-Apollo years saw the consensus on space goals dissolve. The technical and budget resources available for space did not match the commitments made, leading to cost overruns, postponed accomplishments in space science and applications, erosion of the national space technology base, and the prolonged disruption of American access to space.**

**Thus, long-term, durable, and widely accepted goals for the nation in space are essential, both to sort out priorities within the space program, and also to match the pace and direction of the space program with the larger set of national priorities. Such goals might include automated scientific exploration. They might propose human exploration of the Moon or Mars in the next century, for which a space station is a prerequisite. These goals, established in consultation with the Congress, would provide the stability and consistency that**

## **The President-Elect of the United States**

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**the space program has lacked, and should be an early priority for your civil space policy.**

#### *Structure of the Civil Space Program*

**We believe the national effort to realize your goals requires two structural components. The first is a base program, balanced and stable enough to ensure U.S. competence in the essential space activities. The three highest priorities should be assured access to space by a variety of manned and automated launch vehicles; a balanced space science and Earth remote sensing program; and advanced technology R&D to support current missions, national security, and the goals you set for the future. This could be accomplished at an annual budget of approximately \$10 billion.**

**This core competence would provide the foundation for selected special initiatives, the second component. These large, long-term projects would serve U.S. scientific, political, cultural, and foreign policy objectives. Examples include the space station, or a program of expanded monitoring of the Earth for environmental and scientific purposes. Each special initiative would require an additional \$3 billion to \$4 billion in peak years. Each would be funded separately from the base program to ensure that operational expediencies do not erode the nation's basic capabilities in space. Decisions on the staging of special initiatives must of course be affordable within the larger set of national priorities.**

#### *International Partnership*

**The core capabilities and one or more special initiatives, taken together, would provide a strong leadership position for the United States in civil space. Equally important, they must take into account the growing capabilities of other spacefaring nations, especially Japan, China, Western Europe, and the Soviet Union. Through cooperative arrangements, the United States might achieve cost savings or gain political or scientific objectives otherwise unobtainable.**

#### *Management*

**Improved management is also essential. This will require**

## The President-Elect of the United States

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- early appointment of a strong Administrator for the National Aeronautics and Space Administration (NASA), who enjoys your confidence as an adviser;
- redefinition of the now diffuse roles of the NASA field centers, with some being converted to private operation to attract and retain the best people;
- separation of space operations from space science, research, and development; and,
- better coordination of technology development and space infrastructure, including expendable launch vehicles, between the civil and defense space programs.

### *Private Space Ventures*

Finally, the government should use commercial space services where these can be procured at comparable cost and without compromise to legitimate government functions. Your commercial space policy should develop options to stimulate the use of private investment capital. Unclassified technology developed for the space program should be readily available for scientific purposes, commercial ventures, and civil agency use of space.

### *The Budget Context*

We recognize that space must take its place within the larger framework of national priorities. A civil space program aimed at maintaining a respectable position within the growing community of spacefaring nations requires a long-term commitment of significant national resources. But we also believe the nation has received good value for its past investments in space, and that this will be the case for the future.

These points are developed more fully in the following paper "Toward a New Era in Space," prepared at our request by a panel of distinguished scientists and engineers.

Yours sincerely,



Robert M. White  
President  
National Academy of Engineering



Frank Press  
President  
National Academy of Sciences

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# Toward a New Era in Space

## Realigning Policies to New Realities

Committee on Space Policy

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The National Academy of Sciences (NAS) is a private, self-perpetuating society of distinguished scholars in scientific and engineering research, dedicated to the furtherance of science and technology and their use for the general welfare. Under the authority of its congressional charter of 1863, the Academy has a working mandate that calls upon it to advise the federal government on scientific and technical matters. The Academy carries out this mandate primarily through the National Research Council, which it jointly administers with the National Academy of Engineering and the Institute of Medicine. Dr. Frank Press is President of the NAS.

The National Academy of Engineering (NAE) was established in 1964, under the charter of the NAS, as a parallel organization of distinguished engineers, autonomous in its administration and in the selection of members, sharing with the NAS its responsibilities for advising the federal government. Dr. Robert M. White is President of the NAE.

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## PREFACE

Decisions made over the next few years will be critical in determining the future of the United States in space. The National Academy of Sciences and the National Academy of Engineering believe that an informed public discussion of these decisions is fundamental to the creation of wise policies. To that end, the Academies assembled a group of experts in science, economics, engineering, and private technology-based enterprise to examine past policies and their consequences and to recommend policies that should guide the national space program over the long term.

Of special concern was the lack of national consensus regarding the long-term goals of the civil space program. This lack of long-range vision has led to the loss of heavy launch capabilities, the fall of the Skylab, and, for lack of alternative launch vehicles, the prolonged absence of the United States from space following the *Challenger* accident. Without a durable framework to establish priorities, the U.S. space program has promised too much for the resources made available to it. That the National Aeronautics and Space Administration achieved as much as it did under these circumstances is a tribute to the dedication and professionalism of its staff.

The study committee met five times during the summer of 1988. We explored the key components of space leadership and were challenged by the problem of setting priorities in times of severe budgetary constraints. We concluded that major changes are needed in the way the country and its leaders approach national space policy. The committee recognized that the foundation of space policy is its sense of purpose—national goals that are imaginative, durable, and affordable. These goals and the programs to achieve them must recognize the growing capabilities of other nations and, through cooperation, accomplish objectives otherwise unobtainable. The United States cannot expect to be preeminent in all fields of space endeavor, but we must mount a national program to maintain a level of competence in all areas. The committee proceeded to describe the components of a balanced program and to develop the concept of a “base” program that provides a floor of competence and special initiatives—large, ambitious undertakings aimed at major scientific, political, and cultural objectives.

We believe major challenges also provide major opportunities. This paper addresses those near-term decisions that we believe can lead to a fruitful, consistent U.S. space program in the decades to come.

H. Guyford Stever  
Chairman

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## ACKNOWLEDGMENTS

The U.S. scientists, engineers, and policy experts who shared information and views with the committee during the course of its considerations are too numerous to mention individually. Nevertheless, they made valuable contributions to our thinking. Special thanks are in order for those who spent time with the committee discussing their and our concerns. These include in alphabetical order: The Honorable Edward C. Aldridge, Jr., Colonel Roger G. deKok, Dr. Thomas M. Donahue, Mr. Daniel J. Fink, The Honorable James C. Fletcher, Dr. Jay Goldberg, Dr. Noel W. Hinners, Mr. Dale Myers, Dr. Norine Noonan, Mr. Willis M. Shapley, and Mr. Andrew J. Stofan. The committee also drew on a wealth of past studies and reports, which are listed in the bibliography.

## INTRODUCTION

The United States has received remarkable benefits from its space programs over the past thirty years. Our investments in space have enhanced our national security, advanced commerce, furthered scientific research and exploration, and provided critical public services such as weather forecasting and environmental monitoring. Even greater benefits can flow from future space activities if they are guided by clear goals and objectives, adequately funded, and implemented by vital, effective, and efficient institutions.

The full potential of the U.S. space program, however, will *not* be achieved unless policy changes are made. These changes are needed to align the nation's policies with the new realities that dominate worldwide space activity. These realities include the rapidly growing space capabilities of other nations; the lack of long-term, widely supported, attainable goals that has led the U.S. space program to promise greater performance than its resources enabled it to deliver; the necessary transition away from a period during which the space shuttle held a monopoly on space launches; and protracted constraints on the federal budget.

Many of the benefits from U.S. space activities today flow from the momentum established during the 1960s, when Project Apollo was the centerpiece of a strongly supported national commitment to space preeminence. No similar commitment has emerged since, and the 1986 *Challenger* accident only emphasized the need to rethink U.S. space policies and programs.

The uncertainties surrounding the U.S. civilian program have become evident at a time when other nations are pursuing vigorous, goal-oriented space programs of their own. In 1969, as American astronauts took the initial steps on the lunar surface, the United States was clearly the preeminent space power, and others looked to it for leadership. This is no longer true. In addition to a continued Soviet commitment to a broadly based space effort, many other countries possess sophisticated technologies and skills with which to pursue their interests in space.

American preeminence in every field of space activity is no longer a realistic option. Even if budgetary resources were available, the scope of space science, applications, and exploratory missions under discussion around the world clearly call for increased international cooperation. Partnerships with other nations and organizations can serve to demonstrate leadership, to forge productive relationships, and to broaden the range of available opportunities, but only if international commitments are made carefully and honored fully. Indeed, the time may be approaching when the old ways of thinking about competition and cooperation must fall behind, and large activities will be pursued jointly with many nations to benefit all humanity.

A key problem in U.S. civil space policy is the lack of a widely understood purpose, direction, and time scale for the manned program. In the absence of a consensus regarding such issues, the National Aeronautics and Space Administration (NASA) has achieved only limited success in gaining support for an ambitious program built around a continuing commitment to manned space flight—sometimes at the expense of other important space activities. Faced with expectations that it would provide leadership in all areas, particularly in manned flight, but without adequate funds, the space agency attempted to move ahead on a broad front. The result was a brittle program that could not be sustained over the long term.

The severity of the situation became clear after the *Challenger* accident, but this recognition also coincided with growing concerns for the federal budget. Faced with spending constraints for all scientific and technological endeavors, the resources required to correct past policy mistakes—especially sole reliance on the space shuttle for access to space—have been diverted from more forward-looking efforts.

Thus, the future direction of the civilian space program will remain uncertain without strong leadership by the President. But this is also a moment of opportunity, when well-conceived policies can propel the United States into a leadership position for the next century. This paper is intended to assist the new Administration in developing the policies, capabilities, and national consensus needed to rebuild a vigorous space program.

## THE LEADERSHIP ROLE OF THE PRESIDENT

The civilian space program can be a powerful instrument of national policy. A leading position in space, one that is the result of setting challenging goals and achieving them, reflects the technological capabilities of a nation. Space can provide an international showcase for American technology and for goods and services based on that technology. The challenge of space can motivate many young Americans to excel in engineering and science and can draw high-quality foreign researchers to U.S. universities and laboratories. For these reasons, a purposeful, technically competent U.S. space program should be fully exploited to advance U.S. national interests.

Leadership does *not* require U.S. preeminence in all space activities, and much can be gained by partnerships with other nations. Leadership *does* require that the United States be a competent participant in all areas of space activity—national security, applications, science, and exploration—and that it be in the vanguard in those activities most clearly associated with the President's

goals for space. Activities involving humans are of particular importance in this context.

This is the arena in which presidential decisions and continuing involvement are required. Without a strong commitment from the President, it is difficult, if not impossible, to gain the broad public support and commitment of resources required to initiate and carry out long-term, necessarily expensive programs. This is because many of the benefits of space leadership—such as national prestige or geopolitical advantage—are long term and intangible. These cannot readily be quantified, even though numerous examples of direct benefits can be found. By contrast, the costs are apparent to all. Thus, steady and affirmative leadership from the President is required to maintain national space priorities within the larger context of the federal budget.

Manned space flight is a necessary element of space leadership, a consequence of cultural values and human aspirations to expand beyond the Earth's confines. The space shuttle and space station represent early elements of this expansion. It is crucial, however, that the manned program be so designed that it is not carried out at the expense of other important civilian space activities in technology development, science, and applications and that it can be paced to be affordable on a sustained basis.

Because space leadership is important to U.S. national interests and space is properly a presidential issue, the President should ask the country to support national space goals that are sufficiently imaginative and bold to assert a commitment to space leadership. To give visibility to the importance of his space program, the President must establish his goals early in his Administration. He should then support them strongly with the public and the Congress to help ensure their achievement.

To implement these goals, a formal policy development and coordinating mechanism for the government agencies involved in space activities could be of benefit. But such bodies cannot substitute for presidential leadership and commitment.

As an indication of his commitment to a strong civilian space program, the President should give high priority to recruiting as the new NASA Administrator an individual who shares his goals, who can work effectively with the Congress, and who is widely respected for managerial effectiveness. This individual should be selected as early as possible in the transition process so that he or she will be ready to take charge of the agency when the new Administration takes office. Conversely, delay in filling this position would be demoralizing within the space community and would suggest that this aspect of the national agenda is being given low priority.

## TOWARD STABLE BUDGETING: A BALANCED BASE PROGRAM AND SPECIAL INITIATIVES

A civil space program capable of achieving national goals should have two distinct components. The first should be a balanced, stable *base* program to ensure ongoing U.S. competence in fundamental space activities—for example, astronomical observation, Earth observation missions, microgravity research, planetary exploration that is not a specific precursor to manned missions, space commercialization, tracking and data processing, a robust research infrastructure and its associated human resources, technology development, some space transportation, and some manned space flight. (It would not include major, multibillion dollar programs such as a space station, a return to the Moon, an automated Mars sample return mission, or human missions to Mars.) Within the base, the highest priorities should be assigned to assuring access to space with a variety of launch vehicles; ensuring the availability of advanced technology to maintain a competitive posture in national security and civil undertakings and to enable challenging missions in the future; and building a varied space science and Earth remote sensing applications program. The motivations for this component of the space program are largely scientific, technological, and economic.

Stable funding for this base, or core, effort should be assured before any additional large-scale leadership initiative is undertaken. It must rest on a strong foundation of modern facilities and high-quality human resources. Earlier cuts from the base program to support large initiatives have put the U.S. space program in a position where adequate technology is not available for application to advanced program requirements in such areas as propulsion, life support systems, robotics, or automation.

The second component of the civil space program should consist of large-scale, long-term *special initiatives* that the President and the Congress decide are in the national interest and for which they seek public support. This component, which would depend heavily on a stable base program, is motivated primarily by political, cultural, and international considerations, although it also may serve scientific and technological purposes. Much of the manned program falls in this category. Clearly, such initiatives should not be undertaken without the commitment to fund and support them adequately over the period necessary for their accomplishment. Since Apollo, NASA has entered into major projects without that commitment and has been forced to either cut back its base programs or compromise on the achievements of the new initiative.

To ensure that primary space capabilities are not eroded by the costs of special initiatives, it is useful to think in terms of a base program with a stable annual budget of about \$10 billion (1988 dollars). Each special initiative could

require additional funding on the order of \$3 billion to \$4 billion in peak years. (The committee did not undertake a detailed budget analysis, and all estimates are based on existing budget information.) Figure 1 shows historical and current NASA budgets, and Figure 2 illustrates the decline in the NASA portion of the federal budget over time.

The notion of the NASA program consisting of national *special initiatives* and a *base program* need not be translated into formal separate budget or organizational terms; it is rather related to the character of the presidential and congressional support required to initiate and carry out the different types of activities. NASA should manage both the base and large special initiatives as a unified whole. The point is that the country's fundamental competence in all areas of space activity should be assured before substantial resources are invested in any major program thrust. When commitment is made to a new special initiative, adequate funding must be provided or it should not be undertaken.

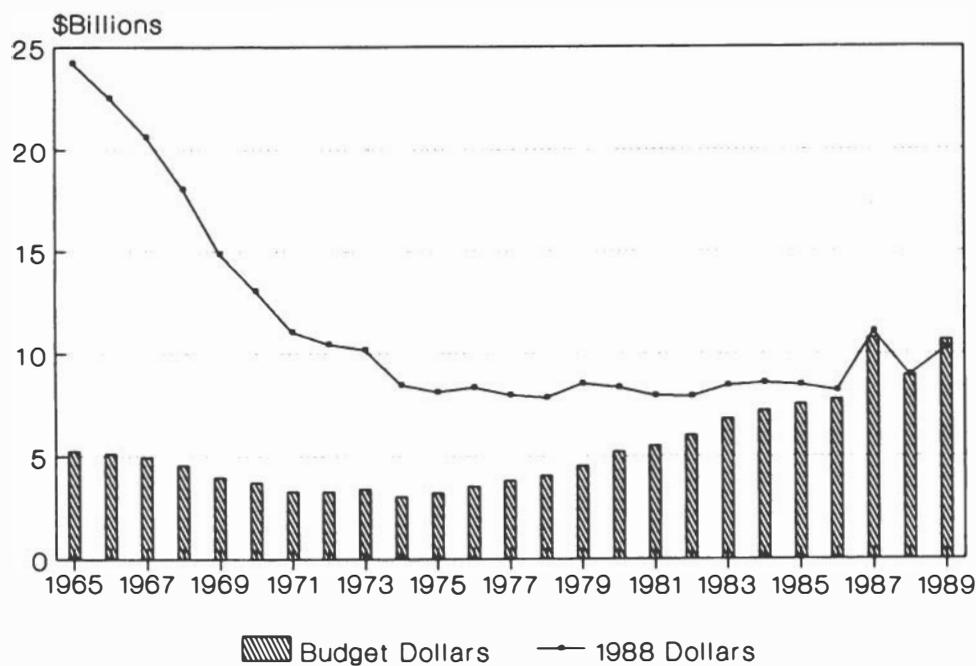
### Special Initiatives

The special initiative requiring immediate decisions is a permanently manned space station, already subscribed to by international partners and well along in its design. The issue is whether or not to proceed with the space station as currently planned. The committee believes that some form of space station is essential to establish the feasibility of extended human space flight. It is the only way to properly research the need for artificial gravity in extended manned missions and to develop the necessary technologies for these missions.

In 1987 a committee of the National Research Council (NRC) examined the various configurations for a space station that NASA had considered and that others from outside NASA had proposed. The committee found none met the broad requirements of the potential communities of users better than the revised Phase One of the currently planned station.<sup>1</sup> But these requirements are poorly defined, largely due to the lack of widely accepted, long-term goals. To deal with this uncertainty, Phase One of the current station has been made quite flexible, and Phase Two postponed. Nevertheless, the current concept in its entirety will require revalidation to ensure that it fully supports the goals established by the President. Goals that emphasize human exploration, for example, would require that the U.S. space station module be optimized for research in the life sciences.

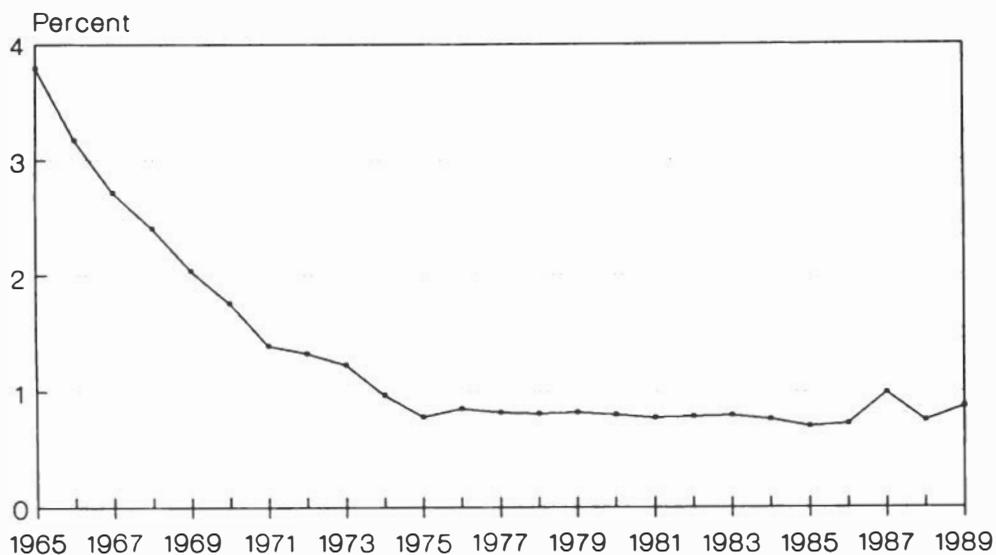
Finally, the committee noted that the logistic systems supporting the station, and particularly, its dependence on the space shuttle, are principal sources of risk. NASA has adopted many of the NRC committee's recommendations, but continued special attention will be required.

**Figure 1 NASA Appropriations\***



\*Including DOD Transfers

**Figure 2 NASA Budget as Percent of Federal Budget**



A second possible special initiative is articulated in the Report of the National Commission on Space,<sup>2</sup> the Ride Report,<sup>3</sup> and in the February 1988 White House space policy statement—the expansion of “human presence and activity beyond Earth orbit into the solar system.”<sup>4</sup> The schedule for a program leading to human exploration and expansion could be adjusted to budgetary realities and still demonstrate sustained progress that could help build an enduring national consensus in support of the space program. A campaign of this scope could be accomplished at a measured pace over many decades, starting on the space station with the study of the effects of long-duration space flight on animals and humans.

There is substantial disagreement on the specifics of the best plan for human expansion, and in particular whether an outpost or scientific base on the Moon should be established before or at the same time as initial exploratory missions to Mars. Further discussion within both the technical and political communities and between the United States and other spacefaring nations is in order before a commitment to a specific program for human expansion beyond Earth orbit.

Another type of special initiative that would not require substantial in-space human involvement has been termed “Mission to Planet Earth.” As conceived, it would be an international multisatellite program to provide simultaneous remote sensing information of all the Earth and predictive models of the global environment in conjunction with ground-based observations. This initiative promises significant near-term rewards in information about the Earth and its environment.

An additional special initiative might be an accelerated program of solar system exploration using automated systems and carried out in collaboration with other spacefaring nations. A Mars sample return mission could be a central part of this initiative.

U.S. special initiatives should be undertaken in consonance with other nations. The Soviet Union, Western Europe, Japan, and China are leaders among many nations that have developed advanced spacefaring capabilities. Through cooperative projects, the United States could achieve technological, financial, and geopolitical benefits that might otherwise be unobtainable. However, the United States must participate in these joint ventures as a reliable partner or not at all.

A principal catalyst for international cooperation can be the International Space Year (ISY), which will begin in 1992. Planning for the ISY is under way in the United States and abroad, but prompt decisions about the nature of U.S. participation are needed if that participation is to be meaningful.

## The Base Program

To achieve competence across the board in space endeavors, the base program should include some elements of space infrastructure and the manned program as well as the following: investment in the technical capabilities needed to pursue advanced space programs; a vigorous, balanced space science program; an aggressive civil space applications program; and support for the commercialization of space.

### *Investment in Technical Capabilities for Advanced Space Programs*

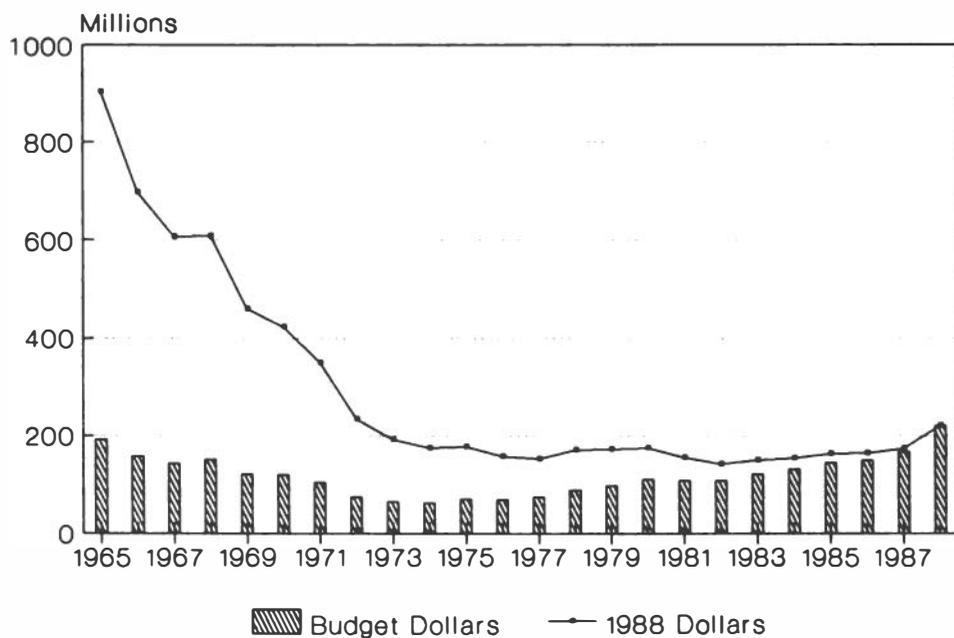
In recent years most of the increased investment in space, both in NASA and the Department of Defense (DOD), has supported the development of large systems rather than basic engineering research and technology development. Figure 3 illustrates the long-term decline in research and technology funding, and Figure 4 shows the decline in research and technology as part of the overall NASA budget.

Operational pressures and short-term commitments have contributed to this turn from more basic research. If the United States is to be in the forefront in space, however, it must soon take action to fill the pipeline with the most advanced technologies. Programs designed to enable future missions, such as the Pathfinder and Civil Space Technology Initiative, are steps in the right direction but are not of sufficient magnitude to satisfy future needs for technology.

The need for these investments—in space propulsion, materials, energy systems, sensors, and the technologies to enable long duration undertakings by humans in space—has been described in the 1987 NRC report *Space Technology to Meet Future Needs*.<sup>5</sup> Such a program would be characterized by the following critical elements: (1) stability and continuity of funding to carry out long-term research and development (R&D) in the most effective manner, (2) a strengthened basic research program for generating new options to meeting technology requirements for long-term goals, (3) interagency coordination of program formulation and budgeting stages to enhance synergy and avoid redundant investments, and (4) demonstrations of space technology to establish technical feasibility and to facilitate the creation of competitive technical teams in the private sector working in partnership with NASA to translate advanced technologies into applications.

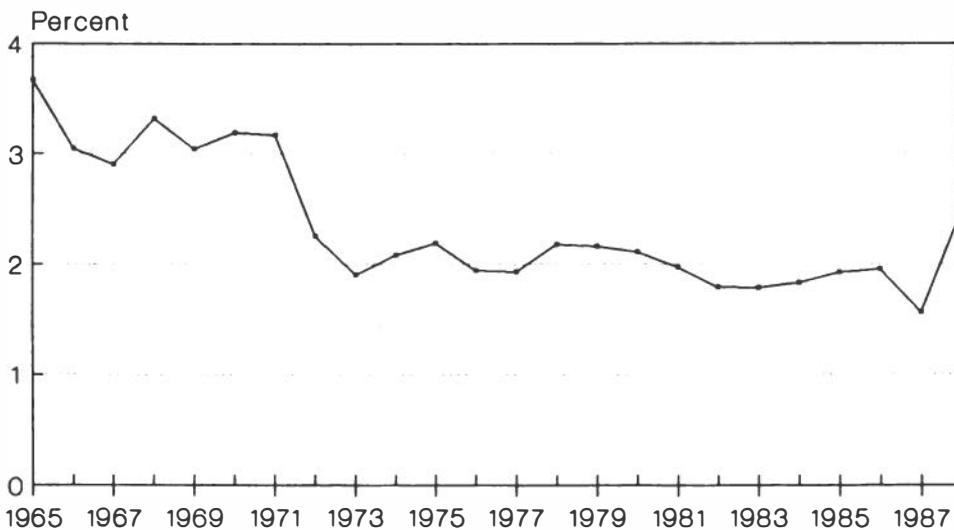
Finally, NASA must ensure its technology development is carried to a stage where it can be picked up by industry or other government agencies. The nation should invest in technology demonstration to ensure transition of new technologies to industry—as it has with experimental aircraft (X-airplane) programs. Investment should be made selectively in proof-of-concept demonstrations to facilitate technology transition. One way the federal govern-

**Figure 3 NASA R&T Funding\***



\*Excludes Nuclear and Standards and Practices

**Figure 4 NASA R&T Funding as a Percentage of NASA Appropriations\***



\*Excluding Nuclear and Standards and Practices

ment can help U.S. industry to remain competitive is by advancing technologies that industry is unlikely to undertake because their chances for success seem low, even while their potential payoffs are high. These technologies often require long lead times to mature and the initial investments impose large barriers for individual firms.

### *A Balanced Space Science Program*

James Van Allen's startling discovery that the Earth is surrounded by regions of intense radiation trapped in the geomagnetic field was the first major success in U.S. space science. Since that unexpected finding thirty years ago, space science has altered our view of the universe, the Solar System, and the Earth and its environment. These discoveries provide a firm basis for a program of continuing leadership in this area.

A challenging space science program should be pursued both as an instrument of U.S. leadership and for the intrinsic knowledge that can be gained. Scientific objectives addressing outstanding, fundamental questions must be the dominant factors in defining the space science program and in determining the characteristics of individual missions such as spacecraft, launch vehicles, and instrumentation.

Space science is a principal objective of the overall space program and one that is best accomplished with a large degree of independence from other major elements of the program. Although the manned program is central to life sciences research and can provide opportunities for other research in areas such as microgravity science, in general the space science program should not be forced, as it has been at times in the past, into a manned mode.

A *base* program in space science would be designed to increase understanding of astrophysical phenomena and the origin and evolution of the universe; the Earth and the solar-terrestrial environment; the origin and evolution of the Solar System; fundamental physical, chemical, and biological processes; the effects of the space environment on living beings; and the factors governing the origin and spread of life in the universe. Assured, predictable, and frequent access to space is critical to an effective base program. There should be a spectrum of flight opportunities, with major facilities such as the Hubble Space Telescope balanced with increased opportunities on Explorer-class missions and continued availability of low-cost opportunities using aircraft, balloons, rockets, and shuttle-carried experiments.

There also must be a strong program of research and data analysis that sustains intellectual vigor both through the development of the scientific and technical basis for future missions and through detailed study of results from current and past missions. This requires investment in university facilities and educational programs to train the next generation of scientists and engineers.

Future national leadership in space will depend critically on the supply of top scientific and engineering talent from our colleges and universities. The education of this talent will require that university investigators have access to space to conduct meaningful experiments and that they be involved in R&D programs and missions at the NASA centers and in industry.

The important elements of a base program in space science have been outlined in the strategy documents prepared by committees of the National Research Council's Space Science Board and in the report of its Astronomy Survey Committee. Many of these elements are incorporated in the 1988 Strategic Plan of NASA's Office of Space Science and Applications.<sup>6</sup>

Possible *special initiatives* beyond the base program include an automated Mars sample return mission (which is also a logical precursor to a manned Mars mission), space-based interferometry, and a Mission to Planet Earth. These and other challenging major science initiatives described in *Space Science in the Twenty-First Century*<sup>7</sup> should eventually be considered, but only with the commitment of sufficient additional resources beyond those required for the base program.

The current NASA space science program development and coordination processes work well and should be pursued. Although many of the currently operational U.S. spacecraft continue to return unique results, including observations of Supernova 1987a, the planet Uranus, and the ozone hole, most were launched before 1980 and have completed their primary missions. There is an impressive array of new U.S. missions that will be active through the middle of the next decade due to the backlog of launches delayed from the 1980s. However, U.S. leadership beyond the mid-1990s must take into account the increasing strength of other nations' programs, which have continued to expand and mature. Plans for the next generation of missions should be established to continue the momentum that the United States is expected to regain in the next several years.

### *An Aggressive Civil Space Applications Program*

Communications, navigation, Earth remote sensing, and the use of the microgravity environment to conduct research on materials and processes are the primary applications of space technology for the benefit of society.

In less than three decades the use of satellites for communications has revolutionized global telecommunications. Satellite mobile communications systems and navigation networks hold similar promise for the future. Weather and environmental monitoring, resource location, mapping, and assessment of agricultural productivity and natural disasters are a few benefits of Earth remote sensing. Remote sensing may be key to understanding, and eventually predicting, the consequences of human actions for life on planet Earth. Al-

though the benefits cannot be specified today, space can provide the medium for novel and important research on materials and processes as well.

Each of these applications has unique problems. Since NASA itself is not an end user, NASA's technology development for applications is weak. In communications the current U.S. policy provides for minimal government involvement. Technology research and development are not actively pursued, and government-industry coordination is lacking. Previously, U.S. industry dominated this market by using superior technology; now, other nations are seeking an expanded niche. Competition from fiber optics also can be expected to drive the communications industry toward different types of services, and new technology could be instrumental in assuring future successes.

The diminution of NASA's earlier role in remote sensing research and technology demonstration has left voids that other user agencies have been unable to fill. Thus, the U.S. Geostationary Operational Environmental Satellite (GOES) program is in jeopardy, the transfer of land remote sensing capabilities to the private sector is foundering, and there are no firm plans to capitalize on remote sensing of the oceans to meet research and operational needs.

Last, with the lack of space flight opportunities and problems in developing a long-term program, other nations are challenging the United States in microgravity research and applications experiments.

Clear goals are needed to provide long-term, stable commitments to program development and operations that are commensurate with needs and opportunities.

- In space communications, government-industry cooperation in developing advanced technology should be pursued. Affordable, reliable launches are also essential.
- In remote sensing, coordination should be enhanced between government agencies such as the National Oceanic and Atmospheric Administration (NOAA), the DOD, and NASA in technology development and demonstration.<sup>8</sup>
- In microgravity research, as discussed in *Industrial Applications of the Microgravity Environment*,<sup>9</sup> NASA should play a key role in providing access to the space environment for microgravity research, encourage collaboration between U.S. and foreign microgravity scientists, and maximize multisectoral (industry, university, and government) participation in the program.

Some of the mechanisms described below in the discussion of space commercialization are applicable here as well. Finally, in each area of space applications, efforts should be strengthened to assure full cooperation with other nations where such cooperation broadens the technological base in the interest

of the United States, reduces cost and technological risks through sharing, or results in equal or better return of benefits to the United States.

### *Private Capabilities in Space*

With the exception of communications satellites and possibly launch vehicles, the development of commercial space activities is far off. Efforts to achieve success will take time and will require partnerships between government and industry. The foremost need for space businesses and entrepreneurs is access to capital and to technology developed by the government. Two principles should guide all aspects of commercial space policy: first, the government should procure private space services wherever feasible; and second, government commitments should be long term and stable.

Specific government actions that would help U.S. industry to compete internationally include

- Continued support for the Air Force family of expendable launch vehicles and their commercial derivatives.
- Use of government-owned facilities. Factory tooling, launch facilities, range safety facilities, and down range tracking support during launch represent capital investments that the commercial launch industry cannot afford to provide. These facilities should be made available when their use does not compromise the government mission.
- Commitment to purchase services from the commercial sector. Apart from communications, the largest customer for most space system services is the federal government. With the exception of security requirements and vital public services, the government should not provide its own services if equivalent services are available or can be procured commercially at comparable cost.
- Engineering research and technology development. These are needed to reduce costs and increase reliability in areas of high risk without immediate commercial application and in areas that require long technology maturation lead times. As noted earlier, proof-of-concept demonstrations are sometimes necessary to enable technology transition to industry.
- Indemnity against hazards that cannot reasonably be covered with conventional insurance, perhaps by means of limited third party liability in the event of a launch disaster.

It seems clear that the federal government must continue to be directly involved in supporting and in regulating national efforts and in seeking international fair trade in space-related goods and services for the foreseeable future.

Only communications satellites have proven to be true commercial successes; the commercial futures of other space applications and of the commercial launch industry without government involvement appear highly uncertain.

### **PURPOSEFUL, LONG-TERM MANNED SPACE FLIGHT**

The appropriate long-term reason for putting humans into space remains an area of continuing controversy. Given the costs of a manned space flight program, and its role as the most visible segment of the U.S. space effort, the committee believes that the next Administration should address the rationale for a continued manned program directly, recognizing that there are significant disagreements among thoughtful individuals on this question. Some call for commitment now to a bold program of human exploration and expansion beyond the vicinity of Earth. Others believe that the emphasis should be on discovering the capabilities of humans as permanent residents in Earth orbit and the impact on crews of living and working in the space environment. Still others believe that a large program of manned space flight activity should be postponed in favor of other space activities with more immediate scientific and economic benefits, particularly because a manned program would require a large commitment of U.S. scientific and technological resources, substantial government funding in quest of returns that are largely intangible, and political support that may not be forthcoming.

Although there are situations in which human involvement as an operator of space systems is justified, the most sustainable rationale for today's manned space program is related to the research and technology development activities that are necessary precursors to any decision to commit the United States to sending humans to Mars for initial exploration or back to the Moon for extended stays. Humanity's aspiration to explore other worlds, and perhaps eventually to expand human presence and activity beyond the immediate vicinity of Earth, provides a vision that gives meaning to current activities involving humans in space. To pursue this aspiration, an orbital laboratory—a space station—and a focused life sciences program are essential. Giving primary emphasis to life science and technology development activities, linked to long-term human exploration and expansion, in plans for utilizing a space station provides a long-term focus for that effort. The ultimate decision to undertake further voyages of human exploration and to begin the process of expanding human activities into the solar system must be based on nontechnical factors, and this is appropriately the province of the political process. There is, however, a clear need for substantial scientific and technological research to provide a foundation on which such a decision can be intelligently made. Given human aspirations and technical capabilities, it is difficult to deny that

some men and women will eventually live and work on other celestial bodies. For many visionaries, the question becomes what role, if any, the United States wishes to play in humanity's quest to become a multiplanet species.

The committee accepts as a reasonable answer to this question a plan that focuses for the next decade or more (1) on a space station as a facility for learning how humans fare in extended-duration space flight and for developing the technological capabilities for deep-space human exploration, and (2) on developing the space transportation capabilities to support such a station. Although this kind of plan implies a reorientation in the primary rationale for the space station and a rethinking of plans for outfitting and utilizing it, it may not require major shifts in the current design. Whether such changes would be necessary will depend on the review of the station based on the space goals of the President.

Properly aligned with these goals, the space station program would become a national special initiative, with presidential and congressional commitment to its purposes and to a funding level above that of the base NASA program. This would imply NASA budgets in the \$13 billion to \$15 billion range during the first half of the 1990s.

## SPACE INFRASTRUCTURE

The Congressional Budget Office report *The NASA Program in the 1990s and Beyond*<sup>10</sup> points out that the planned NASA program for the next decade has as its primary aim putting in place an infrastructure designed to support a variety of space missions, including many that are ambitious in scope and that have not yet been approved. Before the country invests in such an infrastructure, there needs to be assurance that it is well matched to future missions and to continuing space activities that are likely to be approved and carried out. Many of those missions and activities would be part of the special initiatives described earlier.

The most important element of the space infrastructure is the capacity to launch payloads into orbit. The country is slowly recovering from the crucial and expensive policy mistake of depending on one system for its access to space. The transition to a diverse, robust, and resilient launch capability is under way but will take a number of years to complete. The Air Force has taken the lead in this process by ordering upgraded versions of the Delta, Atlas, and Titan expendable launch vehicles (ELVs) for most of its space transportation needs, and by planning to use the space shuttle only when its unique capabilities are required. NASA is not as far along in this transition, and its plans for the immediate future still call for primary dependence on the shuttle. In this period, the emerging commercial ELV capacity is treated by NASA as a

backup, even when expendable vehicles could meet mission requirements, for example, for launching planetary missions. A constraint on NASA's ability to diversify is the additional cost of ELVs, but NASA and Congress should make ELV procurement a high budgetary priority, especially where ELVs are needed to support base programs and capabilities.

For future launch systems, NASA and DOD should continue to work together on requirements and technology development. The key desiderata for these advanced launch systems are reliability (because payloads are costly to lose), a capacity for rapid processing (to ensure the timeliness of launches), low cost (allowing access to space for a wider community of users), and diversity and redundancy (so that failure of one element of the launch infrastructure does not shut down the nation's entire launch capability).

The development of commercial launch vehicles and supporting facilities can be an important contribution to the U.S. space infrastructure. Indeed, the reentry of the Air Force into the ELV market has enabled U.S. companies to open their production lines for commercial launchers. This, together with the policies described in the previous section, can help U.S. industry compete. Nevertheless, U.S. launchers face intense competition from foreign enterprises, which often enjoy government support and can charge prices that do not reflect total enterprise costs. In addition, the worldwide overcapacity in launches will make it difficult for private companies to compete without some form of government participation. At issue is the extent of such assistance and whether it should be supplemented by prohibitions on the use of foreign launch vehicles by U.S. users of space.

There is a natural tension between the users of space and the commercial purveyors of launch vehicles and services. For the users, inhibitions against the use of foreign launch vehicles are not desirable because they would increase the cost of access to space. In the view of the committee such restraints should not be imposed, except where national security considerations take precedence. In the absence of restraints, however, the President should commission an inter-agency review of the national support required for a private U.S. industrial launch capability. This group should recommend to the President whether alternative support should be implemented.

With regard to the shuttle, NASA's plans for launching each vehicle three to four times a year appear optimistic, given the uncertainties surrounding the return of the shuttle to routine flight operations under demanding new procedures and safety requirements. Further in the future, the sole dependence on the shuttle for resupplying the space station has the potential of repeating the mistake of depending on a single system for any critical task. A more productive policy would be to husband the shuttle as a valuable resource with a limited life and to depend on unmanned launch vehicles unless the presence of humans is essential. To give resilience to the program and to provide for contingencies,

access to the station by ELVs is highly desirable. A crew emergency rescue vehicle is essential.

The nation has underinvested in advanced technologies related to space transportation systems; this situation must be remedied if intelligent future choices are to be possible. Technologies such as advanced propulsion, lightweight materials, and miniaturization, along with nondestructive testing and cost-reducing techniques, need greater emphasis. A decision on when the United States needs a heavy lift capability or other new manned or unmanned space transportation system must depend on choices of future space missions, but NASA should aggressively develop the technologies needed to enable such decisions.

The currently planned space station program, a key element of an in-orbit space infrastructure, is intended to support a variety of uses. Emphasis on microgravity research as a major station justification has not provided a strong political or scientific foundation for the program. By contrast, an aspiration to extend human presence and exploration beyond the near vicinity of Earth would require understanding the impacts on humans of long-duration exposure to reduced gravity. If such a goal is chosen by the President, the U.S. portion of the space station should be optimized to perform research in life sciences such as space biology and medicine in preparation for future long-duration manned missions. Although this would represent a policy shift away from the previous emphasis on manufacturing in space, a significant amount of microgravity research would still be possible in the European and Japanese modules, where room has been provided for U.S. experiments by agreements signed with these nations. A dedicated U.S. module, a free-flying laboratory, or additional on-board shuttle facilities could be added later if needs for additional microgravity research develop.

Other aspects of the planned space infrastructure, such as orbital maneuvering and transfer vehicles, upper stages for deep-space missions, and tracking and data relay satellites should be carefully and continually evaluated in the context of both NASA's base program of science and applications missions and those special initiatives that are actually pursued. In short, the nation must avoid investing in unneeded capabilities while ensuring the availability of the capabilities required for mission success.

## **A STREAMLINED AND REVITALIZED NASA**

NASA is still able to attract capable young people to its work force and retains a base of skilled, highly motivated individuals eager to take on challenging new missions. But it is also an aging institution, with an urgent need for physical and human revitalization. The agency has shown an organizational cul-

ture resistant to change and oriented strongly to carrying out large-scale, highly visible, relatively short-term missions, rather than far-reaching campaigns that must be sustained over decades. Many doubt the present capability of the institution to carry out the important missions of the future. Some of NASA's institutional problems could be diminished if the agency is given a mandate for carrying out bold, imaginative, and technically challenging missions. But other problems are systemic in character and must be addressed directly. Sustaining an organization capable of excellence in carrying out programs that may take decades to complete requires innovative management approaches.

To reinvigorate the space agency, the committee believes it will be necessary to strengthen Headquarters' management capabilities, redefine the roles and missions of the NASA field centers and make adjustments as needed, examine conversion of field centers to semiautonomous status, and separate NASA's development and operational capabilities.

### **Strengthen Headquarters Management Capabilities**

Although steps have been taken in recent years to address some of NASA's institutional problems, the agency has had great difficulty in attracting and retaining people of experience and capability into Washington for Headquarters positions, a situation due in part to competition with private industry, noncompetitive civil service salary levels, and restrictions on employment after leaving government. This has led to major weaknesses in program management, institutional management, and conduct of external affairs, all areas in which the Headquarters must be strong and competent to be effective in leading the centers and managing the affairs of the agency. This is a general government problem that will require legislative relief from some federal civil service regulations. NASA should have flexibility in hiring and personnel advancement similar to that recently given the National Institute of Standards and Technology to help deal with the issue of noncompetitive salary levels.

### **Reassign Field Center Roles and Missions**

Within NASA, research and technology development is administered largely by the Headquarters Office of Aeronautics and Space Technology (OAST). OAST directs three NASA research centers: Langley, Lewis, and Ames. These centers were the core of NASA's predecessor, the National Advisory Committee for Aeronautics, where they played distinct technology development roles. When NASA was chartered in 1958, additional centers were created to meet mission needs for the space program.

After the Apollo program, as budgets declined, the NASA centers sought new areas of employment. This has resulted in diffusion and blurring of the roles and missions of the centers until the focus of activity in most program areas has been greatly diminished, leading to duplication of physical and personnel resources and skills and increased overhead costs.

The specific roles and missions of the various field centers should be reassessed. A study should be undertaken of these roles and missions with the objective of refocusing efforts and realigning projects with appropriate centers. Changes should be evolutionary and executed over a period of several years.

### **Give Semiautonomous Status to Field Centers**

NASA programs are beginning to suffer because of retirement of skilled people and the difficulties in replacing them and in training and retaining qualified new scientists and engineers. Many facilities at the NASA field centers need rehabilitation as well.

To be competitive from a personnel point of view, NASA needs relief from the civil service limitations it now bears. The Jet Propulsion Laboratory is recognized as an outstanding NASA center. Much of its strength derives from its status as a federally funded research and development center that is operated by a private university and thus able to offer competitive benefits to its personnel.

Converting other NASA centers into government-owned, privately operated institutions would afford them a degree of autonomy similar to that of the Jet Propulsion Laboratory, Lincoln Laboratory, or the National Center for Atmospheric Research and would provide them flexibility to hire and retain outstanding people by offering more attractive salaries—without increasing overall expenditures. However, any attempt at such conversion should be thoughtfully planned to ensure that commitments can be kept and research is not disrupted. Initially, such actions might only be taken at a single center. The experience gained in due course could be applied to other centers. An attempt should be made to associate each center with at least one first-rank technical university, private laboratory, or industrial laboratory and to negotiate facility renovation, when necessary, as part of the conversion process.

### **Separate Development and Operational Capabilities**

NASA's current organization does not distinguish between those responsible for developing new systems and those responsible for long-term continuing operation of existing systems such as the space shuttle. There is concern that NASA may become so consumed by operational matters that the bulk of

its resources will be increasingly devoted to operations to the detriment of NASA's primary function, namely to develop new space systems in support of continued space research in science, applications, and exploration.

The term "operational" as applied to commercial aircraft, ships, or mass-produced defense equipment probably will never apply to space systems in the same context. However, large complex space systems such as the shuttle and the space station are, or will be, driven largely by operations issues—turn-around time between flights; manifesting; or retrofitting of design changes for reasons of safety, cost, payload capability, logistics, and training of crew members. These are not the basic work of research and development leading to new concepts and ideas for future space systems nor for expanding knowledge of the universe and discerning the implications of that knowledge for life on this planet and elsewhere.

There should be within NASA an organization for space flight operations that is separated from developmental activities. Two types of expertise are involved, and it is important that people working in flight operations recognize that as their job and be committed to excellence in its execution. It is equally important that people working in space systems research, development, and program management have the same recognition and commitment and that their activities be separated from engineering maintenance and other operational tasks.

### **NATIONAL SECURITY AND CIVIL SPACE: THE NEED FOR HARMONY**

Although the nation has reaped many benefits from its civil space program, a strong national security space program (intelligence and defense) is fundamental to the welfare of the country. While this paper has focused almost exclusively on civil space policies, defense uses of space can and should both draw on and reinforce the civil program. This is especially relevant because defense and security expenditures for space are now substantially more than civil expenditures. However, neither program receives the full measure of benefit that would derive from closer cooperation between the two.

Relations between the civil space program and national security space activities as envisioned in the 1958 Space Act were to be close and cooperative. The DOD was to benefit from space research and development carried out by NASA, and, under properly controlled circumstances, technology could also flow in the other direction. Cooperation was generally satisfactory up to the point that the shuttle became a divisive issue, but in more recent times the relationship has been particularly strained, due largely to each agency's percep-

tion of its mission. Yet, critical areas of mutual interest remain—common, dual-use technologies; launch vehicles; and launch facilities.

The situation clearly demands more effective liaison between the agencies. NASA needs a high-level person who reports directly to the Administrator to serve effectively as liaison with the DOD. This person should have a strong background in DOD space matters. Waiver of government regulations regarding restrictions on retirement pay should be made if necessary to attract the right individual.

Strong, cooperative programs, particularly in space engineering research, and better liaison between the two agencies would strengthen the national security space program, lend new vitality to civil efforts, and enable the country to receive the maximum benefit from its investments in space. Technical coordination also serves to communicate the existence of new technology, and joint efforts among the players could enable greater accomplishment. Wide awareness of the degree of coordination and of the total national effort will enable the rational assignment of budget priorities. Such coordination has been accomplished effectively in the past—the X-15 program is a salient example. Currently, space power provides another. The Defense Advanced Research Projects Agency, Department of Energy, and NASA/OAST together have undertaken expensive research into the use of nuclear energy in the SP 100 program, research that neither agency would be likely to undertake alone.

Last, the direct merger of civil and defense assets offers the potential for improved efficiency and economy. However, each case is unique and requires thoughtful analysis prior to action. In the area of meteorology both NOAA and the Air Force have run operational meteorological satellite systems in polar orbit for more than twenty-five years. Over time, the two programs have tended toward becoming more complementary. They now use the same basic satellite “bus” and back each other up in case of a loss of in-orbit assets. In the past, foreign policy concerns have been the basis for rejecting a converged system managed by the DOD. In these times of extraordinary pressure on the federal budget, however, this issue should be revisited. By negotiating joint DOD/NOAA management and satisfactory arrangements with international partners, significant savings could be achieved.

Other areas with apparent potential for such efficiency gains include oceanographic and geodetic satellites and launch services. With regard to launch services, the current cooperation between the Air Force and NASA on an advanced launch system is a welcome development.

## SUMMARY AND CONCLUSIONS

The successful launch of the space shuttle *Discovery* on September 29, 1988, restored the U.S. capacity for manned space flight and reopened an important avenue to space. These restored capabilities, however, raise questions regarding their use—what are the U.S. purposes in space, and how can we best achieve them in a time of protracted constraints on federal spending?

These questions require early, yet thoughtful, resolution. Early, because postponed decisions tend to bind policy to ongoing programs, such as the current space station, that become increasingly costly to alter. Thoughtful, because choices made now will shape the capabilities of the United States in space for many decades and will affect commitments to our closest allies. These decisions are a matter of public choice, not technological imperative, and so presidential leadership is essential.

### Decisions Regarding Goals

The most important space decisions the new President must make concern the nation's goals. These must be sufficiently bold to maintain the United States as a leading spacefaring nation, yet paced to be achievable within a constrained budget.

The most controversial decisions concern our goals for human activity in space. The will to explore is a fundamental trait of mankind, and the aspiration to extend human presence beyond the Earth's orbit will lend meaning and support to many aspects of the space program. But human exploration requires a strong scientific and technological foundation. This foundation should be strengthened before it can sustain long-duration exploratory missions.

Finally, U.S. space goals should take into account the rapid progress in space science and technology made by the Soviet Union, Western Europe, China, and Japan. Through cooperative projects, the United States might achieve technological, financial, and political advantages otherwise unattainable. This nation, however, must participate as a reliable partner or not at all.

### Decisions Regarding Methods

To accomplish these goals, the President must select an Administrator for NASA who shares his vision and can work effectively with the Congress to bring it about. This should be an early priority. Interagency policy setting and coordinating mechanisms might be useful, but these cannot substitute for a strong Administrator who enjoys the President's confidence.

NASA itself must be revitalized. This will require stronger management capabilities in the Headquarters and redefinition of the now diffuse missions of the field centers. Some centers should be privately operated to ensure their ability to attract and retain technically qualified people. Space operations should be managed separately from space science, research, and development.

### **Decisions Regarding Programs**

A civil space program capable of achieving national goals should have two distinct components. The first should be a balanced, stable *base* program to ensure U.S. competence in key areas of space activity, resting on a strong foundation of modern facilities and high-quality human resources. The second component should consist of large, long-term *special initiatives* serving U.S. political, cultural, and foreign policy interests and proposed by the President with congressional support.

The space station, which has been the object of much study and for which international agreements have been signed, is one such special initiative and will require an early decision by the new Administration. The committee believes a station is essential to establish the feasibility of human exploration beyond the Earth's orbit and to develop the necessary technologies. However, final decisions regarding the configuration of such a station should await the President's decisions regarding goals. Goals that emphasize human exploration, for example, would require that the U.S. space station module be optimized for research in life sciences. Later, potential special initiatives might include an automated Mars sample return mission, a return of humans to the Moon or a trip on to Mars.

A basic technical competence in space activity is essential to ensure effective use of the resources invested in the special initiatives, and a capable space infrastructure is essential for both the base program and special initiatives. Launch vehicles and services must be reliable, diverse, and affordable. There should also be closer coordination between the civil space program and the defense space program to make better use of common technology and infrastructure.

### **Decisions Regarding Budget Priorities**

The current NASA budget of \$10 billion to \$11 billion provides for a base program and the early stage of one special initiative, a manned space station. The three highest priorities in the base program should be assured access to space by a variety of launch vehicles, advanced technology development to support national security and civil undertakings and to enable challenging mis-

sions in the future, and a varied space science and Earth remote sensing program. A more ambitious base program would also include a vigorous space applications program and support for space commercialization.

Beyond the base program, far-reaching presidential goals for science or human exploration would necessarily lead to one or more special initiatives, recognizing that each could be expected to add approximately \$3 billion to the NASA budget in years of peak expenditures. With a space station among these, the current budget would need to grow to approximately \$14 billion to meet the peak spending years of the station, without reflecting any other growth in the NASA program.

In summary, the new President has a historic opportunity to create a space program that will continue and expand the role of the United States as a leading spacefaring nation. In the committee's judgment the decisions described above are essential to realizing that opportunity.

## ENDNOTES

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