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The space age is 25 years old. Yet in this short time period, one-third of an average citizen's lifespan, the United States has landed men on the Moon, explored portions of the two nearest planets, Mars and Venus, and flown near Jupiter and Saturn. A thriving satellite communications and data transfer industry has also been established, and a highly successful satellite weather observation system has been developed. The United States is on the threshold of an operational land remote-sensing system and will soon be experimenting with new industrial processes in space. In just a quarter of a century, this country has come to rely in a significant way on the unique vantage point and special properties of space.

The stunning success of the first flight of the space shuttle raised anew U.S. aspirations for a vital, useful space program, reflective of the recently developed technical capabilities. Yet in spite of substantial technical progress and a new capability to place men and objects in orbit, this country's civilian space policy lacks a coherent strategic framework. Though lack of clear direction affects the entire space program, public and private, it has had a particularly detrimental effect on the **applications** of space technology. In spite of the increasing dependence on space technologies, there is some uncertainty about the future direction and what questions should be asked.

Requested by the Senate Committee on Commerce, Science, and Transportation, [1] and endorsed by the House Science and Technology Committee[2] this assessment attempts to lay the foundation for a broad review of national space policy, particularly as such policy may relate to civilian applications of space technology, including space transportation but not including tracking, data, and relay or navigation systems. Because the "changing nature of this country's activities in space raises a number of economic, social, legal and political questions," OTA was asked to develop "criteria and analyses to assist Congress in deciding the many complicated public policy issues that are likely to arise in charting the Nation's future in space. "

Although this report analyses the effects of policy decisions on applications of space technology, it also takes a broader view. In examining decisions made in an applications context, certain issues surfaced that affect the entire space program. The course of shuttle development, the emphasis on cost-benefit analysis, and the absence of broad consensus and consistent support for the overall space program goals have had their effects on programs outside of space applications. As far as is possible, this assessment addresses these wider policy areas and suggests policy options for making the civilian space program a more robust part of the Nation's future. It does not explore the national security space program except insofar as it affects the civilian space program.

Applications of space technology involve rather different assumptions than do scientific missions such as planetary exploration or the deployment of telescopes in space. They therefore necessitate a different policy treatment. The National Aeronautics and Space (NAS) Act of 1958 established the National Aeronautics and Space Administration (NASA) as a research and development (R&D) agency for space technology. In that role, it has served the Nation well. Yet **development** implies that a point will be reached when a new device or technical system is ready for use in an operational mode. It is at this juncture, in the transfer of developed technology to the realm of routine operation, that many of the most important issues in applications of space technology surface. Technology developed with NASA funds is technology paid for by the U.S. taxpayer. Will another agency or a private firm receive the technology? If so, how will the transfer be made? The history of the space program provides us with several examples of how that transfer can be ef-

[1] Letter from the U.S. Senate Committee on Commerce, Science, and Transportation requesting the OTA Space Policy and Applications Assessment, September 1978.

[2] Letter from the U.S. House of Representatives Committee on Science and Technology, June 1981.

[3] Letter from the U.S. Senate Committee on Commerce, science, and Transportation, op. cit.

fected. Communications satellites were "spun off" to the private sector very early, weather satellites to the National Oceanographic and Atmospheric Administration (NOAA). Navigation satellites have remained under Department of Defense control; terminal equipment for civilian use is available commercially. Land remote-sensing satellites are at a historic juncture in their development as they pass from R&D to operational status, This assessment examines different possibilities for their future operations.

In addition to the issues raised in considering the transition from Government-supported R&D to operational status, there is a prior concern: when, where, and for how long should the Government involve itself in funding space R&D efforts? By its nature, space R&D is expensive, largely because the costs of raising people and materials beyond the atmosphere and supporting life in orbit are very high. The **risks** of R&D in space are also high, not only because traveling to space is inherently risky to humans and equipment, but also because so little is yet known about the effects of extended microgravity and high vacuum on physical and chemical processes. Even with more than two decades of experience the United States still has little more than 8 hours of experimental results on space-based processing of materials. These risks also bear an economic cost that must be taken into account when considering R&D in space. What is the proper balance between Government and private funding for R&D? What incentives are needed to encourage the private sector to assume a major role in innovation of space technology? What are the effects of emerging foreign competition on the U.S. space program?

These and other issues in the space program exist in the context of similar issues relating to Government-supported R&D in other Federal programs. Accordingly, a considerable body of analysis on this broader subject is already available. For space, however, many of the issues are too current to have been discussed in detail. Hence, a major part of OTA's task was to determine just what are the important issues for space applications. In order to identify and refine the issues that are amenable to policy treatment, OTA convened a series of workshops that drew together experts from the major space technologies OTA selected to study. They treated:

- ***Remote sensing: Government user concerns.*** Though still an R&D system, the Landsat program has provided data to users of remote-sensing data since 1972. This workshop was an effort to learn what problems some of the major users of the data had faced in the past and what concerns they have for the future as the Landsat program moves into operational status. It included Federal, State, and local users of the data, as well as representatives of two private corporations that process Landsat data, and the international banking community.
- ***Commercialization of remote land sensing.*** Several proposals have been made to transfer part or all of the current Landsat system to the private sector. This workshop convened to: 1) assess the strength of the market for remotely sensed data from space and to identify the factors that affect this market, and 2) explore appropriate models for commercializing remote sensing. Since space communications technology is already highly commercialized, OTA invited several participants who have had considerable experience with the communications satellite industry as well.
- ***Space transportation issues.*** For the present, NASA will be operating the space transportation system. What interest does private industry have in owning and/or operating a reusable shuttle-like transportation system? Is industry interested in marketing and launching expendable launch vehicles? This workshop asked these questions and, in addition, explored the nature of the incentives that the aerospace industry sees as necessary to help it do further space transportation and space construction research, development, and demonstration.
- ***Materials processing in space.*** The shuttle has raised expectations for using the special properties of space to manufacture low-mass, high-value products that cannot be made on Earth. This workshop explored the state of national and international programs in materials processing and the prospects for

manufacturing products in space. It discussed the NASA/industry Joint Endeavor Program, which brings NASA into working partnerships with other firms, and suggested other incentives that could attract industry to invest in R&D in space.

- ***International issues in commercial space systems.*** Other industrialized countries of the world also have a strong presence in space, some components of which will compete directly with U.S. systems. This workshop explored the complicated relationship between cooperation and competition in space in the free world and compared commercialization policies in the United States, Europe, and Japan. Among other topics, it discussed the private French corporations Spotimage and Arianespace, and the competitive challenge that they present to comparable U.S. systems, as well as the prospects for future multinational applications organizations like INTELSAT.

Following the development of the issues in these five workshops, OTA convened a ***Workshop on Policy Alternatives*** to consider a variety of options for addressing the major concerns identified. The workshop identified as crucial the need to develop a high-level Federal forum for reaching consensus on the direction of the space program and devoted substantial discussion to policy options addressing this need.

In addition to the workshops, several contractors contributed to this report, as well as a number of individuals conversant with the issues discussed herein. A large body of literature now exists on the space program, but we as a society are just beginning to understand the depth and breadth of its effects on our economic, social, and political fabric. Policy analysts are now able to perceive long-term effects of past decisions and can assess with more boldness the possible future effects of our efforts in space.

ORGANIZATION OF THE REPORT

Space technology, whether we are aware of it or not, is pervasive in our lives. After the presentation of the report's chief issues and findings in chapter 3 the main body of the report begins in chapter 4. Conceived out of concern over Soviet achievements in space in 1957, the NAS Act remains a basic foundation for national space policy. Chapter 4 discusses the policy history of the U.S. space program and outlines the changes that have been made since 1958 in space policy. Based on an analysis of past history, it also suggests areas for review today.

Chapter 5 begins with a discussion illustrating our dependence on space technology, followed by a summary of the current status of the U.S. space program and a short section on U.S. public attitudes and perceptions about space.

After summarizing the major features of the militarv space program and how it interacts with the civilian program, chapter 6 discusses the question of the separation between the two programs that is built into the 1958 NAS Act. It also explores the important question of transfer of technology developed for the military space programs to civilian uses, and how the pace of that transfer might be increased for the ultimate benefit of the civilian program.

Chapter 7 presents the current status of foreign space achievements and future prospects for continued cooperation and competition between the United States and other states in space science. Of major concern is the competition in space applications that foreign entities pose for U.S. efforts. This chapter also outlines some of the general foreign policy questions raised by different space policies, along with the outstanding international legal problems that could affect U.S. applications programs.

Chapter 8 summarizes the prospects for transferring the results of space R&D to the private realm for commercial exploitation, it also describes the process that American industry follows in deciding to do R&D. In a more specific way,

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it further develops the kinds of incentives and barriers to entering upon a program for space R&D.

Institutional effectiveness is critical to policy success. The institutional questions that have to be solved in transferring an R&D system to operational status, whether it be operated for the public good or for private profit, are complex. Because Government policy strongly conditions the framework within which private sector activities exist, chapter 9 builds on the issues concerning commercialization of R&D that are developed in chapter 7, as they relate to institutions. It also reviews the institutional frameworks that have been set up in the public good.

Whereas each of the preceding chapters raises several policy issues, chapter 10 summarizes the policy foundation of U.S. space activities. Further, it suggests new policies and integrates them with the policy framework that now exists. It analyzes a range of major policy options that could form the foundation for the U.S. future in space.

The appendixes contain material that was considered germane to the assessment, but too detailed for inclusion in the body of the report. Among these are summaries of case studies prepared for this assessment by the Bureau of Land Management and the Foreign Agricultural Services of the Department of the Interior and the National Climate Program in NOAA of the Department of Commerce. Three contributed reports on materials processing in space from the TRW Corp., McDonnell Douglas Corp., and from NASA, plus material gathered by an OTA contractor make up the case study on materials processing.