Chapter 9

INSTITUTIONAL CONSIDERATIONS

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INSTITUTIONAL CONSIDERATIONS

INTRODUCTION

National civilian space policy is implemented in a specific institutional framework, one which has evolved over the almost 25 years of U.S. space activity. (The evolution of that framework is described in app. A.) This framework is the **means** for accomplishing policy objectives, and it must be evaluated by how well it has done so and, more importantly, can be expected to do so in the future. Is the current institutional framework, which was largely established in the early years of the civilian space program, still appropriate, given the options for future national space policy? This chapter will examine this question and suggest the characteristics of alternate institutional frameworks for the U.S. space applications effort.

Policy

policy formulation includes, first, the identification and evaluation of alternative objectives and ways of achieving them, and second, the choice of a particular set of objectives and courses of action (i.e., policies). Policy implementation is the application of policies to achieve particular goals. Although policy choice and policy execution are closely intertwined, this chapter focuses on the **institutional framework for implementing policy,** not on the mechanisms for policy formulation and choice, which are discussed in chapter 10. What receives attention, rather, are the links between policy objectives and institutions, and the difficulties of establishing any one framework to meet significantly differing or changing objectives.

One qualification to this distinction is immediately necessary. If the activities of a particular institution are not tied to some set of externally determined needs or goals, then the internal needs and objectives of the institution itself—growth, maintenance, or, at a minimum, survival—can emerge as dominant influences on policy. The U.S. space program has not been immune to this tendency. For example, in 1969 the proposals for a future space program built around orbiting space stations and a space transportation system operating in the region between the Earth and the Moon, with an eventual goal of manned planetary exploration, emerged from within the National Aeronautics and Space Administration's (NASA'S) manned space flight organization, not in response to some externally imposed goal or objective.

overall, this assessment explicitly recognizes that the private sector can play an increasingly important role in space. The present chapter, in treating Government institutions and public policy mechanisms, provides some guidelines for determining the appropriate division between public and private sector roles in space, and it considers various methods and incentives to stimulate and support private sector activity, including potential mechanisms for Government/industry cooperation or collaboration in space applications.

In summary, this chapter analyzes issues related to alternative institutional frameworks for organizing the Government's share of the national civilian space applications program. It does not attempt to identify a single "best" framework; the choice of an institutional arrangement is a derivative issue, one dependent on answering the question, "Best for what?"

CURRENT INSTITUTIONAL FRAMEWORK

Before alternative institutions are examined, it is important to characterize the current structure within the Federal Government. The major Government actor for civilian programs is still NASA, although other Federal agencies are becoming increasingly involved in space. Table 20 lists the

Table 20.—Federal Agencies Active in the National Space Effort[a]

Agency	Budget for space activities (FY 1982 estimate in millions)	Significant space-related work
Department of Defense	$5,916.3	Communications, command and cent rol. Navigation, environmental forecasting. Surveillance R&D related to future military applications.
NASA	$5,617.3	R&D related to science and applications; transportation
Department of Commerce	$126.3	Environmental monitoring. Remote sensing (in 1983). Weather satellites.
Department of Energy	$38.0	Space nuclear power systems.
Department of Agriculture	$17.2	Crop assessment. Monitoring of soil, water, and vegetation.
Department of the Interior	$12.6	Surveillance and monitoring of natural resources. Mapping.

[a] It is not ~O~~ibla t. ~r~vlde a separate budget estimate for irltelllgence-related space activities, some of which are included in DOD figures.

SOURCE: Office of Management and Budget.

Government agencies with significant space-related activities.

Current NASA Structure

The institution with primary responsibility for the civilian space program is NASA, created in 1958 in response to Sputnik and mobilized in 1961 to achieve a goal of preeminence in all areas of space activity, particularly the development of the (large) technological systems required for the Apollo program. It is essential to emphasize that NASA was **not** designed to conduct routine operation of space systems that provide services to public and private users. Instead, operational responsibilities have been assigned ad hoc:

1. The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite Services (formerly the Weather Bureau) operates meteorological satellites, while NASA continues to do relevant research and development (R&D); NOAA is also scheduled to assume management of the Landsat remote-sensing system in early 1983.
2. COMSAT was chartered to be the initial operator of communications satellites used for international traffic; later, the domestic communications satellite market was opened to any firm that could meet regulatory requirements.
3. NASA operates space launch systems as well as conducting R&D on space transportation.

NASA's internal structure has remained basically unchanged during the past two decades. NASA headquarters in Washington is responsible for overall management and technical direction of the various activities carried out by NASA field centers (many of which were inherited from the National Advisory Committee on Aeronautics), and outside contractors. it is also the focal point for relations with the Executive Office of the President, Congress, and other Federal agencies. The various NASA field centers are in charge of specific projects; most of the actual R&D work is performed by private contractors. The Federal Government initiates programs and projects, monitors technical performance of contractors, and (to date) has been the primary user of the spacecraft and launch systems incorporating the results of

R&D. Some 80 to 90 percent of NASA's annual budget goes to external grants and contracts; this pattern has remained relatively constant over the years. Though NASA has maintained a substantial in-house research capability, the bulk of its expenditures have gone to establish an extensive network of research organizations in industry, universities, and nonprofit organizations. Table 21 shows the past and present size of NASA and its support base.

The set of NASA field centers today is the same as it was during the early 1960's, except that a recent reorganization has led to a reduction in the number of centers reporting directly to NASA headquarters. Table 22 gives information on the current NASA field center structure. Because NASA is responsible for different kinds of space activities (as well as experimental aeronautical work), including science, applications, and development of technical capability, and because responsibility for each of those missions and its associated projects is rather closely tied to one or more field centers, one of NASA headquarters' major responsibilities is allocating priorities and resources. Decisions on policy and program priorities thus directly affect the associated field centers, and the current structure fosters competition among the centers within NASA's overall program. In this competition, for reasons to be examined, technology development and space science and exploration have traditionally been more successful than space applications.

NASA's institutional base constitutes an impressive national resource for space R&D. NASA's personnel, facilities, and contractor support base provide the means for carrying out challenging and significant efforts, as Apollo, the space shuttle, and Voyager (among many other accomplishments), have demonstrated. As Congress and the Nation consider future objectives for the U.S. space program, the resources NASA has already developed must be considered. If these resources are not used wisely and well, they will disperse and will be difficult to reassemble.

Department of Commerce Space Activities

The Department of Commerce's (DOC'S) involvement in space dates to 1961, when Congress directed DOC to establish and operate a meteorological satellite system to observe worldwide environmental conditions and to report, process, and apply data obtained by this system. This responsibility is now borne by NOAA. More specifically, NOAA's meteorological satellite programs are lodged in the National Earth Satellite Service (NESS) (until recently the National Environmental Satellite Service). In November 1979, NOAA was also assigned responsibility for operating the U.S. land remote-sensing satellite systems, beginning with Landsat-D, in 1983.

Through the years NASA and NOAA have worked closely together to improve the Nation's ability to observe Earth from space: NASA conducts R&D, and NOAA operates the satellite systems once they have been proved. This relationship dates back to the initial TIROS weather satellites and will continue in the Landsat program.

Table 21.—NASA and Its Contractor Base

Year	NASA budget in millions	Personnel at NASA headquarters	Personnel at NASA field centers[a]	Funds provided to NASA grantees and contractors, in millions: Industry	Funds provided to NASA grantees and contractors, in millions: University and nonprofit
1962	$1,825.3	1,641	26,938	$1,030	$50
1966	$5,175.0	2,152	35,903	$4,087	$178
1971	$3,312.6	1,894	31,805	$2,279	$162
1981	$5,537.2	1,658	25,755	$3,746	$361

[a] Jet propulsion Laboratory is included, although formally it is part of the California Institute of Technology

SOURCE: National Aeronautics and Space Administration.

Table 22.—NASA Institutional Structure

Name of center	FY 1980 R&D funding	FY 1980 research and program management funding	FY 1980 personnel complement
Headquarters (Washington, D. C.)	$ 133.8	$89.5	1,658
Johnson Space Center—manned flight (Houston, Tex.)	1,347.3	164.1	3,616
Ames Research Center (Mountain View, Calif.)	159.7	87.8	2,212
Goddard Space Flight Center—remote sensing (Greenbelt, Md.)	548.3	151.2	3,941
Kennedy Space Center—launch services (Cocoa Beach, Fla.)	277.1	133,2	2,291
Langley Research Center (Hampton, Va.)	169.8	114.0	3,094
Lewis Research Center—aeronautical research (Cleveland, Ohio)	168.1	94.8	2,901
Marshall Space Flight Center—space propulsion (Huntsville, Ala.)	846.8	155.9	3,646
National Space Technologies Laboratory (Bay St. Louis, Miss.)	9.2	4.9	111
Jet Propulsion Laboratory[a]-space science (Pasadena, Calif.)	276.5		—
	$3,936.6	$995.4	23,470

[a] JPL is federally funded but is operated by the California Institute Of Technology.

SOURCE: National Aeronautics and Space Administration, Office of Technology Assessment.

Satellites currently operated by NOAA/NESS include: 1) polar orbiting satellites with day and night global coverage and 2) geostationary satellites that provide continuous viewing of cloud and storm patterns in the Western Hemisphere. In addition, NOAA was to have been a participant, together with NASA and the Department of the Navy, in a proposed National Oceanic Satellite System; (NOSS) the project, however, has been indefinitely deferred.

NESS disseminates its data and products within a few hours of acquisition to a wide variety of users, the most prominent of which are the National Weather Service and the Department of Defense (DOD). The data are also recorded and archived by NOAA's Environmental Data and Information Services. The data from the geostationary satellites are distributed in real-time to seven satellite field services stations, which further distribute them to a number of users. Meteorological data from NOAA satellites are also widely disseminated and used by foreign countries.

NOAA integrates satellite-derived data with data derived from other sources in preparing weather forecasts and warnings about disturbances on the Sun, in space, in the upper atmosphere, and in the Earth's magnetic field; integrated data are used in various resource management tasks as well. In addition to using satellite-derived data for operations, NOAA conducts a variety of R&D programs which make use of these data or directly support its space-related activities.

Other DOC organizations involved in space-related activities include the Maritime Administration, which uses satellites to improve the efficiency of ship communication, navigation, and operations, and the National Telecommunications and

Information Administration, which is the Federal agency responsible for policy on the use of the frequency spectrum and geostationary orbit and for exploring new applications of telecommunications technology.

Other Federal Space Efforts

The largest Government space program, at least as measured by budget outlays, is conducted by DOD. This chapter focuses on civilian space activities; for a description of DOD programs, see chapter 6. The space programs of other agencies are as follows:

1. The Department of Energy (DOE) carries out technology development and production efforts for nuclear-powered electric generators to be used on long-duration spacecraft suitable for planetary missions. DOE has studied space systems to dispose of nuclear waste, and makes use of remote sensing data in support of its responsibilities to seek energy sources and to site facilities for nuclear waste disposal. and other energy-related needs.
2. The Department of the Interior (DOI) uses space-derived data in executing its responsibilities in resource management. The U.S. Geological Survey, part of DOI, manages the Earth Resources Observation Systems (EROS) program, which develops, demonstrates, and encourages applications of remotely sensed data acquired from both aircraft and spacecraft (see app. B on the Bureau of Land Management).
3. Other agencies of the Government, particularly the-Department of Agriculture, but also organizations such as the Environmental Protection Agency, make routine use of space-derived data (particularly from Landsat) in carrying out their missions. They do not, however, participate in space-related hardware development. The Department of Agriculture has been a major participant in such R&D efforts as LACIE (large area crop inventory experiment) and AgRISTARS, and integrates Earth observation data in its crop assessment and forecasting operations (see app. C on Foreign Agricultural Service),

DIFFERING GOALS, DIFFERING STRUCTURES

There is no single institutional framework that is “best” for the civilian space program. Rather, different national objectives in space can best be accomplished by different institutional structures; goals and the means to achieve them should be matched. The three scenarios below suggest the wide variety of institutional frameworks possible, and how they are related to various futures for the civilian space program:

- an expanded program, focusing either on a new goal comparable to Apollo or the shuttle, or on a variety of advanced applications projects;
- continuation of the status quo; and
- further reductions in the Government share of the civilian space program.

An Expanded National Space Program

One possibility for the national space effort is setting another Apollo-like goal, i.e., a large and challenging enterprise to be achieved on a pressing schedule. Several such enterprises have been suggested over the past few years; most involve the development of capabilities for routine manned operations in low-Earth orbit, now that the shuttle has made this location more accessible for a variety of purposes. Other proposed objectives include: 1) a large structure in geosynchronous orbit, and development of reusable transportation to GSO, and 2) solar power satellites. NASA’s current leadership has endorsed the concept of some form of low-orbit, manned, space operations center as NASA’s **next major** project, and congressional space committees have, in general, supported such proposals.[1] Like the shuttle, an orbiting operations center would be a **means** to carry out a variety of space applications and science missions, not an end in itself.

Such a high-technology development project would require the kind of engineering effort which current NASA development centers are best able to provide. NASA's present institutional structure is largely a product of the 1961 commitments to preeminence in space, particularly the Apollo program. One consideration is that the ability of NASA and its contractors to undertake a substantial engineering effort will erode without a commitment to such an enterprise. Scientific and engineering talent of the highest quality is in short supply in the United States. Given the current shortage of manpower available to support military and private sector space activities, NASA's personnel will be lured away to more challenging work elsewhere if NASA does not soon undertake a major new effort. Some have suggested that NASA and its technical and managerial capabilities should be mobilized for nonspace R&D projects, particularly in energy. Whether NASA's technical expertise, problem-solving approach, and institutional characteristics are relevant to meeting other national goals requires further analysis, and is outside the scope of this assessment.

Another scenario would be based on a judgment that the current and potential benefits of applying space technology justify increased Government investment in applications R&D, particularly in the face of international competition and foreign government support for applications programs. Included in this scenario would be Federal commitments: 1) to take the policy and institutional initiatives needed to move from development to operations in the public sector, and 2) to introduce innovative methods to bring the private sector into full partnership. There would be no overriding Apollo-like project to key the national effort; rather, the program would become more pluralistic. Several mission agencies and private firms could participate substantially.

Continuation of the Status Quo

Development and testing of the space shuttle have been the major components of NASA's budget over the past few years, and they are likely to dominate for the next three or four. Partly as a consequence, there have been few "new starts" in any program area—science, exploration, applications, or technology development. Continuation of this situation would reflect a policy decision that NASA's major role should be developing space transportation capabilities for other users, such as DOD, the private sector, and other civilian agencies. Activities in space science and applications would continue, but at relatively low levels.

The United States probably could not afford to maintain NASA's entire institutional base under this scenario. Although it may be in the national interest to maintain NASA's capacity to undertake a major technology program, NASA as it currently exists would eventually become outdated. Certain applications activities, and their associated centers, might be "spun-off" to the private sector or the military.

A Tightly Constrained Program

A variation of the preceding scenario with somewhat the same institutional implications is one in which no compelling rationale for a large-scale civilian space program gains acceptance. In this case, NASA's size, scope, and mission would be reduced to a continued but restricted investigation of potential space applications. Aggressive pursuit of other promising opportunities would be postponed until the potential payoffs can justify investment of substantial public resources. One possibility is the gradual retrenchment of NASA toward a research and early technology development organization with close links to the users of R&D. This restricted range of responsibilities would be similar to that of NASA's predecessor, the National Advisory Committee on Aeronautics (NACA).[2]

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[1] Administrator James Beggs has repeatedly made this point, and there is currently a top-level study underway within NASA related to future space station plans. See, for example, *Aviation Week and Space Technology,* July 27, 1981, pp. 23-25.

[2] For a discussion of NACA, see Arthur L. Levine, *The Future of U.S. Space Program (New* York: Praeger, 1975), ch. 2.

A key issue in all the above scenarios would be the division of roles and responsibilities between public and private sectors, and between NASA and other agencies within the Federal structure. There are two possible basic alternatives, and the remainder of this chapter provides criteria for evaluating them. These alternatives are:

1. NASA could become **the** civilian space agency, not just the space R&D agency. In addition to continuing to do R&D, NASA would operate space transportation services, the space segment and initial data processing for Earth observation systems (weather, land remote sensing, ocean remote sensing), public service communications satellites, and other space systems pro bono publico. NASA would also develop common "in-orbit infrastructure, " i.e., platforms, power supplies, communications and telemetry systems, construction and servicing capabilities, etc., which public and private organizations could use on a reimbursable basis. In this scheme, NASA would assist firms in transforming new space applications into profitable commercial ventures.
2. NASA could remain limited to an R&D role, and other Government agencies, such as NOAA, or private or quasi-private sector entities, such as COMSAT, would undertake various operational activities. NASA, in this option, could either: a) conduct an R&D applications program to advance technology without regard for its immediate commercial potential, b) concentrate on public good applications of space technology, leaving it to the private sector to invest in developing commercial applications, or c) focus on supporting public and private users. One issue related to this scenario is the allocation of responsibility for operating "space utilities" such as transportation, power, communications, construction facilities, etc.

In either alternative, more effective instruments would be required to link private and public sector users of space technology with NASA, the central R&D space agency. A tradition of collaboration between NASA as an R&D agency, operators of space systems, and the user communities has not yet developed, but is a necessity if this alternative is to be viable. NACA, NASA's predecessor, had a mixed public-private governing board representing all interests involved in aeronautics, both civilian and military. While not necessarily a relevant model for a "new NASA, " this pattern of developer-user linkage proved very successful in advancing the U.S. position in aeronautics.[3]

Much of the remainder of this chapter is a detailed analysis of the institutional issues involved in operating space technologies and in strengthening coordination between governmental and nongovernmental developers, operators, and users of space technology.

As the issues relating to commercialization are discussed in chapter 8, the following will concentrate on Government operations, though many of the issues involved are similar. For the purpose of this analysis, it is possible to separate the process of applying space technology into five distinct phases, each of which has different institutional implications. The following sections discuss generic institutional implications.

1. research and development;
2. demonstration;
3. transition to operational status;
4. operational status; and
5. support of operational systems, including continuing R&D in an applications area.

After this general discussion, and after analysis of the international institutional aspects of space applications in the next section, the last section discusses the institutional issues specific to each applications area,

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[3] Ibid.

INSTITUTIONS FOR SPACE APPLICATIONS R&D

NASA was assigned Government responsibility for civilian space R&D by the National Aeronautics and Space (NAS) Act of 1958. However the act was not specific about NASA's (or anyone else's) role in using or operating the results of that R&D. In space applications, almost by definition, R&D is conducted not as an end in itself but as a necessary step in reducing uncertainties and developing methods for the use of space systems to provide public or private benefits. Since applications are meant to be **used,** the key institutional question is how to create a productive relationship between performers of R&D and the ultimate users.

There are crucial differences between R&D conducted for systems to be operated by the Government and R&D for those to be operated by private firms. In particular, R&D for commercial applications must be influenced by considerations of eventual profitability.[4] However, there are also important common elements, particularly with respect to the relationship between user and developer. In the space sector, NASA has from the start (with the exception of launch services) been confined to R&D. This limitation, reinforced by the fact that NASA attracted in its early years engineers oriented towards advancing the frontiers of knowledge and technological capability, and the institutional culture derived from missions such as Apollo and planetary exploration, have certainly influenced NASA's applications efforts. NASA has developed an orientation towards "technology push" efforts. This orientation militates against being responsive to potential operators and users of space technology, who exercise "demand pull" on the directions of space applications development.

NASA, particularly in its early years, inevitably put more stress on advancing the technological frontier than on developing technology in response to user demands (which were virtually nonexistent) or in anticipation of the kinds of demands likely to arise. As the practical uses of the new technologies began to take shape, however, NASA continued to emphasize the development of more sophisticated applications technology rather than bringing adequate applications systems into early operation. This is in part a reflection of the reality that, once NASA completes R&D for an applications program, it must transfer it to some user outside of the agency. Consequently, the organization tends to hold on to programs, even if that means prolonging the R&D phase beyond the optimum point. The Landsat program, which many users have been treating as if it were already operational, is a case in point.

In recent years, NASA has put a higher priority on developing closer relationships with potential operators and users of space technology, particularly in remote sensing and advanced satellite communications. The management structure which had been adopted for the now-canceled NOSS gave NASA a central R&D role in bringing the demonstration system into being, but involved users, particularly from other Federal agencies, in management committees at three different levels of program operation. Figure 15 illustrates the NOSS management structure; it seems that a similar structure might be appropriate in other applications areas.

Such a structure links R&D managers with users and provides a setting for resolving differences in priorities, technical requirements, and budgetary commitments among involved participants. Few space applications R&D projects serve a single set of user requirements, and few will involve only NASA in their conduct. Thus a management structure for future application programs in which developers, operators, and users are linked from the start appears an improvement over past management practices in, for example, the Landsat program.

There is an unavoidable tension between the developers of a new technological capability and those who hope to use it. The most frequent failure in Federal R&D programs is inadequate attention to the realities and needs of eventual users in the planning and earliest research phases of

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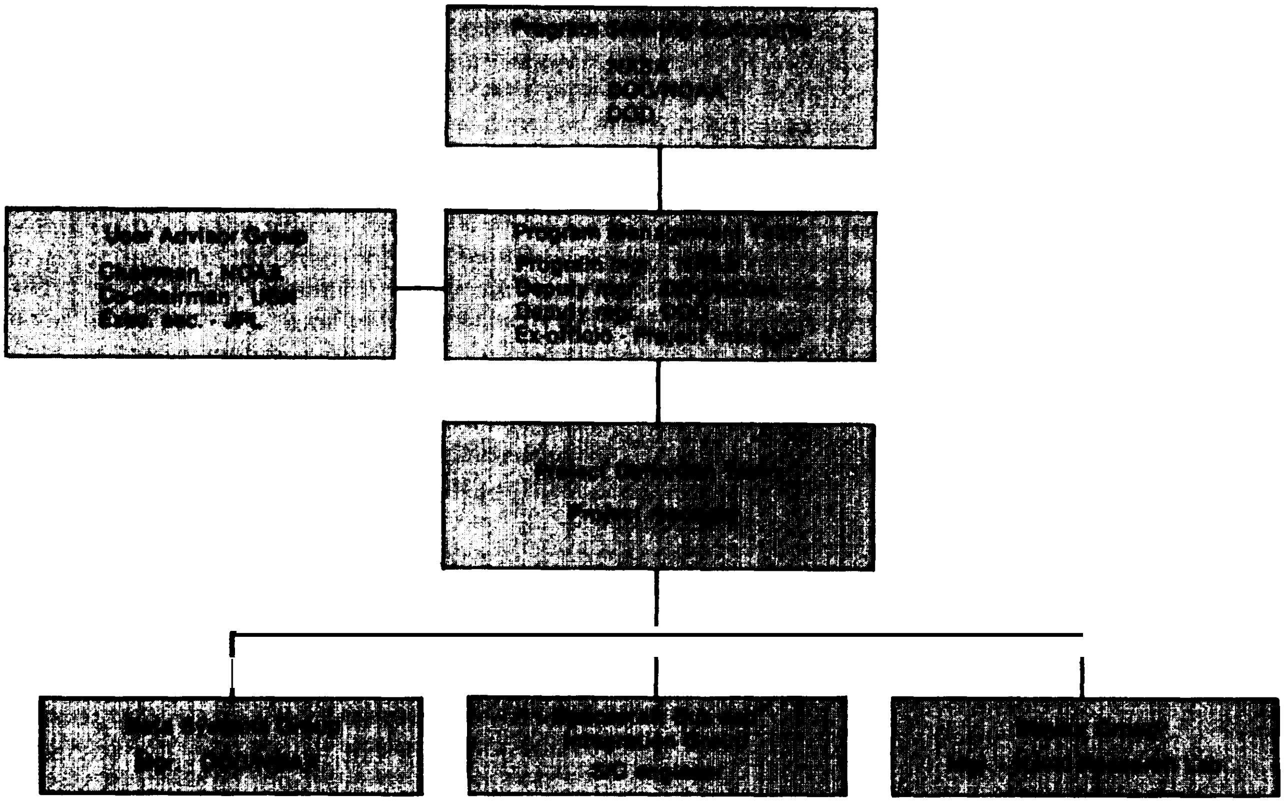
[4] This distinction is well-made in Peter House and David Jones, *Getting It Off the Shelf* (Boulder, Co.: Westview Press, 1977), chs. 3-5.

Figure 15.–Management Structure of NOSS



SOURCE: National Aeronautics and Space Administration.

a programs Engineers prefer to work in an environment where the only constraints are technological. In addition, the resources provided for planning an R&D project, as opposed to conducting it, are often inadequate. As R&D is being planned, users should participate in identifying specific applications, the environment in which they must operate, and the economic factors that will constrain an operational system. None of these factors has been given priority in NASA's applications programs until recently; rather, new technological opportunities have been the driving force in R&D planning.

Space activities are justified by a variety of rationales. But to the degree that space applications are justified by their potential benefits, there should be careful attention to the costs of operating a system. R&D serves in large part as a means of reducing uncertainty, but reducing cost and performance uncertainties may be just as crucial as reducing technical uncertainties. Certainly the benefit calculus will be different for public and private applications, since Government is not concerned with showing a profit. If a service can never be profitable, but society needs it, then it is Government that properly provides such a service. Even for public services, however, operating costs must be a continuing focus of concern throughout an R&D effort.

The LACIE program provides an example of such problems in the space applications area.[6] These problems can be avoided if developers work closely with users in guiding an R&D project.

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[5] Norman McEachron, et al., *Management of Federal R&D for* Commercialization, report from SRI International to Experimental Technology Incentives Program, Department of Commerce, 1978, p. IV-28.

[6] General Accounting Office, *Crop Forecasting by Satellite: Progress and Problems*, GAO Report, PSAD-78-52, Apr. 7, 1978.

If the R&D is in an area intended for eventual commercialization, then market analysis needs to be incorporated even at early stages in the R&D effort. The total range of users, their current patterns of operation, and the ways in which a new application might modify those patterns need to be identified. The likelihood that services or products can be produced at a cost acceptable to private purchasers needs to be estimated, and these estimates refined during the life history of the R&D effort. In this way, R&D intended for commercial application will be guided by private sector considerations from its inception.

In summary, then, the R&D phase of space applications activities needs to incorporate substantially more planning for eventual application than has been the case with NASA's past applications programs. Users must be significantly involved, without stultifying the creativity of researchers. Some means of resolving inconsistencies among user needs is required. Cost performance as well as technical performance must be borne in mind throughout the R&D process. In areas of new applications, the R&D project should be designed to give early and concrete evidence of specific benefits and the ways in which they will assist various classes of users. The kind of management structure which had been planned for the NOSS program might provide many of these features for public sector uses; commercial activities require market analysis and private sector involvement.

INSTITUTIONAL ISSUES AND DEMONSTRATION PROJECTS

The primary goal of an R&D program is to reduce uncertainties about the technical characteristics of an application opportunity. By contrast, a demonstration project is intended to illustrate the performance of a new technological capability in a realistic operating environment, in order to provide the information which potential operators need to bring that new technology on line. When an R&D program provides evidence that a new technology is likely to be commercially viable, potential private sector operators can undertake their own demonstration. But when the R&D program does not provide clear evidence, or when the benefits have a mixed public/private character, then the Government must subsidize at least part of the demonstration phase.

Failure to recognize and adjust to the differences between the R&D and demonstration stages is a likely source of difficulty in bringing new applications into being; it is very difficult to combine R&D and demonstration efforts in one undertaking.

It is possible to specify characteristics linked to the success of a demonstration project in providing the information to decide whether to take a new technology to operational status.[7] Those characteristics include:

1. ***A technology well in hand.*** Demonstration projects are not laboratories for resolving technological problems; rather, a successful demonstration project concentrates on providing information on the nontechnology-related characteristics of a new capability. Thus, demonstration projects should not be initiated prematurely, while major technological uncertainties remain.
2. ***Cost and risk sharing between developer and potential operator.*** If the demonstration project is a marketing tool to demonstrate to potential users the operating characteristics of a new technology, but these users are not included in planning or, where feasible, in sharing the costs and risks of the demonstration project, it is unlikely that the project will be responsive to the users' need for information.
3. ***Congruence with technology delivery system.*** In order to bring a new technology into

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[7] Walter Baer, Leland Johnson, and Edward Merrow, *Analysis of Federally-Funded Demonstration Projects,* report from Rand Corporation to Experimental Technology Incentives Program, Department of Commerce, 1976, p. v.

being there must exist some way to translate a technological possibility into an operating reality. The demonstration project should be organized to reflect the specific characteristics of such a "technology delivery system." When the technological capability does not match existing manufacturing or utilization patterns, particular care is needed to consider how those patterns might be affected.

4. ***Inclusion of all elements needed for operation.*** Successful demonstration projects should include in their planning and execution: potential operating organizations, potential users of a new technological capability, manufacturers of the systems in which the R&D result will be embedded, potential regulators, and other target audiences.
5. ***Absence of tight time constraints.*** Demonstration projects which face tight time and budget constraints are less likely to provide the necessary information needed for an operation decision.

The demonstration phase has proven to be a crucial step in translating R&D work into successful operating systems; experience in the defense sector ("fly before you buy"), for example, confirms this observation. The role of a separate demonstration phase is an area of both policy and program uncertainty in recent space applications efforts, and this uncertainty needs to be resolved in order to make the Federal R&D effort in applications more likely to pay off. In particular, NASA has not been able to secure the budgetary resources or political support required to conduct a demonstration, as defined here, of remote-sensing systems; rather, NASA has attempted to combine R&D and demonstration efforts in the Landsat program. Earlier communications satellites such as the Syncom project in the 1960's and the ATS applications technology satellite projects in the 1970's approximated some of the requirements of a successful demonstration project, although even in these cases R&D and demonstration goals were combined. Experience suggests that operators and users, whether private or public, are not willing to invest in a demonstration effort because of the particular characteristics of space activity, such as high front-end cost and technical uncertainties.

As is implied by the definition of demonstration project as concerned primarily with nontechnical aspects of a new technology, the design and execution of a successful demonstration project requires people trained in marketing, manufacturing processes, and other aspects of system operation in addition to individuals concerned with the technical aspects. Planning of a demonstration project should insure that these capabilities are included in the project teams. Demonstration projects managed and staffed by engineers alone are unlikely to be successful.

INSTITUTIONS FOR SPACE APPLICATIONS OPERATIONS

Properly speaking, the next topic should be the institutional issues related to making the transition from demonstration of a new application to its incorporation in operational systems. However, it makes little sense to discuss institutional alternatives for this transition phase without some prior discussion of "transition to what?" **In addition, there are important differences between a space application operated by Government, and one in the private sector. Therefore, this section** will discuss the institutional framework for making space applications technologies operational.

Private Benefits, Private Operators, Government Regulation

If the benefit to be delivered is primarily or purely private in character, such as point-to-point telephone or television relay, then private sector operators are the appropriate entities for that application. The Government role in this situation, once the transition from a Federal R&D program is complete, is regulatory in character.

Public Benefits, Public Operators

When a service has an overwhelmingly public-good character, it is often (though not always) the case that Government itself operates the system that provides that service. The social security program, the census, and military forces are examples of systems managed under public auspices. In the space applications area, meteorological data closely approximates a pure public good, and the national Government has not only developed but operated weather satellites through NOAA.

The major institutional issue related to Government operation of a space applications system is whether NASA or some other Government agency should operate space systems. The NAS Act has been interpreted to limit NASA to an R&D role, but reviews over the past decade have noted that it is possible, even without legislative revision, to assign more of an operational responsibility to NASA. Certainly, it would be possible to modify the 1958 act specifically to permit or mandate NASA to assume an operational responsibility.

The question of whether NASA or some other agency should operate Government-owned space systems depends on whether it is more desirable to link development and operation in a single organization, or to separate development from operation so that each organization has its own management structure. The major argument for separating development and operation is the likelihood that the conflicts between them will interfere with the ultimate objective of establishing the optimum applications system. The characteristics of a particular organization will determine whether user requirements or engineering desiderata predominate. Users tend to be conservative, to prefer only incremental changes from current practice, and to be driven more by consideration of cost and ease of operation than by the potential of a new technology. Alternatively, engineers tend to stress technological advancement and the development of new equipment, which may yield an impractical system.

New technological capabilities are, after all, only means to accomplishing some set of broader ends; in the organization of the Federal Government, most agencies are assigned a specific mission, rather than being organized around the means needed to provide the services they offer. According to this model, space application systems should not be managed by a "space" agency but by those who make ultimate use of the technology, i.e., the mission agencies. An example is NOAA's operation of weather satellites, which are developed and built by NASA, according to NOAA specifications. NOAA in effect serves as a middleman between the developer, NASA, and the end users, domestic and international. A major problem arises when space systems, particularly remote sensing, serve a number of functions and a variety of users. This diversity makes it difficult to relate these applications to a single mission agency such as Commerce, interior, or Agriculture.

Arguments supporting a single organization for development and operations are to a large degree the converse of those just stated. R&D can best be made responsible to the requirements of both ultimate operators and users if a single chain of command deals with both phases of a project. Organizations with heavy investment in existing systems are likely to be unresponsive to new technologies and associated ways of doing business developed by "outsiders." If a technology is transferred from one organization to another, difficult problems of changes in organizational loyalty, and disruption of prior relationships with suppliers, contractors, and users, are likely to occur. The management of applications systems on the basis of their technological character rather than the function they perform makes sense, it is argued, because of the multiplicity of users with different requirements, and because continuing R&D can be more effectively incorporated into existing systems if both are carried out in the same organizational structure.

The ideal framework for bringing a new application into operation is an effective and meaningful partnership between developing and using organizations. In some cases, particularly where the new technology provides a service that is not presently provided by established agencies, and where extensive technical and managerial expertise is required to operate the system, it is preferable to retain close ties between developer and operator. This is clearly the case for launch vehicles. In land remote sensing, too, it can be argued that NASA is the appropriate agency both to develop and to operate a Federal system, rather than transferring operations either to another Federal agency (i. e., NOAA) or to a private firm. (Commercialization of remote sensing would eliminate NASA's operational role.) Transferring responsibility to NOAA, as is presently being done, may not be desirable. For managing weather satellites, on the other hand, NOAA has the past experience, service orientation, and close ties to users required for effective operation. NASA can be of service by acting as "prime contractor" in meeting specifications set largely by the user agency.

Organizational Alternatives When the Benefits Are Mixed

When both Government and the private sector are major users of a new service, there is a **variety of institutional options. Which alternative is preferred depends on the characteristics of the application and of existing organizations, and on the likelihood that the new application will be integrated smoothly into the existing institutional framework. Thus, general guidelines are difficult to state.** The organizational alternatives in this situation are several. They include:

1. Government-owned and Government-operated system in which private users of the system purchase services or products from Government at a cost which is determined by Federal policy rather than market forces;
2. Government-owned, but contractor-operated system in which the Government uses a large portion of the system's products but where the contractor is also free, within some set of Federal restrictions, to offer service to nongovernmental users and to make a profit on those services;
3. single privately owned and operated system with guaranteed Government purchases and some protection from competition. The owners of such a system would have the responsibility for developing and servicing the private market for the system's products; and
4. privately owned and operated system or systems (depending on the demand) with open competition for sales to both public and private markets and with the prices of its product or service determined by market forces.

The criteria for selecting among these alternatives are specific to particular applications areas and thus are discussed in detail in section X11. In general, the Government-owned alternatives would be preferable if the Government were, at least for the foreseeable future, the dominant user, or if major noneconomic factors, such as foreign policy or national security concerns, constrained the use of the application. Private sector operation would be preferable when it offers greater efficiency, more flexibility, more effective linkages to various user communities, and where the economic incentives for a private operator are strong enough to ensure that the new application gets a fair test as an operational system, Any choice among these alternatives is likely to be controversial, and dependent in large part on political philosophy and the specifics of a particular situation.

A comparison of prior efforts to establish operational systems is important in analyzing institutional alternatives. (This comparison is limited to domestic entities at this point; section Xl contains analysis of the experience of international entities such as INTELSAT and INMARSAT.) In the space area, the most significant institution created so far has been COMSAT; this experience is analyzed in some detail in chapter 8. What is relevant here is to recognize that COMSAT was created for a combination of political as well as economic reasons. One strong motivation was to avoid granting a monopoly in international sateliite communications to AT&T. However, there was a recognition that satellite communications could be a private profit-making venture. Thus, the majority of Congress in 1962 thought it inappropriate to create a Government-owned entry in the communications business, and preferred to establish a private alternative. COMSAT originated out of a desire to move quickly to an international communication system based on satellites; it is only in the past decade that COMSAT General, a subsidiary of the basic COMSAT organization, has begun to seek domestic market opportunities in other areas of space applications. COMSAT General can be seen as a typical private sector firm seeking to maximizing return on its investor's funds, rather than an organization with its origin in Government policy.

There was substantial organizational innovation in establishing a private nuclear industry, and some of this experience may be relevant to space applications. A number of major facilities, requiring large amounts of capital investment, were created; an example is uranium enrichment plants. These multibillion-dol lar facilities were developed by the Government, and now are Government-owned, contractor-operated (GOCO) entities that sell enriched uranium to private nuclear operators while also providing fuel for the Government's atomic programs. In addition, a number of the major energy laboratories in the United States, such as Oak Ridge National Laboratory and Los Alamos Laboratory, are operated under Government contract by private entities as diverse as Union Carbide and the University of California. This kind of organizational flexibility in the energy sector may be appropriate in space applications as well.

A major argument for getting space applications operations away from Government- owned and operated structures is that the bureaucratic rigidities of the public sector are a major hindrance to systems which are servicing both public and private markets. In addition, the character of the civil service system, the need for annual or frequent authorizations and appropriations to cover operating expenses, and the desire to keep the direct Federal payroll as small as possible all lead to the frequent selection of a private sector operator to provide a service with mixed public/private characteristics.

Apparently, other countries find that the flexibility needed for developing markets for space applications is likely to be found outside of the formal government framework. For example, the European Space Agency has created a quasi-private entity called Arianespace to be the marketer and operator of space Iaunch services using the recently developed Ariane booster. There are 50 investors, ranging from major banks and aerospace firms to various European governments, particularly the French; formally, Arianespace is a French corporation. While Arianespace is charged with operating and marketing space launch services, the European Space Agency, an intergovernmental organization, remains in charge of further development of the Ariane launch system. The French are organizing a similar quasi-private organization called Spotimage to market the products of the French remote-sensing satellite SPOT. The major point is that the Europeans perceive that the competitive activities needed to make their launch vehicle and remote-sensing programs successful are better performed outside of government, though closely linked to government programs. It should be noted that both Arianespace and Spotimage will be heavily subsidized by their government sponsors; thus it will be very difficult to get an accurate evaluation of their economic viability. (For detailed discussion see ch. 7.)

TRANSITION FROM DEVELOPMENT TO OPERATIONS: INSTITUTIONAL ASPECTS

The transition from R&D to operations is perhaps the most difficult policy/institutional challenge for space applications. Understandably, both Congress and the executive branch wish to see immediate returns on the investment in space technology which the United States has made over the past two decades. Policy makers are aware of the extensive benefits predicted for space technology, and they exert pressure on the Federal space community to accelerate the delivery of those benefits. NASA, desiring to continue its applications R&D program, is strongly motivated to emphasize the great potential of space applications and to suggest that continued R&D is required to investigate current and future applications fully. The impression that space applications benefits are “just around the corner” is enhanced by the apparent (in retrospect) ease with which the transition from R&D to operations was made in satellite communications. The outlook for other technologies is more complex, however.

Communications satellites provided more efficient means of performing a well-established function. Once the advantages of communications satellites were demonstrated for a few countries already linked by other means of long distance communication, it was relatively straightforward to expand satellite communications to other countries and to other related activities. Other space applications, however, such as land remote sensing, are not substitutes for existing technological systems; rather they offer new opportunities for which established users and operational entities do not exist. Thus, a key to a successful transition is to identify and aggregate users; Government institutions to perform this task are not well developed.

Another important consideration is to initiate the operational system at a time when the user community is ready for it, not prematurely. A willingness to make investments with long-term paybacks and careful policy and program design is crucial to a successful transition from development to operations.

institutional issues are different when the operator is to be a Government agency or an entity operating under Government contract, and when the intended operator is a private-sector, profit-oriented organization. Each of these categories will be treated separately in the discussion which follows.

Transition to Government Operations

Ideally, the eventual operator would be identified when the R&D project aimed at investigating a particular application was initiated. In this way a partnership between the developer and the eventual operator could evolve throughout the project. The developer should pay careful attention to operator and user concerns such as cost, operating requirements, and reliability. An organization which is a candidate for operating a new applications system should have the technical capabilities needed to understand technological options, to assist in translating user and operational requirements into technical specifications, and to consult with R&D project managers as problems arise.

These desirable characteristics are more likely to emerge if the operating entity is identified early on; if development and operation were combined in a single organization, they would be more likely to be present. in addition, early identification of the eventual operator could minimize bureaucratic conflict over the assignment of responsibility for operations. Such has not been the case in past applications efforts, particularly in the remote-sensing area.

Though it would be desirable, in some respect, to designate the eventual operator at the outset of an applications R&D effort, it may not be possible to do so, particularly if the current policy of limiting NASA to an R&D role is maintained. The likelihood of choosing the appropriate operator is diminished when the application produces benefits of value to multiple users. In this situation, it is tempting to wait until the R&D project is further along to assign responsibilities for operations, in the hope that the appropriate operator will become more evident. The history of the remote-sensing program suggests the problems in deferring the designation of a lead agency (see app. A).

By identifying an operating agency early on, policy makers avoid the problem of having the transition plan developed totally within the development organization; such a transition plan is unlikely to reflect the concerns of a user-oriented organization.

Transition From Government R&D to Private Operation

An important issue in commercializing federally sponsored research is what Federal actions beyond R&D, if any, are required to make this transition. Several Federal incentives are discussed in chapters 8 and 10 of this report. The question regarding institutions centers around whether NASA, or any other Federal agency, currently has the authority or capabilities to provide such potentially desirable incentives. Though there has been substantial cooperation between NASA and the private sector, this has generally taken the form of a contract specified by NASA and bid on by private firms. The new Joint Endeavor Agreement is a significant move in developing new patterns of partnership aimed at encouraging private sector investment. The Federal Government, and particularly NASA, is still learning how to collaborate effectively with business in fostering commercial opportunities based on Government-developed technology in all sectors, not just space. This has happened slowly, given the traditional adversary relationship between public and private sectors.

There have been a number of suggestions for creating new Federal institutions to encourage space-based innovation; these include a new investment authority called a Space Bank or a more broadly chartered development organization called a Space Industrialization Corporation. The provision by Government of investment capital or other substantial forms of quasi-commercial support would represent a significant departure from past Federal actions. Although other countries (most notably Japan and some European countries) have provided this kind of support to their private sectors, it seems likely that given the strong U.S. tradition of separating the public and private sectors, and the current trend towards restricting the Federal Government, that there would be strong opposition to creating new Government institutions of this sort. On the other hand, concern for declining American industrial productivity and the increasing threat of foreign competition in advanced technology areas could make such innovations politically attractive.

In bringing the first commercial application of space technology, communications satellites, into being, the Federal Government did take a substantial institutional initiative in creating a semiprivate designated entity, COMSAT, to manage the satellite system. An important issue is whether similar kinds of institutional innovations are required in other applications areas. This question is addressed later in this chapter, particularly in the following section, which deals with providing broad-based infrastructure to support space applications.

INSTITUTIONS FOR SUPPORTING SPACE OPERATIONS

An important institutional question concerns the provision of routine support operations for public and private industrial activities in space. Such operations would include reliable and affordable transportation from the surface of the Earth to low-Earth orbit, and between low-Earth orbit and other desired orbital locations; construction and maintenance of orbital platforms; and providing in-orbit power and communications. it is possible to conceive of some form of "space utility" providing these common services to a variety of users, not only industrial but also scientific and perhaps military.

Should such space utilities be operated by a private or public entity? Almost certainly, given the multiple users of in-orbit facilities and of space transportation, it will be Government that provides the initial investments to develop these capabilities. NASA's plans for a space platform or **operations center are driven by the eventual need for routine in-orbit capabilities** such as those just discussed.

The period during which this kind of "infrastructure" for supporting space operations will be required is a decade or more in the future. Thus, it is somewhat premature to carry out a detailed analysis of institutional alternatives. However, many of these issues will arise in the course of arriving at an institutional framework for operating the space shuttle, and the approach taken to shuttle operations is likely to set a precedent for other forms of support services. Thus, the following analysis of institutional options for shuttle operations is also relevant to other support systems for space.

There are essentially two ways an operational space transportation service using the space shuttle might be organized. One is to create a designated private firm, or use an existing firm or consortium, to own and operate space transportation services for all users (with the possible exception of the military and intelligence services). The second is to have the Government operate the shuttle fleet and sell launch services on a reimbursable basis to private sector users, as is the current practice with expendable launch systems. Of course, either alternative could face competition in providing launch services from a U.S. private organization or Arianespace.

While routine launches of payloads into near-Earth or high-Earth orbit now seems like an exceedingly complex and risky undertaking, there is no technological reason why these services could not be provided by a private operator with sufficient resources and experience. The current shuttle development and demonstration program will provide information on costs and experience with operating characteristics, allowing potential private operators to evaluate the possibility of profitable commercial operation. NASA is currently contracting out large segments of shuttle management and maintenance to private firms, and recently invited aerospace companies and airlines to bid on the provision of a complete package of services for processing the shuttle for launch.

The argument that a Government entity should provide space transportation services is based on several beliefs. One is that the use of launch vehicles for military and intelligence missions makes it desirable to keep launch technology under Government control. Others are that the principal user of launch services in the foreseeable future will continue to be Government, and that no private sector firm without extensive Government subsidy would be able to provide the launch services Government will require. Another is that further Federal development of space launch capability is desirable and R&D toward this capability should be carried out in close conjunction with current operations in space transportation.

Private ownership and operation of space systems would give rise to a need for Federal oversight and regulation. For a discussion of the issues involved, see chapter 8.

Another option for providing space transportation services or orbital support services is international ownership and management of a space utility or a common space platform. The analysis below of international dimensions of space applications raises this subject briefly.

SPACE APPLICATIONS IN AN INTERNATIONAL CONTEXT: INSTITUTIONAL ASPECTS

international cooperation in sharing data from meteorological systems and in operating international and communications satellites has proved successful for almost two decades, and thus it is not surprising that other space applications are frequently suggested as candidates for some form of internationalization. A touchstone for any analysis of such suggestions is the successful experience of the International Telecommunications Satellite Organization (I NTELSAT). The United States took the lead in 1964 in helping to found a multinational entity for using communications satellites for video and voice transmissions among various countries; the original 19 signatories of the INTELSAT interim agreement have grown to 106 owners of a unique international organization. The most striking feature of INTELSAT is that it combines policy management by government representatives (for the most part) with the operation of a successful commercial enterprise returning 14 percent annually on its owner's investment. Thus, INTELSAT provides a seductive model for other areas of space applications. The question is whether this kind of international organization can, or should, be duplicated in other applications areas.

A brief review of various applications areas suggests the limitations of the INTELSAT model. Certainly materials processing is in much too early a stage of development to consider any permanent institutional arrangements, much less a possible multinational one. This is particularly so since the most likely path for developing materials processing applications is through private enterprises. Space transportation at this point is an area of international competition, not collaboration, and there is no indication that the current developers of space launch systems will want to operate them as anything but national public or private enterprises. There are some potential new international dimensions to advanced communications satellites, such as navigation and search and rescue systems, but in general, most advances in communications satellites are likely to be incorporated in INTELSAT or INMARSAT. It is only in remote sensing that the issue of international institutions is currently relevant, and most of this section devotes its attention to this issue. There is also some discussion of the potential for internationalizing space support services, particularly large orbital platforms in low or geosynchronous orbit.

it has been the policy of the United States since 1969 to make the benefits of the U.S. remote-sensing program available to all peoples of the world. At issue now is how best to implement that policy: through a U.S.-owned and operated system which makes its own arrangements for international participation, or through some form of internationally owned and operated system in which ownership is proportional to investment and/or usage.

The institutional choice is between some form of international consortium, a la INTELSAT, or continuation and expansion of the current U.S. national system. A variation of this latter alternative would be if the U.S. system were privately owned and operated, since foreign governments have a number of concerns related to private control over remote-sensing operations. Any private sector operator of remote-sensing systems would have to operate, with respect to non-U.S. imaging, under a specific set of Government policy guidelines.

The most important benefit from a successful international remote-sensing system may well be political, rather than technical or economic. An international system could allow participating countries to have a say in system management; this feature would be especially attractive to a nation that receives substantial benefits from remote sensing but cannot afford to carry out such activities by itself. Other benefits to the United States of an internationally owned and operated system would include some degree of cost sharing, some ability to limit the development of other national systems and the resultant competition for remote-sensing markets, and less suspicion that the United States was appropriating information for its own purposes, It is also likely that limits on resolution could be more easily agreed on if there were a single international system rather than competing national systems. Finally, effective international cooperation for the common good is desirable in itself, transcending the direct benefits to be achieved from remote-sensing technology.

Creating this kind of international institution for remote-sensing operations would not be straightforward. It is sometimes forgotten that it took from 1964, when the interim INTELSAT agreement was concluded, to 1971, when the definitive INTELSAT agreements were signed, to make the transition from a U.S.-dominated communications satellite system to a more equitable arrangement.

Because there are conflicting national interests related to remote sensing activities, and because there are private sector as well as public sector concerns involved, negotiations preceding the founding of an international institution would of necessity be lengthy. In addition, the kinds of problems which have arisen at the domestic level in the process of establishing an operational structure for remote sensing are likely to be repeated at the international level. For example, organizations as diverse as the Food and Agriculture Organization, the World Meteorological Organization, and other, more politically motivated, U.N. organizations are likely to make a claim for some share in the control of any new international organization for remote sensing.

The history of INTELSAT also suggests that the ability of the United States to influence the direction and policies of a similar organization for remote sensing would diminish over time, as the organization itself matured. In addition, if the new international organization is successful the economic benefits will flow not only to the United States but to other countries owning and using the system; the U.S. aerospace industry could lose its dominant position in remote-sensing technology as the institution awards contracts on the basis of international competition. On the other hand, competition for U.S. systems will arise even in the absence of any INTELSAT-type organization; such an institution could serve to regulate or forestall the establishment of competitive systems such as SPOT. Here again, the INTELSAT experience is relevant; INTELSAT contracts have been important in the development of non-U.S. communications satellite technology and launch system capabilities.

Unlike COMSAT, which is essentially a private sector organization, most nation-states' representatives in INTELSAT are publicly owned communications organizations. Thus, INTELSAT demonstrates that it is possible to combine privately and publicly owned organizations in the same institutional framework. However, a number of issues related to remote sensing did not arise in the case of communications. In particular, if an international entity were initially based on a U.S. system owned and operated by a private firm, it is not clear how the current policy of open access to data could be maintained, while at the same time the economic interests of the private entity were protected. There are clearly tensions between the current policy goal of commercializing U.S. remote-sensing operations and the preceding argument that international institutions might well operate a remote-sensing system.

Previously there was discussion of a possible space utility to provide common services required by a variety of operations in space. This space utility would be an international entity, where investment and ownership would be distributed among a set of regional, allied, or global partners. Although internationalization of an emerging space operations utility is not fully explored here, this possibility deserves continued attention as application programs and their supporting infrastructure mature.

INSTITUTIONAL ASPECTS OF SPECIFIC APPLICATIONS

The discussion of generic institutional issues previously discussed provides a basis for identifying institutional concerns for each of the application areas treated in this assessment and for suggesting ways to deal with these concerns. Each application area—communications, remote sensing, materials processing, and transportation-is examined below from this perspective.

Communications

The primary issue in communications satellites is not institutional. As has been discussed in chapters 3 and 8, NASA's major thrust in this area is a proposed research, development, and demonstration effort in the 30/20 GHz range. This assessment has suggested that it may not be necessary for the Government to provide most of the funding for the flight demonstration of a satellite embodying this technology; the private sector could use the results of related R&D conducted under the sponsorship of national security agencies as a starting place to mount a demonstration effort funded primarily from its own resources.

If, however, a decision to continue a NASA communications R&D effort in the 30/20 GHz region were made, then this program should be conducted in close cooperation with both satellite manufacturers and communications satellite users. In both its R&D and its demonstration phases, this program might be amenable to institutional experiments such as public-private cost-sharing and risk-sharing and to joint planning and management structures. It may be possible to move quickly to a demonstration of a 30/20 GHz system, but care should be taken not to undertake such a demonstration if R&D is not essentially complete. As has been discussed earlier in this chapter, attempting to combine the R&D and demonstration phases is not usually a successful approach.

If the proposed NASA 30/20 GHz RD&D program is initiated, and if it is planned and managed according to the principles discussed previously, then no additional Federal actions should be required in order to make the transition from R&D to operations. If this new capability proves to be technically and economically viable, private firms will incorporate it in planning them for the next generation of communications satellites.

Remote Sensing

Many of the problems related to the Nation's R&D program in land remote sensing result from the different perspectives of developers and users. NASA views this effort as one of developing a new and experimental capability; the various users see the results of the program as immediately beneficial and have attempted to treat the system as if it were already operational. NASA has been caught between carrying out its R&D mission and responding to users who want to make immediate operational use of the Landsat system. To date, users of the remote-sensing system have not participated significantly in decisions regarding its status and future. The transfer of Landsat management to NOAA is designed to alleviate this shortcoming.

The division of responsibilities between any future R&D program in remote sensing and the operations of a working land remote-sensing system will have to be negotiated. If, as is suggested below, NASA is assigned the operational role, this issue becomes less problematic. If the operator is another Government agency, or a private firm, it may be desirable for NASA to perform some or all of continuing R&D.

Though Landsat has succeeded in providing the information needed to understand the kinds of public and private benefits that can be gained from remote-sensing technology, it has not been able to provide sufficient information on costs and on the potential market for remote-sensing data. Again, this is largely because the program has been run as an R&D, rather than a demonstration, effort. One heritage of the "Apollo-era" NASA is a desire to control most or all of a system development process, emphasizing its research and engineering aspects, rather than to share control with other entities, including other Federal agencies. This tendency has been noted for the initial Landsat and Seasat programs, and it seems characteristic of the Landsat-D effort as well. Landsat-D involves the first use in orbit of an advanced sensor called the thematic mapper, the characteristics of which are not well enough known to consider it an operational system.

The prospects for successfully achieving the quite different objectives of a NASA R&D program and a NOAA demonstration program within this single flight effort seem limited. Most of the principles for a successful demonstration effort presented previously have been violated in putting together the plans for Landsat-D. Users have not been closely involved in planning the program; there is a poor match between the characteristics of the advanced sensors to be flown on Landsat-D and the needs of the existing or potential user community for remote-sensing data; and a fair degree of tension exists between NASA and NOAA on account of their differing objectives for the program. In addition, technical problems with the thematic mapper have made the effort even more of a development rather than demonstration undertaking.

Undoubtedly there is a tradeoff between separating the development and demonstration phases, and the high cost of flying a fully qualified space system at least twice, but the increased assurance of accomplishing program objectives makes such an investment worthwhile. The Landsat program has not been planned with a clear understanding of the requirements of bringing an innovative new technology into operation. In addition to the problems of incorporating a new way of doing things into existing patterns, Landsat has exacerbated rather than minimized institutional conflicts and differences of perspective affecting operator and user acceptance of the new technology.

It is probably too late to remedy some of the basic flaws in the design of the Landsat effort. Rather, there should be an attempt to recognize the institutional, funding, and programmatic constraints under which the Landsat-D effort now operates, and to determine whether those constraints can be modified in order to reflect a more balanced approach to development and demonstration of a new technology. The issue of the institutional framework for an operational remote-sensing system has been controversial for almost a decade now. There has been extensive analysis both by the executive branch and by Congress; the full range of that analysis will not be reviewed here. This discussion will be limited to applying general principles provided previously to current proposals for operational remote-sensing systems.

The key policy issue in choosing an institutional framework is whether the benefits derived from remote sensing are primarily public or private; the available evidence suggests that they are a mixture of both. Because Landsat has been run as an R&D program, and because the prices of Landsat data have been heavily subsidized, the market for data from an operational but more expensive system is not well defined.

The process of moving remote sensing from R&D to commercial operations has been underway for 3 years now. The current transition planning has been plagued by external and internal difficulties. NOAA, the Government agency responsible for the transition, has not been given the resources to acquire the technical and economic capabilities needed to deal effectively with NASA, the present operator, or with eventual operators and users, public and private. The lack of budgetary and institutional commitment to the commercialization of remote sensing has prevented potential private sector operators from taking the Government's efforts very seriously.

Recently, COMSAT General proposed to assume ownership and operation of NOAA's meteorological and remote-sensing satellites.[8] The prospects for such takeover depend on the baiance between public and private markets for Earth observation data. Certainly the established market for meteorological data is governmental in character, and presumably the Government would contract to buy those data from the privately operated system and to make it available as a public good, if the COMSAT proposal were adopted. There is also a large public sector market for remote-sensing data at the Federal, State, local, and international level, and presumably the Federal Government would also purchase the data needed to serve the public market from COMSAT. If these two public markets turn out to form an overwhelming share of the total demand for Earth observation data, then the COMSAT proposal should be approved if it would provide significant efficiencies in operating performance and cost. An alternative to the COMSAT proposal would be that a Government agency operate remote-sensing systems and make their outputs available to the private sector at a cost reflecting, for example, the marginal cost of obtaining and reproducing the data or some attempt to recoup system development expenses,

If, however, the Government market for meteorological and/or remote-sensing data were relatively soon to become a minor share of the total demand, then the COMSAT proposal would be better understood as an innovative and aggressive institutional initiative on the part of a private firm,

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[8] Klaus Heiss, "New Economic Structures for Space in the Eighties," *Astronautics and Aeronautics,* January 1981, pp. 19-21.

whose risks are minimized by guaranteed public purchases, but not totally eliminated. A major issue would be whether the Government should attempt to recoup any of the R&D and system development costs that made a private venture in remote sensing possible. The alternative is to view the sunk costs as an appropriate Federal stimulus to private sector activity. Access to remote-sensing products by non-U.S. users would be another area of concern. Provision would have to be made to ensure that private, profit-oriented operation (whether by COMSAT or in some other form) is compatible with the current U.S. policy of unrestricted access to all available data. In addition, a national remote-sensing system which is privately operated may not be compatible with eventual internationalization of remote-sensing efforts.

If the current policy of early commercialization of remote sensing were modified or reversed, it might be preferable to have either NOAA or NASA operate remote-sensing systems. The analysis in this chapter suggests that NASA would be a better choice than NOAA as an operating agency, since remote-sensing technology is still evolving rapidly and the existing relationships between the users and NASA form a basis for continuation and expansion.

Materials Processing

The research effort that might lead to widespread use of space for processing or manufacturing is still in its early stages. Much more basic and applied science is required before a wide range of specific applications can be tested. Thus the materials processing program provides the best opportunity within the current program of space applications R&D for applying the principles identified above. Materials processing in space is an example of a technological opportunity where the conditions which call for Federal involvement exist—high risk, high cost, long time to pay back. It is clear that materials processing makes sense only as a commercial activity, and thus any federally funded R&D should be planned with considerations of market and cost in mind. Innovative policy instruments such as the joint Endeavor Agreement (discussed in ch. 8) may be appropriate ways of accomplishing this. What is crucial is designing the materials processing R&D effort in ways that consider the likely future operating environment of commercial activities, rather than exploring exciting technological possibilities, while paying no attention to the commercial potential.

The demonstration phase for most kinds of materials processing activity is still some years in the future. However, the McDonnell Douglas/ Ortho Pharmaceutical joint venture experiment is planning for a flight demonstration in the mid-l 980's. The basic technology will be tested in orbit first; if successful, a separate effort will to demonstrate that technology in an operating environment.

This approach to developing and demonstrating materials processing capabilities seems appropriate for other projects as well. Given that materials processing must ultimately be commercialized in order to be successful, there should be continuing strong, emphasis on the involvement of private industy in MPS activity, especially as the transition from R&D to the demonstration phase is planned. The kind of risk- and cost-sharing that currently characterizes the joint Endeavor Agreement (and is discussed above for demonstration efforts in the communications satellite area) should also characterize any further demonstration of materials processing technology.

A great deal of attention has been given to the general question of possible Government initiatives to stimulate the transition from the demonstration phase to private operations. Two sets of congressional hearings have been held, and a proposal to establish a Space Industrialization Corporation, as a source of investment and other policy stimuli, has received extensive analysis.[9] While this attention to transition planning for materials processing is laudable, the relatively early stage of the materials processing program suggests that it would be premature to select any particular form of government subsidy for the post-demonstration transition phase. Much more

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[9] House of Representatives, Committee on Science and Technology, hearings on Space Industrialization Act, 1979 and 1980.

needs to be learned from the experience of, for example, the joint endeavor experiment before an efficient and equitable mode of Government-industry cooperation can be identified for materials processing or other new space technologies.

Transportation

Continuing improvement and upgrading of the space shuttle and development of a truly reusable orbit-to-orbit transfer stage appear to be crucial elements of the Federal R&D effort in space transportation. Given its strong institutional capabilities in space propulsion and vehicle design, NASA is the appropriate focus for further R&D in this field. Essential to an R&D effort that serves space transportation users will be stability and predictability, so that users can expect to have new launch capabilities available on schedule and at predictable prices.

The initial flights of the space shuttle are billed, correctly, as development rather than demonstration efforts. However, there is no separate demonstration phase as part of the STS program; after the initial four flights, the system will be declared operational and begin to fly payloads regularly. In reality, demonstration of the operating characteristics of the space transportation system, and particularly those of the shuttle, will come over time as the costs of each incremental shuttle flight, and the potentials and constraints of the shuttle as a launch system become better known. It should be recognized, therefore, that the actual demonstration phase of the shuttle program is likely to extend beyond 1985, and the information needed for private-sector operators to make an accurate assessment of the potential returns from shuttle operations is unlikely to result from the early years of the shuttle effort.

The transition to an operational system will require that, whoever the eventual operator may be, policies with respect to patent and proprietary information protection, launch assurances, Government preemption rights, and costs must be developed. A variety of institutions will have to evolve, especially those for marketing, insuring, and financing operational launches. The competition from potential privately developed expendable launch systems with lower performance but also lower costs than the shuttle may play an important role in future private sector operations. The transition phase is particularly complicated by the mixture of military, intelligence, and civilian Government requirements, together with private sector requirements for space transportation services. Institutions for resolving these conflicting demands will be required.

Providing routine space transportation services is different from operating the three applications discussed above: transportation services support operations in space, rather than being integral to a particular applications system. The issues related to the operational form for space transportation services have been discussed previously.