Chapter 3
ISSUES AND FINDINGS

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OVERVIEW

As its title indicates, the scope of this assessment has been determined by two axes: space policy as it pertains to applications and space policy in general. Although the major consideration has been to explore the issues surrounding space applications technologies, it has been important to frame that exploration by a consideration of issues germane to the entire civilian space program.

This chapter gathers the principal issues and findings of the entire assessment. Some of these are treated in greater detail elsewhere in the assessment; others, particularly those which concern the technologies themselves, are discussed in full here. The chapter has, therefore, been divided into two major sections: "General Policy Issues" and "Applications Policy Issues."

SECTION 1: GENERAL POLICY ISSUES

Introduction: The Inadequacy of Current Policy

From the beginning of the space age nearly 25 years ago, there has been general public agreement that the United States should play a major role in the utilization of space. Although there continue to be questions about appropriate funding levels and the relative priority of specific projects, the United States as a nation has been and remains committed to the development of space activities.

The National Aeronautics and Space (NAS) Act of 1958 articulated the policy principles for overall guidance of the U.S. civilian space program, but the act alone has not provided (and cannot be expected to provide) the particular goals for civilian space activities. Lacking such guidance, the space program has instead been directed by political and budgetary pressures not always relevant to a logically ordered exploration and use of space. At the same time, none of the policymaking bodies successively established in the executive branch nor any of the congressional committees have been able to ensure that a long-range plan of particular policies and programs would be pursued.

Furthermore, it may be important to recast the NAS Act to reflect the development over the past 25 years of significant U.S. capability to conduct space operations. The act was designed to develop these capabilities rather than to give guidance on how to make use of them once developed. In particular, very important services are or soon can be provided by space applications technologies, but specific policies to ensure that their potential is fully realized are not in place. The goal of this assessment, therefore, is to examine the interrelation of space policy and space applications technologies, four of which—satellite communications, land remote sensing, materials processing in space (MPS), and space transportation—are treated in detail. Weather observations and navigation are not covered except by reference. It should be noted that space transportation is not usually considered an applications technology. OTA's reason for so classifying it is that it, like the other applications, is a means to further ends, and also has a strong potential for commercialization.

Six policy principles form the core of the NAS Act. These six, which are discussed in detail later in this chapter, have provided the framework and goals in accordance with which the civilian space program has evolved to the present day. These principles may be stated as follows:

- that U.S. preeminence in space science and applications be maintained;

- that economic and social benefits be derived;
- that knowledge be increased;
- that civilian and military activities be separated (though they are to be coordinated and are not to duplicate one another unnecessarily);
- that the National Aeronautics and Space Administration (NASA), the civilian agency, be limited largely to research and development (R&D); and
- that international cooperation be fostered.

Issue 1: What Are the Key Factors of the Current Situation?

Reliance on Space

We depend increasingly on space for vital public and private services (national security and commercial communications); we rely on it for useful services (remote sensing of land, navigation, and weather reporting); we can foresee commercial possibilities for MPS in the near term. All of these space applications require an adequate space transportation system, including launch vehicles, spaceports, and tracking networks. Because of our significant reliance on space, we will certainly retain some sort of space program. However, broad agreement about the direction or scope the program should assume in the future has not been achieved. Furthermore, there is no set of procedures in place whereby a national consensus about the future program can be generated.

Need for Continued Federal Activities

Lack of basic agreement is of concern for the whole U.S. space program, not only for applications technologies. But it is of particular concern for the latter because the range of desirable civilian space applications, on account of their economic risk and high expense, cannot be undertaken by the private sector alone, in accordance with ordinary market forces. On the other hand, it is inappropriate and unnecessary for the Federal Government to undertake all of the space activities in the United States. For the foreseeable future, we will continue to be in a period of mixed public and private responsibilities. In order to ensure the success of our space ventures, a determination of the appropriate Federal role should be made and, once made, pursued consistently. In this assessment, at least four areas in which the Federal Government should continue to be involved are identified: contribution to advanced R&D, provision of public goods and services, continuation of space science, and coordination of national efforts, particularly with respect to international agreements.

International Competition

The United States no longer has a monopoly on free world space activities. The Europeans and the Japanese have targeted specific space technologies for development and are already providing stiff competition for a number of services and facilities heretofore offered only by the United States (e.g., launch facilities and communications ground stations). in particular, the French will soon be marketing an expendable launch vehicle, the Ariane, to compete with the shuttle, and they plan to begin operating, in 1984, the Systeme Probatoire d'Observation Terrestrial (SPOT) remote-sensing system to compete with the land remote-sensing satellite system (Landsat). Making good use of available U.S. technology, the Japanese are developing their own launchers, as well as communications and remote sensing satellites, particularly for ocean surveillance. The Europeans and the Japanese have also developed excellent space science programs.

The Europeans are not only technologically competitive, but have founded new semiprivate institutions, e.g., Arianespace and Spotimage, to operate and market their new systems. These institutions are subsidized by their sponsoring governments and are, therefore, able to price their services significantly lower or offer more attractive financial terms than could unsubsidized firms. In addition, their profitmaking character encourages them to seek efficiencies that a program managed by government agencies might not. Through the European Space Agency (ESA), member countries cooperate in developing advanced systems for which no one country has all the resources required (expertise as well as capital).

Need for Greater Private Sector Participation

A great part of the promise of the European and Japanese programs results from the structure of their institutions, under which private and public sectors can work well together. Their plans, however, should not necessarily cause the United States to imitate their institutional arrangements, but to discover equally effective arrangements compatible with our political and economic traditions. The twin factors of the diminution of Federal resources for civilian space activities, and the dynamism of the private sector, make it important that private corporations participate more actively in U.S. space efforts whenever commercial success is possible. if we are to develop space applications that have the most social value, signals from users must guide our efforts; it is the private sector that responds to and uses such guidance most effectively in the marketplace. Above all, we must remain flexible in determining whether one sector or the other, or some novel combination of the two, should assume the responsibility for particular activities. As responsibilities are divided, it is essential to consider both the stage of development–basic research, development, demonstration, or operations–and the kind of application—communications, remote sensing, materials processing, or transportation,

To help meet foreign commercial competition as well as to foster the more efficient use of our national resources, the United States should continue to seek further innovative relationships, like the Joint Endeavor Agreements (JEAs) sponsored by NASA, which bring public and private sectors into effective partnership in planning for and carrying out space activities. Because we have been less than effective in discovering such arrangements, many of our space applications systems have not evolved smoothly from research to operational status.

Present Government Institutions Ill-Suited to Current Conditions

By charter and by subsequent legislation, NASA is primarily responsible for the R&D of civilian space systems, not their operation. The exception to this rule is NASA's operation of space transportation systems, including launch vehicles, spaceports, and tracking systems. Responsibility for operating other federally owned civilian systems rests with the National Oceanic and Atmospheric Administration (NOAA); it operates U.S. weather satellites and is scheduled to manage the Landsat system as well.

NASA's emphasis on developing new technologies makes sense in the context of a highly visible project on which national prestige is staked. In the current political and economic context (i.e., diminishing Federal resources allocated to space, increasing competition from abroad, and growing need to involve the U.S. private sector more substantially), NASA and other Federal institutions which make extensive use of space-derived data may require reorientation, first, to ensure that a balance of diverse space activities emerges, and second, to be more responsive to user needs. Some specific suggestions for possible reorientation appear in chapter 10; chapter 9 explores the principles upon which such reorientation could be based.

Issue 2: How Are We to Manage Our Future in Space?

Future Options for the Civilian Space Program

This section considers a range of legislative approaches the Congress could take concerning applications of space technology. Although these options are derived from considering the specific technologies we have addressed in this report (i.e., satellite communications, land remote sensing, materials processing and space transportation), they generally reflect the needs of the entire spectrum of space applications. At one end of the range, Federal involvement dominates, and public goals drive the development of all space applications. At the other, Federal involvement is very low, and the pursuit of space applications is a function almost solely of private sector activity.

The U.S. space program is an investment for the Nation. Consideration of options for the U.S. space program must take into account what we **can** do, what we can **afford** to do, and what we **must** do, to meet external competition and internal demands. What we can do is determined by our technical and institutional capabilities; what we can afford to do is bounded by overall Federal resources and judged by ranking the value of space activities against other Federal programs; what we must do is driven by external challenge and domestic requirements. The relative importance to be granted these various determinants is, finally, a political decision. The shape of the resulting program can vary widely, but it is important that Congress recognize the cost of inconsistent Federal support of planned programs. The time stretching from initial concept, through research, development, and demonstration (RD&D), to final operations may include major political changes. if these changes occasion major financial perturbations, both money and talent are lost.

Our technical and institutional capabilities provide, perhaps, the least constraint. The success of Apollo proves that we can undertake and complete challenging new projects. We have a wide range of future possibilities to choose from, and we have much of the experience and expertise necessary to carry them out. The availability of Federal resources, on the other hand, is less predictable, depending, as it does, on the overall state of the economy. It is expensive to develop space technology, and for the next 3 or 4 years, at least, many Federal programs are likely to be under severe financial constraint. In addition, the relative priority of space activities in the national economy depends on an evaluation of their contribution to overall national goals. Though the need for some civilian space program is clear, its appropriate level is not. Finally, as international competition increases, serious thought must be given to planning an effective response.

Space applications exist in the context of an overall Federal commitment to the exploration and use of space for civilian and military purposes. Accordingly, the following discussion outlines the legislative choices OTA has selected for discussion and relates them to the sorts of overall programs within which they might exist. The three levels of overall commitment presented below are determined by different evaluations of foreign competition.

HIGHLY COMPETITIVE APPLICATIONS PROGRAM

As other parts of this report have stressed, the competitive challenge from other nations is strong and growing. With the exceptions of materials processing, in which competition has not yet developed because it is too new, and of navigation satellites, all space applications originally developed in the United States now face competition from other countries. For both economic and political reasons, foreign activities must be taken seriously by U.S. policymakers. Strong Federal intervention might be warranted if failure to pursue new technologies would result in significant loss of revenue or U.S. prestige, or if the threat was much greater than could be met by current Federal and private programs. A highly competitive applications program would fit most appropriately into an overall space program that seeks to achieve ambitious goals. Two different approaches bear consideration.

- ***Apollo-like program.*** Such a space program would likely arise only in response to a perceived threat from the Soviets. If they were to initiate an ambitious and highly publicized project such as a manned planetary mission, or a large, advanced orbital base, space might again become an area of superpower competition in which we tried to best Soviet efforts.

  New applications and enhanced capabilities for existing ones could result as byproducts of a singly focused space effort. The institutional structure and large budget required to complete the R&D for a single large project could lend itself, for example, to development of a new generation of communications or land remote-sensing satellites. If competition were to focus on a single dramatic project, it could spill over into a broad range of areas if the United States attempted to emphasize its across-the-board capabilities, as it did during the Apollo program. The development of the shuttle, however, argues the reverse: a single showpiece program might drain all others of much-needed funds.

  Because this program would be politically motivated, it would be aimed primarily at increasing U.S. prestige in a short period of time, and therefore would inevitably be dominated by the Government. The private sector would be seen as the source of expertise and contracting capability, but would not, at least immediately, be a prime beneficiary of U.S. programs. Encouragement of commercial activities other than those directly supportive of the major project would depend on the overall resources available: unless these resources were substantial, large crash programs could absorb funding and expertise to such a degree that other interests would receive little attention.

- ***Applications-dominated program.*** If competition from European and Japanese and, possibly, Soviet applications systems were seen as especially threatening, it might be appropriate to concentrate an aggressive Federal effort on maintaining U.S. preeminence across-the-board. This course of action would place a high value on civilian space technology as an instrument for maintaining U.S. technical capabilities and general economic strength. It would be based on the estimation that the support and subsidy of foreign governments for their own programs could be met only by similar support in the United States.

  This program would emphasize the applications segment of NASA's activities, including space transportation, and could be carried out even without a commitment to a very large single project. It would require a significant redirection away from NASA's present orientation toward spectacular missions. Except for use of the shuttle, manned programs would be reemphasized and made a part of specific applications projects, where pertinent. Space science research that contributed directly to applications efforts would receive priority; basic research that used shuttle capabilities in near Earth orbit would be favored over expensive planetary probes and long-term experiments. Like the politically motivated Apollo-type program, this highly competitive course of action would be dominated by the Government, but insofar as its aim would be leadership in commercial applications, private industry would be encouraged to become a full partner. various joint-ventures and other cooperative agreements might be encouraged.

  The high costs of Government subsidy in such a program could be justified as leading to eventual commercial payoff, as well as considerable public sector benefits.

MODERATELY COMPETITIVE APPLICATIONS PROGRAM

Such a response to foreign commercial competition would arise from the judgment that the United States retains significant strength in many sectors and should target "areas of opportunity" for Federal attention. Private-sector involvement in development projects and in planning for eventual takeover of potential commercial systems would be encouraged. In the near term, 30/20 GHz communications technology, land remote sensing, and space transportation are the most likely areas to receive Federal attention under this scenario. Materials processing projects would be aided, largely through use of JEAs. Federal involvement would be initiated on the grounds that the private sector cannot afford the high risks of entering a given area without help. Industry groups would be encouraged to expand their involvement by entering into joint ventures with each other and with the Government where appropriate (see ch. 8 for a full discussion of some of these possibilities). Technology transfer from military to civilian use would be increased wherever possible.

This applications program could fit the following general scenarios:

- ***Budget-constrained, with most resources devoted to a single large project (e.g., the shuttle).*** This reflects the current situation where more than 50 percent of the NASA budget is devoted to the shuttle. Although the effort to develop less expensive transportation to space will eventually benefit the entire space program, at present it has led to foreclosing or deferring many opportunities in space science and in applications. Under such conditions, if the applications program (exclusive of space transportation) is to prosper, the private sector must be involved to a much greater extent. If that involvement is not forthcoming, the U.S. competitive position will necessarily suffer. Of particular concern is the future of 30/20 GHz communications technology (see "Communications Technology," below) and land remote sensing by satellite (see "Land Remote Sensing," below).

- ***Budget-constrained– "balanced spending. "*** This is not the current situation, but one that might prevail when the shuttle is fully operational and its costs are borne by the users—provided NASA's budgets stay relatively level. Under "balanced spending" conditions, an applications program (including advances in space transportation) would consume a significant portion of the budget. Space science would receive a comparable share. NASA would play a strong role in developing new communications and remote-sensing systems, in conducting experiments in materials processing, and in planning and constructing space platforms and large structures. The private sector would be solicited to participate in many of these activities.

NONCOMPETITIVE APPLICATIONS PROGRAMS

If the competition from other states is not considered especially threatening to the U.S. economy, and to our general position of leadership, and if space applications are not viewed as worth developing for the public benefits that might be derived, a greatly reduced Federal effort in space applications would be a potential policy option. Such a stance would force dependence on private investments to develop and operate space systems, but would not provide appreciable Federal funding to do so.

Although this option could apply to any of the civilian space programs considered above, it is more likely to be part of a highly constrained civilian space program:

- ***Severely constrained.*** Such a program, some 30 to 50 percent smaller than the current one, would allow little room for a civilian Federal applications effort, especially given the large percentage required for continued development of the shuttle. Major programs and perhaps entire categories of activities would be eliminated. Depending on the size of the cuts it might be necessary virtually to eliminate space science and/or defer production of parts of the space transportation system. It could not allow for a major Federal role in developing the next generation of communications satellites or remote-sensing technologies. In this situation, private attempts to develop or operate space systems would be encouraged, but significant Federal funding for joint projects would not be available. Transfer of technology developed by the military to the civilian realm could provide incentives for private involvement, especially if military spending on space were relatively unconstrained. This might allow the private sector to concentrate on modifying military-derived technologies to civilian uses and on developing areas, such as materials processing in space, where the military is not heavily involved.

DISPERSAL OF NASA'S RESPONSIBILITIES

This would result if, because of budget constraints and a desire to consolidate all Government space programs, the shuttle and other applications developments were to be transferred to the Department of Defense (DOD) and other Government agencies. Under such a scenario, advanced communications, atmospheric (weather and climate) sensing, and land and ocean remote sensing would be developed first for the military, and spun off to the private sector or civilian agencies later, if ever. Desensitized data could be made available for civilian consumption and sale to other nations through public entities or through specially licensed private corporations. However, a much more relaxed view of security would have to prevail if the data were to be as valuable as data derived from competitive international systems. Launches would be conducted by the military, with appropriate arrangements for private sector and foreign users.

NASA would retain responsibility only for basic research in space science. NASA's centers now working on applications and operations would be turned over to DOD, Interior, Commerce, or universities and private firms. Such a scenario would contravene a major premise of the NAS Act, that civilian and military space activities are to be conducted separately, and hence might require explicit legislation. It would certainly raise questions about the act's premise that "activities in space should be devoted to peaceful purposes for the benefit of all mankind."~

Toward a Coherent Federal Space Policy

partly because most civilian space technologies arise within NASA, which is primarily an agent of technology push, commercial interests and initiatives have not developed to the extent that they ordinarily do in industry. Other contributing factors include: lack of consistent congressional or executive policy direction facilitating the development of a stable market, the complexity of the technologies themselves, and the high costs and economic risks the private sector would have to bear. Aside from the general public, whose interest is periodically sparked by space spectaculars, the communities NASA serves have up to now been users rather than partners. Lacking on the one hand effective guidance from the Congress or the President, and on the other an adequate forum in which user needs may be expressed, civilian space policy is often made de facto by NASA and the Office of Management and Budget (OMB). Essentially, there are two problems. First, the United States currently lacks the appropriate means to bring the scientific, commercial, and political communities into consensus about the broad goals for civilian space activities. Second, the Federal Government has given insufficient attention to establishing arrangements whereby the private sector can be brought into effective partnership in the development and operation of civilian space systems.

Lack of foresight and, especially, lack of coordination have characterized much of the recent U.S. space effort. Increasingly, the direction and scope of our space program are determined by the annual budget deliberations among the executive agencies, OMB, and the Congress. This approach presents several problems, one of which is that annual budget cycles bear little relation to the long-term evolutionary cycle of space systems. Another is that by its nature, OMB is not well suited to view investment in space activities in long-range perspective, Finally, insofar as the civilian space program remains essentially NASA's to direct, it suffers from inattention to the concerns of users, those in the public sector, as represented by Government agencies, as well as those in the private sector. In order to focus the U.S. civilian space program and to introduce more consistency into all U.S. space activities, the President or the Congress must set forth new goals. In the absence of such direction the current drift will continue and worsen.

In order to focus attention on the country's objectives in space, periodic high-level review and discussion are needed. The Carter administration undertook several reviews of space policy under the aegis of the National Security Council which resulted in Administration Policy Directives PD-37, 42, and 54 (see ch. 10). In the Reagan administration, the Office of Science and Technology Policy (OSTP) is conducting a major policy review for a Cabinet Council chaired by the Secretary of Commerce. It is scheduled for completion sometime in 1982. Such reviews are useful for focusing attention on the needs of the space program. However, these short-term, highly focused reviews cannot substitute for sustained examination of our long-term goals in space and high-level attention to policy setting.

The many authorization and appropriations hearings on space within the Congress, as well as reports from its support agencies, keep the Congress informed on pressing space policy issues. However, because of the press of other items on the national agenda, the relatively small weight that space matters receive in most congressional districts, and the fact that space issues are dealt with in several different committees, space policy has not received sustained and broad-based attention. It would be helpful to establish a high-level, multirepresentative body to recommend goals and objectives for the overall U.S. space effort. Such a body should be able to articulate, and gain support for, the broad goals of our civilian space program, and to suggest major programs to implement these goals, though it should not be expected to achieve consensus on all the details of our future space effotts. Indeed, consensus on specific activities, e.g., the

'National Aeronautics and Space Act of 1958, as amended (Public Law 85-568, 85th Cong.,H.R. 12575, July 29, 1958, 72 Stat. 426.) sec. 102 (a).

level of effort devoted to space science, may never be reached, for at that level, the political process of balancing competing interests (with input from the scientific establishment) properly takes precedence.

Several alternatives for this proposed body, varying in potential effectiveness and feasibility are as follows:

- ***Establish a new version of the National Aeronautics and Space Council (NASC).*** As it operated in the past, the NASC consisted of a permanent White House group, chaired by the Vice President and composed of representatives from the major Federal agencies. It was charged with recommending policy and programs directly to the president. If a future council is to be effective, its chairman would have to take a significant personal interest in space activities. A membership restricted to Federal agencies, however, would not include all of the potentially interested parties. To represent the broader perspective characteristic of the maturity of the U.S. presence in space, a reconstituted NASC should also include several members from the private sector in addition to those of the Federal agencies.
- ***Activate the Policy Review Committee (Space)*** in ***the National Security Council*** (NSC), the body charged in the Carter administration with advising and recommending on space matters. If chaired by a civilian Cabinet-level officer, it would have visibility. However, such a course of action might have the drawback of overemphasizing national security interests at the expense of the scientific, Government-user, and commercial representatives.
- ***Establish a Presidential or national commission*** composed of representatives from all the major communities interested in space. The terms of the commissioners should be long enough to outlive any particular administration. The influence of such a commission would depend on the personalities and talents of its members and the receptivity of various administrations rather than on a solid political/institutional base. Key Members of Congress should be included as members of the commission.
- Raise ***the importance of OSTP.*** Within the executive branch, civilian and military space policy is studied and formulated in OSTP and NSC. Currently, OSTP is conducting a policy review. Although this arrangement may serve as a focus for developing space policy, access to the President may not be direct enough to insure his attention to the needs of the civilian space program.
- ***Institute joint congressional hearings.*** At present, civilian space activities are reviewed by separate subcommittees of the House and Senate. For many years, both Houses had full committees responsible for space. One way to put space more prominently on the congressional agenda might be to reestablish full committees whose staff and members would have a strong interest in establishing goals and supervising their implementation. Periodic joint hearings between committees responsible for various aspects of the civilian and military space programs would help to provide coordination of national policy.

Though each option has attractive features, none appears to resolve completely the twin issues of representing all major participants fairly and adequately, and of influencing key decisionmakers. Without a commitment from the legislative and the executive branches to pursue a long-term course, none of these alternatives can be effective. However, their activities could at least define the major problems over time and ensure that regular reports are sent to the President or Congress.

Overall Prospects for Space Applications Technologies

Whereas the military and political threat of the Soviet Union sparked the initial drive toward U.S. preeminence in space, the challenge to U.S. leadership in applications programs now and for the forseeable future will come from commercial competition from our allies. The Japanese and the Europeans have heavily involved their private sectors with government programs. These government/industry partnerships have made for vigorous space programs; government contributes various kinds of subsidies and technical resources as well as a sense of national interest, the private sector contributes a whole range of commercial and technical expertise along with risk capital. Although the United States still retains its lead in technology in most space applications, foreign technical and managerial capabilities are growing rapidly.

Of the four space applications technologies here under review, U.S. success with satellite communications is in many respects exemplary. To begin with, it is flourishing. The rate of growth in this industry has been and probably will continue to be over 20 percent per year. It provides an increasingly greater range of services on which users worldwide have come to rely. The keys to its success seem to have been the early and major involvement of the private sector and a firm understanding of the potential market.

There is, however, no single model for commercializing space applications technologies. Markets for each are in different states of development; the proportion of activities aimed at public (rather than private) good varies from one technology to the next; and the maturity of the technologies themselves is not the same. Furthermore, there may be some portions of these technologies that are not at all suited for commercialization. The special needs and effects of each technology should therefore be considered in commercializing technology developed by the Government.

Issue 3: What Policy Principles Have Guided the U.S Civilian Space Program?

Before the issues specific to each of the technologies are addressed, it is useful to consider the foundation upon which the space program now rests, the 1958 NAS Act. The discussion in this section considers six of the major policy principles articulated in the act and in subsequent executive and legislative directives. Although the act contains other principles (e.g., that peaceful uses of space are to be developed, and that benefits to all mankind are to be sought), the principles selected for discussion in this assessment suffice to allow reasoned consideration of civilian space policy. Indeed, these six principles form the core of U.S. civilian space policy, and they have helped to shape the programs and institutions for implementing that policy.

The six policy principles may be stated as follows:

- that U.S. preeminence in space science and applications be maintained;
- that economic and social benefits be derived;
- that knowledge be increased;
- that civilian and military activities be separated (though they are to be coordinated and are not to duplicate one another unnecessarily);
- that NASA, the civilian agency, be limited largely to R&D; and
- that international cooperation be fostered.

Thus, the issues and findings organized by these six policy principles include those that are generic to all four technologies under review, and those that extend beyond space applications to the conduct of the entire civilian space program.

To Maintain National Preeminence

[n what sense has the United States been a leader in space applications? Is it still so today? For how long can we expect to maintain our leadership?

Especially since World War II the United States has seen itself as preeminent in science and technology and as having a special expertise in both the military and civilian applications thereof. Maintaining a technological edge has been considered crucial for several reasons. First, national security has become increasingly dependent on rapid and sustained technical advances in electronics, aerospace, and nuclear energy. Second, high technology has increasingly become a strategic sector of the economy; that is, high technology so thoroughly pervades other sectors of the economy that the United States cannot afford to be dependent on foreign countries to provide it. Other advanced nations behave similarly. Third, economic competitiveness in global markets, as well as continued domestic prosperity, stems in large part from a broad R&D base in high-technology industries. Particularly in highly developed countries such as the United States, where the costs of labor and raw materials are high, advanced technology products are a major export item. For the preceding reasons, and also because scientific and technical progress gives a general impression of vitality and strength, scientific and political decisionmakers often believe our political influence abroad to be directly dependent on national programs in the sciences and on advancements in high-technology sectors of the economy.

Attention to national preeminence has been the major formative influence on the conduct of the U.S. civilian space program. The 1958 NAS Act states as one of its aims "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof . . . "2 At its inception, the space program had to meet the perceived threat to U.S. national security from the launch of Sputnik and subsequent Soviet space initiatives. The design of our manned programs of the **1960's** and the shape of NASA's institutional structure were driven primarily by considerations of national security and political prominence, and only secondarily by regard for potential economic and scientific benefits. If the Soviets had been allowed to achieve clear superiority in any major category of space activity, they would, in the judgment of U.S. political leaders, have been likely to gain increased political support from neutral countries. As a nation, we refused to accept second place. Therefore, the United States embarked on a comprehensive and accelerated program that included the development of a variety of expendable launch vehicles, communications satellites, manned vehicles, and several orbital and planetary scientific probes. By the end of the 1960's, we succeeded in matching or bettering achievements of the Soviets in virtually every area: in addition to our celebrated victory in the race to the Moon, U.S. communications satellites were providing operational global service in the International Telecommunication Satellite Organization (I NTELSAT) system; U.S. meteorological satellites were making local weather coverage available to many parts of the world; U.S. launchers were available to other countries for scientific and applications projects; an ambitious program of unmanned planetary missions to explore Mars and the other planets was underway; and a **promising** remote-sensing technology was under development, the data from which were to be made available at low cost to all countries. As a result, the United States was able to reap the political and economic gains of unchallenged superiority in space applications.

In the following years, however, this picture began to change. Defeated in the race to man the Moon, the Soviet Union concentrated on developing a permanent manned Earth orbital laboratory, the Salyut. From 1975 to 1981, while the United States flew no manned missions, the Soviets flew 20, some of up to 6 months in duration. The Soviets conducted extensive experiments in materials processing, remote sensing, and the biological sciences, and they gained additional experience in remote-controlled rendezvous and docking, and operation of manned systems. The U. S. S.R. 'S investment in planetary exploration and space science and applications has also been extensive, in some cases more than that of the United States, but for the most part has yielded fewer results. Though less spectacular than the U.S. flights of a decade ago, the steady program of the Soviets has produced valuable experience largely unavailable in the West. Cooperative ventures with other Communist countries, as well as with India and France, have provided them significant political gains, too. Future Soviet plans are unclear, but are likely to include development of larger permanent orbital stations, an operational land remote-sensing system, high-performance boosters, and, eventually, manned planetary missions.

More important to the present situation is that Japan and several European countries have recently developed a number of advanced space technologies, many of which are comparable and in some cases superior to those of the United States and the Soviet Union. In addition, they have established a number of innovative institutional arrangements that allow significant private-sector/government cooperation. Beginning in the

Zlbid., Sec. **102 (C)** *(5).*

early 1960's, Europe and Japan saw the importance of developing competitive space capabilities to avoid political and economic dependence on the superpowers. Though their space budgets have only been a fraction of those of the United States and the Soviet Union, their programs have achieved success by eschewing development of expensive manned capabilities, borrowing technology from the United States, and concentrating on a few key applications. Their motivations have varied, from France's highly political desire for independence and a domestic technology base to support military programs, to Japan's perception of the space market as an arena in which advanced technology is likely to yield high long-term profits. Especially significant has been the devleopment of an independent launch capability in the form of ESA'S Ariane and Japan's N-1 and N-2 vehicles.

Because of the U.S. space program's historical emphasis on very large, expensive manned programs, and because of institutional and political difficulties in transferring technology from the public to the private sector and in coordinating private sector activities, commercial competition from heavily subsidized foreign space systems may prove difficult to meet, Though the United States will retain its lead in state-of-the-art technologies and especially in manned flight, its institutional and financial capacity to support operational systems and to meet user needs is very much in question.

To Derive Economic and Social Benefits

The civilian space program has been the source of an important flow of economic and social benefits. Some of these benefits have been derived indirectly through the spinoffs from technology developed for NASA, while others have resulted from direct technology transfers to the private sector and to Government agencies. Insofar as commercialization of space applications technologies is a natural and accepted process in a capitalist society, the problems inherent in industry's attempts to commercialize technology orginally developed by or for NASA are of particular importance for this assessment.

Does the commercialization of space-based technology differ from the commercialization of Earth-based technology?

The commercialization of new technology is the last state of a complex process of innovation. Generally, this process begins with a period of basic scientific research, proceeds through a stage where practical applications are sought, and terminates in the identification of potentially marketable products. The time required for such a project, the number of participants, and the cost will all vary, depending on the nature of the research and the existing store of knowledge.

In the private sector, the decision to invest in innovation is generally motivated by desire to sustain profits. Investments in innovation, like other investments, are required to meet criteria of return on investment. Profitmaking enterprises tend to invest in projects which are designed to satisfy a recognized market or management need. Expensive, long-term, and high-risk endeavors have to be justified by a reasonable expectation of high payoff and future profit. This basic rule applies, whether the proposed innovation is in Earth- or space-based technology.

Innovation in space-based technology is inherently expensive and highly dependent on Government interest and cooperation; it involves untried technology and is often not driven by clearly defined markets. As a result, such activities cannot easily attract corporate capital. Given this generalization, it is important to review the pattern of past and current private sector investments in space technology.

The most obvious example of the successful commercialization of a space technology is the communications satellite. Early private sector interest in satellite communications was motivated by the realization that satellites provided a more efficient and less expensive alternative to the then-existing means of long-distance communication. Substantial private sector investment was later required to utilize this technology; however, the investment was made with the knowledge that the technology was well-understood and the market large and well-defined. Other space-based technologies, such as remote sensing and materials processing, do not share these advantages. Much of the present dialog about the commercialization of new space systems concerns untried technologies directed toward undefined markets. As a result, the private sector's aversion to expensive, high-risk endeavors and undefined markets has prevented and will continue to militate against major private investment in these areas.

Though reluctant to undertake the commercialization of specific space-based technologies, the private sector has been actively involved in space-related support services, providing such necessities as flight hardware, project financing, insurance, and tracking and control facilities. This limitation of private sector involvement is understandable, for these suppont services require only limited risk, and rely on preexisting and/or Government-funded technology or contracts.

To date, the major industrial participant in space activities has been the aerospace industry. This fact may be attributed to that industry's familiarity with space technology, to its close working relationship with Government, and to its willingness to take a long view of product development. Other industries have been reluctant to engage in research projects which require knowledge, personnel, and support facilities which they do not already have.

Without substantial budget support from the Government, private investment in new space technologies, such as materials processing, remote sensing, and space transportation systems, can be expected to proceed at a pace and in a manner consistent with normal investment practices in the private sector. There is some cause to believe, however, that the amount of private sector resources devoted to space may increase in the near future. This inference is largely the result of what might be termed a disaggregation of space investment opportunities. In other words, as the opportunities for relatively small investments in space technology multiply, different industries are likely to pursue individual profitmaking activities. Instead of one firm attempting to undertake a major space project, numerous firms, pursuing their own interests in particular segments of a space system, may indirectly accomplish the same result. Examples of such a situation now exist in land remote sensing and materials processing.

In land remote sensing, it is very unlikely that the private sector could finance and operate the presently structured Earth observation system. (See Issue 5.) However, it is possible that if the space and ground segments were separated, one or more private firms could profitably operate the ground segment of such a system. Similarly, in materials processing, the investment required for a single firm to identify a product, to design and launch the necessary experiments, and then to manufacture the product in space, is too great to attract industry's interest. However, recent activities in the aerospace industry indicate a willingness to design multiuser instrumentation to be used in conjunction with the shuttle for a wide va'riety of in-space research. After its development, this instrumentation would be rented to other private sector organizations for specific research projects. As the cost of in-space research is gradually spread among a number of participants, the risk to any single firm will be reduced, and the industry's investment in space should increase. (See Issue 6.)

To Increase Knowledge

The goal of increasing knowledge is more characteristic of the space sciences than of the development of applications technologies. Nonetheless, the goal of achieving a balanced and sound space policy requires that it be fostered. In addition, space science, especially studies of the near-Earth environment, plays a key role in the design and implementation of successful applications projects. An important aspect of this goal is that it mediates between maintaining national preeminence and promoting international cooperation.

NASA, the National Science Foundation (NSF), and the universities set the agenda and direction of basic space science research. The National Academy of Sciences, through its Space Science Board, also plays an important role in this process, The yearly budget process determines the level of funding for space science among the many other competitors for portions of the Federal budget.

Although this study did not assess the adequacy of the U.S. space science effort, nor the institutions and procedures used to determine its goals, it is clear that a thriving space applications technology program depends on maintaining a strong U.S. base in many key areas of science and tech nology.[3]

What problems are associated with assuming a continual growth of the knowledge base?

Conducting research in space is becoming more expensive, primarily because the easiest studies have already been done. Furthermore, justifying basic science research is difficult because direct tangible benefits from a quest for knowledge cannot be immediately shown. Thus, it is somewhat more difficult to generate public support outside of spectaculars such as the Mars Viking landing or the Voyager missions to the outer planets.

As missions have become more complex and expensive, and therefore more infrequent, it is becoming increasingly difficult for Government and universities to maintain their science teams.[4] As a result, there may soon be a narrowing of the base from which new ideas can come.

Finally, there is a tendency within NASA to focus on development and launch of new spacecraft or payloads. Anaiysis of data and interpretation of existing information or of material from past missions tend to be given lower priority and funding. In addition, the planning for data analysis prior to missions has often been inadequate. Space science has suffered from budget reductions caused by the growing costs of the shuttle program in an era of fiscal constraint. For a long time, there has been inadequate integration of space-based and ground-based science priorities, as well. Here, as in space applications, the appropriate allocation of financial resources could be assisted by an effective forum in which comprehensive and long-term national civilian space policy goals could be established.

[3]James A. Van Allen, "U.S. Space Science and Technology, " *Science,* Oct. 30, 1981, vol. 214, No. 4520.

[4]"Space Science Research in the United States, OTA Workshop," May 5, 1982,

To Keep Civilian and Military Space Activities Separate

A cornerstone of U.S. space policy has been that civilian and military programs are to be conducted separately. Up to the era of the shuttle, this separation has served the Nation well: independence of the civilian space program has reduced concerns of other nations that the United States might impose a Pax Americana in space or that space might become just another arena for military competition; good relations between NASA and DOD have reduced unnecessary duplication and promoted technology transfer; and the civilian space program has served as a high-technology analog of the Peace Corps—a point of focus for peaceful and scientific national aspirations and international cooperation.

Recent developments have led to serious concerns that the separation of the two programs may be diminished, that NASA funding and technical resources may be preempted by military uses, or even that much of the civilian program may be subsumed under the military. The shuttle in particular, which will be operated by NASA, though used by both NASA and DOD, is a compromise between the requirements of both. Because of this joint usage, there have been suggestions that DOD assume all responsibilities for space transportation.

Within certain boundaries, technology transfer from DOD to NASA has generally worked well enough in the past, but the current climate of fiscal restraint argues for a more effective, more timely transfer of military technology to the civilian sector. The United States finds itself facing considerable competition from Japan and Europe. Two different technologies illustrate the problems we face:

- ***Development of 30/20 GHz technology. In*** order to meet this competition, the United States is being pressed to begin a program to develop and demonstrate a civilian 30/20 GHz communications system. At the same time, however, military contractors are working on systems related to such a civilian system. Many believe that the technology developed for the military can be transferred to the civilian sector at a cost saving that

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would permit a commercial system to reach operational status rapidly.

- ***Development of multilinear array (MLA) technology for a civilian land remote-sensing system.*** The French are already working on MLA technology for their SPOT remote-sensing system. Although this technology is well known to military engineers, independent development of a U.S. civilian system would entail an expensive R&D program and, subsequently, an expensive demonstration project.

How can technology transfer from the military to the civilian sector be facilitated and increased?

There has been, and continues to be, a recognized need for military use of various space platforms to accomplish national defense missions. Though the civilian program is separate from DOD's program, they interact at both the management and technical levels. The 1958 NAS Act specified the establishment of a civilian agency, called for technology transfer between the civilian and military programs, and established an external coordinating mechanism, NASC, to mediate any interagency conflicts. In the intervening years, NASA's program has been subject to extensive public scrutiny, and it has developed an applications component which, because of our political philosophy and tradition, is oriented primarily toward developing systems that will eventually be operated by the private sector. The programs of DOD (and the intelligence community) have been highly classified, subject to no extensive public debate or scrutiny, and have been highly focused on mission applications. These differing objectives (and others mentioned elsewhere in this report) have led to the development of separate systems in many areas, but have not precluded common usage of certain systems.

The primary example of a common system is, of course, the shuttle. This system, the major elements of which are funded by NASA, was intended from its very beginning to satisfy the mission needs of both NASA and DOD. DOD funded the development of an interim upper stage, the shuttle launch complex at Vandenberg AFB, and extensive missions applications studies. In addition, DOD will bear the costs of producing its own shuttle-compatible payloads. Overall, the two agencies have worked well together on the shuttle program, their cooperation ensured by commitments at the highest policy levels.

At the same time, the payload programs of the two agencies (focusing on applications only) have developed along parallel, but generally separate paths. in some areas, though, DOD's technology has not been unique and, in fact, has benefited from work done by NASA and the private sector. For example, first generation military sea communications services were supplied by transponders leased from civilian maritime satellites; the FLTSATCOM system became operational later. Similarly, DOD has learned from, as well as contributed to, the technologies of geosynchronous satellite emplacement, of orbit control and station-keeping, and of satellite housekeeping (i.e., thermal control, power supplies, signal processing, etc.). In addition, the two sectors have shared information on satellite structures, altitude and attitude control, sensors, and a miscellany of such items as composition of the upper atmosphere and transmission/reflection characteristics of the Earth and its atmosphere.

There remains a significant concern about the store of military technology, largely unknown to the public, that lies behind the curtain of security classification blanketing most of DOD's activities and interests in space. It is important to recognize the nature of the barriers that exist with respect to accessibility of DOD's technology—for use either in the private sector or in the civilian public sector (by NASA or NOAA). The technology may be:

- ***Unique to a given DOD mission.*** To reveal that DOD possesses a given technology would be to reveal that a specific classified mission was being pursued.
- ***Not suitable for civilian use,*** Missions unique to DOD may require the development of systems with characteristics (and associated costs) unnecessary in the civilian sector. For example, the security and survivability criteria driving the design of many DOD systems result in a degree of redundancy and circuit hardening unneeded in civilian sat-

ellites. If, **in addition, a satellite with such characteristics were introduced into civilian use, the measures employed to ensure the survivability and security of its military twin might be compromised.**

- ***More advanced than needed for civilian applications.*** **In** Earth observations, for example, military intelligence requires that data of very high **resolution be collected-a standard of performance well beyond that required (or even desired) for most civilian purposes. Adoption of specific military systems or specific technology may be restricted** for several reasons: it may reveal how capable U.S. systems are, and it may reveal that a particular technology, generally considered to be well understood, achieves higher performance through special modifications. These barriers apply to a greater or lesser degree to specific Earth-sensing and communications capabilities, and they derive from concerns for national security, concerns that cannot be ignored in assessing the question of technology transfer from DOD to NASA.

However, there are cases in which the existence of a DOD technological capability (though not necessarily the latest development) has been shielded unnecessarily. In such a case, NASA has had to develop a demonstration system incorporating the same technology before it can be transferred to the public domain. Such measures are wasteful of public resources and should be given careful review in the light of current resource constraints.

To Limit NASA to R&D

With the exception of launch facilities and space transportation in general, NASA's work has been confined to R&D–largely because when the 1958 act was written, the question of Government operation of, as yet nonexistent, space applications technologies was not of great concern to the framers of the act. In addition to its many contributions to aeronautics technology, NASA has developed communications and Earth observations systems, and has studied the potential for manufacturing products in space. The experience of the past quarter century with respect to NASA's limitation to R&D has been mixed. A primary benefit of NASA's emphasis is that it has been able to make rapid technological progress because it has not had to develop expertise either in operation of service systems or in commercial development. Drawbacks include pursuit of some projects that may be impractical because they are developed with insufficient appreciation of user requirements and constraints, and inefficient transfer of technology and services to potential operators.

Prior to 1958, the National Advisory Council for Aeronautics (NACA) operated according to a general policy, set in 1946, that directed R&D to cease prior to development of specific designs of commercial aircraft equipment. This specific development was viewed as the proper role of industry. Government research was oriented toward proving a concept and generating sufficient data to permit an industrial designing process to start with a good chance of successful completion from both the technical and economic point of view. This mission is simpler for the case of aeronautical research than for space applications efforts, however, because the civil aviation market has been well defined for decades. Unfortunately, this same high degree of market articulation is not the case for all space applications technologies. The market for international communications services was rather well understood in the early 1960's. Consequently, commercialization could proceed from NASA generic R&D much as aeronautic technology did in the past. For materials processing in space, however, the market is embryonic, and simple proof of concept will not move MPS into commercialization. Thus, the precedents of how and when to shift development into the private sector fit less well for MPS.

Primarily because the NAS Act is silent on the question of who is to operate space applications (except for **transportation)**, decisions about when a system is ready for operation, and who should be given responsibility for operating it, are made ad hoc. For satellite communications, Congress decided after much debate that responsibility for operations should reside in the private sector, but because of fears that open entry would result in a virtual communications monopoly by one firm, namely, the American Telephone and Telegraph Co. (AT&T), it created the Communications Satellite Corporation (COMSAT) in 1962. The polar orbiting TIROS weather satellite system was given to the Weather Bureau, within the Department of Commerce, to operate in 1961. When NOAA was formed in 1970, operation of the weather satellites was given to that agency. It now operates the geostationary operational environmental satellite system as well.

Land remote sensing from space, after considerable infighting among the mission agencies, was finally assigned to NOAA in 1978, principally because of its expertise in operating satellites, though it had no prior experience in the special issues surrounding land remote sensing. According to that policy decision, NOAA was also to investigate and develop mechanisms for eventually transferring Landsat to the private sector. Meanwhile, the Government committed itself to assuring continuity of the data flow from Landsat. Current policy calls for transfer of Landsat to the private sector "as soon as possible" and provides for no follow-on to the program if private operators do not assume operational responsibility. NOAA was also to operate the now-cancelled National Ocean Satellite System.

In materials processing, NASA is pursuing a vigorous basic research program. As the commercial viability of this technology becomes clearer, it seems likely that private industry, with NASA's help, will pursue specific opportunities for developing manufactured items in space. As with aeronautics or communications satellites, the Government's role in materials processing R&D will change as the technology matures.

The rationale for maintaining a separation between R&D and operations is that better, more innovative research may be done by an agency in which finding new and better ways to accomplish a task is the agency's primary concern. On the other hand, leaving an agency free from the ofien pedestrian tasks of operating a complicated technology for the public good may result in a configuration of technology that will not serve the eventual user well, either technically or economically, Also, without a closely involved client intending to assume responsibility for operations, an R&D agency may not be motivated to make appropriate tradeoffs between cost and performance; there may be unnecessary "gold plating." Furthermore, the user agency can concentrate on operations and avoid unproductive conflict between engineers and users. Users tend to be conservative: they would rather stay with a working system that they know and trust than risk their time and resources on an untried system even if it promises a vast improvement in capability. Clearly, a proper balance must be struck.

The primary issues of concern in Government-operated applications systems are when and how the transition is to be made from R&D to operational status and who has control over the course of R&D. Though different systems should be treated with flexibility as this transition is planned, the lack of clear and consistent principles for transfer introduces uncertainty and inefficiency. Perhaps the most important consideration is that potential users of a new system must be identified as soon as possible and brought into the process of planning its eventual operation. The cases of Landsat and the weather satellites have shown how difficult this transition can be to carry out. With all good will on both sides, the perceived needs of the users and the far-seeing vision of the engineers and scientists were not always compatible. One of the reasons for the user community's current dissatisfaction with certain aspects of Landsat is that it has remained an R&D system too long.

If the Government is going to be the operator of an applications system, one way to avoid interagency transition problems is to assign operational responsibility to the development agency. For space applications, NASA would assume this role, which has worked well for space transportation. In such a case, NASA would then have to develop competence in a variety of new fields in order to plan effectively for the operational phase and to carry out the plan when it is implemented. If NASA were assigned an operational role in areas other than space transportation, the transition from development to operations could be made smoother and would be more likely to lead to early returns from investment in space applications R&D. Where the period of governmental operations is likely to be of limited duration (e.g., for remote sensing), making NASA the operational agency seems appropriate.

When the private sector is to operate the applications technology once Government R&D is complete, the issues are somewhat different and involve the vital question of whether Government should be doing the R&D at all. The primary reason for the Government to sponsor R&D, as well as demonstration, in technologies intended for eventual commercial exploitation is to reduce uncertainties about the technical and economic risks associated with space applications systems. The key issue in making the transition from a Federal R&D program to a commercial operation is what additional Federal actions, if any, are needed once the technology has proved its viability, The Government has a generally weak record in understanding the marketplace, although the aeronautical program in NASA has had a long history of moving technology successfully to the private sector. As a further complication, nonaerospace industry has had little experience in working with Government on space activities.

The Federal agencies are learning how to collaborate effectively with business in the development of commercial opportunities based on Government-developed technology. Effective collaboration has been most effective in certain specific areas such as aeronautics, where the sometimes adversarial relationship between the public and private sectors has not developed. Eventually, however, the Government is likely to become more sensitive to commercial considerations in its dealings with new technology. As this kind of learning continues, Government can become a more effective partner with the Nation's investment firms and industries in maintaining U.S. economic leadership based on technological supremacy. However, there are probably inherent limitations in Government's ability to accommodate all private sector priorities.

To Foster International Cooperation

What benefits has the United States received from its cooperative programs? How is the desire for cooperation reconciled with maintaining U.S. preeminence?

The 1958 act encourages "Cooperation by the United States with other nations and groups of nations in work done pursuant to this act and the peaceful application of the results thereof."[5] Though in some ways opposed to the goal of maintaining national leadership, U.S. cooperative efforts have made useful contributions to overall political and foreign policy aims. By entering into a variety of formal and informal agreements with foreign governments (ranging from provision of scientific and technical data and participation in NASA science experiments to direct access to U.S. applications technology), the United States has encouraged potential partners to look favorably on the U.S. space effort.

In return, the United States has gained a variety of tangible and intangible benefits. At first, in the context of competition with the Soviet Union, the United States enlisted the support of allies and potential allies by offering them a stake in the new and adventurous space program. In addition, we gained access to a large number of foreign sites to provide tracking and relay stations for manned missions. Scientific data as well as general information were widely disseminated, in accordance with our basic decision—diametrically opposed to that of the Soviets—to provide the world with open coverage of U.S. successes and failures. Our civilian space program has provided a concrete demonstration of what we mean by an open society.

The United States took a leading role in establishing INTELSAT in 1964 and in arranging for broad international participation in the system. The United States profited through its initial

[5]National Aeronautics and Space Act of 1958, Op. cit., sec.102. (c) (7).

dominance of INTELSAT and its position as the main supplier of INTELSAT hardware. Because of the position of the United States, the Soviet Union did not join INTELSAT, leaving the United States as the central figure in international satellite communications.

The United States has attempted in a number of ways to involve third-world countries in its space program. The direct-broadcast experiments conducted by NASA's applications technology satellites in 1976 enabled India and Brazil to evaluate the feasibility of transmitting educational programing to remote rural areas. The Landsat remote-sensing system was made accessible to all countries through the sale of global data at low prices, the establishment of foreign ground stations, and technical/economic assistance to less developed countries provided by the Agency for International Development. In addition to fostering goodwill, U.S. openness has helped forestall criticism directed at direct-broadcast and remote-sensing systems that operate across national boundaries.

The United States has long had a policy of selling launches—vehicles and tracking facilities—to foreign users for peaceful purposes. In one major instance of direct technology transfer, Japan has been allowed to produce Thor-Delta expendable vehicles under license. Many scientific and R&D missions have been carried out for developed and less-developed countries, in addition to cooperative ventures between NASA and outside agencies.

More recently, the rise of competitive European and Japanese capabilities, along with increasing antagonism toward the United States on the part of third-world countries, has strained our cooperative posture. European participation in the space transportation system has been extensive; the European Space Agency is building Spacelab (at its own expense), in return for free flights on the shuttle. European and Japanese payload specialists will participate in upcoming Spacelab missions. Though, overall, the Spacelab/shuttle arrangement appears to be satisfactory to both sides, differences have arisen over timing of delivery, costs, and participation in operational decisions. More generally, there are unresolved issues concerning the proper extent of cooperative ventures and of information sharing about potentially competitive commercial products, particularly in materials processing. Cancellation of the U.S. portion of the international solar polar mission (ISPM) has made the Europeans wary of entering other cooperative ventures with the United States.

In international organizations, especially the UN's Committee on Peaceful Uses of Outer Space, the U.S. position on several important legal and regulatory issues has increasingly come under attack. The United States was instrumental in drafting the major treaties dealing with outer space and in establishing the principle that broadcasting and data collection from satellites could be carried out without interference based on claims of national sovereignty. However, many third-world and Communist countries are resisting possible transmission of radio and, especially, television programing across their borders, as well as the collection and dissemination of high-resolution imagery of their territories without prior permission. Cooperation with the United States may be disrupted by disagreements over these issues, especially as Japan and Europe are rapidly becoming alternative sources of comparable services and products and may make concessions to third-world and Communist countries as a means for gaining commercial advantage over the United States.

SECTION 2: APPLICATIONS POLICY ISSUES

Introduction: Generic and Specific Technology Issues

Each of the major space applications technologies raises certain issues that are generic to all space technologies—e.g., the appropriate rate of transfer from military to civilian uses, or the appropriate role of the Government in supporting R&D. In addition, each technology also creates several issues that are specific to it alone—e.g., the resolution limit of civilian land remote sensing by satellites.

Through a series of workshops, OTA established a set of generic and specific issues that underlie this assessment. Table 1 groups these issues by technology and the policy principle under which they fit most appropriately. The generic issues were discussed in the previous section. The following section discusses the most important specific issues, technology by technology.

Table 1.—Summary Matrix of Primary Policy Principles Across Four Major Space Application Technologies

Policy principle	Communications	Land remote sensing
Civilian/military split	1. Is the transfer of technology from the military to the civilian sector adequate? 2. Common/shared systems: a) What problems may the civilian sector face if the military can preempt civilian use? b) How should costs be shared?	1. Is the transfer of technology from the military to the civilian sector adequate? 2. What limits of resolution are appropriate to civilian systems? 3. What impact would declassifying existing military data have on prospects for transferring satellite remote sensing to the civilian sector?
International cooperation	1. How should the United States respond to foreign competition in ground and space hardware? 2. What are the impacts of Third World requirements for spectrum frequency allocation? 3. What policy focus should the United States develop toward foreign cooperation in satellite communications R&D? 4. What are the implications of U.S. application of its antitrust policies in foreign countries?	1. How will the problems of sovereignty and/or fairness be addressed? 2. What are the benefits/drawbacks of an international system for remote-sensing system? (a la INTELSAT or some other model). 3. What problems arise in our relations with other countries regarding private v. U.S. Government ownership of remote-sensing system? 4. What should U.S. policy be regarding U.S. agency use of data collected by foreign systems? 5. What is the impact of the U.S.S.R. as a competitor in remote sensing? 6. What are the effects on the foreign user of an interruption of the data flow from Landsat?
Leadership in science and technology and application thereof	1. What improvements need to be made in policy implementation? 2. How should United States respond to foreign competition? 3. What national goals or programs should the United States pursue?	1. Are we losing our leadership in land remote sensing?
NASA focus on R&D	1. What is NASA's role vis-a-vis the private sector? 2. How should program discontinuities be handled?	1. Is the policy regarding flights of opportunity adequate? 2. What steps might be taken to improve user inputs to the R&D process? 3. What continuing roles do NASA and NOAA have?
Expansion of scientific knowledge (basic science research)	1. What is NASA'S role?	1. What is NASA's role?
Development and operation of space vehicles (spacecraft)	1. What should NASA's role be regarding demonstrating publicly useful systems? 2. Do civilian agencies have a role to play in operating satellite communications systems?	1. Why hasn't the system been made operational? 2. What mechanism(s) is (are) needed to decide on the operational readiness of a technology?
Promote commercialization of civilian applications	1, How should regulatory problems (delays) be handled? 2. How should the Government regulate DBS nationality and internationally?	1. How can the market for data be aggregated and expanded? 2. How should the technology be transferred to the private sector? 3. What should policy be regarding data availability from R&D systems? 4. What incentives does industry require to commercialize remote sensing? 5. What institutional models might be appropriate? 6, How do we determine that a technology is ready for commercialization? 7. Should system continuity be assured? 8. Who should decide what sensors are required for an operational system?

Table I.—Summary Matrix of Primary Policy Principles Across Four Major Space Application Technologies (continued)

Space transportation structures	Materials processing (MPS) and manufacturing in space	Common issues
1. What should be DOD's role and share? What problems arise from the military's right of preemption of a launch opportunity? 3. What problems occur from military influence on space transportation system design? How would this affect cost and pricing?	1! Is there adequate coordination of efforts between military and civilian sectors? 2. On what basis can a potential space-based materials lab be shared?	1. Is there adequate transfer of technology from military to civilian? 2. How should systems be shared?
1. What problems arise with the perception of shuttle as a military system? 2. How should we respond to competition from foreign transportation systems?	1. To what extent is the prospect of commercial competition detrimental to scientific cooperation?	1. What should our policies be regarding international competition? 2. What institutions may be needed to address international competition? 3. Is the United States a reliable partner for cooperative programs? 4. Is it possible or desirable for the United States to institute Government-indust~ cooperative ventures similar to those of other nations? 5. How should the United States protect technology developed by Government R&D?
1. What should the policy be regarding maintaining national facilities?	1. How should the United States respond to potential foreign competition? 2. Is Spacelab an adequate base for future MPS experiments?	1. Given that portions of U.S. policy are sound, how can policy implementation be improved? 2. Is the lack of program goals the problem with the space program or is it lack of implementation of existing policy?
1. What role can industry play as potential operator/owner of space transportation? 2. Who decides what continuing R&D is needed? 3. Should the operational system(s) pay for further R&D?	1. Who should pay for basic ground-based research? 2. Who decides what space-based research to do? Who pays?	1. What different role should Government and industry play? 2. Who should perform oversight? 3. What is NASA's role in continuing R&D after commercialization of a system?
1. What is NASA's role?		1. What is NASA's role?
1. Who will operate the space transportation system in the near term? The far term?	1. How should costs of space-based materials lab be allocated? a) How is the lab shared between Government, industry, and academia?	1. Who decides when a technology is ready for the operational mode? 2. What criteria should be used to determine the operational readiness of a technology? 3. What role should NASA have in operating proven space systems?
1. How can the market for space transportation services be aggregated? 2. How can shuttle pricing policies be made more certain? 3. What regulatory/political constraints are needed for privately run systems? 4. What incentives might be needed to encourage private investment In owning and operating space transportation components or systems?	1. What new facilities may be needed to promote space-based materials processing?	1. What steps should be taken to reduce risk to the private sector? 2. What incentives are needed to encourage private investment in space technology? 3. What should be the policy regarding operation of expendable launch vehicles? 4. What legal agreements/restraints are needed to transfer technology developed with public funding to the private sector?

SOURCE: Off Ice of Technology Assessment.

COMMUNICATIONS SATELLITES

Issue 4: What Are the R&D Needs for Optimal Advances in Satellite Communications?

Because the satellite communications industry has already achieved the status of big business, R&D is a significant part of its competitive stance. Nonetheless, there is a point, based on industry's own view of return on investment, beyond which it is unwilling to commit funds for advanced R&D–where the risks are great, the payoffs uncertain, the technology unproved, and the time-scale of needs unclear. For this reason, the pioneers in advanced R&D are likely to be the Federal Government, industry/Government joint ventures, or, if antitrust laws permit, private consortia formed ad hoc. It is widely believed that individual firms cannot afford to finance the front-end costs of performing truly advanced development or substantial basic research,

Up to now, U.S. leadership in this field has not been threatened. But recently, Japan and several European countries have entered this field determined to compete successfully.[6] Supported by government-sponsored R&D as well as contracts awarded by INTELSAT, European and Japanese firms have developed competitive satellite subsystems and are now capable of designing, building, and operating complete telecommunications systems. In several areas, foreign development programs are more advanced than those in the United States. More concerned to maintain their competitive position with respect to one another than worried about possible antitrust violations, U.S. firms seem unwilling to coordinate an industrywide response to this potential threat to their markets.

NASA took an early lead in the development of communications satellites, and even after commercial success had been achieved, the agency continued to conduct R&D for advanced technologies. These included advanced stabilization techniques, the control of satellite position in synchronous orbit, and, in the last of the series, a demonstration of broadcast technology from the satellite to small, low-cost ground stations.

In 1973, OMB, acting on recommendations from the Office of Telecommunications Policy, greatly restricted funding for NASA's R&D **in advanced communications.** The assumption **underlying this decision was that the U.S. private** sector could conduct its own advanced R&D, making NASA's further participation mostly unnecessary. In the event, however, the private sector has, for the most part, been content to exploit proved technologies already available and to package them in even larger satellites; it has done little R&D of advanced systems. As a result, many of the new developments in satellite communication have come from the Europeans and the Japanese; in some areas they seem to have leapfrogged U.S. technology.

In this situation it is appropriate to ask what role NASA should play in responding to current needs for advanced R&D. One possibility is for NASA to proceed with plans to complete a demonstration flight of a 30/20 GHz satellite system. Other possibilities include demonstration projects for a large communications platform, and, at a much lower level of expenditure, a large deployable antenna. In addition, NASA could continue to support a number of smaller projects for 30/20 GHz subsystem work.

Increasing Use of the Geostationary Orbit

By far the most useful communications satellites are those stationed in geosynchronous orbit (GSO) in which they rotate about the Earth, in the plane of the Equator, at an angular velocity equal to that of the Earth itself. Stationed at a point above the Earth's Equator, a communications satellite in GSO can provide continuous coverage of nearly a third of the Earth's surface with a broad beam antenna.

Because many satellite systems must share relatively small numbers of orbit slots in space and frequency bands in the spectrum, there is a limit to the number of spacecraft that can be stationed in a given arc of GSO. Satellites must be sufficient-

[6] Anthony J. Calio, statement before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 8, 1981, p. 13.

ly separated to avoid radio interference, the separation required for a given level of technological maturity being subject to several physical constraints. In general, satellites along the geostationary arc can use the same frequencies only if they are far enough apart so that ground stations can point at one and not receive an interfering signal from its neighbor on either side.

To guarantee noninterference, the Federal Communications Commission (FCC) and international regulatory agencies have established minimum orbital separations and have assigned satellites to specific locations called orbital slots. Each slot can accommodate one or more satellites that, between them, utilize the full range of suitable frequencies. All the slots in view of the United States are filled with existing or authorized satellites, and FCC has had to choose from several competing carriers for allocating the last few slots. When the capacity of these satellites, operating at either C or Ku band, is fully utilized (projected to occur in the last half of this decade), the growth of this industry will come to a halt–unless a solution is found and implemented.[7] Two possible solutions that will be examined here are Ka band technology and large communication platforms.

NASA'S Past and Future Roles

Through the middle 1960's and 1970's, NASA played a leading role in R&D for communications satellite technology. Beginning in 1973, however, NASA's program was phased down considerably, on the assumption that the private sector would continue necessary R&D. The industry did indeed make noteworthy progress in a number of areas, but only because these areas offered: 1) a modest risk for the cost, 2) a relatively immediate market payoff, and 3) affordable development costs. As it has turned out, however, the private sector has not funded long-term, high-risk, and high-cost satellite communications research.

While the U.S. satellite communication R&D program slowed between 1973 and 1979, the Japanese and European efforts accelerated. The Japanese have already launched a direct broadcast satellite for tests and preliminary operations in the Ku band. Although the first two satellites in this program were bought from U.S. industry, all subsequent models will be made in Japan. It is also noteworthy that the Japanese have become the leading supplier of INTELSAT Earth stations and, because of very advanced technology and established production lines, are likely to take the world market lead in the sale of TV receive-only (TVRO) Earth stations designed specifically for direct-broadcast reception. Some see these efforts by the Japanese and similar activities in Europe as serious threats to the U.S. lead in satellite technology, systems, and market share.

Opportunity at 30/20 GHz

There are three frequency bands allocated for the use of civilian communications satellites: the C bands (6 GHz uplink, 4 GHz downlink), the Ku bands (14 GHz, 12 GHz), and the Ka bands (30 GHz, 20 GHz). The technology for transmission and reception in the C bands was developed first; almost all commercial satellites now operate in the C band.

Crowding at 6/4 GHz

While it is true that satellite communications systems operating in the C band (6/4 GHz) are successful and cost effective, two major problems are becoming increasingly apparent. First, the number of useful locations in GSO has been used up. With current technology, a 4° orbital separation between satellites operating in the C band is required. Not long ago, a 50 separation was required, and, as transmitting and receiving technology improves, a 3" separation may soon become standard.[8] Although it is theoretically possible to reduce the separation between satellites further, each reduction increases the costs of controlling the satellites' susceptibility to interference. Despite the introduction of new beam-shaping technology that will further reduce interference, the point at which it becomes impractical to squeeze additional satellites operating at 6/4 GHz into desirable parking spaces in GSO is nevertheless rapidly approaching. Therefore,

[7] General Dynamics, Convair Division, and Comsat Corporation, "Geostationary Platform Systems Concepts Definition Follow-On Study," final review, July 28, 1981, pp. 8-38; see also, Calio, op. cit. p. 14.

[8] Calio, op. cit., p. 14.

we are indeed running out of GSO locations with good "look angles" for 6/4 systems.

The second problem is coordination with ground microwave systems operating in the 6/4 GHz bands. These ground-based systems are radio relay systems, used primarily for telex, telegraph, and voice traffic. The problems are that the satellite ground transmitters cause 6 GHz interference at the radio relay system receivers, and that the radio relay system transmitters cause 4 GHz interference at the ground receivers of the satellite system. As these ground-based systems proliferate, it has become too costly to protect colocated two-way satellite ground terminals near metropolitan areas against interference. This problem is especially acute in heavily populated areas such as Japan, Western Europe, and the Northeast United States.

FUTURE NEEDS

As demand rapidly outpaces capacity of C band satellite systems, the United States has to make some difficult decisions as to what step to take next. Should we fully develop the Ku band? Should we jump to the Ka band? Should we attempt to deploy fibre optics more rapidly? Should we buy facilities and technology for service **in the** Ku and Ka bands from the Japanese and the Europeans?

There are two main advantages of going directly to Ka: first, the enormous spectrum spread between 20 and 30 GHz allows for transmissions of much greater bandwidth and, hence, much greater versatility; and second, there are many more orbital parking slots if the Ka band is used. Projections of demand for transponders in the 1990's differ on the question of the ability of the Ku band to handle the traffic. If projections are limited to increases in voice and data traffic, technical improvements will probably allow the Ku band to suffice up to approximately 199s-2000. On the other hand, if there is a large increase in video traffic, particularly for teleconferencing, the Ku band will be exhausted by about 1992. It follows that while the Ku band represents a near-term solution to the problem of crowding in the C band—e.g., the decision of Satellite Business Systems (SBS) to operate at 14/12 GHz–projected long-term requirements can be met only by moving to the Ka band. On the other hand, there are several unresolved technical and economic questions that prevent immediate establishment of an operational Ka system.

The main advantage of developing Ku systems is that the technology is already fully tested. The disadvantage is that the Ku band will not be able to meet the needs of a greatly expanded video market. In particular, with Ku only, full action, large screen video teleconferencing will almost certainly not be possible; only the expanded capacity of 30/20 can handle the large data flow of such a high-quality system. Ku band is, however, an important interim solution; whereas C band allocations total about 700 MHz, Ku provides 1500 MHz. As a ready technology, Ku can meet a service market having three times the capacity of the already crowded C band. Ka technology on the other hand is not ready for commercial use, and experiences three to five times the transmission losses experienced at Ku.

A potential competitor to satellite systems is transmission by fibre optics. By the 1990's, fiber optics will have come into its own as a major ground-based supplier of communications needs, However, no matter how well this technology performs, or how extensive its network becomes, it will not be on-line widely enough to fulfill the requirements of the expanding markets of the 1980's. Furthermore, unlike satellite beams, fibre optics is line-switched, not area-covering; therefore, it is not so likely to be competitive for broadcast or distribution services.

COMPETITION ABROAD

The Japanese and the Europeans have already begun to develop 30/20 Ka systems. One reason that they have moved to 30/20 is that they already use the 14/1 2 Ku band for commercial radio. Therefore, if they paid exclusive attention to developing satellite systems in the Ku band, they would face the same kinds of interference problems there that plague the United States in the C band. Similarly, the United States already has INTELSAT-V and an SBS satellite and will soon have TDRSS/AW–all operating in Ku band. Five new Ku systems, to be launched in 1983-85, are under development.

More important, however, the Japanese and the Europeans have concluded that the future of satellite communications systems lies in developing systems to exploit the Ka band, though they are deploying Ku systems as well. Precisely because the Ku band represents only an interim solution, they have decided to attempt long-range domination of the satellite communications market. The Italian firm, Telespazio, for example, hopes to be in the forefront of 30/20 development, and plans to introduce a system to handle domestic telephone service and data traffic. In congressional testimony, some U.S. companies in effect agree with the foreign evaluation, albeit in hindsight, for they argue that without the continuation of a strong U.S. Government program, foreign countries will almost surely dominate the multibillion-dollar international communications satellite markets of the 1990's.[9] A strong U.S. program is, however, not synonymous with 30/20 exclusively; aggressive deployment of Ku is important also. But a renewed effort by NASA would concentrate on development and demonstration of Ka technology because the agency has already completed these tasks for Ku with the CTS experimental satellite, from 1971 to 1977. At this point, the industry has the knowledge and technology to proceed at Ku, without further need for NASA to do product improvement.

One course of action made possible by the development of 30/20 systems abroad is that U.S. firms could buy the facilities and services developed elsewhere. But to allow ourselves to fall into second place in an important area of space applications would be to ignore a basic tenet of U.S. space policy -i.e., that the United States will maintain a position of leadership. Once the United States allows itself to take a back seat in the development and deployment of this (or any) technology, it becomes ever more difficult to regain the lead. The United States cannot lightly abandon any area of technological leadership (especially in a strategic sector such as communications), given the economic importance of maintaining a favorable trade balance in high-technology products.

[9] David McElroy, Martin Newman, and Johan Benson, statements before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 9, 1981, p. 149.

POTENTIAL MILITARY INTERFACE

U.S. aerospace companies are developing significant new satellite technology for the military, some of it designed for use at 30/20 GHz.[10] Those firms do not (and could not afford to) maintain separate working groups for military and civilian applications of a given technology. Rather, it is standard procedure for the same group to work on both. As important work has been done for the military at 30/20 and higher bands, the expertise exists to initiate a civilian program in short order (see ch. 6 for the broader context of this discussion).

By 1980, NASA and the Air Force had decided on joint funding of traveling wave tube development, in which the Air Force Space Division would provide 30 percent of the total funding. The Air Force, on the other hand, would handle the IMPAIT transmitter development, with NASA funding only a portion of that. For antijamming purposes, DOD is interested in a 44 GHz uplink band, but NASA is not. Thus, it seems clear that with the military interest in 30/20 (and 40), the research will continue with or without NASA.[11] Although there would be some problems with transferring the technology because of military emphases on security and survivability, such problems have been solved before and, in principle, could be in the present case.

RESPONSE OF THE PRIVATE SECTOR

In congressional testimony, private industry representatives have provided an unequivocal answer: no individual firm can finance the R&D costs of 30/20 technology.[12] On the other hand, though the industry as a whole, acting as a consortium, might be able to provide the financing, the structure of such an arrangement would have to be carefully drawn so as to conflict neither with

[10] Thomas F. Rogers, Edward C. Aldredge, Jr., and Elizabeth Young, in separate statements before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 2d sess., Mar. 2, 1982.

[11] John H. McElroy, statement before the Subcommittee on Transportation, Aviation, and Communications and the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology, U.S. House of Representatives, 96th Cong., 2d sess., May 21, 1980.

[12] Donald B. Nowakoski, statement before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 8, 1981, pp. 56-57.

present antitrust laws nor with the competitive positions of the corporations.

This is not to say that private industry has not in the past and will not in the future engage in significant R&D. **It is, rather, to say that industrial** R&D is generally conducted in support of primary business goals. Unlike NASA's R&D, it is product- or service-oriented. Furthermore, an acceptable percentage of industrial R&D must result in profitable business applications.

Furthermore, firms in the industry see themselves as spending to the corporate limit in fulfilling needs for short-term R&D. There are not enough funds to be applied to a long-term program like civilian 30/20. NASA estimates, and industry concurs, that the agency's flight program to test 30/20 technology will cost $250 million to $400 million over 3 to 5 years. A commercial R&D program in satellite communications hardware (which a carrier conducts in a lab) is, by contrast, on the order of $10 million per year.

SOME CONCERNS

One reason for concern is that the costs of flight testing 30/20 technology are estimated on the assumption that NASA would do the tests. It is often the case (and industry makes it frequently in other contexts) that industry can do certain kinds of tasks more economically than government can. Presumably, therefore, if one of the large aerospace companies conducted flight tests of 30/20 technology for civilian use, the costs would be substantially lower. Whether industry would argue that they still could not undertake the necessary R&D, even if the Government furnished launch, data acquisition, and tracking services free, is an open question. The complicating factor, however, is that no appropriate spacecraft bus exists. It is not certain that a Ku-band bus will suit Ka-band technology. if a new spacecraft is required, it will cost over **$100** million, excluding the costs of the new communications hardware to be tested. Nevertheless, if, for example, a consortium of the major satellite firms, builders and carriers, received contributions of $10 **million dollars** per year from each, over a 5-year period, a demonstration project could be privately funded.

A second reason for skepticism is that the risks seem somewhat overestimated. The technology has already been bench-tested; the launch systems are not problematic. Thus, besides the complex but manageable business of developing a suitable spacecraft, there remains only the task of mating proved technology and reliable launch facilities. Additionally, market studies of the commercial potential of Ka-band technology have been made and have been uniformly encouraging.[13] In short, the technical risks do not seem great, while the prospects of return are high.

A final area of concern, one which verges on questions of policy, is that insufficient consideration seems to have been given to the possibility of establishing a joint management structure for development of 30/20 technology. The Government might be a guarantor or a partner in such an arrangement, One potentially attractive Government-industry relationship for 30/20 technology, as well as for the large communications platform, might be a variation on the JEA currently instituted to promote materials processing in space. In such an agreement, the Government could offer to bear the cost of launching a communications satellite in return for a guarantee of a specified amount of public service communications from the satellite. If successful, both parties would benefit, If not, the losses would be shared.

Large Communications Platforms

TECHNICAL CHARACTERISTICS

As ***one*** important means of meeting the problem of crowding in GSO, large communications platforms (LCPS), on which several transmission facilities are mounted together, are a promising new configuration of technology. In addition to fixed and mobile communications an LCP may provide direct broadcast, navigational, meteorological, and Earth observation services, and support for scientific payloads, thus becoming a multimission platform. The large capital expenditures and the number of technological advances re-

[13] Elizabeth L. Young, statement before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 10, 1981, pp. 122-123.

quired make LCPS a much more speculative prospect than are 30/20 GHz satellite systems.

In general, an LCP is distinguished from conventional communications satellites by greater capacity, connectivity, and switching capability. The LCP would provide high capacity by means of multiple spot beams and multiple bands. It would provide good connectivity for a wide range of communications users, and it would offer very substantial in-orbit switching capability, far beyond that attainable by conventional satellites.[14]

The use of LCPS would bring several substantial changes:

- The high power of the platform would drastically lower the power needs and therefore the cost of the ground segment, resulting in a proliferation of Earth stations. Space segment costs per channel would drop, despite the larger initial investment required.
- The large capacity of the platforms would result in a requirement for fewer slots in the geostationary orbit. This would relieve the congestion that would result from the use of conventional satellites.
- The switching capability of the large platforms would eliminate the need for complex switching at the Earth stations. Earth stations would no longer be required to access more than one spacecraft.[15]

The cost savings for LCPS, estimated to be substantial,[16] would result from three areas in which economies of scale could be achieved. These economies result from:[17]

- reduced mass in orbit:
  - –lower bus mass per pound of payload, and
  - —much lower payload mass to perform the same mission,
- slightly lower production cost per pound of hardware, and
- much lower transportation cost per pound
  - —more efficient utilization of shuttle capacity.

The critical need of the satellite communications industry of the 1990's will be a spacecraft capable of supporting the large multi beam antennas and switches needed to provide large-scale frequency reuse for point-to-point services. A large platform in GSO is ideally suited for this task. All other services provided by the platform must be compatible with this primary mission–i.e., they must not interfere with or compete for bandwidth with the point-to-point payloads.[18] The primary and secondary services of LCPs in geostationary orbit may be broken out as follows:[19]

Primary use:

- Fixed ***point-to-point services:***
  - –direct-to-user (DTU) or customer premise services (CPS) network, and
  - –high-volume trunking (HVT), domestic, regional, and international.

Compatible services:

- ***mobile services:***
  - —air mobile,
  - —sea mobile, and
  - –land mobile,
- ***Broadcast and relay services:***
  - –TV distribution (separate Ku-band allocation,
  - —educational TV,
  - –direct-to-home TV,
  - —tracking and data relay, and
  - –data collection.

DEVELOPMENT REQUIREMENTS

The development of large space platforms would require a significant number of technical accomplishments, though what has to be done to make them successful is, as theory, well-understood. Thus, they represent significantly more than a relatively larger step in the evolutionary pattern that satellites have always followed–from smaller to larger, from less to more reliable.

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[14] Future Systems Inc., Large *Communications Platforms Versus Smaller Satellites,* prepared for NASA Headquarters, February 1979, p. ii.
[15] Ibid., p. 203.
[16] Ibid., pp. 203-204.
[17] General Dynamics, Op. cit., Pp. 8-15.
[18] Ibid., pp. 8-44.
[19] Ibid., pp. 8-45.

There are definite prerequisites that can, for the forseeable future, be provided only by the United States. First of all, the shuttle itself must be brought to operational status. Second, a vehicle capable of transferring a platform from low Earth-orbit (LEO), where its components would be brought up on several shuttle flights and then assembled, to its destination in GSO must be developed and proved. Third, satellite servicing and construction techniques (including extensive life-support and extra-vehicular activity (EVA), will have to be developed and demonstrated by NASA in LEO before the private sector will consider deploying LCPS in GSO. Next, certain improvements in the technology for the platform itself are needed. Of these, one is the design of antenna beams capable of very accurate pointing; this project, however, is an extension of present technology. Another is the development of a high-speed, low-power switch to interconnect the several antenna beams. Finally, the general requirements of long life and high reliability must be assured to compensate for the much greater expense of an LCP.

The requirements of long life and high reliability could be met in two ways. Either the hardware might be constructed to maximize these characteristics, or it might be deemed more feasible to rely on in-orbit maintenance of the platform. Maintenance, in turn, might be accomplished robotically by, for example, NASA's projected teleoperator, a remotely controlled device that would replace certain modules aboard the platform. Alternately, a manned orbital station in LEO, which might be deployed in 1990-2000, could be assigned maintenance duties; personnel would be dispatched to a platform on a transfer vehicle, not only to replace modules, but, if necessary, to make more extensive repairs. All of this must be accomplished at GSO and will require substantial development for an upper stage and for the shuttle itself.

LAND REMOTE SENSING BY SATELLITE

Issue 5: What Role Should the Federal Government Play in Developing or Operating a Satellite Remote-Sensing System?

Characteristics of Satellite Remote Sensing

Satellite remote sensing is one component of a broad range of technologies and techniques that are used to acquire data about the Earth's resources. They range from simple direct human observation and measurement, to high-altitude aircraft photography, to sensing by satellite. Thus, satellite remote sensing exists as one element of an activity that has been part of the human scene since it first became desirable to survey the extent and kind of resources available for human use.

Satellite sensing has unique properties that separate it from earlier methods: ease of operation, once established; the ability to see other lands without intruding in the country or its airspace; the ability to sample very large areas in a single "scene"; and the ability to produce an enormous data flow in digital form suitable for direct computer processing. Unlike other methods, its development and present operation rest solely with the Government.

Each of these characteristics, as well as others that will become apparent in the ensuing discussion, present new opportunities to the traditional users of remotely sensed data, but they also raise issues that must be resolved before satellite remote sensing can become a large and thriving component of resource observation and development.

Current Status of the U.S. Land Remote-Sensing Satellite Program

The world's first civilian land remote-sensing satellite was launched by NASA in 1972. Originally named the Earth Resources Technology Satellite (ERTS), the name was later changed to Landsat 1. The Landsat 1 and Landsat 2 satellites no longer provide data to users. Landsat 3 functions only partially. The present sensors are a multispectral scanner (MSS) that can sense the surface of the Earth in four different spectral bands, each with 80 m resolution, and two television-like cameras called return beam vidicons (RBV). Used together, the two sensor systems can produce data products that achieve 30 m resolution. The data from Landsat are transmitted to Earth by radio link and received at some 12 stations located in various countries around the world (fig. 6). The MSS sensors aboard Landsat 3 are returning only partial data, though the RBV sensors are functioning normally. A new satellite, having a broad resolution, high spectral coverage sensor called a thematic mapper (sensitive to emissions in seven spectral bands) is scheduled for deployment in late summer 1982. This satellite is designated Landsat D. A second satellite with similar sensors, Landsat D', has been scheduled for launch in 1985.

Although the system has been an R&D system designed to verify the potential of satellite remote sensing, through the efforts of NASA, the data from Landsats 1, 2, and 3 have attracted a wide variety of users (resource managers) in this country and abroad. These users consider Landsat data to be an invaluable component of the larger realm of resource inventory data from all sources (see apps. B and C for details). For some, data from Landsat have become a baseline requirement of their daily routine. For others, these data serve the secondary, but important role of a comparison data base. Generally, the users treat Landsat as if it were an operational system, even though it is still officially an R&D system managed by NASA.[20]

Although the system has found a variety of users, it has yet to demonstrate that it can attract a large enough market for satellite data to support even the management and operations of the system without large Federal outlays. Part of the problem is simply one of technological maturity. Very few technical improvements have been made in the characteristics of the data available from Landsat since 1972.[21] Many applications will require a satellite system of greater capability: higher spatial resolution, stereo imagery, and broader spectral coverage. A more important reason Landsat has not attracted a larger number of customers, however, is the uncertainty about whether the Landsat system will continue.

Many users of remote-sensing data from civilian satellites express considerable frustration with the current U.S. program. Though it is at a relatively primitive stage, the technology is far ahead of the institutional arrangements necessary to collect and distribute the data in a timely and predictable manner. From the users' viewpoint, the program is in disarray, and is characterized by a lack of clear direction and by organizational ambivalence.[22] According to U.S. policy, as articulated in the Carter administration's Presidential Directive 54,[23] NOAA will be responsible for managing civilian operational land remote-sensing activities after the multispectral scanner aboard Landsat D becomes operational in January 1983. NASA will remain in charge of R&D of satellite remote sensing for the civilian sector. This administration, as well as the previous one, is committed to transferring land remote sensing by satellite to the private sector. The current policy is to make this transfer "as soon as possible."[24]

Criteria for a Satellite Remote-Sensing System

Regardless of who operates a civilian satellite land remote-sensing system, the Federal Government or the private sector, the major users of satellite data have basic general needs for the conduct of an operational system, needs which they have expressed clearly.[25 26] Because each user has specific data needs (e.g., resolution, spectral ranges) closely related to his applications, each will have a different view of the specific technology most suitable for his purposes. However, given an operational system for acquiring remote-sensing data by satellite, most users agree on the following minimal criteria:

[20] "Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options," Department of Commerce, June 1980.

[21] "Department of the Interior Position paper on the Private Sector Transfer of Civil Land Observing Satellite Activities," Department of the Interior, October 1981.

[22] "Remote Sensing Government User Concerns," OTA Workshop, May 1981.

[23] Presidental Directive 54, White House Press Release, Nov. 20, 1979.

[24] J. Wright, Department of Commerce statement, U.S. Senate and House of Representatives hearing on Civil Land Remote Sensing Systems, July 22, 1981.

[25] OTA Workshop, op. cit.

[26] U.S. Senate and House of Representatives hearing on Civil Land Remote Sensing Systems, July 22 and 23, 1981.

- ***Continuity of data flow.*** Reliable, continuous flow of data is regarded by operational users as mandatory. For each user, the term "continuous data flow" has a slightly different meaning. However, it generally means being able to acquire the data that a satellite could have taken, or did take, in a timely manner appropriate to a given application. In the past, the data flow has been interrupted or slowed by failure of the tape recorders on the satellites, a natural enough occurrence in an R&D system but unacceptable in an operational one. Therefore, in order to ensure continuity, the users need the most reliable possible system, consistent with obtaining the necessary data. A backup satellite for deployment should the first satellite fail in a major way is also an important requirement.

  Delivery of data to the user has also been interrupted or slowed by the inability of the data center at NASA's Goddard Space Flight Center to process Landsat data fast enough.[27] Domestic users have experienced delays of up to 6 months in the delivery of Landsat data. Certain time-dependent data needs, such as those of agriculture or pollution control programs, cannot be served if the data cannot be processed within a few days (see table 2). The work of other programs is also slowed considerably by such delays.

  Continuity of data also means retaining data acquired in previous years. Landsat satellites have provided data since 1972, when the first remote-sensing satellite was launched. The data are stored on magnetic tapes that deteriorate over time. Thus, the tapes must be rerecorded in order to save the data. Because of the storage problems involved with saving everything, the EROS Data Center has selected standard scenes of cloud-free data over the world. The NASA Goddard Data Center is transferring these scenes from the early tapes to the computer compatible tapes (CCT), that will be stored at the EROS Data Center and available upon request to users. In the course of identifying the scenes to be saved, the EROS Data Center notified users of Goddard's intentions and asked them to suggest which scenes to save. Some early data, which are currently being stored at Goddard, are scheduled for destruction. However, for many users, these early observations represent a valuable and irreplaceable baseline for comparison with later observations. In addition, much of the only cloud-free global coverage dates from this early period in space remote sensing. Users agree that it is important to retain these early data and make them available upon request. They represent a large investment and a valuable global resource for the future.

  Looking toward the future, the users of Landsat data are concerned that data will not have begun flowing from Landsat D before the flow from Landsats 2 and 3 ceases. Will Landsat D be available soon enough to assure continuity of the data flow? There are presently no plans for backup should D fail to operate as planned.

- ***Quality and integrity of data.*** It is important that data acquired in different time periods be comparable and of uniform quality.

  Landsat data are initially "preprocessed" at Goddard; the results are in the form of high-density digital Tapes (H DDTs). These HDDTS are then sent to the EROS Data Center for processing. EROS in turn supplies data to users either in the form of film imagery or as CCTS. Some additional special process-

Table 2.—Data Needs of Foreign and Domestic Users

- *Agriculture* **(Federal, State, and private): specific sampling areas** chosen according to the crop; time-dependent data related to crop calendars and the weather patterns
- Forestry (Federal, State, and private): specific sampling areas; twice per year at preselected dates
- Geology and nonrenewable *resources* (Federal, State, and private): wide variety of areas; seasonal data in addition to one-time sampling
- Civil *engineering and land use* (State and private): populated areas; repeat data required over scale of months or years to determine trends of land use
- Cartography (Federal, State, and private): all areas; repeat data as needed to update maps
- Coasta/zone *management* (Federal and State): monitoring of all coastlands at selected dates depending on local seasons
- *pollution monitoring* (Federal and State): broad, selected areas; highly time-dependent needs both **for routine monitoring and in response to emergencies**

SOURCE: Off Ice *of* Technology Assessment.

[27] OTA Workshop, op. cit.

ing of data to meet particular user needs is done at EROS; other similar processing is done by various value-added companies.

Four problems have surfaced in the data stream from satellite to user. First, the quality of data tapes is not always maintained at a high level. Users complain that errors introduced in the HDDTs from Goddard are passed through and appear in the CCTS from EROS. Second, abrupt changes over time in the format of CCTS, again a function of the R&D nature of the system, have seriously inconvenienced users. These changes have made it impossible to process older CCTS with the techniques for processing current CCTS. Users must therefore go to unanticipated and sometimes extraordinary lengths to process the earlier tapes. These format changes were made without sufficiently consulting the needs of the user community. Thirdly, not all users want to purchase preprocessed data because preprocessing necessarily causes some degradation of quality or loss of information. For some applications, it is better to have raw data as they come off the spacecraft. Finally, maintenance and management of the data base have been inadequate.

- ***Adequate collection of primary data.*** For a truly global satellite remote-sensing system, all data must be collected.

As the example of Costa Rica illustrates (see below under "Foreign Uses of Landsat Data"), the United States lost an important opportunity to sell Landsat data because Costa Rica is just out of range of receiving stations and because Landsat 3's tape recorders are unreliable. The tracking and data relay satellite system (TDRSS), when it is completed, will serve to gather and relay data from Landsat D and D'. Until then we will be dependent on foreign ground stations for MSS data received by D and D', because these spacecraft will carry no tape recorders. Although the U.S. agreements require the foreign ground stations to make their data available to others in accordance with our open data practices, it is not clear that the foreign ground stations will respond to requests for data in a timely and efficient manner. Users in some countries, including the United States, have experienced difficulties in the past in obtaining needed data quickly from foreign ground stations.

- ***Adequate consultation with the user community.*** This is an essential element of an operational space remote-sensing system, whether run by the Federal Government or by the private sector.

Although NASA has consulted other Federal agency users, neither users in the private sector nor those in State and local government have been included in any way in the key decisionmaking processes. A successful operational system depends on the full participation of all elements involved on an ongoing basis.

In an effort to build interest in the capabilities of Landsat, NASA has sought the advice of the user community about its needs with respect to sensors and resolution limits. However, as maybe appropriate in an R&D system, NASA has approached the problems of the future orbital height, orbital planes, and orbital path of the Landsat D satellite from the point of view of optimizing spacecraft design, rather than the data product. This approach will result in abrupt changes in data format and further disruption of the data base, to the discomfort of the potential purchasers of the data from Landsat D. Consequently, the user community displays considerable skepticism about the Federal commitment to operate a complete land remote-sensing system via civilian satellite, tailored to providing standard and predictable data products for the public and private organizations that are attempting to integrate Landsat data into an ongoing operation,

- ***Continuation of remote-sensing R&D.*** The current Landsat capabilities, though they satisfy the basic needs of a large portion of the potential users, are also limited.

Users such as those represented by the Geosat Committee[28] are very interested in using stereo images of the Earth for exploration of mineral and energy resources. Geosat has suggested development of the so-called

[28] "Satellite Remote Sensing Data–An Unrealized Potential for the Earth Science Community, the Geosat Committee Inc., 1977."

"stereosat" remote-sensing satellite.[29] Cartographers would benefit from stereo imaging and from higher resolution. Many other users agree that an automated mapping satellite system based on multilineal array technology (MLA), a so-called "MAPSAT," would serve their needs for high-resolution (20 m)[30] stereo imagery as well as their multispectral and spatial requirements ***and*** be far cheaper than Landsat D or D',[31]

Even the heavy users of current Landsat data will find their needs expanding as they gain experience with the data and understand their potential. They are likely to find needs for data from new sensors and advanced data relay subsystems.

- Price ***of data.*** The major concern of the users with regard to price of data is that inevitable price increases be reasonably predictable and incremental.

  Current data prices are much lower than the marginal costs of generating the data. Users recognize that future data prices will be higher as the prices are increased to reflect marginal costs. However, users would not purchase the same volume of data if the prices were doubled or tripled suddenly. Some State and local government users also face the difficulty of a 2-year budget cycle .32 If data prices are raised precipitously, these users cannot adjust to the increase for up to 2 years, and will be forced to purchase fewer data products than their needs would actually dictate. At a minimum, there should be a declining Federal price subsidy to bridge the gap in budget adjustment.

On the whole, these are not hardware or technology problems, but rather derive from the management and structure of the system. The larger problem, at least in part, seems to be that NASA, in an effort to test a broad spectrum of applications and to interest potential users around the world in using remote-sensing data, created a de facto operational system .33 Its effort was driven, in part, by a desire to justify the R&D program to OMB. However, being by established policy an R&D, not an operations agency, NASA has not been able to manage or fund an operational system, and has therefore been unable to guarantee its continuity. Nor was NASA directed to assume operational responsibilities by the President or the Congress. NOAA, in turn, is not scheduled to assume the management of the system until 1983 (after Landsat D is launched). Circumstances such as these have made the users extremely wary of investing in the manpower, hardware, and software to process Landsat data, Further, these uncertainties have limited the size and vitality of the market for Landsat data as well as that of the private data-processing (value--added) industry.

In short, the future direction of satellite land remote sensing has reached an impasse: the users refuse to invest further in Landsat data because the system is not operational, but many of them also oppose changes because they have become dependent on the system as it is currently configured. On the other hand, no existing institution, Federal or private, seems appropriate to undertake operations: first, because there are not enough users, and second, because the present system is not advanced enough to generate a **large** market. Among other things, this has led to a situation in which the French, using technology originally developed in this country, will shortly provide very strong commercial competition in land remote sensing. They have designed their SPOT system from the first to be an operational system and have included user needs in the system specifications.

Foreign Users of Landsat Data

One of the basic tenets of the 1958 NAS Act is that "activities in space should be devoted to peaceful purposes for the benefit of all mankind."[34] Our Landsat system, with receiving stations distributed around the world and a prac-

[29] I bid.

30A. P. Colvocoresses, "Proposed Parameters for Mapsat: Photogrammetric Engineering and Remote Sensing, " vol. 45, No. 4, pp. 501-506, April 1979.

31 Itek Corp., final report, "Conceptual Design of an Automated Mapping Satellite (Mapsat), " January 1981.

32B. Rado, statement to U.S. Senate and House of Representatives, hearing on Civil Land Remote Sensing Systems, July 22, 1981.

33P. Mack, "Space Science for Applications: The History of Landsat. ' in *Space Science Comes of Age,* P. A. Hanle and V. D. Chamberlain (cd.), Smithsonian Institution Press, 1981.

34National Aeronautics and Space Act of 1958, op. cit.

tice of open data sales, certainly satisfies the injunction of the NAS Act. It also satisfies section 102c (7) of the act, directing "cooperation by the United States with other nations and groups of nations in work done pursuant to this act and in the peaceful application of the results thereof." In fact, from a pure cost-benefit approach, remote sensing by satellite only makes sense as a global system. For the continental United States alone, the investment in Landsat far exceeds the cost of obtaining equivalent data by other means. However, U.S. corporations and Government agencies also need foreign data in order to pursue their operations abroad. More importantly, Landsat, by providing low-cost images of the world to all purchasers, has enhanced our status in the world. Our willingness to join others in solving problems of regional or global import cannot but strengthen our overall position in the world as a leader concerned for the good of all.[35]

Importance of Landsat Data: Three Asian Countries

Foreign users of Landsat data have found them very helpful for problems of resource management and control. The experiences of several Asian countries illustrate the potential of Landsat for these uses. Asia serves as an excellent example because it is the location of five of the original 10 countries selected by the U.S. Agency for International Development (USAID)S6 in 1975 for initial testing of the applicability of using Landsat data for resource management problems in developing nations. Two criteria have to be met for this technology to be successful in resource management applications: a practical means of transferring it to the country must be found, and the data flow should be maintained over an extended time. A brief historical review of three of the original Asian programs and their present day applications provide insight into the ability of Landsat to meet these criteria.

Bangladesh began its use of Landsat data with the help of USAID. This Asian country was interested in testing the use of Landsat data for deriving information on agricultural production and land use in order to promote optimal development of a section of northeastern Bangladesh. The initial project was quite successful and regional information on rice and other crop production was obtained during the 1975 winter season. Interpretation of Landsat data during this project also provided detailed information concerning changing pond, stream, and flood patterns, data that are invaluable for planning at both regional and village levels.[37] After this initial introduction of Landsat technology, its use in Bangladesh has rapidly expanded with diverse government programs in agriculture, forestry, oceanography, fisheries, and disaster prevention. In 1980, in an effort to enhance the return from this effective and developing technology, Bangladesh established the Space Research and Remote Sensing Organization (SPARRSO), a lead government agency for R&D and operational activities.[38]

Sri Lanka is an island nation whose economy is highly dependent upon agricultural production. Because of such constraints as the rugged topography and its effect on transportation, as well as a paucity of trained field personnel, continual effective ground survey of agricultural production is not feasible on a continuing basis. In 1975, the Ministry of Agriculture and Lands requested USAID assistance for establishing local capability to use remote-sensing technology for accurate agricultural inventories. Specifically, the Ministry requested assistance in digitally processing Landsat data. This project resulted in the development of an operations manual and digital analysis capability in that country. Although the accuracy was less than would be desired in a mature program for estimating agricultural acreage, Landsat was recognized as a valuable resource management tool, and in 1978 a national remote-sensing center was established.~ USAID

[35] C. K. Paul, and A. C. Mascarenhas, "Remote Sensing in Development," *Science, vol.* 214, No. 4517, 1981.

[36] T. W. Wagner, and D. S. Lowe, *AID's Remote Sensing Grant Program* (Ann Arbor: Environmental Research Institute of Michigan, 1978, pp. 11-22).

[37] M. A. H. Pramanik, and A. K. M. Alam, "Space and Remote Sensing Activities in Bangladesh," proceedings of the Second Asian Conference on Remote Sensing, Beijing, China, 1981, 1-2-l.

[38] T. w. Wagner, op. cit., pp. 69-81.

[39] Christopher Nanayakkara, "The Sri Lankan Experience in Remote Sensing, " proceedings of the Second Asian Conference on Remote Sensing, Beijing, China, 1981, 1-7-l,

[40] V. Geiser, M. Sommer, and E. Nanayakkara, *The Sri Lanka/Swiss Satellite Imagery Interpretation Project: **Report** on Test Phase* (Colombo: Center for Remote Sensing, 1981).

provided a followup grant in response to a Center request for the development of a simplified low-cost Landsat data-processing system to address specific resource needs. This system will be delivered to the Center in 1982. A unique program also currently under way in Sri Lanka reflects the value that another industrial nation places on the application of U.S. space-derived data for development assistance. The Swiss are training Sri Lanka resource managers in techniques for using U.S. Landsat data for monitoring rice production. Sri Lanka is also using remote-sensing data for monitoring land use and for mapping its forest cover. Sri Lanka views Landsat as a successful technology that can be employed without heavy capital investment if the project is well planned, and is optimistic about the possibilities for using future satellites.[41]

Thailand began its leadership role among the developing nations of Asia by establishing a national remote-sensing program in 1971. The major goal of Thailand's program was to develop the means to use remote-sensing technologies effectively for natural resource management. As a result of its early initiatives, Thailand's Royal Forestry Department was one of the first departments of any country to develop an operational Landsat-based system for monitoring deforestation. Today, information derived from Landsat data is a major component of the forestry policy decisions of this Asian nation.[42] USAID'S 1975 joint project with the Thai agricultural department that sought to obtain acreage information as part of the annual rice, corn, and sugar cane survey was of limited value. Two major constraining factors affected this project: 1) continuous cloud cover during scheduled sampling periods and prior to harvest prevented data acquisition by Landsat; and 2) the available Thai computers had not been programmed for Landsat data analysis prior to terminating this project.[43] However, the USAID project was beneficial in providing experience with Landsat sampling and data analysis techniques. This experience contributed to later successes such as the national rubber plantation survey and a continuing soil erosion study by the agricultural department. Landsat data are being widely used by other government agencies, including the Department of Mineral Resources and the Royal Irrigation Department. Thailand is completing a major Landsat/Metsat ground receiving station that should provide timely data to the Thai user service center beginning in late 1982. Thailand has not only committed itself to using data from Landsat, but it has also shown its determination to assist other Asian countries. Data from this ground station will be made available to these nations.

These selected Asian cases demonstrate the utility of Landsat technology for peaceful uses and its applications to the resource management problems of developing nations. Landsat technology has not only been successfully introduced, but has been shown to be effective in monitoring resources over time, These factors make it an effective tool in global resource development. One must remain cognizant that Landsat technology, although transferable to developing countries, is not a simple technology. **It** therefore demands complex man/computer interaction and timely current data for the analysis of most renewable resource problems.

However, though foreign users of Landsat data have made good use of them, they often face problems very similar to those troubling domestic users. The experiences of an Italian land planning firm are not atypical of user experience in the United States and abroad[44]. This firm attempted to integrate Landsat data into its normal data stream from aircraft and ground survey. After first learning how to make the best use of the data, it then experienced difficulties in obtaining timely data and data that were of high quality. As a result, it has made much less use of Landsat data then originally planned. Instead of being a major component of the firm's land planning efforts, these data serve only a secondary role in its total scheme.

[41]Christopher Nanayakkara, "The Sri Lankan Experience in Remote Sensing, " proceedings of the Second Asian Conference on Remote Sensing, Beijing, China, 1981, 1-7-6.

[42]Sanga Sabhasri, pradisth Cheosakul, Boon Indrambarya and Suvit Vibulsresth. "National Remote Sensing Activities in Thailand," unpublished report to the Second Asian Conference on Remote Sensing, Beijing, China, 1981.

[43]T.W. Wagner, op. cit., pp. 77-81.

[44]G. C. Bernardino, "European Industrial Space Projects, " American Astronautical Society, 19th Goddard Memorial Symposium, March 1981.

A short case history of one country's attempt to use Landsat data will illustrate other problems foreign users have faced. It also provides another illustration of the usefulness and cost effectiveness of Landsat data for attacking important renewable resource problems.

Importance of Landsat Data: Case of Costa Rica

Deforestation and subsequent desertification have become problems of great concern in many countries throughout the world. The case of Costa Rica demonstrates the importance of Landsat data for dealing with these problems and the potential tragedy of unavailability of these data through discontinuity in Landsat service.

The Government of Costa Rica (GOCR) Ministry of Agriculture was aware in the early 1970's that loss of forest cover and watersheds had become a major problem. Personnel in the ministry knew that a complete forest inventory would be necessary in order to assess the extent of the problem, but that if contemporary ground truth and survey methods alone were used, 25 years would be needed to complete the inventory. By that time, there might be no forests to save. Recognizing that the problem was beyond the capabilities of his staff, the Minister of Agriculture requested assistance from the USAID to determine whether Landsat technology could be applied effectively to map the resources of Costa Rica. USAID commissioned a study that was completed in March 1977.[45] This initial study concluded that the deforestation problem was even more severe than GOCR had thought, and that a combined aircraft and satellite remote-sensing program might be the most cost-effective way to determine the full extent of the problem. Data from Landsat could not alone do the entire job because some areas (the watersheds most at risk) required detailed mapping and analysis at scales and resolution beyond the capability of the current Landsat series.

As a second step in determining the feasibility of relying on Landsat data, USAID contracted for a test and demonstration project, which was completed in March 1978.* The principal conclusions for the forest sector were the digital-processed Landsat data would be the most cost-effective alternative for "Level I" forest cover maps at a scale of 1 :200,000, and that color infrared (CIR) photography would be the best choice for "Level 11" and Level III" mapping. Landsat data could also be used effectively for urban mapping and analysis, but would be cost effective only if coupled with a project to maintain the forests that would absorb the primary costs.

The major problem confronted in the second phase of the project was that of obtaining "current" Landsat data. After an initial request to NASA was ignored, it was necessary for the President of Costa Rica to make a direct personal request to the White House in order to have the tape recorder aboard Landsat 3 activated, so that data on Costa Rica could be collected, stored, and relayed in a timely fashion.

The third phase of the Costa Rican study was the pilot project (conducted between January 1978, and June 1979).47 Here the objective was to develop in Costa Rica an operational system for resource management. The system was to be tested and established on a cross-sectional area representing more than 20 percent of the entire country and running from the Caribbean to the Pacific. This project demonstrated that a nationwide program based on CIR photography and Landsat data was both possible and practical. Such a program would be remarkably cost effective: the entire forest survey task could be accomplished in less than 3 years for about $1 million (compared with the earlier GOCR estimate of 25 years and $20 million, using only ground and aircraft surveys.)

Despite the clear need for such a nationwide program in Costa Rica, despite its cost effectiveness, and despite significant investments both by GOCR and by the United States, today–3 years later—no system to use Landsat data is yet

[45] "An Assessment of Resource Inventory and Environmental problems in Costa Rica," Report to USAID, Office of Development Resources, LA/DR, contract No. AI D/afr-c-1 135-8, March 1977.

a"The Utility, Cost, and Effectiveness of Remote Sensing for Forest and Urban Sector Assessment in Costa Rica, report to USAID/ROD/LA/US and USAID/Costa Rica, contract No. AID/afr-C-1 135-9-10, March 1978.

[47] " Design of a Natural Resources Inventory and Information System for Costa Rica: The Pilot Project Report, " report for USAID, contract No. AI D/la-C-l 253, June, 1979.

in place in Costa Rica because of the unreliability of the present Land sat system. The system for deforestation analysis does not exist because sparse data were supplied and because the United States made no credible assurance that continuity of data would be maintained in the future. During the entire period of the pilot project (January 1978 through June 1979), only six images were obtained over the western half of the area and only two over the eastern half. Wet-season data were never obtained, and no CCT was ever available for the one usable image over the eastern section. On the basis of this experience, GOCR decided not to fund a nationwide operational program.

Many of these user problems are due to the R&D nature of the current system, but they point up the care that will be needed in planning for a future operational system, whether operated by the government, the private sector, or a mix of both.

Market for Satellite Remote-Sensing Data

Whatever entity (ies) operates a U.S. satellite land remote-sensing system, the size and breadth of the market for the data it supplies is of major concern. in either case, recovery of the costs of investment and upkeep (particularly those of the space segment) is necessary. In a publicly owned system, political benefits, such as its use as a tool of foreign policy or its value in enhancing U.S. technological superiority, may justify a reasonable shortfall in cost recovery. But in a privately owned system operating with no taxpayer subsidy, the market alone must bear the entire burden of recovering these costs.

The market for remote sensing data from space divides naturally into two categories: The market for ***primary data*** provided directly from the space segment, and the much more lucrative market for ***value-added data,*** which represents the largest part of the ground segment. Based on its review of the size and nature of the market,QB OTA can make the following observations:

- Size ***of the market.*** The true extent of the market for primary satellite remote-sensing data is unknown. The domestic market consists of two kinds of users, the government (local, State, and Federal), and the private sector. Federal Government users generate the largest demand in this category today. Although the records of the EROS Data Center and the NASA Goddard Distribution Center indicate a relatively small primary market (approximately $5.7 million per year sold by the United States directly)49 this estimate reflects only a portion of the true market, which could be at least as much as 50 percent greater. Some users obtain data directly from other users at a portion of the original cost, or gratis (i.e., a certain amount of data sharing occurs). so
- Even if the exact distribution of original satellite data were known, however, it would represent only a fraction of the value of data after they are computer-processed to provide particular information. For example, the cost of a CCT is currently $200 to $300. To process the data contained on a specific CCT and to present it in usable form to the ultimate user of the data can cost between $1,000 and $20,000, depending on how much information is extracted from it or merged with it, and the number of steps taken to enhance the original information. Processing satellite remote-sensing data thus represents a significant investment opportunity for a firm, especially one that is already capable of digitally processing remote-sensing data from aircraft. Currently, some 60 firms are known to be capable of processing Landsat digital data. Another 35 firms (28 United States, 7 foreign) sell computer-processing equipment for Landsat, which range in price from $50,000 to $500,000. Firms providing digital processing of photographic data might also be interested, because the basic techniques for enhancing image data by computer are similar for all applications, though most film processors would lack the analytical expertise in land resources.
- Nature ***of the market.*** One of the major difficulties in defining the full extent of the

[48]"Commercialization of Remote Sensing, " OTA Workshop, May 1981.

[49]" Status of NASA's Landsat—D," GAO briefing, July 1981.

[50]" Commercialization of Remote Sensing, " OTA Workshop, May 1981.

market is its extremely diffuse and dispersed condition. Each major category of user, both foreign and domestic, has different spectral and resolution requirements, is interested in different geographical areas, or needs data on a different time schedule. Table 1 summarizes the categories of major users and their general needs for Landsat data.

In order to understand fully the data needs of each user group, it would be necessary to analyze in detail the records of the EROS Data Center, the NASA Goddard Data Processing Center, and the foreign ground stations to determine:

- Who uses the data (specific users identified by discipline)?
- What regions are requested? With what frequency? Under what time constraints?

From this information and a projection of user requirements, future market potential might be determined. Predictions about new markets, foreign and domestic, would have to be added to this information to reach an estimate of the total size of the market for Landsat data. To OTA's knowledge, no analysis has reached the level of detail required for making reasoned decisions about the potential for commercialization of the technology,

Commercialization of Remote Sensing: Domestic and Foreign Concerns

If commercialization of civil land remote-sensing satellite activities is to occur, the major questions before the country at this time are how and at what speed the transition to the private sector should be accomplished. Conversion from public to private ownership and operation of the civilian land remote-sensing system would affect the user community in a variety of ways. Users perceive that both advantages and disadvantages will result from the change. In addition to the concerns of users previously expressed in relation to an operational system, they have raised the following concerns specific to a commercial enterprise:

- Open data. The U.S. current [y supports and follows the practice that any party, regardless of nationality, may purchase Landsat data, regardless of the country from which they are derived. This conforms to long-standing U.S. policy on the sale of maps prepared by the U.S. Geological Survey. Users fear that this practice may be discontinued. The question of whether unrestricted dissemination of remotely sensed data violates the sovereignty of a sensed nation has occasioned vigorous debate in the U.N. and other forums for many years; no agreement has yet been reached. Many countries have objected on the grounds that they do not wish important information about indigenous mineral resources, crop conditions, or military activities to be made public. Private operation may heighten suspicion that such data will be used to enable interests outside the country to gain a competitive advantage, or that data may be sold secretly to political adversaries. These concerns will increase sharply as new sensors improve upon the current resolution of 80 m for the MSS aboard Landsats 2 and 3.
- Resolution limits. What regulations will be imposed concerning the limit of resolution of the sensors? The thematic mapper on Landsat D and D' will be capable of 30-m resolution. The SPOT sensors will reach resolutions down to 20 and 10 m. Will there be restrictions on dissemination of high-resolution data from some areas? For some applications (e.g., forestry), resolutions of 1 to 5 m over small areas would be useful. Further, as other users become more accustomed to the capabilities of remote sensing, and as their ability to handle massive amounts of data improves and costs decrease, they are likely to find need for data of higher resolution. As in other aspects of satellite remote sensing, users want to be involved **in the decision making process** for determining the limits to resolution. Resolution limits will also be of major international concern.
- ***Competition from governments.*** Both the potential operators of remote-sensing systems and the value-added firms are concerned about potential competition from governments, either the United States or foreign entities. For example, NASA may

now compete with private industry when it institutes an R&D project in a university or government facility to process Landsat data. These projects often result in computer software that competes directly with software packages developed by private value-added data processors.

- Price *of data.* The user community is quite concerned about the price of primary data from a privately owned satellite system. It fears a dramatic increase in price if total costs are to be recovered.[51] This is especially true for users who require repeat data on a time scale of weeks or months. For users whose needs are largely for one-time data from a particular region, the cost of a single CCT is not as critical. It is doubtful that the price elasticity is sufficient to allow prices to be raised to a full cost recovery level in the next few years,
- Continuing ***Federal R&D.*** users recognize that neither they nor the actual operators of land remote sensing are willing to provide the resources to fund continuing R&D in the private sector. Yet there are a number of technological improvements that could be made to the system even after Landsat D and D' are operational (e.g., stereo imagery, higher resolution, greater spectral coverage). Users therefore see the need for continued research by the Federal Government, and for substantial involvement by the user community in the decisions about the directions such research should take.
- ***Archived data.*** What will happen to the archived data that have already been provided by Landsats 2 and 3, the shuttle, Skylab, and other means if the private sector assumes responsibility for U.S. satellite remote-sensing activities? As mentioned earlier, users are very concerned that the previous data be retained. But retaining them is very costly because the high-density digital tapes have a limited lifetime and, therefore, must be recopied at regular intervals.

[51]Joint hearings, July 1981, oP. cit.

Foreign Policy Concerns

W/hat commitments does the United States have to foreign purchasers of Landsat data if the entire system is in private hands? Other countries, particularly LDCS, are well aware that the possession of remote-sensing data carries with it the concomitant power to affect resource development. In considering transfer of Landsat or other satellite information systems to private hands, U.S. policy makers must consider the effects on our relationships with other countries. In addition, there is an added foreign and domestic problem of conflict of interest if a private corporate operator or its subsidiaries are allowed to offer value-added services. Advance knowledge of certain time-dependent data such as crop condition or water availability has the potential for exploitation by the firm before others could obtain the data.

The largest market for satellite land remote-sensing data might eventually be the totality of foreign users. if foreign governments are to depend primarily on U.S. satellite data, they will, in most cases, have to restructure any systems they presently use for monitoring and managing their resources. If the space and primary delivery system were publicly held, and if a country experienced problems with the pace of data delivery, or with the continuity or quality of data, it could then petition for redress directly through diplomatic channels. If the space and/or reception component were in private hands, such recourse could be only indirect. Competition from other satellite systems could mitigate this difficulty somewhat, if the data were totally compatible. Private operators would then have considerable incentive to meet contractual agreements. However, data from other systems (French, Japanese, or Soviet) will not be exactly compatible with those from the Landsat MSS. Will the U.S Government therefore regulate the sale of remote-sensing data to other states? If so, guidelines will have to be drawn up by an agency designated for the purpose.

Foreign users of Landsat data have purchased ground stations and data on the understanding that the system would be subject to possible data gaps, change of data format, and other deficiencies peculiar to a system in development. According to the policy of the previous administration, however, they could look forward to data continuity through the 1980's. In light of the resolve to transfer Landsat technology quickly to the private sector, foreign users who have invested in Landsat receiving stations and data-processing equipment are questioning the value of our commitments. Total foreign investment in ground stations is about $60 million. Additional investments in data-processing equipment have also been made, as well as systems to integrate Landsat data with other necessary data. How will these ground stations and associated processing capabilities be integrated with a private system?

As sensors improve, the civilian capabilities for land remote sensing will grow uncomfortably close to military/intelligence standards. The satellites owned by the private sector will therefore require close supervision and oversight by the Government to: 1) monitor their technical capabilities, and 2) prevent use of the data derived from them inimical to the security of the United States.

Foreign Competition

Direct commercial competition to the U.S Landsat system will come from France's SPOT satellites starting in 1985, at about the time Landsat D' is now scheduled to be launched. The SPOT sensors will provide multispectral spatial resolution of 20 m, and panchromatic resolution of 10 m (compared with Landsat D's TM resolution of 30 m); in addition, SPOT will be able to "point" its sensors to the side, allowing it to acquire stereoscopic data. Unlike the more expensive and fragile optical-mechanical sensors on Landsat, SPOT will use relatively simple solid-state MLA. The establishment of a semiprivate company, Spotimage, to market SPOT data and services greatly enhances its competitiveness, especially in the absence of similar organizational certainty for Landsat; pricing for the two systems is not yet firm. Spotimage is heavily subsidized: the French Government has funded purchase and launch of the first satellite as well as all preliminary R&D, and owns the overwhelming majority of stock in the company. The first SPOT satellite will be launched in 1984 on the French launcher Ariane, and Spotimage is committed to maintaining an operational system for 10 years.

In the area of ocean surveillance, the Japanese Marine Observation Satellite (MOS) system is scheduled to begin operations in 1985. The satellite's sensors will be capable of observing land masses as well; this satellite is likely to be the precursor to an operational land remote-sensing system (for further details, see ch. 7).

Potential Policy Initiatives for a Land Remote-Sensing Satellite System

If the United States is to continue to play a role in the operation of a satellite land remote-sensing system, what mode of operation would be most desirable? OTA has explored a number of options for continued operation of a Landsat-type system (see ch. 10 for further details). Before a decision is made to proceed with any one of them, each option would require much more detailed study than it was possible to provide in this assessment.

- Designated ***private entity.*** The Government could ensure that its data needs were met by private operators by licensing a single U.S. entity to operate the satellite system. This could be done fairly quickly if a sufficient subsidy were provided, either through direct support for the difference between income and expenditures or through a Government guaranteed market.

  This option might suffer the objection from some foreign countries, particularly less developed countries (LDCS), that leaving the data distribution function in private hands might allow corporations from developed countries to use the resource information in remote-sensing data unfairly for their own profit. This objection could be circumvented if the licensed corporation were a separately incorporated firm prohibited from entering other fields; it would be, essentially, a regulated monopoly.

- ***Continued Federal operation of the space segment only.*** In this scenario, the Federal Government would continue to operate the space segment while turning over the distribution of preprocessed data to private sector operators. The rationale for such an approach is that the private sector cannot make a profit by operating the entire land remote-sensing system, but the Federal Government does not have the expertise to market satellite data effectively and promote their expanded use. Even if the relevant market experience could be obtained in the Government, Federal operation of an enterprise that the private sector might operate more efficiently would be inappropriate.

This option might meet with the same objection that private ownership of the entire system would, viz., that it gives too much power over resources to a private corporation.

- ***Laissez-faire private ownership and operation.*** The Government could declare that after Landsat D & D' reach the end of their useful life, it will terminate operation of land remote sensing from space (present administration policy) and leave the field open to all participants. The data needs of the U.S. civilian agencies would be filled by any supplier of satellite data, including foreign companies, and U.S. ground stations and related equipment would be sold to the highest qualified bidder or converted to other uses. The Government might be able to protect its future data needs by aggressive marketing of Landsat D & D' data in the expectation that a strong market **would encourage active private sector participation** in land remote sensing, or by using suitably degraded data obtained from reconnaissance satellites. As for the designated private entity option, the Government could provide the incentive for this option by guaranteeing a market.

  For the near term, however, a number of factors make this option the least likely to result in an operational satellite remote-sensing system:[52] 1) the market is likely to remain small enough that private ventures would sustain very high risk; 2) other, less suitable, but less expensive data alternatives are available (if full recovery of Landsat operating and maintenance costs is assumed); and 3) the largest benefits to accrue are likely to be public good benefits (i.e., the Government will remain the largest purchaser of data). Therefore, this option carries with it the danger that the U.S. data source will simply disappear if the private sector fails to find customers to cover the cost.

  If U.S. companies chose not to launch a satellite, or if the data taken by U.S. satellites were not of the sort or quality to meet the needs of mission agencies, the Government might be in the position of having to purchase data from the French or the Japanese.

- ***Broad-based cooperative arrangement.*** The United States could follow a policy that would include other nations in the ownership and operation of satellite remote sensing by setting up an international entity patterned after the interim INTELSAT agreement in which this country retained majority control for a specified period.

  Under this arrangement, a single management authority with multinational participation would assume responsibility for global operation of a land remote-sensing system, including establishing technical specification, procuring and operating satellites, and receiving and preprocessing satellite data. Such an approach would spread the investment risk, as well as encourage other nations to be more aggressive in developing their own internal markets for satellite data. It could also facilitate the eventual development of joint ocean remote sensing systems and lead to global systems that would join land, ocean, and weather data in order to monitor critical environmental factors. Perhaps the major advantages of this option are that it might well forestall wasteful competition among national entities and that it would provide an important forum in which international issues could be resolved within the confines of responsibility for an operational system.

  The major disadvantage of this approach is that the United States would no longer control its own system, still the only one in existence. U.S. users would face strong competition for their views in an organization that included other major users of remote-sensing data, and U.S. technology suppliers could no longer count on assured sales. Because of sen-

[52]"Commercialization of Remote Sensing," OTA Workshop, May 1981.

sitive issues involving national sovereignty and resolution limits, the United States would have no guarantee that the resulting system would continue to serve U.S. needs as well as a U. S.-operated system. If the Landsat system is discontinued, however, a multinational entity, with its possible drawbacks, would be far better than the alternative of having to purchase data from Spotimage.

On the other hand, a multinational system might alleviate fears of the less developed nations that the industrialized nations will use their superior technology to exploit the resources of the LDCS. By buying shares in a multinational system, the LDCS would have the same access to data as any other country in the system.

- ***Continued Federal ownership.*** Although current policy is to transfer Landsat to private ownership, it would still be possible to reverse that decision and make a thoroughgoing commitment to a system owned and managed by the Federal Government. Meteorological satellites, which, like Landsat, provide data of benefit to the general public, have always been owned and managed by the Government. Unlike satellite communications, which is already fully commercialized, and materials processing in space, which, if successful at all, seems particularly appropriate for private-sector operation, satellite remote sensing could certainly be retained as a Government system on the grounds that the good it provides is primarily public. At the present time, about 50 percent of the data sold is purchased by Government agencies. The Government, in effect, makes the market.

  This comes about because most of the needs for data are for the management of renewable natural resources (e.g., agriculture, forestry, range lands). Even for those resources owned by the private sector, Federal and State government agencies set policies, quotas, and price supports on a regional basis that direct and constrain the management of these resources. Few private operators own enough land to find the expense of using Landsat data worthwhile, but the government agencies find the use of Landsat data highly cost effective for their functions (see the Bureau of Land Management and Foreign Agricultural Services case studies in apps. B and C).

As the last part of this section on land remote sensing argues, the data needs of the developers of nonreusable resources are large. However, even though the extractive industry finds Landsat data highly useful, its data needs will remain less than those of the managers of renewable resources simply because the latter require repetitive data. Therefore, in the Unites States, the majority user of data from a Landsat system is likely to remain the Federal and State Governments.

Potential of Land Remote-Sensing Data and the U.S. Economy

There is no doubt that satellite land remote-sensing data are useful for inventorying and managing the world's renewable and nonrenewable natural resources. Table 1 lists the areas in which satellite data are already being used in cost-effective ways for these purposes. Appendixes B and C illustrate the use two Federal agencies make of Landsat data. As emphasized above in the section on the data market, however, the variety of users and their different data needs, coupled with slow technical advancement and considerable uncertainty about the status of the Landsat system have acted to inhibit the market that many users[53] insist is there to be tapped.

Continuing to develop land remote sensing thus represents a certain economic risk for the Government or the private sector. If the market cannot sustain the investment, the losses could be great. However, the Government and private industry have already committed more than $1 billion to the Landsat venture. To fail to make the best use of these sunk costs represents a considerable loss as well. As the need to manage global resources efficiently and inexpensively grows with the expansion of the population, the need for a land remote sensing system increases proportionally. The use of Landsat data by Costa Rica is a case in point. For that country, use of Landsat data is not only the least expensive and

[53] "Analysis of the Private Market for Landsat Products and Applacations," report by OAO Corp. for NASA contract No. NASW3358, 1981.

the most efficient way to monitor the rate of depletion of its forests, it seems to be the only means for meeting the problem in time. [54]

As large-scale forestry management methods improve, the worth of satellite-derived data will likely increase for domestic uses as well. The same is likely to be true for the other categories of table 1. However, perhaps the most critical area for the U.S. economy is in nonrenewable resources such as coal, oil, gas, and minerals. Even at the slower rates of energy consumption increase we have recently experienced, [55] our dependence on foreign petroleum sources has and will continue to be strong, primarily because our own recovery rate for oil will continue to decrease in the future.[56] Greatly increased exploration efforts will be needed to keep pace with the loss of U.S. reserves. Landsat data now play an important role in energy and minerals exploration, especially in regions where vast land areas must be evaluated. However, as far as the extractive resources industry is concerned, the use of Landsat data is still in its early development stages.[57] In spite of this fact, it is the largest single private purchaser of Landsat data. The extractive industry has now bought data covering from 10 million to 15 million square miles of the Earth's land surface. This is in spite of the fact that the current system lacks stereoscopic capabilities, nor does it gather the most appropriate spectral data for this industry's use.[58] Though it is difficult to assign a precise worth to the use of satellite data, because the process of exploitation involves a variety of techniques and often takes many years to achieve success, those who use the data are convinced of its usefulness and argue that if the present capabilities were increased, their task would be greatly simplified. [59] The support of an operational surveillance system tailored to mineral resources does not appear to be outside the financial capability of a consortium of resource companies, though there would be problems of competition between members of such a consortium to be solved.

The French SPOT system offers the sort of significant improvement in data capabilities that would be most useful to the exploration industry. However, American industry is reluctant to be forced to rely on foreign sources for their data, since it is unclear to what data they may or may not have access. Similar concerns apply to minerals exploration in this country and abroad. The question of what to do with the U.S. land remote-sensing system is a critical one for the future of the management and development of U.S. natural resources. Whatever is decided, the question should be resolved with dispatch.

[54] "Design of a Natural Resources Inventory and Information System for Costa Rica," June 1979, op. cit.

[55] Weekly petroleum Status Report, U.S. Department of Energy, Energy Information Administration, Mar. 5, 1982.

[56] U.S. Congress, office of Technology Assessment, "World petroleum Availability, 1980-2000," technical memorandum, October 1980, OTA-TM-E-5.

[57] "Satellite Remote Sensing Data–An Unrealized Potential for the Earth Science Community," the Geosat Committee, Inc., 1977.

[58] Ibid.

[59] "Department of the Interior Position Paper on the Private Sector Transfer of Civil Land Observing Satellite Activities," U.S. Geological Survey, 1981.

MATERIALS PROCESSING IN SPACE (MPS)

Issue 6: What Are the Technological and Commercial Prospects for MPS?

The primary motivation for MPS research is to use the microgravity environment unique to space for scientific and commercial applications. process variables such as temperature, composition, and fluid flow may be controlled far better in an environment of microgravity. As a result, some materials can be manufactured in space with greater precision and fewer defects; others, which cannot be made at all on Earth, may become possible for the first time. MPS looks particularly promising for pharmaceuticals, electronic devices, optical equipment, and metal alloys.[60]

[60] NASA, *Materials* Processing in Space: Early Experiments, Washington, D. C., 1980.

The U.S. civilian program has so far conducted rather limited MPS experimentation in space, and the results have been inconclusive.[60] if there are great days ahead for MPS, they must be preceded by years of research and major improvements in orbiting facilities.

Despite the need for further basic research, there may well be near-term opportunities for commercializing particular, carefully chosen technologies. Under a Joint Endeavor Agreement with NASA, the McDonneil Douglas Aeronautics Co., (working with Ortho Pharmaceutical) and the GTI Corp. are both moving vigorously ahead on R&D projects. Several other major corporations, including John Deere, TRW, INCO, and DuPont, have made significant commitments to early exploratory R&D. If MPS is found to be well suited to commercialization, several issues arise with regard to how and when it can be taken over by the private sector and by what means the U.S. Government can facilitate the transition.

Requirements for the Commercialization of MPS Technology

The space processing experiments that have been conducted so far have focused on identifying potential new processes and products. Because the research conducted to date has been basic, with subsequent commercial applications uncertain, there has been little private investment in this area. Private industry will invest its risk capital only if it is reasonably confident that the five conditions listed below are met.

1. There is a reasonable chance that research efforts will result in a commercially viable product or process.

A firm seeking investment opportunities must be reasonably certain that a proposed product or process innovation can be developed in a given time, at an affordable cost, and that there is a market capable of supporting a price that provides an adequate return on investment. The twin factors of time and cost are extremely important to a firm, especially during periods of economic instability. Projects that require large initial investment and take a long time to show a return usually do not compete well for corporate capital. Projects that stimulate further corporate investment as they begin to show promising returns are much more attractive; however, there are currently few such opportunities in the MPS area. In order to make a reasonable projection as to a project's possible rate of return on investment, a firm must have a clear view of the relevant market. When dealing with a new technology without a well-defined market, the firm's projections become more suspect, so that its investment in that technology would be at greater risk. The combined burden of developing new markets simultaneously with new technology may inhibit investment in MPS. It should be noted, however, that some MPS technologies (e.g., electrophoretic processing) will be directed toward well-defined Earth markets (e.g., pharmaceuticals). In these instances, the decision to invest in MPS technology may be preceded by standard market analyses.

2. The benefits of processing in space will be substantially greater than those of processing on the ground.

The MPS experimentation conducted to date indicates that many innovative uses of the space environment are possible. From a commercial perspective, however, the question is not what projects are technically possible, but rather which are economically viable. For example, it has been claimed that if semiconductor electronic crystals were grown in space, they would be purer, with fewer imperfections, and would therefore perform better. However, a recent study by the National Research Council has found that the quality of the preprocessed material is not the limiting consideration for most devices presently manufactured.[61] Therefore, though space-based manufacture of these devices may offer certain improvements, it is not clear that the benefits of the improvements outweigh the costs of producing them.

3. The market for the product will not be replaced by advances in Earth-based production.

It is possible that improvements in Earth-based technology may make certain processing tech-

[61] The National Research Council, *Materials Processing in Space*, Washington, D. C., 1978, p. 5.

[62] Ibid., p. 38.

niques possible that previously could only be done in space. Evidence for this view is provided by recent advances in the manufacture of glass products through the use of acoustic levitation, and by the enlargement of latex polymers by means of new chemical tech niques.[63] To the extent that such improvements confer some of the advantages of space-based processing without the high costs of in-space production, there is less incentive to'invest resources in expensive space technology.

4. intellectual property rights in space technology must be assured.

Though NASA has given assurance that industry will retain the rights to patents and trade secrets developed while working with NASA, such assurances are in the form of policy and regulations, not law. The present law vests the ownership of intellectual property developed under contract with NASA in the Government, but allows the Administrator to waive such rights. NASA has been consistent in its policy of not claiming an interest in such rights, but the specter of patent and trade secret loss, either through a change in policy or as a result of a legal challenge by third parties, still remains.

There is current congressional interest in new patent legislation that would grant greater rights to private developers working under Government contract.[65] Present law, however, is more liberal with small business, universities, and nonprofit firms than with large contractors. The status of proprietary information and trade secrets is consistently more uncertain.

5. National commitment must be certain.

Industry's planning is hindered by the fact that all space research depends on a Federal funding commitment to NASA, but the level of that commitment remains uncertain. Decreases in NASA's appropriations will cause delays in the flight testing of space technology. Such delays are costly, and in some circumstances could mean, at the corporate level, the difference between a successful project and a failure (as measured by dollar-return). Should MPS technology appear to offer a commercially viable product, some type of long-term, in-orbit facility may be necessary to assure the continuing supply of specific quantities of the product. At present, NASA cannot provide credible assurance that such a facility will be provided.

Government Incentives for MPS Research

In chapter 5, NASA's MPS activities are described. What follows is a discussion of the programs NASA has initiated to enlist commercial support in moving MPS toward operational status. The ultimate goals of NASA's MPS program are to:[66]

- perform research to improve industrial technology or to develop new products;
- prepare research quantities of space products for comparison with Earth-based products; and
- encourage the production of commercially viable materials.

In hope of commercializing MPS, NASA has established three levels of working relationships with the private sector. On all three levels, the relationships are agreements between NASA and its partners to cooperate in a defined area. Each agrees to accomplish specific tasks and to provide its own funding. The grading of these relationships marks the degree of the signatories' commitments.

For companies interested in the application of microgravity technology, but not ready to commit themselves to a specific space flight experiment or venture, the ***Technical Exchange Agreement*** (TEA) has been developed. Under a TEA, NASA and a company agree to exchange technical information and to cooperated in the conduct and analysis of continuing ground-based research programs. In this agreement, a firm can familiarize itself, at minimal expense, with microgravity technology and its potential applicability to a product line. Under the TEA, the private company funds its own participation and

63 *Industry* **Week, Mar. 3, 1980, p.** 90.

64 NAS Act 1958, **see 305 (a); 42 USC 2457.**

65 Gerald J. Mossinghoff, **"intellectual Property Right in Space Utilization, " address before the** ALI-ABA **Conference, "Doing Business in Space," Washington, D. C., Nov. 12-14, 1981.**

66 Robert A. Frosch, **"NASA Guidelines Regarding Early Usage of Space for Industrial Purposes, " NASA Internal Document,** June **25, 1979.**

obtains direct access to and results from NASA's facilities and research; in return, NASA gains the support and expertise of the company's research capability.

In an ***Industrial Guest Investigators Agreement*** (IGIA), NASA and industry share sufficient mutual scientific interest that a company arranges for one of its scientists to collaborate (at company expense) with a NASA-sponsored principal investigator on a space flight MPS experiment. Once the parties agree to the IGI's contribution to the objectives of the experiment, he becomes a member of the investigating team, thus adding industrial expertise and insight to the experiment.

The ***joint Endeavor Agreement*** (JEA) is a cooperative arrangement in which a private sector offeror and NASA share common program objectives, program responsibilities, and financial risk. The objective of a JEA is to encourage early private sector investment in MPS by sharing in the cost and risk of initial space ventures and to determine the ability of MPS to meet needs of the marketplace. A JEA is a legal agreement between equal partners; it does not initiate procurement. Under a JEA, NASA and its partner exchange no funds. An offeror from the private sector selects an experiment and/or a technology demonstration in compliance with NASA's objectives for its MPS program, conducts the necessary ground investigation, and develops flight hardware at company expense.

As incentive for a JEA investment, NASA agrees to provide transportation on the shuttle, provided that the project meets certain basic criteria, such as technical merit, contribution to innovation, and acceptable business arrangements. As a further incentive, the participant is allowed to retain certain proprietary rights to the results, particularly the proprietary information that would yield a competitive edge in marketing products based on the MPS flight data. NASA agrees not to enter into a JEA with a second potential source to investigate a similar space-based process. NASA also receives sufficient flight data to evaluate the significance of the results, and can require as part of the JEA that any promising results be applied commercially on a timely basis; if in NASA's judgment the participant does not commercialize the results within a reasonable time, NASA is allowed to publish the research findings.

By establishing legal and managerial mechanisms by which the cost and risk of early commercial ventures can be shared, "constructive partnerships" have been formed between the Government and the private sector. A number of cooperative agreements are in various stages of discussion. Agreements now in force, and those that have been publicly disclosed are:hz

- A TEA was signed in 1981 with Deere& Co., to study the effects of microgravity on solidification of metals. More recently, TEAs have been signed with INCO and DuPont.
- An IGI was appointed in 1980 by TRW to study directional solidification.
- Signed in January 1980, the first JEA pairs NASA with McDonnell Douglas. The process to be investigated is continuous flow electrophoresis (CFE), in which materials in solution are separated by subjecting them to an electrical field as they flow continuously through a chamber. The CFE experiment, to be flown in the shuttle, is designed to demonstrate the applicability of the process to the production of marketable quantities of pharmaceutical products. Ortho Pharmaceutical Corp. has joined McDonnell Douglas as a partner in this MPS business venture.
- GTI Corp. signed the second NASA JEA in January 1982. Under this agreement, NASA will fly a multiple microexperiment flight package (MMFP) to be developed for GTI by a third party. The MMFP will be a furnace with multiple subenclosures designed to perform and control several separate experiments in solidification, GTI's role in this JEA is to serve as a broker between NASA and potential investors, customers, inventors, and hardware manufacturers.

How Business Sees NASA

Industry's respect for NASA's accomplishments and technical talent is high. However, doing business with NASA is complex, involving par-

[67]R. L. Brown, and L. K. Zoner, "Avenues and Incentives for Commercial Use of a Low-G Environment, " MPS Projects Office, Marshall Space Flight Center, Alabama, undated.

ticular NASA policies and general Government policies. Uncertainty about NASA's level of funding, short- or long-term, makes for an unstable environment for private investment. To date, industry has not been assured that NASA will have enough funding to continue development of MPS systems beyond the early research stage. If unable to rely on NASA for continued basic development of new technology, industry sees no long-term future for MPS (whatever the temporary success of McDonnell Douglas and CT!).

Additionally, industry not involved in MPS generally finds NASA's JEAs to be in various ways unrealistic. Some industry observers read NASA as (in order to free itself to do little other than basic R&D) seeking partners who can do everything—marketing, financing, hardware development, etc NASA's agreement with GTI is a bold step toward meeting this objection. Through the guest investigator, technical exchange, and joint endeavor process, individual companies, concentrating on discrete tasks, can more easily enter the MPS field.

Businesses that have considered some commercial activity in space have also expressed concern over the potential loss of intellectual property rights (e.g., patent, trade secret, and industrial techniques). There are several reasons for this concern: 1) should such intellectual property become a matter of "Government record," competitors might be able to obtain this information through the Freedom of Information Act, 2) the 1958 NAS Act provision which states that NASA shall "provide for the widest practical and appropriate dissemination of information concerning its activities, " is at odds with the industry's desire to maintain the secrecy of R&D directed to potentially valuable products; and 3) section 305 of the NAS Act vests in the United States, subject to the discretion of the NASA Administrator, the right to any invention "made in the performance of any work under any contract" with NASA. Though NASA's Administrators have consistently waived the Government's rights under the act, industry's concerns remain.

'Possible New Institutional Frameworks

Though NASA is attempting to encourage private-sector interest in MPS through its TEAs, IGIs, and JEAs, a different institutional framework may eventually be needed, if the private sector is to be brought into MPS in a major way. To date, discussion has centered around three possible structures: an organization like COMSAT, a space industrialization corporation, and a possible consortium of industries. No consensus on this question has yet emerged.

The COMSAT Model. **In this scenario, a private corporation, established by legislative action, but financed through the issuance of capital stock, would** be given a monopoly **in the provision of processing facilities in** space. The Government would retain some degree of internal control over the organization by holding a number of positions on the board of directors, by regulating competition **in the procurement of equipment and services and by involvement in the ratemaking** process.

The purpose of such a corporation would be to supply a space platform with various facilities and services that users could rent. The extent of use by NASA, as a customer, and the degree of Government R&D performed on such a platform would be matters of policy to be decided at some point in the future.

A **structure like COMSAT'S has certain advantages. First of all, even with the substantial interest generated in** MPS over the past 2 years, private corporations might not wish individually to provide all the services needed to support separate processing facilities. Secondly, despite the obvious differences between communications and materials processing, one can envision an important similarity in the ways in which they might be conducted in space. A private concern might well operate a space platform with various facilities and services that users could rent. So described, such a platform could as well be used for materials processing as for communications. In neither case does the operator of the platform concern itself with the use to which its rented facilities are put. In both cases the operator might be expected to put some of these facilities to its own use.

[68] OTA workshop, Materials **Processing in Space, May 1981.**

The biggest obstacle to the creation of a federally chartered structure is that the basic science on which MPS would be founded is insufficient for marketable quantities of products to appear in the near term. It is the view of ESA, for example, that at least 10 more years of basic science are needed before serious consideration of commercializing MPS can be given.[69] ESA, therefore, considers MPS a scientific rather than an applications program.

Two objections to the federally chartered structure have surfaced. One is that, at its founding, COMSAT was supported by significant expertise already existing in corporations and Government agencies. No such MPS expertise now exists. The other is that COMSAT entered an established and revenue-producing market, whereas a similar MPS corporation would be entering an unknown market. In any case, objections to the COMSAT model for MPS that are founded on various insufficiencies (whether of basic science, of relevant expertise, or of ready markets for products) argue for no more than a delay in the time when such a corporation might be chartered.

Although no organizations are now processing materials in space, to the extent that processes to be implemented in an MPS program are extensions of current terrestrial processes, relevant expertise exists in abundance. 'o Furthermore, to the extent that MPS products may improve the quality of similar terrestrial products by one or more orders of magnitude, marketability for some of them appears high.

The Space Industrialization Corporation (SIC)

Introduced primarily as a means to provoke public discussion, the Space Industrialization Act of 1979 (H. R. 2337) called for:[71]

> **Establishment of a Space Industrialization Corporation to provide a means for financing the development of new products, processes, and industries using the properties of the space environment.**

[69] See ch. 7, p. 179.

[70] OTA Workshop, Material Processing in Space, May 1981.

[71] The Space Industrialization Act of 1979, Hearings on H.R. 2337, before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 96th Cong., 1st sess.

> **H.R. 2337** was introduced to address the problems of the private sector in developing space processing capabilities and to provide a thorough and orderly examination of **the** means to reduce the business venture risk of using **space for commercial purposes.**

If SIC were established, it would function essentially as an investment bank, providing capital through direct equity investments, loans, and loan guaranties. The problems most often cited by those opposing SIC in its present form are that such an organization is premature and that it may interfere with the activities of NASA.[72]

Some fear that given our limited knowledge of MPS science and engineering, SIC might encourage technically and economically unsound projects, which could have a negative impact on the evolution of space industrialization. They also argue that if companies are not required to put up their own money, they will take excessive risks and give projects inadequate management attention.

A different set of concerns regarding the SIC center around how this organization would affect NASA's continuing activities. NASA has been given a broad mandate to serve as a research and development center for U.S. space technology. SIC, as described above, would function primarily as an investment bank. Viewed in the abstract, these two entities would appear not to interfere mutually, but to be perfectly compatible. What many fear, however, is that, because space industrialization technology and its commercial applications are yet unproved, SIC could do little more than supply funds for basic R&D. If this were the case, then instead of complementing NASA, SIC would act as a competitor.

INDUSTRY CONSORTIUM

One way to encourage high-risk, expensive MPS research is to allow firms jointly to fund these activities. By allowing the sharing of key resources such as facilities, personnel and capital funds, the cost and the risk of space-based innovation would be reduced. A consortium of these firms-would also have considerable market strength because it could share the combined expertise of its

[72] Ibid., testimony of Robert A. Frosch, p. 78.

members, which normally address differing customer communities or markets.

The structure of such a consortium would have to be carefully drawn so as not to be in violation of U.S. antitrust laws.[73] Simply stated, these laws are designed to prevent monopolistic market structures and/or collusion between competitors leading to price fixing and market or customer allocation. It is possible that a consortium as described above could violate both of these tenets.

Because of the time and expense involved in most antitrust litigation, firms tend to be cautious when dealing with their competitors. it is unlikely that in the absence of a well-articulated Government policy condoning such conduct that potentially interested firms would form such a consortium. In 1980, however, the Justice Department issued guidelines "clarifying" its position on cooperative ventures: as long as these ventures are open to all prospective participants and the research they undertake is fundamental and long range, the Department will probably not object.[74] More than a score of the largest U.S. computer manufacturers and their semiconductor suppliers are forming just such a research consortium under the Semiconductor industries Association.[75]

International Competition in MPS

The European states and the Japanese agree that MPS has great long-term promise, and they support extensive basic research preparatory to possible commercial ventures. The ESA-funded Spacelab designed to be flown on the shuttle will provide facilities for such MPS experiments.

The Germans, who are the prime contractors on Spacelab, are particularly interested in MPS and plan an extensive combination of scientific and industrial projects, with some hope of significant near-term results.[76] The French have fewer near-term activities, but are hoping for extensive future use of the Ariane launcher to orbit processing facilities for scientific and industrial uses.[77]

The Japanese program is similar to that of the Germans.[78] The Japanese plan to conduct MPS studies aboard Spacelab, and are using an extensive sounding rocket program to gain preliminary knowledge. The Japanese expect that in the long term at least some MPS work will result in the development of marketable products.

Far more extensive than any MPS efforts in the West, the Soviet MPS program has, so far as can be ascertained, been geared to manufacturing process research, much of which extends to studies of terrestrial production techniques.[79] Because there is no private sector to participate in the Soviet space program, and perforce, no concern for commercialization, any inference from Soviet experience in MPS to Western attempts to commercialize would be risky. Soviet MPS experiments, which have been conducted aboard the Salyut 6 manned orbital lab, appear likely to continue at a high rate during the next few years.

Perhaps the best lesson to be drawn from this cursory review of the activities of other nations is that the United States has a variety of paths it may follow in the development of MPS technology. If it is to establish and sustain a successful, long-term MPS program, basic research must surely go forward. The speed of this research and the extent of private sector involvement are matters of policy to be decided in the context of our overall space goals.

A key question for the near future is the extent of international cooperation in MPS basic research. U.S.-European collaboration on Spacelab makes it possible to conduct joint efforts at the basic science level, provided competitive strains are not too great.

[73] U.S. Department of justice, Antitrust Guide Concerning Research Joint Ventures, November 1980.
[74] Ibid.
[75] Tom Alexander, "The Right Remedy for R&D Lag," Fortune, Jan. 25, 1982.
[76] See ch. 7, pp. 192-193.
[77] See ch. 7, pp. 190-191.
[78] See ch. 7, pp. 201-202.
[79] See ch. 7, p. 207.

SPACE TRANSPORTATION

Issue 7: What are the Major Barriers to Commercialization of Space Transportation Facilities and Services?

Though the shuttle opens the door to relatively inexpensive access to space, it makes the problem of transferring the U.S. civilian space transportation capability to the private sector more complex. Because the shuttle is new, its track record is insufficient to allow corporations to assess its long-term expenses and risks. Full commercialization of expendable launch vehicles (ELVS), however, is possible now. But whether a private launch service using ELVS could offer a price competitive with the technologically superior shuttle or the ESA-subsidized Ariane remains an open question. Therefore, the near-term prospects for commercializing U.S. space transportation are unclear, and the long-term prospects ride with the shuttle. In any case, the single major impediment to commercialization of U.S. launch systems is the absence of a comprehensive Government policy that favors and encourages the participation of the private sector.

The Background

In the United States the Federal Government has heretofore provided launch vehicles and launch services for all users. While DOD generally launches its own spacecraft, NASA has provided these services for its own missions and, on a reimbursable basis, for other U.S. Government users, foreign governments, and private entities. (NASA's policy on reimbursement seeks, in general, to recover incremental, out-of-pocket costs only, not capital already invested.) Of the roughly 20 to 30 U.S. launches per year over the last 10 years, about one-third were DOD's, one-third were NASA's own spacecraft, and the remaining third were for other United States or foreign government users and private entities. NASA's mission model[80] for the space transportation system (STS) for the next 10 years or so shows about the same ratio. A recent study by the American Institute of Aeronautics and Astronautics (AIAA), however, has projected a significant additional need for total launches, primarily for commercial communications satellites.[81]

Until 1981, all U.S. experience had been with ELVS. Until recently, civilian ELVS were to be phased out by the mid-1980s, and the sole U.S. launch capability was to be the NASA STS, represented primarily by the shuttle and its associated upper stage components. However, delays and uncertainties in the shuttle program have caused NASA to reexamine this policy. Proponents of retaining ELVS argue that the number of launches that will be needed will exceed the capacity of the shuttle, leaving the United States without sufficient launch capacity if ELVS are phased out.

Private industry has not generally marketed launch hardware or services directly to customers. ELVS are sold to NASA, which then charges the customer. Industry has, of course, built the launch vehicles under Government contract and to a degree, lesser (for NASA) or greater (for DOD), provided contracted-for launch services at Government launch facilities. However, NASA has remained responsible for providing launch facilities and support services to all users. Already, NASA is facing its first competition. Arianespace, a private French corporation with substantial Government ownership, has begun selling launches after a successful development program. Certain private corporations, such as Space Services, Inc., of the United States, hope to offer launch vehicles and services within a few years. An investment banking firm, William Sword, Inc., has offered to fund a fifth shuttle orbiter in return for exclusive rights to market commercial payloads. Already, small military rockets and satellite kick stages have been commercialized, and one of the shuttle upper stages, the SSUS-D, is being

80"Final Flight Manifest for Space Shuttle," Aerospace *Daily,* Dec. 18, 1981, pp. 253-257.

El American Institute of Aeronautics and Astronautics, projection of non-Federal Demand for Space Transportation Services Through 2000, Jan. 19, 1981,

82*Aviation Week* arid *Space Technology,* "Firm Sets Down-Payment for Buy of Space Shuttle," Jan. 18, 1982.

sold by the manufacturer (McDonnell Douglas) directly to the end user rather than to NASA.

Military and Civilian Use of the Shuttle

DOD is the only other U.S. launch agency, handling many of its own launches. How will DOD share the shuttle with civilian users? DOD has the right to preempt civilian flights in case of need. How will that right and its other special requirements affect hardware and launch costs? Generally speaking, OTA has not found any of these concerns to be major impediments to civilian use of the shuttle—provided that the projected launch schedule of one flight every 2 or 3 weeks is attained. Once this planned flexibility of the shuttle system has been realized, a DOD preemption of a shuttle flight would probably have little adverse affect on civilian needs, most of which are not time-sensitive over periods of a few weeks. For now, it is essential that at least one line of ELVS be retained, both to provide additional capacity and to back-up the shuttle, In addition, it may be prudent to continue development of expendable launch vehicle technology for certain payloads (see ch. 10).

The questions of DOD's share and requirements in STS decisions are mostly settled, but retain historical interest. The shuttle was planned to be a "national" program; i.e., it would serve all customary U.S. launch needs for payloads that were in the shuttle range. Specifically, this implied that NASA and DOD would need to define a common, acceptable payload bay size, operating characteristics, and compatible subsystems. The major premise was that such a substantial investment in a new technological capability could not reasonably be made unless it could serve the broadest set of national needs. The initial concept included the possibility that DOD would assume some degree of responsibility to fund development of the shuttle. This was subsequently modified in view of DOD's rather substantial budgets already in existence for other weapons systems and space developments; the shuttle was included in NASA's budget, though, of course, support for the program rested on congressional recognition of its military uses. It was agreed that DOD's direct share of the program development costs would be limited to two items: a west coast launch site for the shuttle, and development of an interim upper stage (I US) for boosting shuttle payloads into higher orbits.

The resulting agreement gave NASA the responsibility to purchase and operate the STS for everyone. DOD would have missions solely for its use, but NASA would own and operate the launch capability equitably for all users. Certain DOD requirements did drive initial shuttle costs higher than the estimates of NASA's original proposal, but most requirements also resulted in greater, if more costly, capabilities. As DOD has generated additional requirements (for its own mission control center for example), the Department has itself bought these capabilities. This division of responsibility is expected to hold henceforth. NASA's pricing policy for the shuttle remains problematic, especially in view of the 73 percent increase in the projected average cost of a standard mission (from $16.1 million in June 1976 to $27.9 million as of September 1980). According to a recent General Accounting Office (GAO) study, NASA is "locked into a pricing policy that encourages space transportation system use at NASA's expense and at the expense of the space science, applications, and aeronautics programs. GAO believes DOD and other government agencies should bear a greater share of the shuttle's early years operations costs . . ."[83]

The division of the U.S. space program into civilian and military components has been a valuable tool of foreign policy. DOD's involvement with and ultimate use of the shuttle have raised the issue of the possible militarization of the entire U.S. space program, a possibility that is unsettling to other nations, especially the third world and the Soviet Union. The United States has assured other nations that the programs will remain separate, but their concerns are likely to remain until the passage of time and experience with the shuttle show whether or not the civilian program remains unmilitarized.

83 General Accounting Office, "NASA Must Reconsider Operations Pricing Policy to Components for Cost Growth of the Space Transportation Systems," Feb. 23, 1982, pp. ii-iii.

Foreign Competition in Space Transportation

Currently, the United States has no policy regarding foreign competition in space transportation. Though the Soviet Union has had a reliable launch capability for 25 years and has launched satellites for several other countries, it does not sell launches. However, commercial competition from the ESA'S Ariane ELV is now a reality. The Ariane (which is approximately twice the size of the U.S. Delta) has recently completed a successful series of test flights, and the Europeans are now selling space on future launches. Already several U.S. telecommunications companies have switched from NASA launches to Ariane, and more such decisions can be expected because fewer shuttle opportunities are available and U.S. ELVS have become more expensive. The Ariane's attractiveness is enhanced by the creation of Arianespace to market the Ariane and provide launch services. Arianespace, in conjunction with European banks, is offering customers below-market financing and other financial incentives that compare favorably to present U.S. pricing procedures. Arianespace plans initially for five to six launches per year, rising to 10 per year in the mid-l 980s.

The Japanese space agency, NASDA, is currently building and operating modified Delta launchers, designated N-1 and N-11, built under license from McDonnell Douglas. At present the Japanese are prohibited from selling launch services to third parties without U.S. permission; development of a completely Japanese launcher is planned but is not likely to be completed before the end of the decade.

Regulatory Needs

There is now no clarity with regard to regulation of private launches from the United States, largely because there is no single Federal authority for overseeing private space activities from launch to flight termination. The absence of such authority creates a number of problems. First, although certain agencies (FAA, FCC) exercise limited authority over private rocket launches, the absence of clear Government policy and procedures creates confusion as to who has the authority to authorize a private launch. Second, existing Federal launch centers, because of launch conflicts and space limitations, may not be sufficient to meet the future demands of private spaceflight operations. The proper role of Government in the construction, operation, and regulation of new commercial launch sites has yet to be addressed. Indeed, the issue is so recent that the Federal agencies that have interest or jurisdiction have just begun to address it. Finally, it may be prudent to devise some type of mandatory insurance scheme to indemnify the Government and protect the general populace from the possibility of accidents resulting from private launches.

Once a comprehensive regulatory scheme is adopted and a clear Government policy articulated, the institutional risks inherent in operating a private launch system will be diminished, and greater private sector participation may occur.

Prospects for Commercialization

Though the complete transfer of shuttle operations to the private sector does not seem likely in the near future, there is no reason why the private sector could not eventually supply this service. As technical experience is gained, the reliability of shuttle systems proved, and information is obtained concerning the real costs of operating the shuttle, the commercial potential of this system will also begin to be understood. If the transfer of the shuttle to the private sector is determined to be in the national interest, firm Government policies to this effect must be articulated and, where necessary, supported by financial incentives.

No private sector firm has yet expressed interest in operating the entire shuttle system (i.e., orbiters and related launch hardware, and ground support and maintenance facilities), but there has been some interest in the operation or ownership of discrete parts of the launch service. Currently there are three areas where private sector involvement may become important:

- ***Tracking, telemetry and control.–In*** 1979 COMSAT established the first commercial launch control facility that offered services previously only provided by NASA. As space activities become more common, opportunities for the private sector to provide these services will increase.

- ***Shuttle refurbishment.–currently,*** NASA contracts with more than 25 private firms to refurbish the orbiter between flights. NASA has **recently decided to find one firm to act as a manager** for the entire process.
- ***Orbiter ownership.–As*** mentioned above, a U.S. investment banking firm announced its interest in purchasing the fifth orbiter, with the provision that NASA would continue to operate the vehicle but that its payload capacity would be marketed by the private owner. Should this venture prove to be successful, the likelihood that other orbiters will be privately owned will be greatly increased.

Full commercialization of ELVS, however, is possible now. There are few if any unknowns surrounding their operation. The market for launches is steadily growing: though it is not large enough to support all the expendable lines (Titans, Atlas-Centaurs, Deltas, etc.), it could certainly support one of them. Because of various uncertainties, the aerospace companies have not shown much interest in dealing directly with any group backing private launch services. A possibility here would be the mediation of a third-party broker, A further possibility might be the formation of a Government-chartered private corporation to provide launch services, leasing facilities at Kennedy Space Center. Rapid commercialization of U.S. ELVS would provide immediate advantages: competition for the Ariane, added incentive to NASA to bring the costs of shuttle operations down, and a backup system for the shuttle should it meet unexpected problems.