Chapter 8

COMMERCIALIZATION OF SPACE TECHNOLOGY

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COMMERCIALIZATION OF SPACE TECHNOLOGY

INTRODUCTION

A commercial activity is generally understood to be one undertaken for profit in the public marketplace; "commercialization" then implies the transfer of technology from a research and development (R&D) and/or federally supported operations stage to a for-profit stage, usually under private sector ownership and control. It is difficult to give a precise definition for commercialization because the term assumes a variety of specific meanings depending on the context in which it is used. For example, aerospace companies earn a profit on the aircraft they manufacture for the military, but military aircraft are generally not considered to be commercial products, except insofar as they are sold to other countries. Civilian aircraft, on the other hand, are considered thoroughly commercial, in that they are designed, developed, and sold to make a profit in a competitive marketplace. Nonetheless, such aircraft depend partly on technology developed by the Federal Government, either for military use, or in a Government research program.

Though the desired result of all efforts toward commercialization may be similar (i. e., to earn a profit in a competitive environment), the processes necessary to achieve this result and the sources of the technologies involved are often quite different. Such differences become significant in a context such as the U.S. space program, in which commercialization of space technology is encouraged as a matter of policy. The purposes of this chapter will be to: 1) identify some of the problems involved in trying to commercialize specific space technologies; 2) examine private sector attitudes towards commercialization; and 3) describe some of the current Government programs implemented to encourage commercialization.

This chapter begins with a discussion of the special factors that space introduces to the process of industrial innovation. New product, process, and service innovations are analyzed along with the barriers and inducements to their commercialization. The remainder of this chapter discusses several of the current space-related, profitmaking activities and indicates areas in which the private sector may invest in the future.

PROCESS OF INDUSTRIAL INNOVATION IN SPACE

Overview

In most areas of business opportunity, Federal R&D funds support or supplement larger private R&D investment. Public funds are generally thought to be justified for basic research into high-risk pursuits with long payback times, or for technologies having obvious social benefits. With respect to space, and with the notable exception of some communications applications, the private sector has invested relatively little in R&D exploring new business possibilities. This puts the Federal Government in the position of pushing technological opportunities in an area without substantial business interest beyond the aerospace community or an established or integrated market. The purpose of this section will be to explore the Government's recent emphasis on commercializing space technology and the reasons behind the reluctance of the private sector to invest capital in space research.

Although the basic characteristics of the innovative process (see app. H) can be applied to any industry, innovation in space technology raises several unique problems. Among the special characteristics of space-based innovation, the following stand out:

- ***Entry costs are extremely high. No*** form of ground-based research, development, and demonstration can do away with the requirement for testing of systems in space before a new business using space-based technology can apply it commercially. Access to orbit is very expensive, and will continue to be expensive even in the shuttle era, particularly if compared with the costs required to develop and demonstrate the commercial viability of most Earth-based innovations. Even with the less stringent design requirements of the shuttle payload bay, space systems are more expensive to design than their Earth-bound equivalents. The cost of using the shuttle as a laboratory to verify or develop potential innovations may discourage many potential developers. This additional expenditure, incurred well before commercial feasibility has been established, is a radical departure from normal product development on Earth.

- ***Government controls the means ot access to space.*** Until some entrepreneur is capable of operating a reliable space launch system, access to space will be through launchers developed and operated by the Government, In few other business sectors is an essential element of the innovative process totally under Government control. Access to launches, launch assurances,. availability of support facilities, and the cost of space transportation may all be influenced by nonbusiness considerations such as changes in an administration's space policy, national security constraints, or fluctuations in congressional and public support. If the necessary space facilities are not available when needed, the resulting costly delays could be fatal to a new commercial program.
- ***The markets for space industrialization are undeveloped.*** Unlike innovations that emerge from an existing or clearly possible market opportunity, some space-based businesses will be based on totally new capabilities that will have to create new markets. Communications satellites, the often cited example of successfully commercialized space technology, were a more efficient substitute for existing means of long-distance communication. This interchangeability of technologies is not characteristic of many of the other space-based business opportunities which have been identified to date.
- ***Public interests dominate space activities.*** There are few areas of space applications in which one or more of the following public concerns—national security, international economic competition, return to the public from the investment of Government funds, improving the quality of public services provided by Government—are not influential. As a result, it is difficult to disentangle space applications from their public-sector origins. For the foreseeable future, it is difficult to understand how space systems will be developed and operated as totally private ventures without some form of Government oversight or involvement.

Product, Process, and Service Innovation

Much of the current discussion concerning space industrialization has focused on the unique characteristics of the space environment and the new product, process, and service innovations that may result from the use of this environment. There is a tendency in such discussions to regard space industrialization as an undifferentiated set of activities, each offering equal opportunities for investment and commercialization. Important distinctions concerning the sophistication and reliability of the relevant technologies and the presence or absence of a market for the proposed innovation are often overlooked. Consequently, space activities that have pregent commercial potential are often confused with those that merely offer productive avenues for basic research. It is important to review a few of the current and proposed space activities in order to understand how their many individual differences affect their potential for successful commercialization. The following section will take a brief look at satellite communications, remote sensing and space transpiration, with a more detailed examination of the commercial prospects for materials processing in space.

Satellite Communications

To understand how communications satellites fit into the overall scheme of space industrialization, it is necessary to view this technology in an historical perspective and to disregard for the moment its present complex manifestations. I n the late 1950's in the United States there was a great deal of Government and private interest in satellite communications. The private sector, notably AT&T, was keenly aware of the commercial potential of such systems and was proceeding with its-own research while keeping a close watch on the progress of both the National Aeronautics and Space Administration (NASA) and the Department of Defense. The research of AT&T eventually resulted in the design and construction of Telstar, the U.S. first civilian active repeater satellite.[1]

The fact that AT&T initiated and funded its own satellite research program without first obtaining from NASA a guarantee for financial or technical assistance is a point that deserves some scrutiny. Corporate investment in new product development is generally undertaken only after a critical appraisal of the relevant technology, the anticipated development cost and anticipated return, and the market demand. AT&T's decision to extend its communications network into space was no exception to this general rule.

From the technological point of view, communications satellites had three distinct advantages over many of the space projects that are presently under consideration. First, a communications satellite is, or rather can be, a very simple device. All that is required is the proper placement above a specific Earth point and the ability to reflect either radio or microwaves to another Earth point.[2]

Secondly, much of the research and testing of a communications satellite could be done on the ground. This meant that development time would be faster and research costs would be lower and more predictable.

Finally, corporate developers had the assurance of knowing that when their product was finished it would provide them with three distinct advantages over ground-based communication systems. These advantages are insensitivity to distance, broadcast ability, and flexible routing. Distance insensitivity means that the cost of communicating between two points remains the same no matter how far they are apart. This must be contrasted with communications by cable, where the cost is nearly proportional to the length of the cable. A satellite is also capable of broadcasting simultaneously to several Earth points, whereas a cable can carry communications only between two specific locations. Flexible routing means that a satellite's circuits can be switched to different routes as traffic patterns change. Terrestrial circuits, on the other hand, must be plentiful enough to meet peak demands on specific fixed routes,

Another important factor that went into AT&T's decision to invest in satellite communications was its dominant market position. In addition to its large domestic telephone market, by the time Early Bird was launched in 1965, AT&T owned a majority interest in all the transatlantic cables connecting North America and Europe. Unlike the firms which today may be considering some type of enterprise in space, AT&T had a strong hold over the market it was about to enter. In a similar vein, Western Union's development of "Westar," the first domestic satellite system, should be viewed in light of Western Union's position as the sole domestic telegraph carrier. Its decision to offer domestic satellite service proceeded in large part from its evaluation that a market for this specialized service existed.

In the early 1960's, communications satellites were also attractive from a financial point of view. A Rand Corp. report published at this time had estimated that a low-altitude satellite system would cost approximately $8,500 a year per channel, compared with $27,000 for a new underwater cable system.[4] Though these projections were not entirely accurate, the commercial results of the use of communications satellites are reflected in the history of transatlantic telephone charges. In 1966, immediately after the first com-

[1] D. Smith, *Communications Via Satellite,* 1976, p. 82.

[2] Using this basic concept, the U.S. Army Signal Corp, in 1945, undertook project Diana, which was an attempt to use the Moon as a passive reflector of radio signals. This research led to the development, in 1959, of a two-way transmission system between Washington and Hawaii. Ibid., p. 30.

[3] M. Kinsley, *Outer Space and Inner Sanctums, 1976,* p. 131.

[4] D. Smith, op. cit., p. 67.

munications satellite went into operation, monthly charges for transatlantic phone circuits dropped sharply and have continued to fall since that times This reduction in price reflects the fact that satellites are a cheaper, more efficient means by which to accomplish long-distance terrestrial communications.

Remote Sensing

Remote sensing of the Earth from space is the second of the space applications with near-term commercial potential. (For a more detailed discussion of this subject see ch. 3.) When Landsat 1 was launched in July of 1972, the U.S. Government owned and operated, through NASA, both the space and ground segments of the system.[6] Recently, responsibility for the operation of a civilian remote sensing system has been assigned to the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). Eventually NOAA will take over the operation of the Landsat spacecraft now operated by NASA with the ultimate goal of transferring both the space and ground segments of the system to the private sector.

Though there is a considerable amount of interest in remote sensing, it is unclear whether the private sector can accept the full responsibility for a complete Earth resource system. There are three main reasons for this reluctance.[7] The first is that, unlike satellite communications, the market for remote sensing is quite new. Though it is potentially strong, it is now too undefined to allow accurate projections of return on investment. The second problem is that the Government is now and will probably remain the largest user of remotely sensed data. The success of private enterprise in this area will depend on whether or not the Government decides to satisfy its civilian remote sensing data requirements from a private operator, the price it will pay for such services and whether the Government will agree not to compete with the private sector. The third problem is that the prices now charged for data will not support systems costs. Up until this time the costs of data have reflected only the marginal cost of reproduction. This has been possible because NASA, during the R&D phase of its remote sensing program, subsidized all of the operational costs. In the near future the French and Japanese may be operating government-subsidized remote sensing satellites. If this is the case, U.S. firms, whose price structures must reflect the total costs of operations, may not be able to compete in the world market.

As a result of these factors, it is unlikely that the private sector will be interested in owning the remote sensing system as presently configured until investors perceive that the probable return on investment is at least comparable to that available from other risk-investment opportunities. It should be noted that Landsat may not be an appropriate model by which to gage the costs of a commercial remote sensing system. Because Landsat is an R&D system, it is encumbered with many costs and inefficiencies that could be eliminated in a commercial system developed to meet specific user needs with appropriate and cost-effective technology.

At this time corporations are involved only indirectly in remote sensing from space. In addition to the products and services developed and manufactured by the aerospace industry for the various Federal programs, the private sector has also developed and provided analytical hardware, software and services to private and Government users.

presently, there are over 50 organizations in the United States involved in the analysis of remotely sensed data on a commercial basis. These organizations use the imagery acquired from space to evaluate areas of the Earth's surface for such varied purposes as hydrocarbon resource potential, estimating crop production and land use surveys. Several firms are also selling hardware designed to process remotely sensed data.

[n the near future, it would appear that private involvement in remote sensing will be limited to providing the above mentioned hardware sales and "value-added" services. Only when the markets are sufficiently large, with data prices reflect-

[5] J. E. Schnee, "inventory of Space Activities (Economic), " presented at the Symposium on *Space Activities and Implications,* Institute of Air and Space Law, McGill University, October 1980.

[6] For a brief history of the Landsat program and technology see: National Academy of Sciences, *Resource Sensing From Space, 1977.*

[7] *See* generally: An Interagency Task Force "Private Sector Involvement in Civil Remote Sensing, " June 15, 1979.

ing the true costs of acquisition, can the private sector be expected to own and operate remote sensing systems.

Space Transportation

Recently there has been considerable discussion concerning the possibility of establishing privately owned launch systems. This discussion has focused on three alternatives: 1) commercialization of the U.S. present expendable launch vehicles; 2) transfer of shuttle ownership and/or operation to the private sector; and 3) private development of a new generation of low-cost expendable launch vehicles. At present, the absence of a comprehensive Government policy which favors and encourages the participation of the private sector in launch system ownership has inhibited such developments.

The present expendable launch vehicles (ELVS), such as the McDonnell Douglas Delta and the General Dynamics Atlas-Centaur, are already operated on a quasi-commercial basis. These vehicles are commonly purchased through NASA by communications companies for communications satellite launches. Although the vehicle is launched by the Government, its cost and and those related ground services are borne by the private sector purchaser. The transition from the quasi-commercial provision of launch services to a purely commercial system may be difficult to accomplish. Because the Government has historically developed and operated launch vehicles and presently owns all of the sophisticated U.S. launch facilities, some form of Government-industry cooperation would seem to be a necessity. This, in itself, should not be a cause of concern because, as the aeronautics industry proves, Government and industry can work together to the mutual benefit of each. The problem that does arise, however, is that in certain instances the goals of the Government are not those of industry.

For example, the present Government commitment to the shuttle entails several costs which NASA, at present, does not intend to recover from shuttle users. This type of subsidy allows the shuttle (and likewise the Ariane launch vehicle of the European Space Agency (ESA)) to be priced in a manner that does not reflect the true costs of operations. From NASA's standpoint as an R&D agency this subsidy may be desirable because it encourages the use of a newly developed system. However, the shuttle price then becomes the price the private sector must match in order to compete for commercial payloads. Because a commercial operation must not only meet its costs but also generate a profit, it is questionable whether proven technology such as the U.S. ELVS can be commercially competitive in the absence of some form of Government assistance. Such assistance couId come in the form of a promise of a certain number of government launches, access to government launch facilities or more traditional incentives such as tax breaks. However, given this country's long-term commitment to the shuttle, it seems unlikely that such assistance will be forthcoming.

There has been some discussion concerning the possibility of converting surplus military rockets, such as the Polaris or Minuteman, to commercial launch vehicles. Given that the Government would support such a plan, the main advantage to using these vehicles would be their extremely low cost. There would, however, be a number of disadvantages. Because these vehicles do not have the power to carry large payloads to geostationary orbit, they could not be used to launch many of the newest communications satellites. Furthermore, the fact that these launch vehicles would be surplus equipment operated by nongovernment personnel would make it difficult, at least initially, to obtain launch contracts from companies accustomed to the security of dealing with NASA. It would be unlikely that customers would be willing to entrust valuable payloads to an unproved private company particularly if adequate launch insurance were not available.

Transfer of the shuttle to the private sector has also been considered. Such a decision would involve a major policy shift on the part of the Government, with substantial institutional and financial reprecussions. Important questions would have to be examined: 1) what part, if any, of the shuttle development costs should the Government attempt to recoup; 2) could the national security needs of the United States be met by a privately owned shuttle; and 3) could a private shuttle compete in the international arena with foreign, subsidized launch systems? None of these problems necessarily prevents the shuttle from being owned and operated by the private sector; however, the resolution of any of these problems requires a substantial degree of Government involvement.

Several private firms have also consitiered the possibility of developing a new generation of low-cost launch vehicles. However, even using proved ELV technology, the high cost and long development time associated with such an endeavor have so far prevented the successful development of such a vehicle. Were such a firm to be technologically successful, commercial success would still depend on a positive Government attitude toward such an enterprise. Questions such as launch safety, payload regulation, acquisition of new launch facilities, and launch agreements with foreign governments would still require resolution. The time and expense involved in developing a private launch system combined with government delays and regulatory complications may well create too heavy a burden for the private sector to carry alone.

Materials Processing in Space (MPS)

As indicated earlier in this report (see ch. 3), the unique properties of outer space, most notably microgravity, are amenable to a number of industrial processes. Some of the organic and inorganic materials that may in the future be processed in space have already been mentioned above. it should be noted, however, that the nascent state of MPS technology and the lack of clearly defined markets place materials processing in a long-term, high-cost, high-risk category that is generally beyond the interest and financial capabilities of most private commercial concerns. It is unrealistic to expect any major financial commitments from the private sector until the technical capability and economic feasibility of new space processing techniques have been demonstrated. At least for the near future, the responsibility for proving the technical and economic feasibility of new space technologies will rest on the Government acting, either alone or in joint ventures with the private sector. Because of the emphasis NASA placed on commercializing MPS technology, it is useful to examine this space application in some detail.

BARRIERS TO COMMERCIALIZATION OF MPS TECHNOLOGY

Most of the products and processes presently being considered for development in space are, at best, in the basic research stage of the innovative process. Though it would be correct to say that the private sector will begin to invest in space industry only after achieving a more sophisticated understanding of how materials and processes behave in space, such an analysis identifies only one aspect of its reluctance. A number of commercial, legal, and organizational factors must also be considered.

Few ***attractive*** investments.—of all the barriers to process innovation in space, the most important is that the ideas for new products and processes that have been suggested simply are not very attractive investments. Industrial R&D projects are a discretionary expenditure, and therefore must compete for corporate capital with other investment opportunities. A project's ability to compete is a function of the amount of risk it involves, its estimated front-end costs, and its foreseeable rate of return.

The risks involved in space innovation are considerable. For example, several pharmaceutical products have been identified that may be produced either more cheaply or with greater ease in outer space. However, before any of these products could reach the market a number of significant problems would face the manufacturer. First, there would have to be a period of ground-based R&D where the techniques to be employed in space would be developed. Next, the process would have to be verified in space. This problem depends on the availability of NASA test facilities, such as the shuttle, which in turn depends on how the current political and economic environment affects NASA funding. Because the Government has the right to terminate contracts unilaterally, a company that has spent millions of dollars on R&D could find itself without access to shuttle flights. Though the Government might have to reimburse a client's costs on a contract it canceled, such reimbursement would not include the opportunity costs—that is, the costs of devoting resources to a space processing program in place of some other business opportunity. If the process were verified in space, Food and Drug Administration (FDA) approval would still be necessary before the new pharmaceutical product could be marketed, and–depending on the complexity of the manufacturing process—new legal and regulatory agencies might be necessary.

Even if all of these R&D hurdles could be cleared, the economic success of a drug manufactured in space would still depend on the company's ability to produce and sell large enough specific annual quantities of a new product. It is unlikely that the shuttle, as it is presently configured, could guarantee such a requirement. Long-term MPS facilities based in space and dedicated to commercial space processing neither exist nor are planned for the near future.

It is by no means certain that a firm wishing to manufacture a product in space would have to face all of the complications enumerated above. The results of MPS experiments undertaken over the next 2 to 5 years may reveal many commercially attractive opportunities for products or services that can be performed on the shuttle as presently configured. Nonetheless, the risks involved in space-based product research do create a substantial barrier to investment.

In addition to the technical and institutional risks involved in utilizing the space environment, there are also uncertainties regarding cost and development time. The present shuttle pricing schedule does not reflect the true costs of operations. A recent General Accounting Office report has suggested that NASA should void its pricing policy (except for those launches that have legally binding agreements) and charge "substantially higher prices for future Iaunches."[8] Uncertainties as to the price of future shuttle missions make it difficult for business planners to estimate the cost of space-based product development.

Firms interested in investing in a new product must estimate that product's potential rate of return. When considering the rate of return that a space-based industry might generate, one must take into account the development time of such a project. Because a dollar held today has greater buying power than a dollar held in the future, the dollar that is anticipated in the future must be "discounted" to reflect its actual value in today's dollars. This means that the longer any project takes from its R&D phase to commercialization, the greater the profit must be when the project begins to make money. This is particularly true during times of high inflation and high interest rates. The combination of technical uncertainties and potential problems in obtaining the shuttle flights necessary for project verification makes it difficult to predict the development time for space-based projects. The combination of high-cost, high-risk, long-payback time and uncertain rate of return makes it difficult for space-based projects to compete for internally generated corporate capital with other, more traditional, investment opportunities. Similarly, conventional methods of financing such as equity capital or borrowing may not be available, and the degree of risk involved here may also discourage the flow of venture capital into this area. g

Uncertainties as to value of space environrnent.-In addition to the view that there is little to be done in space, there is a tendency in the business community to believe that whatever can be done in space can also be done on Earth. Though it is often stated that the microgravity of space is fundamentally different from Earth gravity and cannot be duplicated, new technologies have been developed which do minimize the effects of gravity on Earth. Examples of this fact can be seen in recent developments in containerless processing and in the manufacture of latex polymers.

It is believed that one of the advantages to in-space manufacturing will be that materials can be processed without picking up impurities from the wall of the container that holds them. Recently a U.S. firm working with NASA developed a containerless processing system for making special glass products on Earth. [10] in this system the

"'NASA Pricing Policy on the Space Transportation System," GAO Report to Congress, Feb. 23, 1982.

[9]The Space Industrialization Act of 1979: statement Of Russell Carson at hearings on H.R. 2337, before the Subcommittee on Space Science and Applications, 96th Cong, 1st sess., p. 1767.

[10]Industry Week, Mar. 3, 1980, P. 90.

glass is suspended within a chamber by sound beams in a process called acoustic levitation. Another example of an Earth-based advance that has a space counterpart is the manufacture of latex polymers. It is believed that, in space, latex polymers could be enlarged to as much as 40 microns. Although it had been assumed that the gravity on Earth would limit the expansion of these materials to 2 microns, Norwegian scientists using new chemical techniques have increased the size of latex polymers to 10 microns.[11] Though neither process functions as efficiently as would similar space-based processes, they are accomplished without the enormous expense and administrative complexity of space-based manufacturing. Industry will be hesitant to invest in space as long as there is at least some hope that Earth-based manufacturing techniques can accomplish similiar results.

Prior investment in Earth technology.–Even if industry could be sure of the commercial viability of some of the projects that have been proposed, its prior investment in Earth-based technology may make it reluctant to pursue new innovations in space. Radical innovation, whether in space or on the Earth, usually means discarding expensive equipment before a company has had time fully to depreciate it. For example, it has been suggested that the U.S. auto industry's enormous investment in automating the manufacture of cast iron brake drums probably delayed by more than 5 years its transition to disc brakes.[12] Some companies prefer safer methods of maximizing profit, such as advertising, market research, and automation, rather than risking investment in new products and processes. The majority of industrial product and process development is directed at reducing costs and increasing profits in the short run. For this reason it is more common for industry to seek new methods of making existing products more cheaply or marketing them more effectively than to develop new products.

This is not the first time that this conflict between old technology and new has been an issue in the space debate. In the early 1960's, when Congress was trying to fashion an institutional structure and a method of ownership for the Communications Satellite Corporation (COMSAT), there were serious reservations about allowing the existing international communications carriers to invest in the corporation. It was assumed that companies with large investments in existing facilities would be reluctant to take speedy action to implement new satellite systems that would make their existing facilities obsolete. To some extent, a similar concern may be raised regarding companies that could benefit from space-based manufacturing techniques. Even if the product that could be produced in space is better or more efficient than its Earth-manufactured equivalent, a corporation's prior investments may prohibit it from pursuing this new technology.

Intellectual property. -Another potential barrier to process innovation in space is the fact that a large portion of the private sector has no experience in dealing with the Federal Government other than as an occasional vendor of supplies and materials. In the normal course of events, a firm working for the Government is required to submit periodic reports detailing the progress of its work. Such requirements are at odds with the usual desire of industry to protect its investments in R&D by refusing to disclose details or results of current research. Industry is also concerned that a business relationship with the Government could result in the loss of certain intellectual property rights.

The Freedom of Information Act[13] raises a number of problems concerning the protection of data and proprietary rights. It requires the disclosure of "Government records" upon request, unless the records fit into one of the narrow exceptions to the act. Information obtained under a guarantee of confidentiality may be protected and "trade secrets" are a recognized exception to the act. A company working with NASA must carefully screen that which may become a "Government record" and be sure that if sensitive information becomes "Government record" it qualifies as one of the exceptions to the disclosure requirements.

[11] Ibid.

[12] Robert H. Hayes and William J. Abernathy, "Managing Our Way to Economic Decline" *Harvard Business Review,* July and August 1980, p. 70.

[13] 5 U.S. 552.

Several legal issues may inhibit the private sector's involvement in the innovative process in space. The first concerns the question of ownership of the patent rights to new products and processes discovered during the course of a joint endeavor with NASA. Section 305 of the 1958 NAS Act states that "whenever any invention is made in the performance of any work under any contract of [NASA], such invention becomes the exclusive property of the United States unless [NASA] waives rights thereto . . . "[14] A strict reading of this section would vest in NASA the ownership of all inventions discovered while working for, or in a joint venture with NASA. Over the last two decades NASA has limited the application of section 305 to activities performed for NASA which have as their main purpose the development of some new product or process. With regard to joint ventures, it has been NASA's position that neither party assumes any obligation to perform inventive work for the other, and accordingly each party retains the rights to any invention that may be made in the course of the venture.[15]

International Law. –In the area of international law, the private sector seems to be troubled by the growing use in international treaties of "common interest" clauses such as the Common Heritage of Mankind principle which has been discussed at the Law of the Sea Convention and appears in the proposed Moon Treaty.[16] Simply stated, these clauses assert that certain resources, such as the minerals on the ocean floor and on the Moon and the "slots" in geostationary orbit, are presently under the jurisdiction and control of no sovereign power; these resources, being finite and exhaustible, should not be allocated to the developed countries on a first-come, first-served basis, but rather, should be made to benefit all nations. Although these "common interest" clauses have found their way into all the major space treaties, there is considerable uncertainty as to their status within the body of international law. Some writers have suggested that these clauses are merely pragmatic principles without legal force.[17] Others regard them as binding principles which obligate states to be responsive in some form to the interests of developing countries.[18]

The use of "common interest" clauses in international treaties has brought about strong opposition from the private sector. The most common argument heard in this regard is that the concept of equitable sharing is inconsistent with the concept of profit, and in the absence of the profit motive private enterprise cannot be expected to risk capital on space investments. At this stage of space industrialization such considerations have had only a minimal effect on the private decisions whether or not to invest in space.

INDUCEMENTS TO PROCESS INNOVATION IN SPACE

Profit potential. –Though there are substantial physical, economic, and psychological barriers to process innovation in space, certain inducements do exist which may encourage private sector participation in this area. Probably the most important incentive to the private sector is the potential for making a profit. At the present time only ***two*** product areas seem ***to*** offer the combination of technical feasibility and market potential that are necessary for a profitable venture. The first of these product areas is pharmaceuticals.

McDonnell Douglas together with Ortho Pharmaceutical Corp. has investigated the commercial cial potential of several pharmaceutical products, which could be processed by electrophoresis in space, and has entered into a joint agreement with NASA to test this technology. This project has been described by McDonnell Douglas as an "aggressive, well-ordered commercial business venture" in which the combined investment of the pat-ties will be measured in terms of millions of dollars. Clearly McDonnell Douglas and Ortho

[14] 42 U.S.C. 2451, et. seq.

[15] Space Industrialization Act of 1979: statement of Robert A. Frosch at hearings on H.R. 2337, before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, 96 Cong. 1st sess., 1979.

[16] *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies,* U.N. doc. A/34/664.

[17] C. Q. Christol, "The Legal Common Heritage of Mankind: Capturing an Illusive Concept and Applying It to World Needs," XVIII, *Colloquium on the Law of Outer Space, 1976, p. 42.*

[18] S. Gorove, "Limitations on the Principle of Freedom of Exploration and Use of Outer Space," XIII, *Colloquium on the Law of Outer Space, 1973,* p. 74, et. seq.

believe that there is a profit to be made in developing this technology.

Other potentially profitable products that can be manufactured in space are the starting material for electronic devices such as large-diameter crystals. Like pharmaceuticals, these crystals have a high market value per unit mass. The facilities needed to manufacture the basic materials are also small, so that the total orbital mass is low, even for very high production rates. The economic advantage of manufacturing the starting materials for electronic devices in space is less sure than for pharmaceuticals and no one has made a major investment in this technology.[19] It should be noted that the Earth-manufactured electronic devices presently enjoy a sales level of about $16 billion per year with an estimated growth rate of 10 to 15 percent annually for the next 10 years. Such a healthy market is conducive to innovation and may eventually provide the incentive for the private sector to invest in space-based manufacturing techniques.

In addition to products, it is possible that the private sector may find it profitable to offer certain space-based services. The GTI Joint Endeavor Agreement with NASA (discussed below) is based on this assumption. GTI is developing a metallurgical furnace which it hopes to rent to parties interested in the effects of solidification in microgravity. As experience is gained in MPS research, it is likely that other space-based services will be offered by the private sector.

Scientific knowdedge. –Another reason that the private sector may wish to invest in process innovation in space is to gain a better understanding of present Earth-based manufacturing techniques. For example, methods now used for the commercial growth of large crystals have been developed empirically with little theoretical understanding of what occurs at the microlevel during growth. It is possible that significant improvements in Earth-based crystal growth could result if low-gravity experiments were to provide a better theoretical understanding of the growth process. In a similar vein, the John Deere Corp. has entered into an agreement with NASA to study the solidification of cast iron. The purpose of this research will be to gain a better understanding of how the graphite formation of cast iron influences the metal's properties. It is expected that low-gravity experiments will provide insights into this question which, though obtained in space, will have practical use on Earth.

Institutional incentives. —In order to encourage private involvement, NASA has established the Commercial Applications Office in its MPS program. This office forms a bridge between NASA and the private sector which provides assistance to the industrial user and suggestions to NASA on how the commercial growth of MPS might be advanced. Joint projects between industry and NASA are "no exchange of funds" agreements to cooperate in a given area with each party assigned specific tasks to accomplish. The Commercial Applications Office has developed three basic levels of working relationships with private organ izations:

Technical exchange agreement (TEA) .–For companies interested in applying microgravity technology, but not ready to commit to a specific space flight experiment or venture, NASA has developed TEA. Under a TEA, NASA and a company agree to exchange technical information and cooperate in the conduct and analysis of ground-based research programs. In this agreement, a firm can become familiar with microgravity technology and its applicability to the company product line at minimal expense. Under TEA, the private company funds its own participation, and derives direct access to and results from NASA facilities and research, with NASA gaining the support and expertise of the private company's industrial research capability.

Industrial guest investigators (lGl).–ln an IGI agreement, 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 contribution to be made to the objectives of the experiment, the IGI becomes a member of the investigation team, thus adding industrial expertise and insight to the experiment.

[19] Materials processing in Space, report of the Committee on Scientific and Technological Aspects of Materials Processing in Space, National Research Council, 1978, p. 40.

Joint endeavor agreement (JEA)-JEA is a cooperative arrangement in which private participants and NASA share common program objectives, program responsibilities, and financial risk. The objective of a JEA is to encourage early space ventures and demonstrate the usefulness of space technology to meet marketplace needs. A JEA is a legal agreement between equal partners, and is not a procurement action; no funds are exchanged between NASA and the industrial partner. A private participant selects an experiment and/or technology demonstration for a joint endeavor which complies with MPS program objectives, conducts the necessary ground investigation, and develops flight hardware at company expense. As incentive for this investment, NASA agrees to provide free shuttle flights for projects which meet certain basic criteria, such as technical merit, contribution to innovation, and acceptable business arrangements. As further incentive, the participant is allowed to retain certain proprietary rights to the results, particularly the non patentable information that yields a competitive edge in marketing products based on MPS results. However, NASA receives sufficient data to evaluate the significance of the results, and requires that any promising technologies be applied commercially on a timely basis, or published.

NASA has developed these three types of working relationships in order to attract private-sector interest at varying investment levels. It hopes that firms with limited funds and cautious R&D policies may start out with a TEA or an IGI and, if in-space experimentation appears valuable, upgrade their cooperative efforts to a JEA.

Another interesting method for attracting and maintaining the interest of private enterprise in space-based manufacturing is the proposed Space Industrialization Corporation (SIC) .20

The bill which proposed SIC declares that it is a finding of Congress that "space activities have matured to the point where the attributes of space are generally understood" and a "number of potential uses of the properties of the space environment are already known to have commercial applications. " In light of these findings, the bill proposed the creation of a mixed-ownership corporation funded initially by Congress to "promote, encourage, and assist in the development of new products, processes, services, and industries using the properties of the space environmerit. "

As a mixed-ownership corporation, SIC would be managed by a Board of Directors appointed by the President, consisting of a chairman, three qualified members of the executive branch, and eight members from the private sector. The financing of SIC would take the form of a "Space Industrialization Trust Fund." Congress would provide this fund with $50 million per year for the first 2 fiscal years and then additional sums as might be necessary.

When the Board of Directors determined that the corporation was operating "successfully, effectively, and profitably," then it would take steps to transfer SIC from a mixed-ownership corporation to pure public ownership. As a publicly held corporation, the financing for SIC would derive from issuing capital stock and selling nonvoting securities and bonds.

One would assume, in light of the financial difficulties involved in private sector participation in materials processing in space, that a proposal such as SIC would meet with general approval. This, however, has not been the case. Many have hastened to point out that though the proposed SIC is a step in the right direction, the idea in its present form contains some serious problems. The problems most often cited by those opposing SIC in its present form are: 1) that such a proposal is premature in that the attributes of space are **not** generally understood; and 2) that it may interfere with the activities of NASA, particularly its MPS program.[21]

Government Encouragement of Innovation

Government involvement in the process of innovation raises important questions as to the appropriate roles of the public and private sectors

""" The Space Industrialization Act of 1979," H.R. 2337.

[21] The Space Industrialization Act of 1979, op. cit., p. 64.

in the development and operation of new technology. Ordinarily, the private sector bears the total responsibility for funding R&D intended to be incorporated into commercial systems. However, over the past several decades the Government has provided significant support, not only for basic research but also for applied research, technology and systems development, and even demonstration projects in the aerospace industry. In each of these instances, the Government role in the process of innovation was determined by the complex interaction of such variables as: the sophistication of the technology involved, its perceived importance to national goals, the structure of the market to which the technology is addressed, the level of industry interest, and the ability of the private sector to develop the relevant technology without Government support.

The following section presents three different examples of how Government intervention has been used to direct and encourage technological innovation.

Aeronautics

An often-cited example of Government success in moving new technology out of its own control and into the private sector, is NASA's aeronautical research program. This effort began as a direct outgrowth of the program of the National Advisory Council on Aeronautics (NACA), initiated in the mid-1920's and formalized in March 1946 by the National Aeronautical Research Policy. This policy, promulgated to clarify the relationship of NACA with other R&D agencies, charged NACA with the responsibility for conducting "research in the aeronautical sciences." By comparison, the policy assigned to industry the responsibility for the "application of research results in the design and development of improved aircraft equipment." In other words, the Government agreed to assume the responsibility of early applied research but product development would remain the responsibility of the private sector. This approach seems to have worked rather well, inasmuch as the history of U.S. civilian aviation is crowded with examples of technology which found its way into commercial use after initial, early research at government expense. For example, *super critical airfoils,* the *high bypass tubofan jet engine,* the *microwave Landing system,* the *turboprop engine,* and many others were all introduced for commercial exploitation in the American market after years of fundamental R&D work by NACA and later by NASA.[22]

In its generally successful efforts to launch government-developed aviation technology into the private sector, NASA exploys two concepts for identifying at what point the development of a given technology should become the responsibility of the private sector. These two concepts are "technology validation" and its logical followup, "technology readiness."[23] The former describes the state of a technique, still under investigation, when its essential performance characteristics have been proved but before there is confidence in the level of costs associated with fabrication of that device or technique under investigation. The latter term, "technology readiness" is employed to describe a technology that has been demonstrated to have a reasonably high probability of resulting in a commercially manageable fabrication process. Note that NASA does not actually design a fabrication process, but only "certifies" in an informal way that the road seems clear for a private firm to do so. In this sense the technology is "ready" for the private sector. NASA has performed the generic R&D that is necessary to prove the worth of a new application of engineering science to aviation technology. It does this both for the particular technology in question and also, if the success of the first stages warrants, for the fabrication or manufacturing technology necessary to produce the innovation. If at this point industry wishes to shoulder the risk of further specific R&D (which is usually much more expensive than the preliminary, generic R&D) based on its judgment of level of expected return on its investment, it may do so with a much greater degree of confidence than if it were to start a technology validating process from scratch. Essentially, this process is one of lowering the threshold of risk for private investment in a new and promising technical development. Doing so at public expense is justifiable so long as there

[22] NASA, *The High Speed Frontier: Case Histories of Four NACA Programs* (1980).

[23] Office of Technology Assessment, *Impact of Advanced Air Transport Technology,* Part 1; pp. 10, 34, 1979.

are significant public as well as private benefits to be exploited in the innovative product, service, or process. It should be pointed out, in respect to this last notion, that in order for NASA to be confident of the existence of a "significant public benefit" to be had from its generic technology development efforts, a well-developed market for civilian aviation services was an important given condition. The importance of a well-developed market and its effect on Government R&D is examined in greater detail in the following discussion of communications satellites and materials processing in space.

Communications Satellites

Communications satellite technology from its inception was pursued with enthusiasm by the private sector. The initial Government position articulated during the Eisenhower administration was that NASA should "take the lead within the executive branch both to advance the needed research and development and to encourage private industry to apply its resources toward the earliest practicable utilization of space technology for commercial civil communications requirements . . . "[24] At this time AT&T's position as the sole U.S. international telephone carrier and its financial ability and willingness to commit funds to the development of communication satellites made it the obvious industry partner for NASA efforts. By September 1960, AT&T was ready to request that NASA clarify its policies concerning aid to companies working to develop communications satellites[25] and had already contacted the Governments of France, Britain, and Germany about plans for low-altitude satellites to provide transatlantic telephone and television service.[26] Hughes Aircraft had also contacted NASA to express its interest in, and ideas for, communications satellites.

Had the Eisenhower administration's policy been continued, it is almost certain that the private sector would have undertaken the commercialization of satellite communications. With NASA supplying technical assistance and FCC regulating such communication under traditional guidelines, it is probable that the development of this technology would have proceeded without the creation of an organization such as COMSAT.

COMSAT was the product of public policy considerations and not of the marketplace. With the Kennedy administration came a strong commitment to the space program as a means to enhance U.S. prestige and security. It was felt that satellite communications could be one area of early U.S. competence. As a result an additional $10 million was added to the 1961 NASA budget for communications development.

The addition of these funds had several effects on the communications satellite innovative process. The most obvious effect was that NASA had the funds and the mandate to "push" communications technology to maintain U.S. leadership in this field. A peripheral, though seemingly intended result was a postponement of private sector investment in this technology. This development reflected the decision of the Kennedy administration to assess the policy implications before placing the development of communications satellites in private hands. It was also consistent with the administration's desire to keep satellite communications responsive to Government policy and its cautious approach to what seemed an imminent AT&T monopoly in international communications.

In a curious inversion of the normal chain of events, the Government used its ability to subsidize innovation to retard the process of commercialization rather than to speed it. The Government wished to ensure that any transfer of technology occurred under conditions that would be responsive to foreign policy considerations. This desire was accomplished by the statutory creation of the unique public/private COMSAT.[27]

COMSAT is a private corporation with a monopoly in the business of international satellite communications. The Communication Satellite Act of 1962 provided that ownership and financing of the corporation would be accomplished through the issuance of capital stock. The act originally reserved 50 percent of the stock for purchase by communications common carriers au-

[24] D. Smith, p. 70.
[25] Ibid. at 70.
[26] Ibid.

[27] Communication Satellite Act of 1962, 47 U.S. C. 721.

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thorized by FCC. The act also initially provided that the Board of Directors was to be composed of six members elected by the common carrier stockholders, six elected by the rest of the stockholders, and three appointed by the President with the advice and consent of the Senate. [28] In this manner Congress sought to insure that the Government retained some degree of internal control over the organization.

The COMSAT Act also provides certain external controls which allow the Government to regulate and direct COMSAT'S activities. Section 201 (a) of the act grants the President the authority to undertake such activities as aiding the planning and development of the system, reviewing all phases of development and operation, supervising the relationship of the corporation with foreign governments, and insuring foreign participation in the system. Further, the act gives FCC the power, among other things, to ensure competition in the procurement of equipment and service, to regulate technical compatibility between satellites and ground stations, to set ratemaking procedures, and to approve technical characteristics of the system.

The Government's support of innovation in communications satellite technology benefited COMSAT in two ways. First, the technology eventually transferred to the new corporation was more advanced than that which would otherwise have been available for commercialization in the early 1960's; second, this technology was developed at the public expense. The complicating factor is that because COMSAT was not solely a commercial venture founded in response to market demands but rather a hybrid organization designed to implement public policy, the responsibility for innovation in satellite technology has never been clear. After COMSAT was established, there was considerable disagreement as to what role NASA should play in further communications satellite research and development. Many felt that COMSAT, as a private entity, should take the initiative and the risks associated with the evolution of the communications satellite. Others believed that NASA should continue its R&D role because the NAS Act of 1958 mandated it to ensure U.S. leadership in space technology. NASA's position in the mid-1 960's was that it should be allowed to continue research in advanced technology, whereas COMSAT'S R&D would be directed to establishing the initial operating systems.

Using this and similar arguments, NASA continued to receive funding and to do communications satellite R&D until January 1973. At this time, the combination of NASA budget limitations and the success of commercial satellites for both international and domestic service led NASA to phase out its work on advanced communication systems.

The Joint Endeavor Agreement

The primary method by which the Government is seeking to encourage private sector participation in MPS research is through innovative NASA/industry relationships such as the Technical Exchange Agreement (TEA), the Industrial Guest investigation Agreement (IGIA) and the joint Endeavor Agreement (JEA). Since JEA requires the greatest commitment on the part of NASA and the private sector participant, it is useful to examine this arrangement, its problems, and its potential for success.

As of January 31, 1982, there were two jEAs in effect. The first of these agreements, referred to earlier, was with McDonnell Douglas Astronautics Co. (MDAC) and the second is with the GTI Corp.

The subject matter of MDAC/JEA is a process called continuous flow electrophoresis (C-F-E). This process separates materials in solution by subjecting them to an electrical field as they flow continuously through a chamber. The McDonnell Douglas C-F-E experiment will use the shuttle, at NASA's expense, to develop and demonstrate the applicability of that process to the creation of marketable quantities of pharmaceutical products. Ortho Pharmaceutical Corp. has been selected by McDonnell Douglas as a partner in its materials processing business venture. Ortho has completed a detailed market analysis on the first C-F-E candidate product to be produced in

[28] The Communication Satellite Act was amended in 1969. Sec. 303 (a) now states that if the shares of voting stock held by the communications common carriers is less than 8 percent, the common carriers are not allowed to elect directors separately (47 U.S.C. 73 3(a)), Presently, the common carriers hold less than one-fourth of 1 percent of the total shares outstanding.

space. The corporation is now developing a detailed animal test program for the product, to be followed by a clinical test program. "Substantial sums of money" (in the tens of millions of dollars) have been and will continue to be invested by both parties in the venture. According to MDAC, optimization of C-F-E ground units has been completed, and fabrication of apparatus for space flight demonstration onboard the shuttle in 1982 is now under way.

In addition, the conceptual design of a precommercial space flight pilot plant has been initiated. Present plans call for pilot plant demonstration in 1985/1 986, and maintaining this schedule should result in commercial operation by 1986 or 1987.

The subject of the JEA with GTI Corp. is a metallurgical furnace. GTI's furnace is a 200-lb computer-controlled chamber that will be flown in the cargo bay of the shuttle. The furnace will have 37 compartments for the melting and resolidification of some 220 alloy samples. Should this JEA prove the technical and commercial feasibility of this furnace, GTI will market its ability to manage metallurgical experiments in microgravity to interested public and private sector research organizations.

The JEA requires GTI to develop this furnace and NASA to test it on four shuttle flights. The first flight is presently scheduled for the third quarter of 1984.

Because MDAC/JEA has, and probably will continue to serve as a model for future JEAs, and since the industry/Government relationship established in this agreement differs drastically from the Government's relationship to COMSAT, it is useful to scrutinize the structure and purpose of this agreement.

To create a climate suitable for commercialization in the MDAC case, the first JEA had to address the following issues:

- ***Exclusivity.*** — In return for MDAC's promise to make results of the work available to the U.S. public on reasonable terms and conditions, NASA agrees to refrain from entering into similar joint endeavors or international cooperative agreements directly related to the development of processes that would compete with those resulting from the MDAC endeavor. NASA is not precluded, however, from selling flight time on the shuttle to any other organizations wanting to conduct the same or similar experiments.
- ***Patent and data*** rights.–NASA will not acquire rights in inventions made by MDAC or its associates in the course of the joint endeavor, unless MDAC fails to exploit the inventions or terminates the agreement, or unless the NASA Administrator determines that a national emergency exists involving a serious threat to the public health.

  In the event that inventions or improvements are made during the joint endeavor, MDAC need not report these to the Government. Records will be retained by MDAC and, if requested by NASA, the company will provide a brief description of the invention. Such description is protected as data or a trade secret if appropriate.
- ***Confidentiality.*** –The JEA requires that data supplied by MDAC shall not be related outside the Government, except after notice to the originator and agreement by the recipient to protect it from unauthorized use and disclosure.
- ***Recoupment.*** —Lastly, to provide the financial incentive for MDAC'S investment, the jEA explicitly recognizes MDAC'S right to a "fair return on investment." Coupled with patent and data rights provisions of the JEA, a "fair return on investment" is to be measured by what is obtained in the appropriate industry, including such factors as the high-risk, long-term nature of the investment.

It is apparent from this brief review that the Government role in MPS is significantly different from its role in the development of aviation and communications satellite technologies. In part this can be attributed to the fact that the markets and technology for MPS are still in an embryonic stage. In addition, research in communications satellites and civilian aviation can be conducted with only minimal recourse to Government facilities and the commercial operation of these technologies can be accomplished with little

Government oversight. MPS research and product development, on the other hand, are still highly dependent on Government facilities. Should such research result in a marketable product, it is unclear how commercial MPS operations could proceed without close Government cooperation. For the near future, the JEA appears to bean important tool for continuing the unique Government/industry relationship which is essential to the development of a mature MPS industry.

OTHER SPACE-RELATED COMMERCIAL ACTIVITIES

Although this chapter has focused primarily on the private sector's involvement in fields of communications and materials processing, with a less detailed look at remote sensing and space transportation, it should be noted that the private sector has several other opportunities for space-oriented, profitmaking activities. Some of the more important of these activities are discussed below.

Financing Space Ventures

Private banking institutions may have a role to play in the future financing of both governmental and nongovernmental space programs. Because the Government has played the lead role in developing space systems, the involvement of private financial institutions has been rather limited. This is particularly true in the United States, and it seems unlikely that any significant changes will occur in the near future. The situation in Europe is slightly different, in that, though the space projects are primarily funded by the governments, European banks have been involved in these projects as shareholders and as a source of loan capital .29

Financial institutions have generally been reluctant to invest large sums of money in high-risk, long-term space projects of the private sector. As new products are refined and their value as investments proved, financing of private space activities will become more common. Recently, for example, financial institutions have been willing to fund the purchase of satellite transponders because communications satellites have come to be regarded as relatively safe and attractive investments. The cost of transponders (approximately $10 million to $15 million) is a relatively small part of the cost of the satellite, and insurance covering both interruption of service and business loss can be purchased to protect this investment. In addition, by using sale/leaseback arrangements, the tax benefits that accrue from transponder ownership can be sold to a third party.

Presumably, other space technologies will follow the path that communications satellites have followed over the last two decades. As these technologies become more reliable and new financial arrangements allow the burden of their cost to be spread out among more investors, it is certain that the role that private financial institutions play in the commercialization of these technologies will increase.

Though private financial institutions have been reluctant to participate in space ventures, it is possible that innovative financial arrangements such as the R&D limited partnership may provide funds in this area.[30] Basically stated, an R&D limited partnership is a partnership formed for a specific purpose, such as the development of a new product. This arrangement provides important tax advantages, in particular that participants may offset their investment in the R&D limited partnership against their current income, even if the latter was derived from an unrelated source. GTI intends to rely heavily on this mechanism to finance its JEA with NASA. Should the GTI experience be favorable, there is no reason why the R&D limited partnership could not be used to finance other private space ventures.

[29] G. Mazowita, "Space Industrialization, Programs, Policy, and Private Enterprise," Center for Research of Air and Space Law, McGill University, June 1981, p. 60.

[30] "Limited Partnerships: Profits and Danger," *Commodities*, VII (March/April 1978), 46; "Tax Classification of Limited Partnerships," *Harvard Law Review XC (1975), 745-762*; "Tax Classification of Limited Partnerships: The IRS Bombards the Tax Shelter," *New York University Law Review* LII, 2, May 1977, 408-441.

Insurance

The industrialization of space will open up a new market for the insurance industry. As the number and variety of space activities increase, new methods of insuring against unforeseen losses will be needed. If such developments are forthcoming, they will help to make investment in space more predictable and therefore more attractive to the private sector.[31]

Presently, there are four basic categories of satellite insurance available:

- ***Ground insurance*** covers the satellite, launch vehicle, and related launch equipment until launch attempt or lift-off.
- ***Launch failure insurance*** commences immediately after lift-off and remains in effect until the satellite achieves a successful orbit.
- ***Satellite life insurance*** commences when launch failure insurance coverage terminates. Satellite life insurance protects against financial damage caused by loss of orbit or power, or by some technical malfunction. This insurance can be used to cover the replacement costs of the satellite and for economic losses arising from disruption of service.
- ***Liability insurance*** is used to compensate third parties for bodily injury or property damage caused by the satellite or the launch vehicle.

The types of insurance mentioned above were developed primarily with expendable launch vehicles in mind. The introduction of the shuttle as an operational launch vehicle will present substantial challenges to the insurance industry. On the one hand, the shuttle should increase the number of insurable payloads launched per year, thereby providing a wider base over which to spread risk. This should result in lower insurance costs and increased participation by U.S. and foreign underwriters. On the other hand, the fact that the shuttle can carry several payloads on one flight raises serious questions about the effect that the loss of an entire shuttle might have on underwriters and insurance premiums. Potential liability in such a situation could be as high as $100 million to payload owner and an additional $500 million for third-party claimants.[32] The shuttle, therefore, introduces costs at a level and of a complexity unprecedented in the era of single payloads flown on ELVs. Whether the relatively small group of underwriters who insure ELVs will be able to handle the entire liability for space shuttle operations is an open question.

[31] Satellite Communications, "Condo Satellites: Can We Insure Them?" August 1981, p. 45.

Hardware sales

Aerospace Industry

The aerospace industry has been the principal private sector participant in commercial space activities. The reasons for this are rather simple. The aerospace industry has the most complete understanding of the advantages and limitations of the space environment and employs large numbers of people who are knowledgeable in space-related technology. Industries that may profit considerably from space technology, such as pharmaceuticals, electronics, and metallurgy, are reluctant to invest in R&D projects that require knowledge, personnel, and support facilities that they do not have.

Another major advantage held by the aerospace industry is its traditionally close relationship with Government. This relationship has had two important consequences. The first, which was mentioned above, is that the industry, often working under Government contract, has been able to develop the expertise to deal with the space environment. The second is that the Government, particularly the military, and the aerospace industry are accustomed to cooperating and relying on one another. Most other industries, however, have little contact with the Government, except in its role as regulator and taxer. Furthermore, normal Government procurement practices, in which the aerospace industry is well-versed, are complex and raise numerous problems regarding the retention of intellectual property.

The structure of the aerospace industry also provides some substantive advantages for devel-

[32] Aviation Week and Space Technology, Apr. 30, 1979, p. 148; Contact, "Insurance Coverage in Outer Space, " December 1977, p. 5.

oping technologies such as MPS. This industry is composed of a few large and essentially nondiversified companies. This structure is a consequence of an environment where competition is limited and funds are available to engage in large but uncertain research projects. The aerospace industry has frequently been involved in long-term projects starting with basic scientific research and resulting 'in innovative new products. This "long-range" perspective which will be necessary for MPS development is not characteristic of many other industries.

New Markets

Until recently, the efforts of the private sector have been directed primarily to supplying the Government's needs for launch vehicles, satellites, and related space hardware. As the user community for such hardware gradually broadens, it can be assumed that an increasingly greater proportion of industry revenues will be derived from nongovernment sales.

The first nongovernment aerospace market to be developed was that of communications satellites. The private sector revenues from this market are on the order of billions of dollars, and estimates for future demand suggest even greater returns. Other opportunities for private sector aerospace sales will flow from the development of the Boeing inertial upper stage and the McDonnell Douglas spinning solid upper stage. These two upper stages will be used to transfer private-sector payloads from the shuttle to the geostationary orbit. Yet another area of potential private-sector revenue will be the sale and lease of multiuser instrumentation designed for MPS research on the shuttle (discussed above in ch. 4). Examples of such instrumentation include the materials experiment assembly (MEA), developed by NASA, and the metallurgical furnace being developed by GTI Corp. in a JEA with NASA. This last type of private-sector involvement may prove to be quite significant. When NASA began the development of the MEA, it anticipated that private institutions might wish to lease this device to conduct their own experiments. Similarly, GTI's development efforts are predicated on the assumption that a substantial market exists for relatively inexpensive space-based research facilities.

A recent marketing strategy report, written under contract for NASA, found that most firms are unwilling to undertake alone the substantial expense involved in the product identification, financing, hardware development and marketing necessary to commercialize space technology.[33] The report suggested that NASA should attempt to disaggregate this process in order to facilitate private sector participation in MPS. There is some indication that this process of disaggregation will occur as a matter of course, as experience with MPS grows. The JEA entered into between NASA and GTI tends to support this assumption. GTI's willingness to accept the financial responsibility for one aspect of the commercialization process (in this instance, the provision of a valuable research tool), may provide the incentive for other firms to invest research dollars in this area. Small firms, universities, and research organizations generally do not have the capital necessary to undertake independent research in space. However, if the facilities were available at a relatively low cost, then a broad range of otherwise unaffordable research might be undertaken.

Ground Support Services

Space technology requires a rather elaborate network of ground support services and facilities. As this industry continues to expand, the private sector will almost certainly play a disproportionately large part in the provision of such services. A few early examples of this trend have already begun to appear.

The initial placement and subsequent maintenance of a satellite in its proper orbit requires an elaborate tracking, telemetry, and control network. NASA has previously provided these services, but as space activities become more common, commercial firms could provide them. COMSAT has already begun to do so. In 1979, COMSAT established the first commercial facility for satellite tracking, telemetry, and control services.[34] The COMSAT Launch Control Center (LCC) takes control of the spacecraft after lift-off

[33] Prepared by students of the "Creative Marketing Strategy" course, Harvard Business School, "Materials Processing in Space: A Marketing Strategy," June 1981.

[34] Communications Satellite Corp. Magazine, No. 1, 1980, pp. 26 and 33; No. 5, 1981, pp. 9 and 38.

and injection into the transfer orbit, oversees the insertion of the satellite into its proper orbital slot, and then performs the functional checkout. Following verification of proper operation, control of the satellite is then handed over to the owner/operator for further verification, testing, and ultimately, operations. The LCC was used for the first time with the launch of SBS-1 in November 1980.

Another area in which the private sector will certainly play an increasingly important role will be in the provision of postflight processing of the shuttle. Currently, NASA, using more than 25 individual contractors, is responsible for shuttle processing; it has, however, recently invited industry to bid on a contract to perform this function.[35] The company chosen would be responsible for refurbishment of orbiters after flight for subsequent missions, checkout and assembly of the solid rocket boosters, external tanks, and other shuttle elements, and for support operations and materials, including maintenance and facilities operations.

The transfer of shuttle processing to the private sector is an important step toward commercializing the entire space shuttle program. As has been mentioned many times before, industry is reluctant to invest in the shuttle, or any new space technology, because it cannot accurately assess the risks and the potential return. As industry becomes familiar with the shuttle, or other new space technologies, it will be in a better position to make the kind of financial assessments which must precede any major commercial investment.

[35] Aviation Week and Space Technology, "Shuttle Contracts To Be Let to Industry," Nov. 2, 1981, p. 51; Aviation Week and Space Technology, "Processing Efficiencies of Shuttle Studied," Nov. 30, 1981, p. 18.