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THE INTERNATIONAL SPACE STATION COMMERCIALIZATION (ISSC) STUDY

Space Commercialization Experts Panel

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PREFACE

The Potomac Institute for Policy Studies (the Institute) is a not-for-profit organization dedicated to the development and support of non-partisan analysis of technology and technology policy. The Institute has conducted studies that provide insight into the impact of new technologies on our society, the proper relationship between government and industry, and the future of the U.S. industrial base.

The International Space Station Commercialization (ISSC) Study was performed by the Institute, principally under a grant from NASA. Financial support was also provided by the Institute and other companies. We greatly appreciate these contributions, which made possible an interesting and meaningful study. Views expressed are those of the Potomac Institute for Policy Studies and are not necessarily endorsed by NASA or the other contributors.

We would also like to express gratitude to the more than two hundred people from industry, universities and government, who contributed their time and insights. Their views enriched the study immensely. Our Space Commercialization Experts Panel (SCEP) earned special thanks for guiding the study to fruition, and for helping to develop its findings and recommendations.

EXECUTIVE SUMMARY

The National Aeronautics and Space Administration (NASA) was created principally from the National Advisory Committee for Aeronautics (NACA), by the National Aeronautics and Space Administration Act of 1958 (ACT). Missions assigned included performing science and exploration and maintaining U.S. superiority in space. Congress amended the ACT in March 1984 to add the responsibility for fostering the fullest commercial use of space.

The present Administration, Congress, NASA, and the general public have all voiced support of commercialization of human space flight. The issues are who should do it, how it should be done, and how quickly.

The Study

The purpose of the study was to address the three questions stated below. Its findings rested upon the assumption that the International Space Station (ISS) will be deployed by NASA within the next six years.

I. Are there compelling potential benefits from commercialization of human orbital space flight? [1]

II. Are there viable areas of opportunity and plausible commercial ventures?

III. What, if any, should be the government's role in fostering commercialization?

[1] "Human space flight" is a term coined to specify those space missions which require human presence in space ("piloted space" is an alternative term). The Space Shuttle and the International Space Station are examples (even if human presence was not required at all times), while satellites are not. The term "orbital human space flight" is used to distinguish earth orbit operations from interplanetary flights.

Approach

The Institute's Research Team collected a number of pertinent publications. We summarized and challenged results, adopting those which still seemed appropriate, while adding perspectives of our own. Annex A offers a list of references, cited throughout this report by numbers within square brackets, [ ]. In view of the complex issues, and the number of vantage points from which they may be viewed, we sought extensive counsel, forming the Space Commercialization Experts Panel (SCEP) listed in Table 1. Terms of Reference for the SCEP are presented in Annex B. During the course of the study we contacted over 200 people, representing approximately 50 companies, universities, and government agencies. Names of some of those reached, along with summaries of our discussions and case studies are found in Annex C. A full bibliography collected for the study appears at Annex D.

Member	Selected Experience
Mr. James Beggs, Chairman	President, MAKAT, Inc. Former NASA Administrator Former Executive Vice President, General Dynamics Former Deputy Secretary of Transportation
Dr. John McLucas	Former Chairman, NASA Advisory Council Former President, COMSAT General Former Secretary of Air Force Former Administrator, FAA
Mr. James Rose	Former Assistant Administrator for NASA's Commercial Programs
Mr. Howard Schue	Partner, Technology Strategies and Alliances Corporation
Dr. Terry Straeter	President and Chief Executive Officer, GDE Systems, Inc.

Table 1. Members of Space Commercialization Experts Panel

Findings and Recommendations

In this section, the three questions in the study objective are addressed. The analysis of the first two questions yields the study findings, while the third produces the study recommendations.

Findings on Benefits from Commercialization.

Finding: Commercialization through orbital human space flight is beneficial to the nation and to NASA. Assuming that commercial ventures are found to be plausible and practical in orbital space, benefits will accrue on two levels: national benefits, and benefits to NASA's mission.

National Benefits. At least three beneficial areas are evident at the national level. These are discussed below.

1. Enhancement of U.S. industry competitiveness (e.g., U.S. economy, high technology jobs, market shares). There are clearly national economic benefits that transcend NASA's mission-area interests. Enthusiasm for science and exploration, and the excitement of building world class facilities, such as the International Space Station (ISS), should not lead the U.S. to lose focus on the necessity to compete in the global market place. Our failures to commercially leverage our nation's superior science and technology in areas such as the television, the VCR, and the compact disc led to large industries and profits -- in Japan. The ISS and other space assets should be used to our advantage, not only for scientific interests, but also for commercial gain. Today, orbital space is the latest in a number of frontiers opened by various transportation systems and infrastructure that were strongly supported by the federal government. The strategies followed in developing the waterways, highways, railways, and airways called for government to foster commercialization at critical times. It is a conclusion of this study that human orbital space flight is approaching such a stage in its development.

2. Spin-offs of new technologies to non-space industries. NASA has maintained an effective technology transfer program. This important facet of NASA's service to the nation will be enhanced by increasing private sector involvement.

3. National prestige. With the end of the cold war, U.S. prestige depends as much or more upon its economic competitiveness as upon its defensive strength. Commercialization of orbital space will enhance this aspect of our nation's reputation, as will science, exploration, and technology development sponsored by NASA.

NASA Mission Benefits. In addition to these national enhancements, commercialization will directly benefit the conduct of NASA's mission in at least six areas.

1. Increased availability of improved and more affordable space assets. As commercial traffic increases, space technology will steadily improve and cost less. This has been true in virtually every instance where the private sector has moved into a government domain. Past studies have indicated that it costs government up to three times as much to develop and fabricate equipment through conventional contracts as it does by allowing the private sector to accomplish the same job, using performance specifications and best business practices. Statistics are presented in the body of this report to illustrate how NASA has saved significantly in the past by adopting this approach.

2. Utilization of Shuttle, ISS and Reusable Launch Vehicle (RLV). The ISS and RLV are both centerpiece programs for NASA, which will ultimately depend upon commercial customers for success. Lead times for space-based activities are long, and if commercial development is to proceed on the same schedule as the ISS, these activities must begin now. The "pump priming" investment required is not large relative to what we will have made in setting up the Shuttle/Space Station system; however, the investment is unlikely to be made by the private sector without Government working with industry to develop users in the commercial sector.

3. Release of NASA resources for application to new frontiers. Whether the next step in space is human exploration of the planets or the launching of scientific instrumentation from the earth's orbit, NASA is looking ahead to new challenges. These challenges will be easier to pursue if orbital space is "normalized" by commerce.

4. Leverage private investment. Our estimates show that more than two billion dollars are either committed or planned by the private sector for human orbital space flight ventures. This private investment and follow-on funding should be leveraged by NASA.

5. Improved innovation and importation of commercial technology to space endeavors. The private sector controls far more resources to devote to innovation, and research and development than the government does. As industry's interest and commitment to space for financial gain increases so will the development, transfer and application of technology.

6. Increased public support for space operations. The promise of commercial activities could awaken new excitement on the part of the public, particularly if there is an eventual tourism aspect.

Findings on the Viability of Commercial Ventures. This section reflects the "good news/bad news" study results. The good news is that we found interesting and plausible commercial ventures. The bad news is that there are significant problems that stand in the way of commercial success.

Finding: There are emerging commercial ventures for human space flight. Privatization of government functions, such as resupply and operation of the space station, remains the largest area for opportunities of the nine areas discussed later in the report. Of those remaining, biomedical research seems to have had the most effect, although materials research is providing important insights into earth-based processes. The operations, services, and support category is dedicated to designing better (and more affordable) space equipment, such as space modules and test facilities and devices. This category, along with power generation, is concerned mainly with space assets. Education, entertainment, and advertisement may represent significant and near-term growth areas in commercial human space flight, but seem to be the least palatable to NASA. Some viable commercial ventures found during the case studies effort include Macromolecular Crystallography Investigations (University of Alabama in Birmingham), Microencapsulation Systems (VIVO-RX and Vanderbilt), X-Ray Device (University of Alabama in Birmingham), Education Programming (Walt Disney Imagineering), Virtual Presence (LunaCorp), and a Gallium Arsenide Thin Film venture conducted on Wakeshield. These are discussed later in the report.

Finding: There are major challenges which must be overcome. Because of problems such as those discussed in the next paragraphs, corporations contacted tend to assume that space access is (and will remain for some time) impractical, dampening enthusiasm for ventures which require human space flight. Without the eager participation of an innovative private sector, commercialization cannot develop wings.

1. Non-addressable business risks. A new venture which involves human space flight faces the same business risks as any other new start. In addition, there are space-specific problems, such as the constant concern that earth-based processes will be discovered which can substitute for the more difficult space-based processes. Another concern is a dependency on the consistency of government policy for space access.

2. Impediments to space access. Case studies and discussions with industry and government representatives revealed nearly unanimous agreement on the major impediments to space access, four of which are listed below.

- Launch and operation costs are too high
- Flight frequency and schedule reliability are poor and launch lead times are too long
- Indemnification against flight failure is too expensive
- The upcoming hiatus of commercial space flight opportunities (due to ISS construction) will discourage business investments

NASA is already addressing many of these problems; however, priorities, overall strategy, and progress as well as the effects of NASA's plans for the private sector (and vice-versa) must be made more understandable to the business community. Until impediments associated with space flight are dramatically improved, space-based operations will tend to be replaced by terrestrial alternatives whenever the latter option does not degrade the product significantly.

3. NASA's efforts to foster commercialization are diminishing. With manning levels dropping to 17,500 and budgets decreasing by one-third, NASA's mission areas must compete for attention. The commercialization mission is obviously difficult under these circumstances. This is particularly true for human space flight,[2] where NASA's interests have traditionally centered. Much of this difficulty stems from impediments discussed earlier and the infancy of commercial activities in this sector. But there are major problems affiliated with NASA's approach to commercialization. These problems are partly due to the fact that commercialization is seen by some in NASA as threatening an almost exclusive focus on science and exploration. Many do not even view commercialization as a NASA mission, despite the fact that it is assigned to NASA by law, mandated by successive Administrations, and accepted with enthusiasm in numerous published statements by the Administrator. Some of the manifestations of this reluctance are summarized below.

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[2] Commercialization of the satellite industry has proceeded quite well, producing a large affiliated private sector. This is primarily due to the technological maturity of satellite assets and a growing global communications, remote sensing, and navigation market.

- **Budget Allocation to commercialization is low and declining.** The percent of NASA's budget dedicated to commercialization has declined steadily since 1993. At its highest, this portion was still less than one percent.

- **Reorganizations have left NASA without an institutional center to accommodate commercial participants.** An example of the diminishing support for commercialization is found in the fate of offices dedicated to it. During the 1990s, The Office of Commercialization (Code C) was eliminated. The Office of Space Access and Technology (Code X) was given the commercialization mission, and management control of the Centers for Space Commercialization (CSC) was split among some of its divisions. In turn, Code X was eliminated in 1996 and the Centers were either dispersed among the Office of Life and Microgravity Sciences and Applications (Code U) and various NASA Field Centers, or eliminated. These successive reorganizations are viewed by industry as a major defeat for NASA's commercialization interests. Additionally, NASA lacks a coherent outreach program to business. This means that many businesses are unaware of opportunities in space. An outreach effort would also provide a better understanding of the commercial sector to NASA. In effect, industry finds itself back in the '70s – without a central office within NASA to contact on commercialization matters.

- **Lack of fulfillment of policies and promises.** Section 102(c) in the ACT states, "The Congress declares that the general welfare of the United States requires that the NASA Administration ...seek and encourage to the maximum extent possible the fullest commercial use of space…" Successive Administrations have mandated a strong commercialization role to NASA. But, even though NASA itself has expressed support of space commercialization, this support is obviously fading. For example, despite NASA's insistence that commercialization of technology is "comparable in importance to, and an integral part of, its aeronautics and space missions," commercialization funding runs consistently below one percent of NASA's budget. Further, statements of broad interest in commercialization ring hollow when considering NASA's lack of enthusiasm about entertainment, tourism, promotion, and for-profit ventures.

- **Procurement and procedural inflexibilities.** NASA has adopted some innovative non-procurement vehicles, such as cooperative agreements. However, it still does not routinely accommodate profit commensurate with risk, accept future payback through royalty sharing, or serve as an anchor tenant in its procurements and support of dual use development. While NASA nominally provides free access to space for commercialization experiments, this often takes years, and costs can be above one million dollars due partly to red tape and scheduling difficulties. The eight year trek, with its multiple peer, in-house, and safety reviews of science experiments in space, is still too typical of NASA's operation.

Recommendation: The Government Role.

The U.S. should measure the success of the commercialization effort according to the extent to which industry has assumed the responsibilities, funding, and conduct of human orbital space flight ventures and the extent to which government's role declines. This cannot happen today because of reasons previously discussed. But, over the next ten years, government should normalize and hand-off human orbital space flight activities to the private sector and move on to the next level of accomplishment, paving future frontiers for private sector involvement. The commercialization of orbital space flight should proceed as did the satellite business, with the private sector taking over as risks and costs are reduced and business opportunities emerge, leaving government the beneficiary of the technology and affordable infrastructure that flow from a healthy commercial industry.

Although the portion of the commercial sector interested in human orbital space flight is still small, progress must be made in reducing impediments to space access before commerce can "go it alone." For these reasons, the Panel does not advocate a major shift in NASA's budget or staffing at this time. We feel that the two following recommendations can be implemented with little disruption of NASA's other missions, while more effectively addressing the role of commercialization.

Recommendation: NASA should assume broad responsibility for commercialization of human orbital space flight and pursue plans and actions that are consistent with stated policies. Realizing that commercial activities will provide benefits on a national level, as well as to its mission areas, NASA should foster commercialization on a broad front, to include technology development, dual use assets, and purely commercial efforts. In general, this support should be limited to supplying access to space at reduced cost and, in select cases, furnishing seed money to initiate potentially viable ventures. Of greatest importance, NASA should clearly articulate its intentions in fostering commercialization, and formulate and pursue policies and strategies that support those intentions. This is the time to act because of four factors:

1. It is the law. NASA's responsibility has been mandated by Congress and the Executive Branch. This responsibility should be addressed by NASA with strategies that contribute significantly to commercialization, and yet take into consideration the impact of other important NASA missions.

2. The ISS is becoming a reality. The degree to which it is utilized will eventually depend largely upon the state of commercial interests. It is time to begin planning for commercial use of this facility. If past experience is any indicator, it will take years to prepare for creative use and, even so, the private sector must understand its benefits and difficulties. NASA should begin to anticipate commercial needs through design and utilization plans.

3. It is important to act now to maintain our nation's competitive economic posture. The international community is trailing the U.S. in commercialization, but is considering a number of commercial ventures in space. Some may be ready to capitalize on piloted space for commercial purposes before we are. The rapid commercial growth of the satellite business provides lessons for piloted orbital space. For example, although our foreign competitors were initially far behind us, they caught up quickly, partly because of our failure to sufficiently invest in the race.

4. The Mir experience holds many lessons for the U.S. in planning for ISS utilization. Those lessons affecting commercial ventures should be captured and applied.[3]

Recommendation: NASA should adopt a commercialization strategy with three components. There are undoubtedly many ways to approach commercialization of human orbital space flight. We offer a strategy below that focuses on moving private sector money and effort into this sector by an adoption of three goals.

1. Reduce obstacles to space access. There are currently a number of unsolved problems that must be addressed before routine flights are practical for non-astronauts. NASA should implement and articulate clear and decisive plans to address the impediments to human space flight. But these impediments must be addressed in a manner which takes into account ideas and needs from the private sector.

2. Foster privatization-to-commercialization. NASA should adopt a strategy of privatization leading to commercialization. Through extending its existing privatizing efforts, NASA can nurture commercialization through a space industry that is more adept than NASA (or the government in general) at locating and encouraging private sector customers, applying business acumen to customer needs, improving efficiencies, reducing costs of equipment and services, and applying new technology. There must be both government and industrial investment and risk, as well as an opportunity for industry to market the space assets in question. Both can be the result of either direct ownership or lease to the private sector.

3. Support near-term commercial ventures. Congressional prohibitions against direct subsidy of commercial ventures still allow free transport. Traditionally, NASA tends to provide such support to commercialization proposals which are in the scientific or technology development stage. The only other exceptions seem to be those commercial ventures which can be justified by "socially redeeming objectives" (e.g., cures for cancer). NASA should broaden its scope to include ventures motivated by market-share and profit.

The CSCs are filling an important need and should be continued, although some of them need more of a business orientation. This may be a good time to expand the concept to include one or two Commercial Venture Centers, perhaps assisted by an organization such as Harvard or MIT's Sloan Business School.

A Proposed Implementation Plan

The problems faced by NASA in fulfilling its commercialization mission are fairly clear but, even if one agrees with the solutions and strategies recommended earlier, their implementation remains a difficult issue. The Panel felt that decisive implementation demands active support from the highest echelons of NASA. Without proactive attention from the top, commercialization will

[3] See Case Study 2 (Boeing's Mir Pathfinder Program) in Annex C.

remain stunted. Further, there must also be an implementation arm to create a more innovative and productive link between NASA and the private sector, and to develop and husband supporting policies, directives, and strategies. So, two facets of a proposed implementation plan are summarized in this section: the tasks that must be undertaken; and the organizational implementation arm required to accomplish those tasks.

Recommended Implementation Tasks. At least ten specific undertakings must be addressed to implement the proposed strategy, these are listed below.

1. Develop commercialization goals and provide private sector perspectives in planning

2. Shift NASA's space infrastructure to private ownership

- Permit a realistic return on equity, considering the risks involved
- Accept the role of Anchor Tenant, where appropriate, by assuring the use of privately developed infrastructure, if it meets performance specifications
- Consider recommending tax incentives to Congress
- Discourage in-house competition with the private sector

3. Provide encouragement, advice, and space access to a diverse set of commercial ventures

- Initiate Broad Area Announcements to provide "seed money" to develop commercial ideas through cost share projects
- Accept royalties and other future recoupment for provided services and facilities
- Assist the private sector in obtaining government approval for flight
- Bridge the upcoming five year hiatus in carrying commercial payloads

4. Represent private sector aims in NASA's efforts to reduce impediments to space access

5. Initiate an outreach program

6. Represent the private sector in formulating plans, strategies, and policies, and develop incentives for NASA management and personnel to foster commercialization goals

7. Reinvigorate the Centers for Space Commercialization

8. Coordinate commercial activities with other government departments

9. Re-Activate NASA's Advisory Committee on Commercialization

10. Increase the commercialization budget to enable these steps to be taken

Form a Commercial Development Office and a Space Economic

Development Corporation. We were reluctant to suggest adding staff during this time of downsizing at NASA and certainly did not wish to impose additional organizations on potential customers to space. But, we feel that the need for commercial advocacy within NASA is sufficiently compelling to warrant such a recommendation. Organizationally, the study recommends a two-part approach to accomplishing the tasks listed above. First, NASA should form an in-house Commercial Development Office (CDO) to serve as a focal point and to advocate commercialization within NASA. The CDO should then organize a public/private partnership Space Economic Development Corporation (SEDC),[4] which would take over some of the functions of commercialization and, eventually, most of the commercialization effort.

The CDO would begin this process by refining NASA's strategy, developing contacts within the private sector, consulting with NASA Offices and Field Centers, and recommending some early policies to NASA. The CDO should also initiate an intensive effort to develop innovative approaches to privatization. This organization should contain sufficient in-house technical, legal, and organizational expertise to coordinate actions and obtain support from within NASA. The major thrust of the CDO, however, would be business; therefore, it must include personnel with extensive experience in the business world. Venture capitalism, business and legal processes, as well as technology and product development must be represented. The staffing for the business side of the CDO should be found outside of the government. Such people would help to form the SEDC.

The SEDC would represent the link with the private sector, providing a business environment to those industries seeking access to space for commercial purposes, or to those interested in privatization of space assets. It could begin as a self-funding business incubator, or operate as a quasi-government corporation. Its mission should include forming consortia, negotiating business agreements, formulating venture plans and strategies, and performing other functions that government cannot accomplish. The SEDC could accept funds from government or the aerospace industry. Large space assets ventures, such as the RLV could form their own development corporation, or rely on the SEDC. This organization would eventually lead the commercialization effort, acting in the role of a true development corporation. Until this "spin-off" occurs, they would support the CDO in conducting a series of outreach programs, encouraging industry to consider human orbital space flight, reaching a better understanding of the special problems of the private sector, and exploring benefits of space to the commercial marketplace. The SEDC could also help NASA become more appreciative of private sector values and approaches.

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[4] For insight into a specific development corporation, see Case Study 7 (New York City Economic Development Corporation) in Annex C.

THE INTERNATIONAL SPACE STATION COMMERCIALIZATION (ISSC) STUDY

Background

The National Aeronautics and Space Administration (NASA) was created principally from the National Advisory Committee for Aeronautics (NACA) by the National Aeronautics and Space Administration Act of 1958 (ACT). Its missions included contributing materially to the expansion of human knowledge of the Earth and of phenomena in the atmosphere and space, improvement of aeronautical and space vehicles, projection of long-range benefits from the peaceful use of space, and the preservation of the role of the U.S. as a leader in aeronautical and space activities.

In July 1982, President Reagan issued a National Space Policy that specified space commerce as one of the Nation's most important goals. One year later, NASA's Administrator, James M. Beggs, established a task force to examine the potential for commercial use of space. The results of this task force were reflected in a March 1984 amendment to the ACT[5], when Congress added Section 102(c), which stated, "The Congress declares that the general welfare of the United States requires that the NASA Administration ...seek and encourage to the maximum extent possible the fullest commercial use of space activities..." In October of 1984, NASA established nineteen initiatives as the centerpiece of its Commercial Space Policy; however, only eight of these initiatives have been implemented. As an incentive to a growing interest in commercializing the satellite launch industry, Congress passed the "Launch Act" in April 1986, restricting satellites from the Space Shuttle.

In order to focus its commercialization efforts, NASA formed the Office of Commercial Programs (Code C), and initiated the Centers for the Commercial Development of Space, later renamed the Centers for Space Commercialization (CSC), which remain the major NASA mechanism for commercialization. A number of references, including the 1994 Commercial Space Transport Study [1][6] conducted by Boeing, Lockheed, McDonnell Douglas, Rockwell, General Dynamics, and Martin Marietta, agreed that, "the [then] 17 NASA-sponsored and partially commercially supported Centers for the Commercial Development of Space(CCDS) are the primary means of access to space. The CSCs were designed to leverage a broad industry base to develop product-oriented technologies and to stimulate commercially cost effective transportation and infrastructure ventures. In fact, the CSCs have been quite effective, given the size of their budget and the generally narrow focus on technology. At their zenith, 17 Centers represented 60

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[5] The fact that this is the only time the 1958 Space Act has been amended is evidence of the perceived importance of commercialization.

[6] Numbers enclosed in square brackets, [ ], indicate references listed in Annex A.

technology areas, with the involvement of 227 industry partners and 87 universities. From these centers have come test modules, rockets, and flight systems, including CONSORT, SPACEHAB, Wakeshield, and the Commercial Experiment Transporter (COMET).

NASA's commercialization thrust follows on the heels of the long standing U.S. government policy of investment in transportation infrastructure, followed by tax and other financial incentives, to encourage private sector commercial development to use the facilities created. Starting with President Washington's initiative to develop the C&O canal, through building ports and waterways, the Federal Government has promoted the commercialization of roadways, railways, and airways to form what is now 25% of the American economy, and arguably the most efficient transportation system in the world.

NASA's budget trends (Figure 1) provide some insight into the problems it faces.[7] NASA is experiencing the declining budget that is typical of government today. Of even more significance is the pessimism evidenced in the out year forecasts contained in the President's budgets, which, beginning in 1994, took on an increasingly negative slope. During this time, funding for commercialization has been reduced, even when taken as a percentage of the overall NASA budget.

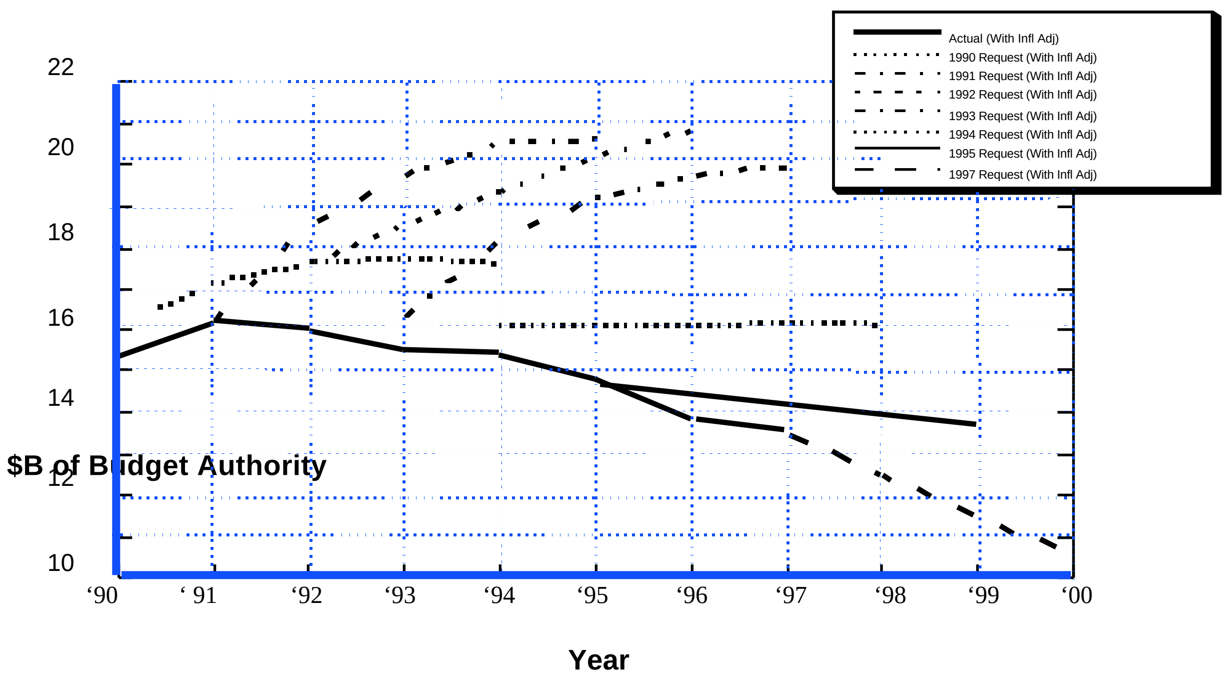

Figure 1. NASA Budgets[8]

[7] A 1996 GAO report [2] stated that, "In the early 1990s, NASA was planning an infrastructure to support a projected annual budget of more than $20 billion and a civil service workforce of about 25,000 by the turn of the century. However, over the last several years, NASA has been directed by the Administration to reduce its future years' budget levels."

[8] Adapted from a 1995 Congressional Budget Office Memorandum [3]

However, even as NASA's budget declines, the present Administration, Congress, and the general public have expressed enthusiastic support for commercialization of piloted space. The questions have become, not whether commercialization should be pursued, but who should do it, how it should be done, and how quickly. NASA has enthusiastically articulated its support for commercialization, raising the expectation of industry, Congress, and the public. Unfortunately, NASA has simultaneously narrowed its focus and reduced its support.

Study Objectives

The International Space Station Commercialization (ISSC) Study was conducted by the Potomac Institute for Policy Studies under a grant by NASA. Its objectives were to present independent, informed and updated perspectives on three questions pertaining to the commercialization of human orbital space flight, and in particular the International Space Station (ISS). Its findings rest upon the assumption that the ISS will be deployed by NASA within the next six years.

I. Are there compelling benefits to be gained from commercialization of human orbital space flight? We attempted to identify benefits of commercialization of human orbital space flight, assuming that viable commercial activities exist, or will emerge during the next ten years. In order to gain insight, we examined the satellite and launch business which grew out of a NASA/DoD monopoly.

II. Are there viable areas of opportunity and plausible commercial ventures? A number of studies have tried to evaluate commercial opportunities in space. Some of these are listed in Annex A and are referenced throughout the report. We permitted a broad definition of commercial gain in order to include space-based research to improve terrestrial products and processes, education, advertising, promotion, and tourism, as well as everyone's dream -- space-based manufacturing.

III. What, if any, should be the government's role in fostering this commercialization? Many mission areas lay claim to NASA's resources. The challenge to NASA is to define and articulate the proper balance in distributing its attention among its responsibilities. Congress has made commercialization one of these, and NASA must determine what funding and space access to dedicate to this end. There are at least three factors in this determination: i) intent, or why NASA is interested (e.g., dual use benefits, national economic competitiveness, improved conditions for mankind); ii) viability, or how likely it is that commercial ventures will pay off at this time; and iii) cost, in terms of percentage of the space budget. All of these factors must be accounted for when developing its statement of intent and the strategies, policies, and organization behind it. So, despite the Congressional demand that "…NASA should seek and encourage to the maximum extent possible the fullest commercial use of space activities…," the Administration must weigh the level of support it offers against these factors. Finally, having decided upon the level of support warranted by commercialization, NASA must decide the best way to render that support (e.g., spin-off, sponsorship of research, technology, or commercial ventures).

Basic Definitions. Three basic definitions used during the study are offered below.

Commercialization. A process to reach a commercial state, free market exchanges of goods and services where the market mediates supply, demand, and value, and government is not the exclusive (or dominant) customer, or source or insurer of capital.

Dual Use. [9] The employment of private sector financial and other resources to provide goods and services which can meet government requirements as well as those of a substantial number of other customers. Government is neither sole nor predominant customer, and therefore bears only a proportionate share of the cost.

Privatization. The transfer to the private sector of responsibility for providing on-going, necessary services or functions currently furnished by the government through in-house labor and resources. Privatization can also lead to commercialization if customers other than government are attracted.

As discussed later, privatization is a key to the commercialization of piloted space. Later in the report, privatization is expressed as part of the spectrum of government/business relationships that spans standard government contracts to free market enterprises.

[9] NASA's definition of commercialization

Study Approach

In conducting the study, we recognized that there have been a number of pertinent publications and investigations by individuals and institutions. We used this information, summarizing and challenging results and adopting those which still seemed appropriate, while adding new findings and recommendations.

In view of the complex issues, and the number of perspectives from which they may be viewed, we sought extensive counsel. To strengthen our understanding and to guide the study, the Space Commercialization Panel (SCEP) was formed. The members of the SCEP advised the Team and developed findings and recommendations. As illustrated in Table 1, this Panel represented a profound resource in intellect and experience. The SCEP Terms of Reference are reproduced as Annex B. Additionally, well over two hundred people were contacted during the study. This represented over fifty companies, universities and government agencies, some of whom are identified in Annex C. Through discussions and case studies, these contacts helped to enrich the content of the study considerably. A full bibliography of reports, books and news stories used in the study is to be found in Annex D. A more detailed description of the study approach is found in [4].

Member	Selected Experience
Mr. James Beggs, Chairman	President, MAKAT, Inc. Former NASA Administrator Former Executive Vice President, General Dynamics Former Deputy Secretary of Transportation
Dr. John McLucas	Former Chairman, NASA Advisory Council Former President, COMSAT General Former Secretary of Air Force Former Administrator, FAA
Mr. James Rose	Former Assistant Administrator for NASA's Commercial Programs
Mr. Howard Schue	Partner, Technology Strategies and Alliances Corporation
Dr. Terry Straeter	President and Chief Executive Officer, GDE Systems

Table 1. Members of Space Commercialization Experts Panel

The structure of the study is shown schematically in Figure 2. Industry (the right side of the figure) received most of our attention since, a credible understanding of the commercial benefits of space, an indication of the commitment to pursue commercial markets through the ISS, and the conditions under which this commitment can be elicited, must all come from the candidate industries. Some industries were reached through the Centers for Space Commercialization (CSC), others were found independently. Through interviews and case studies, we documented potential areas for space exploitation, reasons for industry interest (or disinterest) in space, and what industry needs from government to make commercialization a plausible endeavor. Twelve case studies focused on individual companies to determine their perspectives on the viability of commercialization of their product or process through the ISS, and on conditions which must exist to realize successful commercialization in space. We sought companies who were involved in diverse ways to pursue commercial goals through piloted space. These case studies, and other discussions that were held with industry and government, are published in [5], with results summarized in Annex C.

Unfortunately for this effort, the proposed NASA Working Group shown in Figure 2 did not materialize, so we lacked some approved Administration perspectives. However, we interviewed a number of NASA personnel in an attempt to gain insight regarding their situations.

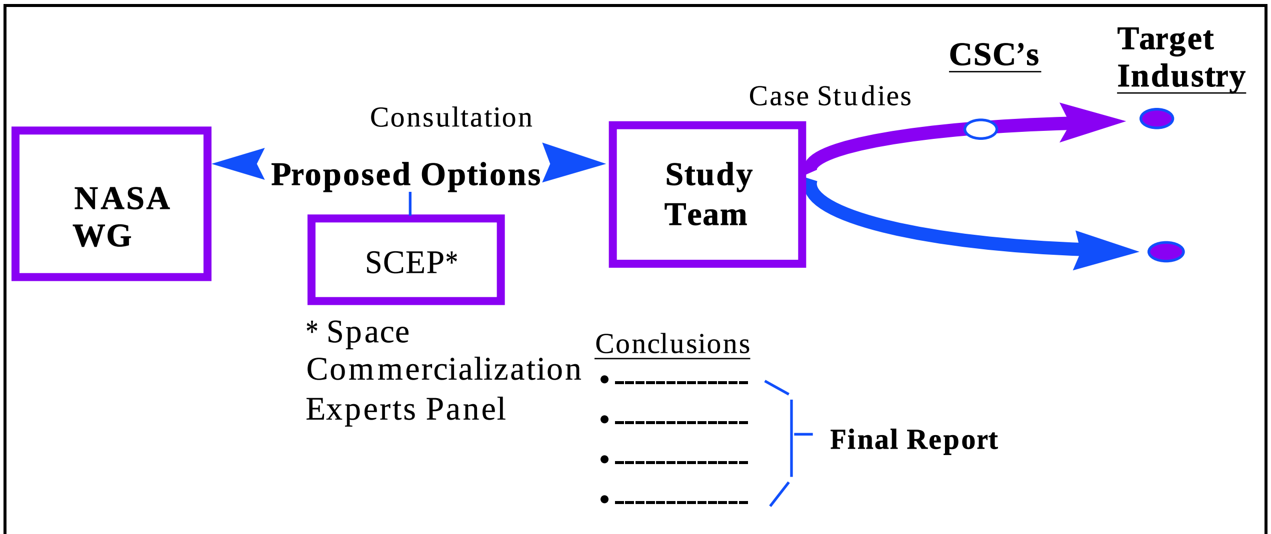

Figure 2. ISS Commercialization Study Process

The time required to complete Phases 1 through 5 was approximately nine months, as indicated in Figure 3. Although there were significant overlaps, the program generally followed the time-line shown.

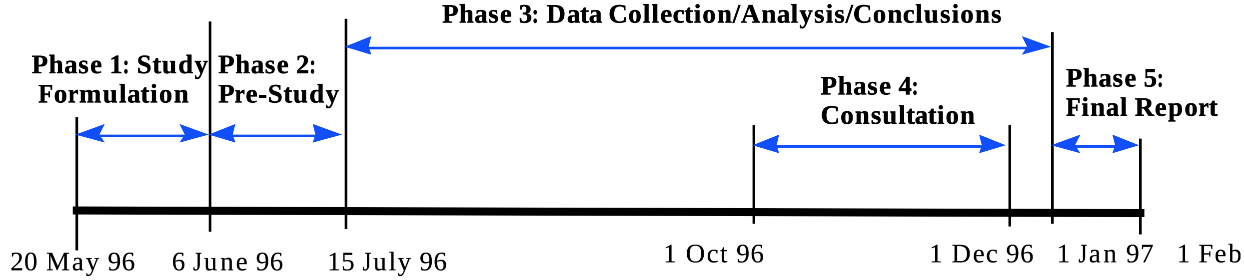

Figure 3. Study Schedule

Findings and Recommendations

The findings presented below are answers to questions 1 and 2 posed in the study objectives. These answers, coupled with the wisdom of the SCEP, were used to form recommendations (and to answer study objective question 3). Finally, in the next section an implementation plan is proposed.

Findings on Benefits from Commercialization: Commercialization through orbital human space flight is beneficial to the nation and NASA.

NASA. Assuming that commercial ventures are found to be plausible and practical in orbital space, benefits can be derived for the nation, as well as for important NASA missions.

National Benefits. There are at least three national benefits which result from commercialization.

1. Enhancement of U.S. industry competitiveness. There are clear national economic benefits that transcend NASA's mission-area interests.[10] Enthusiasm for science and exploration and the excitement of building world class facilities, such as the ISS, should not lead the U.S. to lose focus on the necessity to compete in the global market place. Our failures to commercially leverage our nation's superior science and technology in areas such as the television, the VCR, and the compact disc led to large industries and profits -- in Japan.[11] The ISS and other space assets should be used to our advantage, not only for scientific interests, but also for commercial gain.[12] Today orbital space is the latest in a number of frontiers, opened by various transportation systems and infrastructure that were strongly supported by the federal government. The strategies pursued called for government to foster commercialization at critical times. It is a conclusion of this study that human orbital space flight is approaching such a stage in its development. [13]

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[10] The 1994 Commercial Space Transport Study [1] identified a potential business base of $18.3B in 2000 and $28.5B in 2010, in just four areas (drug production, biotechnology, industrial and university R&D, and materials processing).

[11] NASA's Commercial Programs Advisory Committee [6] indicated that "…the United States has lost a near monopoly in consumer electronics, semiconductors, and machine tools. By 1986, the United States had lost a high-technology balance of trade that in 1980 had exceeded $25 billion. Europe and Japan are challenging the U.S. lead in pharmaceuticals and computer software. American industrial competitiveness has become a major national issue." This committee also concluded that, "The President and top executive branch leaders should vigorously endorse the development of U.S. space enterprise and space industrial competitiveness as national goals. …American industry must be concerned not only with the strategic moves of aggressive competitors abroad, but also with a host of challenges at home – such as national policy, government regulation, …"

[12] The Japanese have major roles in the development of systems and technologies for the ISS. The Japanese Experimental Module (JEM), the development of the robotics, and centrifuge systems are all vital to commercializing orbital human space flight. Additionally, two Japanese corporations, Simizu and Obayachi, have divisions at work on lunar bases and orbiting hotel designs.

[13] In a 1996 report [7], the National Research Council (NRC) suggests that "government-funded [engineering research and technology development] on the ISS will result in the acquisition of much knowledge and the

More specific to space, the U.S. was the preeminent nation for launching satellites in 1970. Since then, however, foreign competitors have all but taken over this business, partly by continuing to upgrade launch assets. For example, according to Marshall Space Flight Center, while the U.S. has developed one new rocket engine for Expendable Launch Vehicles (ELV) during the past 25 years, the rest of the world has developed 27. As a result of this kind of investment, the European Space Agency *Ariane* now holds two-thirds of the commercial launch market. The NASA Advisory Council Task Force on International Space Policy [8] declared in 1987 that "a single $100 million launch contract is equivalent in economic terms to the import of 10,000 Toyotas."

2. Spin-offs of new technologies to non-space industries. NASA has maintained an effective technology transfer program. This important facet of NASA's service to the nation will be enhanced by increasing private sector involvement.

3. National prestige. With the end of the cold war, U.S. prestige depends as much or more upon its economic competitiveness as upon its defensive strength. Commercialization of orbital space will enhance this aspect of our nation's reputation, as will the science, exploration, and technology development sponsored by NASA.

NASA Mission Benefits. In addition to these national enhancements, commercialization will directly benefit the conduct of NASA's mission areas in at least six ways.

1. Increased Availability of Improved and More Affordable Space Assets. Previously, when NASA has engaged the private sector, though performance-based purchases or leases, the result has been significant reductions in both cost and time-to-delivery. Examples include: the Reusable Launch Vehicle (RLV); the SPACEHAB module; Consort; two free-flyers called Wake Shield and Commercial Experimental Transport (COMET); and a number of smaller test and experimentation devices, such as ITA's Materials Dispersment Apparatus and the ADVanced SEParation (ADSEP) system developed and built by SHOT. [14] Figure 4 illustrates this point by comparing the cost and timeliness of several developments undertaken by the government versus similar deliveries by industry. These improvements are possible because of industry's focus on delivering at cost. Even the private sector cannot maintain this focus, however, unless the government restrains itself from imposing secondary goals. Such goals (e.g., prescriptive specifications and standards) have a tendency to become primary and to defeat basic aims, for instance, cost control and timely delivery. Another tendency too common within the government is to seek changes as product development and design progresses. These changes are often justified under the rubric of product improvement. Although improvements can sometimes be made without undue schedule or cost impacts, they frequently fall under the adage "better is often the enemy of good." A well documented case is the SPACEHAB module, a privately and independently developed module which, according to a Price-Waterhouse study,

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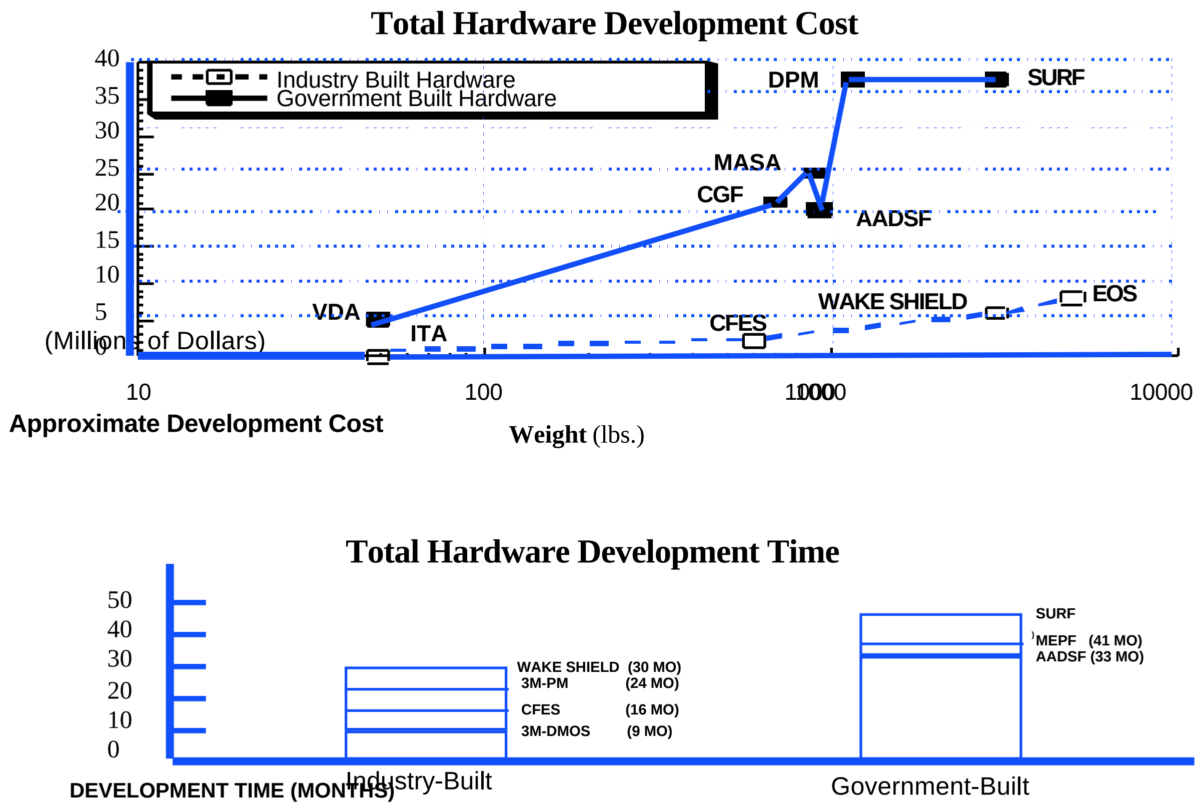
development of numerous new technologies that potentially could be adopted by industry, eventually resulting in superior products and a strengthening of the overall economy."

[14] According to the Institute of Electrical and Electronics Engineers, unless business thinking and private funds are introduced into NASA's mission, it will never become less expensive [9].

was provided at a cost six times less that what it would have been if it had been developed by the government.[15] During the design phase, NASA engineers suggested fifty-three “improvements” to the module. If these changes had been permitted, as would have happened under normal government procedures, schedule delays and significant increases in cost would have most likely killed the program.[16] In the final analysis, only one change, associated with safety, was allowed. The module was delivered on schedule, within cost, and has performed flawlessly in all flights to date.

[15] The Price-Waterhouse Study employed cost figures furnished by NASA, using its own cost models.

[16] According to Mr. James Rose, who was Assistant Administrator for NASA’s Commercial Programs as that time.



VDA: Vapor Diffusion Apparatus
CGF: Crystal Growth Furnace
MASA: Metals & Alloys Solidification Apparatus
AADSF: Advanced Automated Directional Solidification Furnace
DPM: Drop Module
SURF: Space Ultravacuum Research Facility
MDA: Materials Dispersion Apparatus
CFES: Continuous Flow Electrophoresis
EOS: Electrophoresis Orbital System

Figure 4. Comparison of Costs and Time-to-Delivery of Hardware Developed and Fabricated by NASA and the Private Sector

2. Utilization of Shuttle, ISS, and RLV. The International Space Station (ISS) is a two billion dollar per year NASA program that is to be ready for utilization in five years. Motivations ascribed to the ISS include its potential benefits to general science, national prestige, international relations (particularly with Russia), research applied to planetary travel (e.g., research into space-related medical problems), and commercialization. But, in conducting its assessment of science benefits, the National Research Council (NRC) [10] assumed that science was "…secondary to exploratory, technological, engineering, political, educational, inspirational, and other motives." Further, the end of the cold war has reduced (but not eliminated) our need for national prestige, and it appears that the ISS, as a vehicle for international relations, is encountering some hard times as Russian commitments weaken. While applied science for planetary travel is certainly needed if we are to launch humans to the Moon and Mars, it is believed that the public will not support huge expenditures in this area. Commercialization is perhaps the one exploit that has a potential for sustaining public support, particularly over the expected twenty or so year life span of the ISS. Even so, the NRC [7] states that, “NASA’s current plans for commercial use of the [International Space Station] . . . seem more likely to support subsidized research than to result in commercial uses.”

The Reusable Launch Vehicle (RLV) is the logical next step toward more affordable and frequent space access. This program also relies heavily upon a commercial market if it is to become economically viable, since Lockheed Martin plans to invest heavily of its own IR&D funds on the development of its precursor, the X-33. While NASA has agreed to lease the vehicle for its own flights, much of the demand is expected to come from the private sector. As private expenditures increase, Lockheed Martin will be viewing this part of the market with a critical eye. Continuation of this effort will likely demand either a growing piloted space commercial market, or a larger NASA commitment.

The ISS and RLV are both centerpiece programs for NASA which depend on commercial customers for success. Lead times for space-based activities are long, and if commercial development is to proceed on the same schedule as the ISS, these activities must begin now. The investment required is not large relative to the investment we will have made in setting up the Space Station/resupply system, but it is unlikely to be made by the private sector without a commercial motivation.

3. Release of NASA resources for application to new frontiers. Whether the next step in space is human exploration of the planets or the launching of scientific instrumentation from earth orbit, NASA is looking ahead to new challenges. These challenges will be easier to pursue if orbital space is “normalized” by commerce.

4. Leverage private investment. Our estimates show that more than two billion dollars are either committed or planned by the private sector for human orbital space flight ventures. This private investment and follow-on funding should be leveraged by NASA.

5. Improved innovation and application of commercial technologies to space endeavors. The private sector controls far more resources to devote to innovation and research and development than the government. As industry becomes interested and committed to space for financial gain, technology development, transfer, and application will grow.

6. Increased public support for space operations. The promise of commercial activities could awaken new excitement on the part of the public, particularly if there is an eventual tourism aspect.

Finding on Viability of Commercial Ventures: There are emerging commercial ventures for human space flight.

Nine areas where space commercialization is either proceeding or is planned are listed in Table 2. Remote sensing, communications, and power generation are principally satellite-borne, and therefore did not receive much attention during this study. Space-based biomedical, materials, and agricultural research is generally aimed at accomplishing research in space designed to create knowledge to be used for improving earth-based manufacturing and processes. Of these, biomedical research seems to have had the most effect, although materials research has provided important insights. The operations, services, and support category is dedicated to designing better and more affordable space equipment, such as space modules and test facilities and devices. Finally, although education, entertainment, and advertisement may represent a significant growth area in commercial piloted space, it seems to be the least palatable to NASA. In Annex C, some participating companies and their products are identified for various areas of opportunity.

Areas of Opportunity	Some Products
1. Biomedical	· Pharmaceuticals
2. Materials	· Structural materials · Functional materials
3. Remote Sensing	· Radar, infrared, and visible imagery · Meteorological forecasting
4. Communications	· Communications Satellites · Navigational Systems
5 Agriculture	· Plant Research
6. Mining	
7. Power Generation	
8. Operations, Services, Support	· Launch Vehicles · Other In-Space Equipment (e.g., experimentation devices)
9. Education, Entertainment, Advertising	· Tourism · Film · Promotion

Table 2. Areas of Opportunity

We found six commercial ventures that seem promising. Some are quite mature, while others are only at the "idea stage." These six are listed below and are summarized in Annex C. Others found during our survey are confidential or too immature to report. We feel that a search larger than our resources permitted would have yielded (or motivated) many more examples, particularly if conducted with overt support from NASA and the aerospace industry. It should be stressed that no venture was discovered with the near-term potential to get into space and operate without government help.

- Case Study 3. Microencapsulation Systems (VIVO RX and Vanderbilt)
- Case Study 4. Macromolecular Crystallography Investigations (University of Alabama in

Birmingham)

- Case Study 9. Virtual Presence (LunaCorp)
- Case Study 10. Gallium Arsenide Thin Film/Wakeshield
- Case Study 11. X-Ray Device (University of Alabama in Birmingham)
- Case Study 12. Education Programming (Walt Disney Imagineering)

Findings on Viability of Commercial Ventures: There are major problems which must be overcome. Although there is industrial interest, three major areas of difficulty combine to deter private investment. As a result of these problem areas, few corporations contacted have developed plans for space ventures, even when they are in a business area that could eventually profit from a presence in space. This lack of consideration of piloted space in U.S. corporate boardrooms presents a major concern. Because of the perception in the business world that space access is (and will remain for some time) impractical, little creative thought is being given to commercial ventures in piloted space. Also evident is a reluctance on the part of the private sector to do business with NASA, assuming that any attempt to enter into business relations will lead to governmental red tape and frustration. Discussions and case studies were replete with remarks that reflected these attitudes. Without the eager participation of an innovative private sector, commercialization cannot develop wings.

1. Finding: Non-addressable risks for human orbital space flight businesses are high. A new business venture which involves human space flight faces the same set of business risks as any other new start. In addition, there are space-specific problems. One of these is a constant concern that earth-based processes will be discovered which will supplant the more difficult space-based process. For example, the electrophoresis program, conducted jointly between McDonnell Douglas and Johnson and Johnson Corporation (with help from NASA) was an effort to develop a space-based process to separate and purify biological materials. It was very well planned and executed -- and the process worked. But in the end, a DNA process emerged that worked as well as electrophoresis and did not require space.

2. Finding: There are four major Impediments to space access that inhibit business ventures. Case studies and discussions with industry and government revealed nearly unanimous agreement that four impediments to space access must be reduced in order to encourage commercial use. NASA is already attacking many of these problems, but it is difficult to determine priorities, overall strategy, progress, and how NASA’s plans will affect (and are affected by) the private sector. Until impediments affiliated with space flight are improved dramatically, economic considerations will always dictate that space-based operations be replaced by terrestrial alternatives whenever the latter option does not degrade the product significantly.

- Launch and operation costs are too high.[17] NASA is currently sponsoring an effort to identify efforts underway to reduce cost of space access, with a report due soon. NASA's Administrator, Daniel S. Goldin, indicated in a statement before Congress that, "Access to space costs too much…about ten times too much."[18] A further difficulty for business, according to the Boeing/Peat Marwick Commercial Space Group Report [12], is that "the lack of pricing information for conducting space experiments" is an impediment to commercialization. Even when NASA donates "free rides" to space, the cost of long-term involvement in preparation and certification is, as expressed in the Commercial Space Transport Study Final Report [1], "a major factor." This "major factor" was priced by some of the participants in the CSC program at up to one million dollars.

- Flight frequency and reliability are poor and launch lead times are too long. A Battelle report [13] stated that "a wide variety of flight opportunities," including inexpensive sub-orbital flights, are required for space commercialization…. "Long-term guaranteed access to flight opportunities," and opportunities for frequent reflight are required for businesses to successfully pursue commercial use of the microgravity environment." The NRC [10] also complained that, for microgravity experimenters on the Shuttle, it can take up to eight years from an experiment being selected until launch and up to two years to re-fly. With these kinds of delays, "there is a real danger that the scientific goals of the experiment might be bypassed by new developments."

- Indemnification against flight failure is expensive. In 1994 the insurance cost for an *Ariane* flight was 17% of the total payload cost ($55 million for a $356 million flight).

- Limited access to space for the next five years. The Shuttle has been the mainstay of recent U.S. manned space ventures through the CSCs and other avenues. For the next five or so years, it will be dedicated almost entirely to the construction of the ISS. It appears that the ISS itself will be inaccessible to commercial experiments until well after 2002. If successful, the Reusable Launch Vehicle will be a major improvement in accessing space, but it will not be available until at least 2009. This hiatus endangers the continuity of ongoing commercial plans and will severely dampen industry's future plans to employ space in their business. A withdrawal of interest may take place similar to that following the suspension of flights after the Challenger accident.[19] Industry's funding cycle for research normally requires a return on equity within three years. Industry is therefore unable to make decisions at this time on market

[17] Dr. Roger Handberg [11] reports that launch costs dropped considerably during the 1960s, but re-escalated during the 1970s.

[18] House Subcommittee on Space and Aeronautics, Committee on Science (3/28/96).

[19] A forum conducted by the National Academy of Public Administration in March 1996 [15], found that, due to this hiatus, "[a] number of non-aerospace firms and small businesses may abandon space-related research and development projects and/or go out of business. Large firms may divert funding from space-related research and development activities to terrestrially based activities…" Members of the forum also agreed that it might result in a lowering of the U.S. competitive edge and lead to a greater separation between the public and private sectors.

conditions five years from now. Their investment in ISS experiments will therefore be delayed.

3. Finding: NASA's efforts to foster commercialization are in decline.

NASA has made a number of advances in the use of innovative contracting vehicles for R&D (e.g., cooperative agreements) and has taken initial steps in privatizing space assets. But, on balance, NASA seems to be withdrawing from its commercialization role. Much of NASA's reluctance may stem from the difficulties of overcoming the impediments to space access discussed earlier, and from the infancy of proposed commercial activities. There are also problems with attitude. Commercialization is seen by many at NASA as a threat, at least in terms of priority, to NASA's almost exclusive focus on science and exploration. Whatever the cause, its symptoms, discussed in the next few paragraphs, have fed an increasing pessimism in industry. Such pessimism is reflected in the words of a veteran of space commercialization [14], "[E]ven with the full and explicit thrust of Federal law . . . there has been hardly any movement at all toward achieving 'the fullest commercial use of space' in the human space-flight area over the 11 years since the law was enacted. This law has had little if any effect, probably because it conflicts with so many others that . . . the Administrations have decided to give preference to." A few manifestations of NASA's retreat are offered below.

Budgetary decline. As shown in the curve below, the percentage of NASA's budget dedicated to commercialization has declined steadily since 1993. At its highest, this portion was less than one percent of NASA's budget. Note that, along with a reduction in percent-of-budget, is a reduction of the budget itself – multiplying the effect.

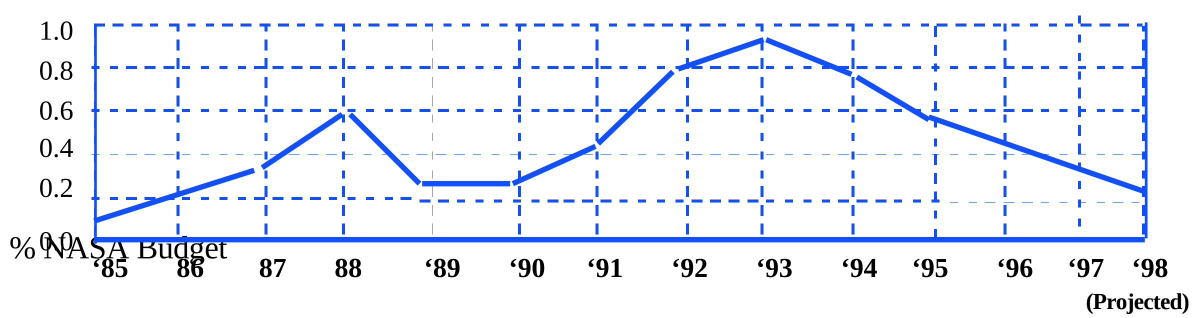


Figure 5. Commercialization Funding as a Percent of NASA Budget

Reorganizations have left NASA without an institutional center to accommodate commercial participants. An example of the diminishing support for commercialization is found in the fate of the offices dedicated to it. During the 1990s, The Office of Commercialization (Code C) was eliminated. The Office of Space Access and Technology (Code X) was given the commercialization mission. Management control of the CSCs was split between divisions within Code X. In turn, Code X was eliminated in 1996 and the Centers were either further dispersed among the Office of Life and Microgravity Sciences and Applications

(Code U) and various NASA Field Centers, or eliminated.[20] These successive reorganizations are viewed by industry as a major defeat for NASA's commercialization interests. In effect, industry finds itself back in the '70s – without a central office within NASA to contact on commercialization matters.

A recurring theme among companies and universities contacted during this study was the difficulties of initiating and completing programs with NASA. It was unanimous among those contacted that the process of commercialization cannot proceed effectively without redress of organizational problems, common to four stages of government/industry interaction.

- Outreach. NASA's ability to communicate the results and excitement of its science and exploration to the public, particularly through schools and youth organizations, is superb. But it has no equivalent effort to reach business. As a result, there is a lack of information on how to initiate business with NASA, and many organizations which could benefit from access to space are unaware that such opportunities exist. Perhaps more importantly, there is a lack of private sector input into NASA planning.

- Initiating dialogue. Even for those few companies who are familiar with NASA, it is hard to find an entry point for discussions of commercial ventures. NASA's organization is particularly challenging to business people accustomed to offices that fill this role for companies interested in their advice or business. There is a lack of information needed by business to make even the most basic decisions (such as whether or not to include space in its plans). For example, there is no established pricing schedule or "offer package", endorsed by NASA, for industry to evaluate.

- Presenting and negotiating "business deals." There has been little incentive for NASA to focus on business, or to apply business expertise in their relationships with industry. Appreciation for, and accommodation of, profit making ideas and strategies is low. This finding is mitigated by some excellent relationships through the CSCs. But even here, emphasis is often on technology rather than commercial ventures.

- Conduct of programs. Even if negotiations are successful, the business venture has far to go. The path to be taken depends upon the maturity of the venture but, in general, the industrial participant must wade through a long set of processes with extremely complex actions required. Most worrisome are charges that criteria for successful completion of these processes are often unclear, and there is considerable inconsistency in demands among NASA centers.[21] A specific problem at this time is the impending five year hiatus of commercial flights discussed earlier. Some types of programs that may be considered by NASA are:

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[20] A case in point is the Space Communication Technology Center. This CSC was recently moved from Code U to NASA Lewis and reportedly informed by them that the CSC was being terminated because it "…was in competition with the NASA Field Center."

[21] This is also true in science, as evidenced by the NRC declaration [10] that the need to deal with several NASA Centers adds greatly to the complication of conducting microgravity experiments, and that there is too much overlap between NASA Centers and Headquarters on integration and safety issues.

- ◊ Science. If basic science findings are needed in order to address the final product, funding is sometimes available from Code U. But Code U processes are rigid. They reflect an academic and deliberate approach to completion, involving many peer reviews and hearings at each stage of progress. The process typically takes eight or nine years from proposal to flight. If a commercial venture depends upon scientific findings, the participating businesses expect to devote time to sufficiently mature their product. However, few are willing to devote the extensive time to the process demanded by Code U. A way is needed to get applied science on a fast track and moved more quickly toward the application.
- ◊ Commercial technology development. If the program is categorized as a commercial technology development endeavor, it generally falls under one of the CSCs, which are specifically dedicated to maturing technology through ground-based and space-based experiments. These centers do a fine job, but time-to-flight is still over a year, and access to repeat flights to move the technology along is poor.
- ◊ Commercial productization. For a commercial product ready for space-based manufacture, there is no apparent contact at NASA. There are grave admonitions concerning promotion or advertisement and even profit. Future payback for services rendered has been difficult for NASA to handle.

Lack of fulfillment of policies and promises. There are broad and enthusiastic statements of intent at every level of the Federal Government. These are widely distributed descriptions of a mission to enhance U.S. competitiveness through proactive government involvement. A few excerpts from policy documents and statements are sufficient to illustrate the level of governmental support to be expected.

- Congress [16]. "The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration . . . seek and encourage to the maximum extent possible the fullest commercial use of space."
- Administration [17].
  - ◊ " The fundamental goal of U.S. commercial space policy is to support and enhance U.S. economic competitiveness in space activities while protecting U.S. national security and foreign policy interests. Expanding U.S. commercial space activities will generate economic benefits for the Nation and provide the U.S. Government with an increasing range of space goods and services."
  - ◊ "To stimulate private sector investment, ownership, and operation of space assets, the U.S. Government will facilitate stable and predictable U.S. commercial sector access to appropriate U.S. Government space-related hardware, facilities and data."
- NASA {"Implementation of the Agenda for Change" [18]}.
  - ◊ NASA's commercialization of technology is "comparable in importance to, and [is] an integral part of, its aeronautics and space missions. ... Every NASA project shall

implement specific plans to ensure that NASA leverages its resources … to convert its expenditures into a national investment. … [to] contribute to an increase in, or prevent the loss of, American jobs, increased export of products or services, and increased national productivity."

◊ "We [NASA] are collaborating with our private sector partners more each day. The results are more jobs, more technology applied to improve our daily lives, a more cost-effective NASA, and a stronger America."

· NASA Field Centers {Stennis Space Center HEDS Briefing, August 1996}. **"**NASA's ultimate objective in sending humans into space is to explore and to enable commercial development of space … Potential space markets [include] movie production, advertising, tourism, entertainment, lodging,…"

And yet, the strategies that are proposed to provide this support are nonspecific or inadequate. For example, despite statements of broad interest NASA seems to be unenthusiastic about entertainment, tourism, promotion, and for-profit ventures, while often funding technology transfer, basic and applied science, and development of commercial technology with "socially redeeming objectives." Further, despite the declaration in [18] that NASA's commercialization of technology is "comparable in importance to, and an integral part of, its aeronautics and space missions," commercialization funding runs consistently below one percent of NASA's budget. These unfulfilled promises are widely recognized as such, from both within and outside of NASA.[22] For example, at last October's Space Transportation Association breakfast, a NASA Associate Administrator stated that, "NASA has shown itself less than careful with guaranteeing [commercial access to the Space Station]. . . If I were trying to decide to put private money against experiments on the Space Station, I would have to look very carefully to see if it's a friendly place to spend money. I think NASA could do a lot better showing that the Space Station is going to be a friendly place for business."

Procurement and Procedural Inflexibilities. With the decline of budgets and an impatience with the costs and inefficiencies of conventional government procurement systems, coupled with the emergence of a commercial sector made cost conscious and innovative through global competition, there is a growing recognition that the government must do business differently. In order to take advantage of the benefits to be gained through the private sector, the government is learning to conduct more of its development and procurement missions in a business-like fashion.

NASA is no exception. The NASA Administration has adopted a number of innovative vehicles. Perhaps the earliest, the Joint Endeavor Agreement (JEA), is a NASA invention which provides impressive flexibility for R&D efforts; however, it normally allows for NASA services to be provided (e.g., access to space) rather than funding. Since NASA funding is not involved, the Bayh/Dole Act is not invoked and intellectual property rights may remain with the participating industry. JEAs were used successfully during the 1980s, but none have been signed for a number of years. As figure 6 illustrates, however, NASA has employed the cooperative agreement,

[22] The Institute of Electrical and Electronics Engineers (IEEE) [9] agrees that the policy of giving low priority to commercial human space activity "stands in contrast to the Government's stated goals," since NASA budget requests showed the importance of developing businesses based on human space activity. The relatively small percent of the NASA budget spent on commercialization is inconsistent with the 1958 Space Act.

which allows for cost sharing by the government, in exchange for adherence to Bayh/Dole. The Cooperative Agreement was pioneered by the Defense Research Projects Agency (DARPA), principally under the Technology Reinvestment Project (TRP). Some TRP programs were managed by NASA, leading to the employment of Cooperative Agreements by the Administration. On the other hand, DARPA's "Other Transactions," arguably the most flexible form of R&D agreement available to the Federal Government today, is largely ignored at NASA.[23]

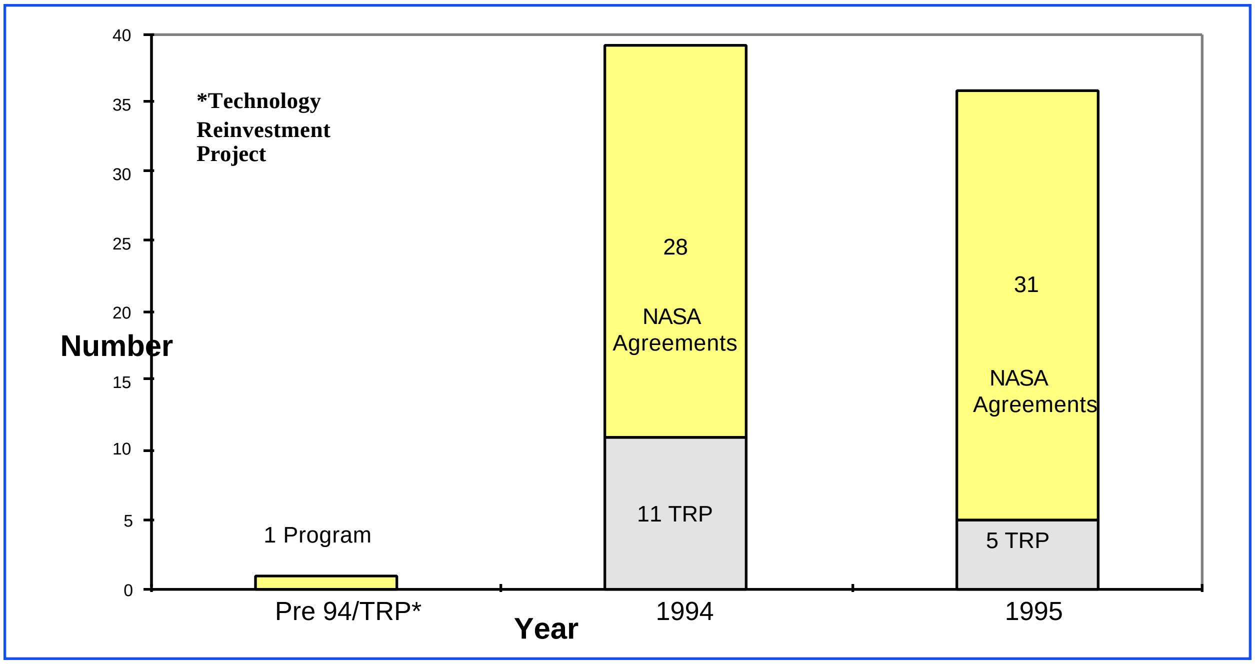

Figure 6. Estimated Number of Dual Use Cooperative Agreements

In general, changes in procurement rules adopted and used routinely by government mainly affect R&D or Commercial-Off-The-Shelf (COTS) efforts. There are still severe Federal Acquisition Regulation (FAR) restrictions on government/industry co-development partnerships, and the procurement of goods when government is the only (or even principal) customer and industry is seeking profit in an extremely risky business area. In this arena, NASA has also explored some unconventional procurement tools, but consensus is that these tools are not employed routinely enough to become a normal part of the Administration's operation.

Of particular importance to venture capital industry is the willingness on the part of the government to accommodate an appropriate rate of return and to conduct negotiations toward mutually desirable goals between industry and government, outside of the rigid set of regulations and rules which govern government procurement. Adjustments must be made to permit reasonable returns on invested capital, given the risks faced by the developer/producer. This

[23] There is a wide array of contractual vehicles that have been used from time to time by NASA. Besides those mentioned above, these include: Memoranda of Understanding, Non-reimbursable Space Act Agreement, Reimbursable Space Act Agreement, Cost Shared Contract, Licensing, Small Business Innovative Research, Cooperative R&D Agreements, Grants, Chiles Act Cooperative Agreements, and so on.

could be accomplished by establishing a method of judging the value of the product or service to be purchased or lease by NASA, rather than by negotiating on the basis of the contractor's cost plus an acceptable, and narrow range, of profit.

In the case of services being offered on a commercial basis, the price offered should be compared to the costs of similar services being produced or supplied by NASA. A case in point is the SPACEHAB, Inc. Shuttle module. As discussed earlier, NASA received a product value of $1.2B (as determined by NASA) for the price of $250M (assuming that NASA paid for the module for the promised number of flights). By SPACEHAB's books, this arrangement paid for the module and the cost of integrating the experiment payloads, plus a relatively low return for the high risks (SPACEHAB had raised and spent almost $80M before the first flight). Moreover, the contractual arrangement provided no R&D recoupment. This had not been lost on the financial community, which has stated that it would never again finance such an endeavor. Had NASA's calculations been based on the value, the return should have been much higher, and competition (with new ideas) may have resulted from this better business environment. As it was, NASA may have found a bargain, but simultaneously reduced the supplier-base for this and future service buys.

Circumstances often arise in an emerging business area when industry cannot pay for services or equipment up-front but, is willing to pledge future earnings, for example through a royalty sharing arrangement. There is precedence for NASA's acceptance of future recoupment. An example occurred in 1982, when NASA provided an M-56A1 solid propellant motor to Space Services International for use in the first private launch of a space vehicle. The rocket was named the Conestoga and payment was made to NASA upon completion of the 150 mile flight. This tool could be employed more frequently, particularly to encourage new businesses in space.

A great deal of controversy has existed over whether or not NASA should serve as anchor tenant when warranted.[24] Anchor tenancy is the agreement by a single user to serve as essentially the sole user for the initial stages of the life of a product or service. This arrangement has penalties associated with the higher cost of money to private industry and the requirement of government to "cover" the loan as if it were in a direct pay situation. But, the panel agrees with a NASA statement implying that the involvement of private funding and the added discipline imposed thereby, will more than compensate for these penalties.[25] The large cost and timeliness benefits illustrated in Figure 4 support this point.

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[24] Again, according to the IEEE [9]: "The government's roles are to act as an 'anchor tenant' for as many of these new activities as possible, to pursue R&D activities that the private sector identifies as desirable, and to work with the private sector to identify national economic objectives and create national programs to meet them."

[25] A Congressional Budget Office (CBO) study [19] probed the issue and suggested that "government's cost of borrowing is always lower than the private sector's, even if a loan to a private party is guaranteed by the government either directly or indirectly through an advance commitment to purchase." Further, the CBO stated their belief that the rules governing lease-purchases "require NASA's budget to record the budget authority and outlays necessary to fulfill the advance commitment as if the government were funding development of the launch system directly but did not enjoy its usual relatively low cost of borrowing." The report continues that, "NASA maintains that the cost of space launches can be dramatically reduced by combining new technology with the private development and operation of new launch systems."

Interviews with many of the industries who do business with NASA (particularly for small space assets, such as experiment devices) felt that NASA's Field Centers were in unfair competition with them and often dictated the choice of NASA-developed equipment. One innovator said that he "could not walk into NASA with an idea without fear of losing it." Others complained that design requirements for equipment were made higher than necessary. The NRC [10] wrote that "the cost of flight instruments . . . should be substantially reduced by lessening bureaucratic overhead, minimizing technical complexity, and eliminating unnecessary requirements." Also, more "off-the-shelf" instruments should be used [7]. One instrument designer indicated that, "Despite offering equipment they believe to be one tenth the cost of equivalent NASA hardware, Code U declined to purchase or fund [our] product."

Finally, the eight year trek, with its multiple peer, in-house, and safety reviews of science experiments in space is still too typical of NASA's operation. Nearly all industry representatives interviewed, as well as several reports by NRC [10], Peat Marwick [12], and Boeing, McDonnell Douglas, et al [1]) agreed that NASA's complex and lengthy procedures affiliated with flight certification was a major impediment to science and/or commercial utilization.

The Recommended Government Role

In answering the last question posed in the study objective, we must first suggest a government intent. We feel that success of the commercialization effort should be measured according to two factors: the extent to which industry has assumed the responsibilities, funding, and conduct of piloted orbital space ventures; and the extent to which government's role declines. Over the next ten years, government should normalize and hand-off piloted orbital space activities to the private sector and move on to the next level of accomplishment, paving future frontiers for private sector involvement. The commercialization of orbital space flight should proceed as did the satellite business: the private sector should take over as risks and costs are reduced and business opportunities emerge, leaving government the beneficiary of the technology and affordable infrastructure that flow from a healthy commercial industry. It is the means to this end that poses the problem.

It bears repeating, however, that the portion of the commercial sector interested in human orbital space flight is still small and progress must be made in reducing impediments to space access before commerce can "go it alone." For these reasons, the Panel does not advocate a major shift in NASA's budget or staffing at this time. We feel that our recommendations can be implemented with little disruption of NASA's other missions, while more effectively addressing the role of commercialization. Of utmost importance, we recommend that NASA should clearly express its intentions in fulfilling its role in commercialization, and then it should develop and pursue policies and strategies that support those intentions.

Recommendation: NASA should assume a broad responsibility for

commercialization of piloted orbital space in the near-term. As discussed earlier, commercialization will directly benefit NASA's mission and U.S. competitiveness. In this report, strategies and alternative implementation plans will be proposed. NASA should implement a more aggressive effort in commercialization now, for the following reasons.

1. It is the law. NASA's responsibility has been mandated by Congress and the Executive Branch. This responsibility should be addressed by NASA with strategies that contribute significantly to commercialization, and yet take into consideration the impact of other important NASA missions.

2. The ISS is becoming a reality. The degree to which the ISS is utilized depends to a great extent upon commercial interests. It is time to begin planning for commercial usage of this facility. If past experience is any indicator, it will take years to prepare for creative use, and the private sector must understand its benefits and difficulties. NASA should begin to anticipate commercial needs through design and utilization plans.

3. The rapid commercial growth of the satellite business. It is important to act now to maintain our nation's economic competitive posture in human orbital space flight. The satellite business can serve as a model. The private sector has taken over most of the satellite business, with the government reaping benefits from their presence; however, a case can be made that the U.S. lost an important lead in this commercial area to foreign competitors. The international community is trailing the U.S. in commercialization of human orbital space flight, but is considering a number of commercial ventures. Thus, we could lose the initiative here as well.

4. The Mir experience. Mir holds many lessons for the U.S. in planning for ISS utilization. Boeing's "Mir Pathfinder" program is especially pertinent. Those lessons affecting commercial ventures should be captured and applied.[26]

Recommendation: NASA should follow a strategy with three components. These components should be directed toward generating more private sector involvement (and money) into piloted space, as illustrated schematically in Figure 7. This is a transition strategy, with the objective of normalizing piloted orbital space operations and getting these operations into the private sector, so that NASA's budget can be shifted to the next space challenge.

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[26] See Case Study 2 (Boeing's Mir Pathfinder Program) in Annex C.

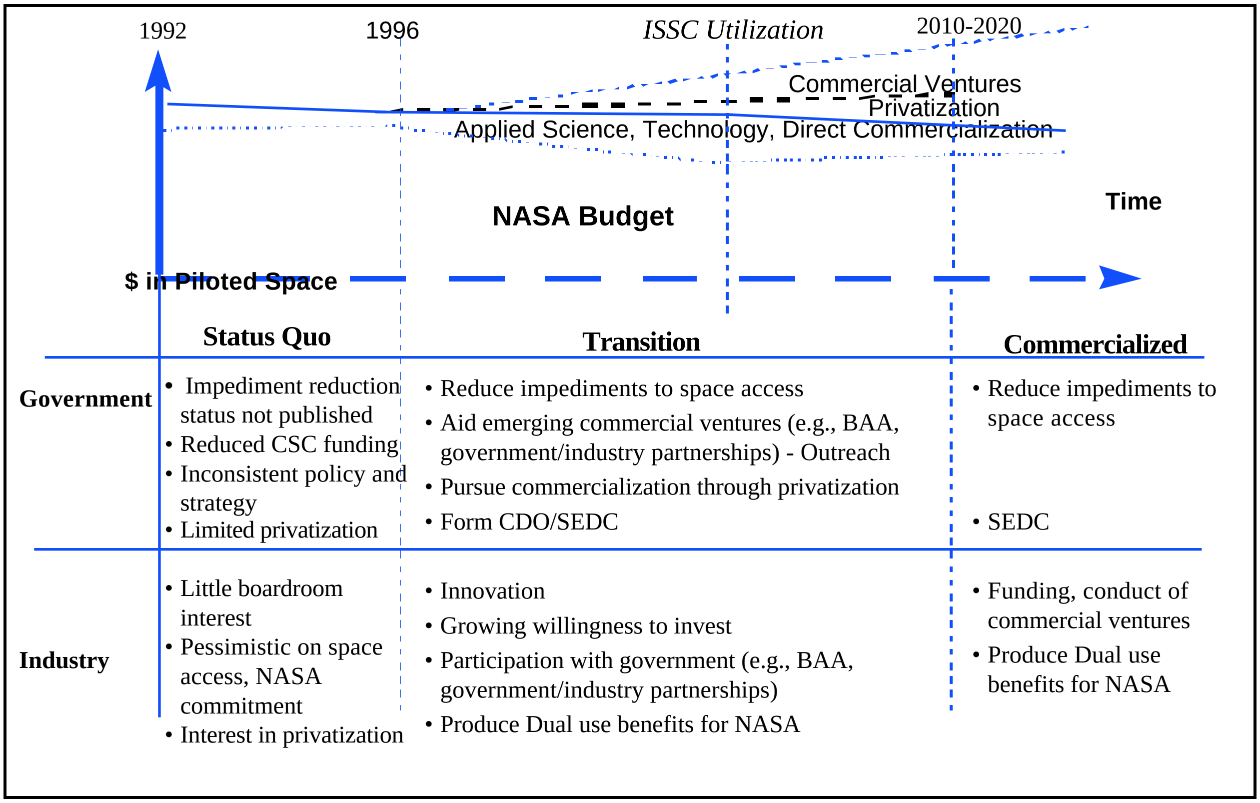


Figure 7. A Conceptual Strategy

1. Reduce obstacles to space access. NASA should implement and articulate clear and decisive plans to address the impediments to space access discussed earlier. These efforts should be conducted in a manner which takes into account ideas and needs from the private sector. For example, business must understand current costs as well as projected cost trends.

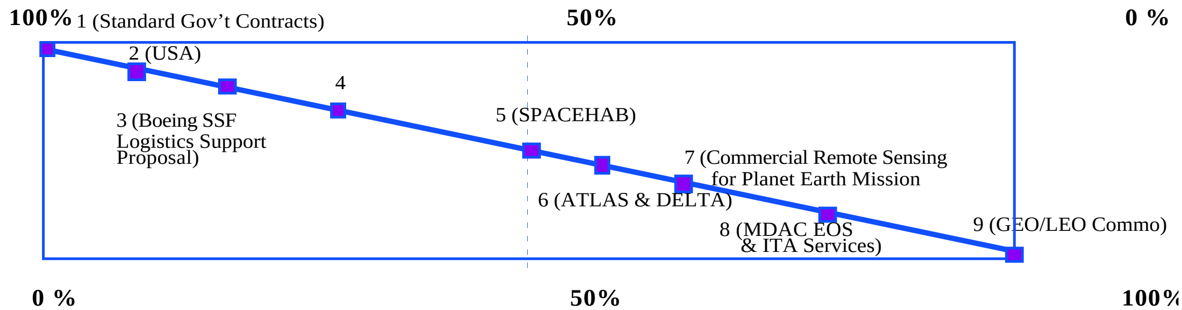
2. Foster privatization-to-commercialization. NASA should adopt a strategy of privatization leading to commercialization. Through extending its existing privatizing efforts, NASA can nurture commercialization through a space industry that has interest in finding customers. But, for privatization to lead to commercialization there must be both government and industrial investment and risk, as well as an opportunity for industry to market the space assets in question. Both can be the result of either direct ownership or lease to the private sector. Privatization would be an effective way to commercialize because the private sector is more adept than NASA in locating and encouraging private sector customers, applying business acumen to customer needs, improving efficiencies and reduced costs of equipment and services, and applying new technology.[27]

[27] The Commercial Space Transport Study Final Report [1] concluded that government (NASA) ownership and operation of the only access-to-space transportation system currently suitable for support of space manufacturing/processing is totally incompatible with commercial ways of doing business. “Commercial ownership

A spectrum of government/private sector relations is offered below, progressing from a standard government contract to a free market exchange of goods and services. Government can employ this spectrum to support and stimulate the private sector. Examples of some of these relationships are shown schematically. Note that many of these examples have moved to the right. For instance, the Delta and Atlas began at step one as part of a government contract. Since then, they have progressed to step six, and arguably to step eight, moving all the way across the spectrum.

INNOVATION CAN INCREASE PRIVATE INVESTMENTAND INVOLVEMENT IN SPACE

Government Control & Influence



Private Sector Control & Influence

1. Standard (Federal Acquisition Regulations) government contracts with the private sector to provide goods and services. Government oversight during all Phases of development and operations is typical.
2. Transfer of Responsibility to the Private Sector for the operation of a developed government system or facility. The government remains the only user. The recent turn-over of Shuttle operations to USA is a good example.
3. Transfer of Responsibility to the Private Sector for operation or development of government systems or facility, where the private company has the opportunity to offer, on a non-interference basis, services to customers other than the government.
4. Transfer of Responsibility to the Private Sector for the operation of a developed government system or facility, where the private company has the opportunity to invest its own resources to expand the scope of assets to provide services to customers other than the government.
5. The procurement from the Private Sector of services or facilities of new equipment developed and financed by the private sector. Future customers other than the government would stimulate private investment and growth.
6. The procurement from the private Sector of equipment and services which can meet government requirements as well as those of a substantial number of other customers. Government market potential is necessary for the private sector to make the necessary investment. Hardware and services can either be sold or leased to users.
7. The employment of the private sector's resources to provide goods and services which can meet governmental requirements as well as those of a substantial number of other customers. Government is neither sole nor predominant customer, and the private sector will invest without government assurances. Hardware and services can either be sold or leased to users.
8. Free market exchanges of goods and services where market mediates supply, demand, and value. The government plays a role to help mitigate the transportation and on-orbit support costs for start-up ventures. Otherwise, the government is not the exclusive (or dominant) customer or source of insurance capital. The initial microgravity commercial efforts will most likely fit here before moving on to step nine.
9. Free market exchanges of goods and services where market mediates supply, demand, and value. The government is not the exclusive (or dominant) customer or source of insurance capital.

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and operation . . . is essential to support commercial utilization and, therefore, development of the market" This would certainly pertain to ISS modules as well as other space assets, such as instrumentation.

3. Support near-term commercial ventures. Congressional prohibitions against direct subsidy of commercial ventures still allow free transport. Traditionally, NASA tends to provide such support to commercialization proposals which are in the scientific or technology development stage. The only other exceptions seem to be those commercial ventures which can be justified by "socially redeeming objectives" (e.g., cures for cancer). NASA should broaden its scope to include ventures motivated by market-share and profit.

The CSC's are filling an important need and should be continued, although some of them should adopt more of a business orientation. This may be a good time to expand the concept to include one or two Commercial Venture Centers.

Perhaps as important as direct support of commercial ventures is the need to improve NASA's ability to get industry excited about obtaining the benefits of human orbital space flight and to provide advice and help in doing so. As will be discussed in the next section of this report, we feel this would require a dedicated interface between NASA and the private sector.

ISS as a Pathfinder. An ISS as a pathfinder makes sense because it will be NASA's most capable facility for commercial use. A suggested pathfinder concept is described in the next section. It is important to ensure that other space assets of interest to the private sector, which are generally less expensive if less capable, are represented as options for commercial use.

A Proposed Implementation Plan

The problems faced by NASA in fulfilling its commercialization mission are fairly clear but, even if one agrees with the solutions and strategies recommended earlier, their implementation remains a difficult issue. The Panel felt that decisive implementation demands active support from the highest echelons of NASA. Without proactive attention from the top, commercialization will remain stunted. Accordingly, there must be an implementation arm to create a more innovative and productive linkage between NASA and the private sector and to develop and husband supporting policies, directives, and strategies.

In order to examine implementation alternatives, three models were developed. The first assumed that NASA would maintain responsibility for commercialization. The second placed another government department into the commercialization role, such as DOC, DOT, or a new agency. Finally, we looked at privatizing the commercialization function. Although there are interesting tradeoffs to be made, there was insufficient time to explore these models to our satisfaction and only the first is discussed in this report.

The objective of this model was to formulate an implementation plan for encouraging the fullest commercial use of human space activities. All recommendations previously listed apply to this model, including the basic components of the strategy for commercialization (to reduce obstacles to space access, privatization-to-commercialization, and support commercial ventures). It is assumed that in the short term, direct government support of some sort is still needed, and that NASA has a major, but not necessarily a dominant role. Finally, commercialization must end up as the responsibility of the private sector. Since there are no "silver bullet solutions" uncovered by the study, we have proposed a conservative approach to transitioning the human orbital space flight business to a normalized operation -- one which can serve the private sector.

The two facets of the proposed implementation plan discussed below are the tasks that must be undertaken and the organizational changes required to accomplish those tasks.

Proposed implementation tasks.

We conducted numerous discussions with industry to discover what government support was necessary to encourage new or continued commercial ventures in human orbital space flight. Contrary to our expectations, many indicated that funding was not the most important role government could play. Some suggested government functions and actions are described below.

1. Develop a realistic set of commercialization goals and provide private sector perspectives in planning and pursuing these goals.

2. Shift NASA's space infrastructure toward private ownership.

- Permit realistic return of equity, considering risks involved. If buying services, capabilities, or equipment development or fabrication from the private sector is a better deal for NASA than acquiring them through normal government processes, it should not matter how much profit is taken by the provider. Obviously, competitive procedures must be used in order to ensure the best price; however, value rather than cost should be the determining criterion.

- Accept role of Anchor Tenant, where plausible. Some actions NASA should consider are: leasing the Space Shuttle for commercial flights by 1998; designing and building a commercial ISS module by 2003; leasing Private Reusable Launch Vehicles, as planned in 2005; and privatizing the ISS by 2010.
- Consider recommending additional tax incentives to Congress. Some industries indicated that additional tax incentives would help them to get into space. We did not attempt to assess the merits of this mechanism.
- Discourage in-house competition with private sector. The Agency should conduct more of its advanced research and development by outsourcing to industry, rather than by conducting it in-house, whenever possible. NASA should become a "smart buyer" of commercial research, rather than recreating an in-house capability to perform research that can ultimately be conducted more effectively outside of government. NASA R&D organizations are sometimes in the difficult position of sponsoring in-house research, and then judging whether commercial research products are as good as their own product or technology.
- Join with private space assets companies to search for interested commercial ventures. Both NASA and the part of the private sector interested in building and operating space assets have a stake in finding businesses with an intent to develop space ventures. The search for these customers would be more effective if approached together. Other governmental departments, such as the DOC, DoD and DOT, would also show interest in joining. The next step could be to encourage agreements and partnerships among private space assets companies and commercial ventures (see paragraph on "outreach").

3. Provide encouragement, advice, and space access to a diverse set of commercial ventures. NASA should have a budget line specifically set aside for helping new ventures to access and operate in orbital space. Figure 8 illustrates two challenges in NASA's placement and support of commercial ventures. The first is to encourage movement of programs from science to applied science or technology, and then to the level of commercial venture. The second challenge is to properly place and support proposed ventures at the right level. Note that, as programs move form left to right in the figure, NASA's contributions become smaller.

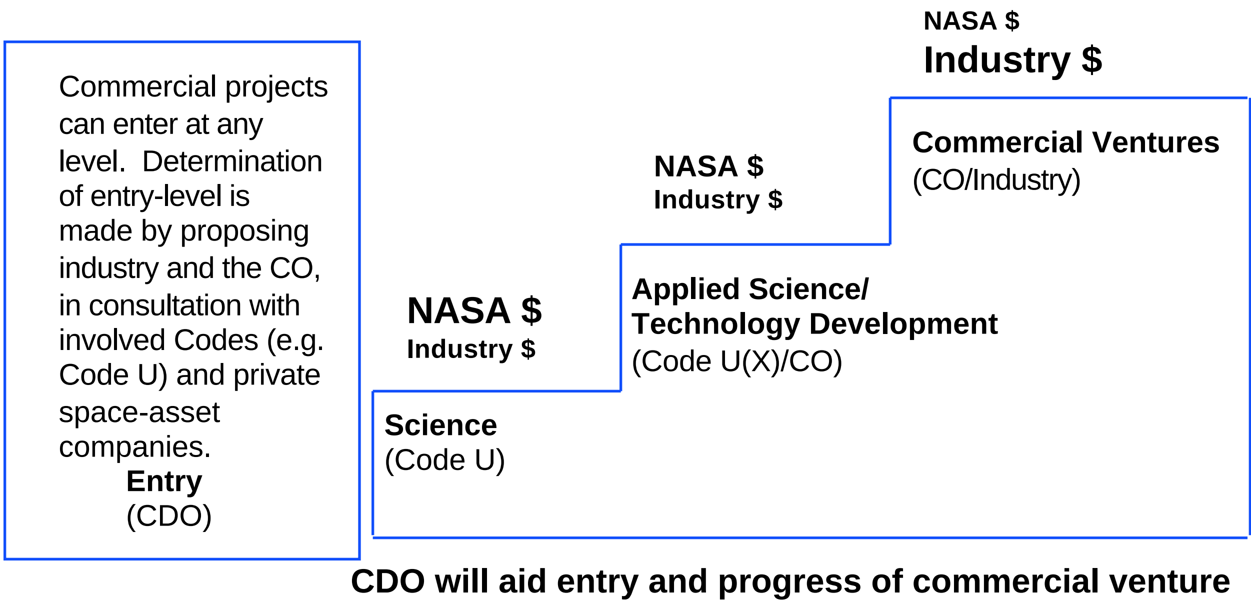

Figure 8. Commercialization Office POC responsibility

4. Represent private sector interests in NASA's efforts to reduce impediments to space access. The important goal of improving access to space has been pursued by NASA for a number of years. As discussed earlier, the private sector should be consulted as to its priorities and needs, as well as for its advice and help.

5. Initiate an outreach program. An outreach program, sponsored and led by NASA, other government agencies (e.g., DOC, DOT, and DoD), and companies involved in privatization should be initiated. A widely publicized series of meetings or workshops in three or four cities across the country could be the initial step. It should be preceded by a solicitation for proposals of commercial ventures (to be submitted after the meetings). The meetings or workshops would begin with plenary sessions followed by private discussions with individual companies to discuss individual plans or proposals. The outreach program would demonstrate NASA's interest in commercialization and willingness to accommodate industry, provide industry with a clear understanding of NASA's intent and strategy, identify interested commercial companies new to space, and to define the needs of the private sector.

6. Represent private sector in planning, strategies, and policies. The objective of this task is to refine and articulate NASA policies and strategies on commercialization through piloted space and to clarify criteria and priorities for NASA sponsorship. For direct commercialization, this would help to improve NASA's ability to deal with commercial business, aid commercial companies to access space, and employ NASA funds to leverage industry in maximizing commercialization. For example, an economic analysis of acceptable costs for launch and operation should be conducted.

Policies to further privatization-to-commercialization goals through appropriate privatization of space asset ownership and management should be pursued as well. For instance, commercial venture opportunities should be "built-in" to privatization agreements and connect appropriate commercial ventures with privatized industries.

7. Adopt the CSCs as part of this effort. New Commercial Venture Centers, described earlier, could also be formed as part of this effort.

8. Coordinate commercial activities with other government departments. Commercial ventures for human space flight should be encouraged more effectively and efficiently through coordination with other government departments.

9. Re-Activate the Advisory Committee on Commercialization. The Administrator's Commercialization Advisory Panel should be re-activated to provide advice to the Administrator and improve connectivity with commercial industry.

10. Increase commercialization budget to enable these steps to be taken. A budget line should be dedicated specifically for fostering commercialization, funding space access for commercial payloads, providing seed money for innovative commercial ideas, supporting the outreach program, and so on.

Form a commercial development office and a space economic development corporation. We were reluctant to suggest adding staff during this time of downsizing at NASA and certainly did not wish to impose additional organizations on potential customers to space. But, we felt that the need for commercial advocacy within NASA is sufficiently compelling to warrant such a recommendation.[28] Organizationally, the study recommends a two-part approach to accomplish the tasks listed above. First, NASA should form an in-house Commercial Development Office (CDO) to operate at the Administrator's level, as shown in figure 9. The CDO should then organize a Space Economic Development Corporation (SEDC), which would take over some of the functions of commercialization and eventually the entire commercialization effort. The CDO should be lean, unbureaucratic, and highly-placed. No amount of staffing can substitute for support at the Administrator's level, and from each of the Offices and Field Centers. It should be staffed with experts in both the commercial (venture capitalists, etc.) and government sectors. This organization should be separate from ongoing NASA scientific priorities and investments, *and should have its own funding to pay for flights and space operations needed.* It should also be empowered to seek and bring into NASA the funding and in-kind reimbursements from

[28] "NASA should establish a single organization to work with researchers interested in conducting [engineering research and technology development] experiments on the ISS and other space platforms….Because many firms do not have the resources to commercialize technologies on their own, NASA should begin a pilot program to use multidisciplinary expert review panels to help companies commercialize new technologies." [7] Space commercialization would benefit from coordination of all activities through a single organization. [13] "There must be more focused support to developing space station users and providers." [12] "[Other barriers include] lack of strong leadership and advocacy by NASA as the 'champion' of space commercialization. [15]"

participating industry. The Office should maintain necessary rigor, fairness and apolitical judgments, and an efficient, streamlined process should be defined and implemented to expedite approval or denial of industrial applicants to space**.**

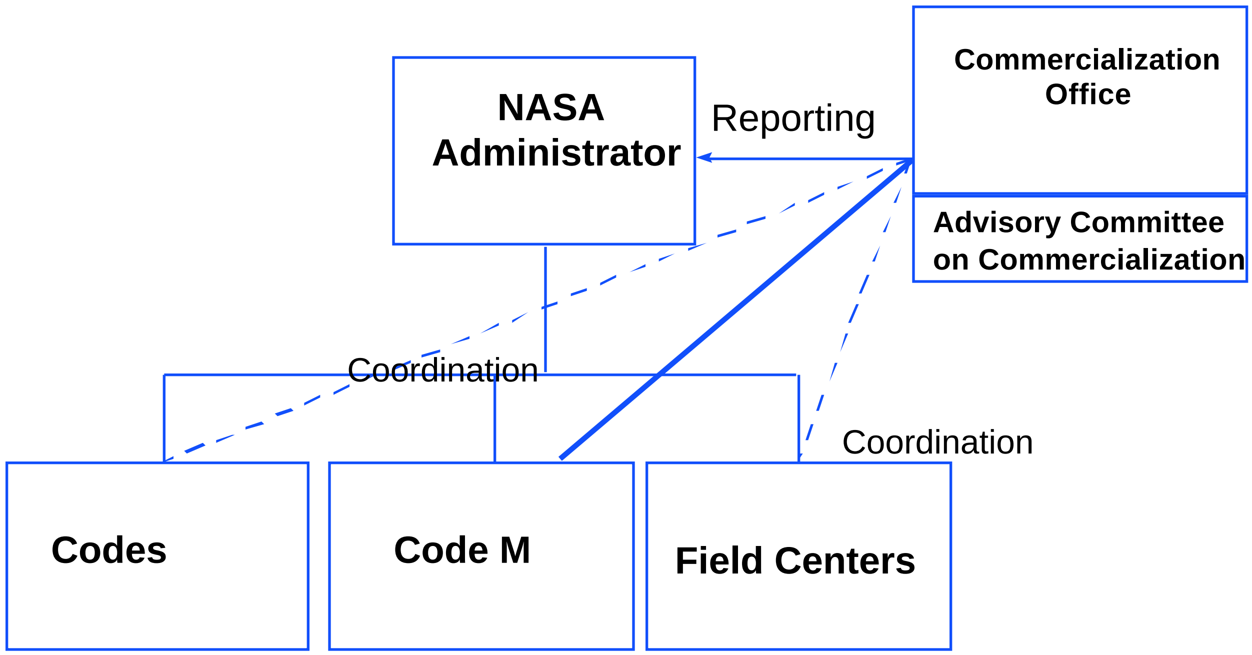

Figure 9. Placement of Commercialization Office

The CDO would begin this process by refining the strategy, developing contacts within the private sector, consulting with NASA Offices and Field Centers, and recommending some early policies to NASA. The CDO should also initiate an intensive effort to develop innovative approaches to privatization. This organization should contain sufficient in-house technical, legal, and organizational expertise to coordinate actions and obtain support from within NASA. But the major thrust of the CDO would be business, and so it must include personnel with extensive experience in the business world. Venture capitalism, business and legal processes, and technology and product development must be represented. This business side of the CDO should be found outside of the government. They would help to form the SEDC.

We based many of our recommendations for an SEDC on Case Study 7, an examination of the New York City Economic Development Corporation (EDC) summarized in Annex C. The EDC has demonstrated success in retaining existing business, and attracting new companies to New York City. We believe that there are certain parallels which can be drawn between the City and NASA. Both are government entities, both have reputations which discourage business development, and both are faced with the need to develop commercial activities within their domain. Although there are some clearly marked differences, we believe that some of the tools used by the EDC are applicable to NASA's situation, and the lessons learned are of use.[29] One

[29] The EDC routinely recruits and retains companies into the City, expands economic activity of small and growing companies, assists in obtaining necessary governmental approvals, and contributes to City planning and feasibility studies.

major exception is that, unlike the EDC, the SEDC should quickly become an independent entrepreneurial activity, building business interests from outside of NASA.

Initially, the SEDC would be in the form of a corporation, allowing it to approach its mission in a more business-like manner than the government, or even the CDO.[30] It would promote a link between NASA and the private sector, providing a business environment for industries seeking access to space for commercial purposes, or interested in privatization of space assets. It would eventually take over the commercialization effort, acting in the role of a true development corporation. Until this "spin-off" occurs, it should support the CDO in conducting a series of outreach programs, encouraging industry to consider human orbital space flight, reaching a better understanding of the special problems of the private sector, and exploring benefits of space to the commercial marketplace. It could also help NASA become more appreciative of private sector values and approaches.

The ISS could be used as a pathfinder by employing the Office of Space Flight as a test bed for the implementation plan described above. One way to adopt an implementation process for commercialization in NASA is to try it out as a pathfinder at a project level. The ISS is an excellent choice for this role, since it will be NASA's most capable space asset for commercial use. Additionally, ISS resupply is a mission which lends itself well to privatization, whether through the Space Shuttle, or eventually, the Reusable Launch Vehicle. Although the pathfinder strategy has major benefits, such as reducing organizational disruption while optimizing procedures, it also has some serious downsides. One of these is that such a test bed cannot succeed in a hostile environment. And it cannot be a vehicle for the radical changes needed throughout NASA. Further, if the pathfinder fails it may condemn the concept at the NASA level. Therefore, it must have sufficient support by the Administrator to get a fair trial throughout NASA. The following specific objectives could be pursued:

- establish new relationships with industry for ISS utilization planning,
- develop new processes for Code M responsibilities, and
- serve as pathfinder for NASA implementation.

The outreach program could also serve as an industry briefing for a Code M solicitation which requests proposals from industry for government/industry partnerships to conduct commercial ventures.

[30] There is a need for a public-private institution to promote space commercialization. [14]

ANNEX A. SELECTED REFERENCES

SELECTED REFERENCES

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ANNEX B. SPACE COMMERCIALIZATION EXPERTS PANEL (SCEP)

TERMS OF REFERENCE

TERMS OF REFERENCE

10 OCTOBER 1996

Membership

Mr. James Beggs
Dr. John McLucas
Mr. James Rose
Mr. Howard Schue
Dr. Terry Straeter

Background

In 1995, U.S. domestic revenue from commercial space activity was slightly less than $7.5 billion.[31] Most of this revenue came from unmanned space activity (such as satellite communication services and remote sensing) or support of unmanned space activity (such as ground equipment, satellite manufacturing, and launch services). The International Space Station (ISS) may present new opportunities for commercial *manned* space activities. For example, there are fluid mechanics and transport phenomena that can be observed in the microgravity environment of space that are masked on earth.[32] In addition, some areas of biological research may have potential for commercial development and perhaps even manufacturing in space. The potential commercial value of these and other areas of interest is unproven. However, the issue of emerging commercial opportunity through manned space activity is important for NASA planning.

In an era of tight budgets, adopting the practices and the competitive outlook of private industry could also benefit NASA's management of space activity. NASA's recent privatization efforts have shown a willingness to improve management, and to consider innovative solutions. However, further steps are needed to define the appropriate relationship between business and government in this area.

Developing services, processes and products in space for markets on earth has long been of interest to business leaders. For instance, ATT developed Telstar, the first commercial communications satellite, which was launched by NASA. In the late 1970s the COMSAT public/private partnership promoted geosynchronous satellite communications systems. Despite formidable initial risks, this business area has grown to billions of dollars per year.

Efforts to find commercial application from manned space activity have had limited success so far. Such activity is almost entirely dedicated to government missions, thus

[31] U.S. Department of Commerce, *Trends in Commercial Space*, Washington, D. C., 1996, Introduction.

[32] National Research Council, Committee on Microgravity Research, Space Studies Board. *Microgravity Research Opportunities for the 1990s.* Washington, D. C., 1995, pp. 3-4.

dominated by government procedures and funding. This situation has been viewed by Congress and many at NASA as a transitory period in space history, similar to the pre-commercial satellite phase - one which awaits a venture capitalist with vision, courage, and the right idea. But NASA must be receptive to such ideas and have both the strategy and organizational structure to further their success.

The ISS is usually justified by appealing to objectives other than its furtherance of commercial activity. These objectives include scientific research, national prestige, and establishing a platform for further exploration of the solar system. But surely the expenditure of more than $17 billion over the next six years should also yield commercial payoffs. If that is so, there are a number of questions which are raised, such as: What areas are most likely to result in future profit? What are government and industry doing to ensure the best chance of commercial success through space-borne ventures?

Among the technology "Areas of Opportunity" for space commercialization are some which have a history of 10 or more years of activity. These include crystal growth, materials processing and some biomedical research efforts. Others, such as tourism or advertising, are relatively new. A related area of potential growth is development and operation of space infrastructure, including launchers, space modules and test equipment. Such infrastructure businesses may provide new or enhanced capabilities in space. This could be valuable in aiding development and production of specialty commercial products to be used in space. They could also make space operations more affordable by reducing the costs, weight, or volume involved.

NASA has recently taken steps to privatize the management of important space infrastructure, such as the Shuttle. NASA may be able to bring costs further down through more use of the best commercial business practices and less use of "build to print" government specifications. However, NASA must also ensure that safety standards are maintained. Finally, for commercialization to be an achievable national goal, NASA needs to develop commercial interests who will want to travel to space regularly. This could lead to economies of scale and therefore cost reductions for NASA activities.

NASA has given the Potomac Institute for Policy Studies a grant to conduct an independent study of ways to commercialize space through the ISS. Our approach is to perform preliminary research with a study team, then solicit comments from NASA and industry on our preliminary conclusions and incorporate the comments into updated findings. The Space Commercialization Experts Panel will then be convened to comment on, and further the research.

The Study Team will focus most of its attention on industries which are interested in commercial opportunities related to manned space activity. Only industry can provide the understanding of the commercial benefits of space, the commitment to pursue commercial ISS activity, and appropriately determine the requirements for this commitment to reach fruition. Our Study Team will identify and contact many of the industries which may have the potential to pursue space-based businesses. We will ask NASA's Centers for Space Commercialization (CSC) to assist in this, but some industries will need to be contacted independently. Through interviews and case studies, the ISSC Study Team will identify potential areas for space exploitation, reasons for industry interest (or disinterest) in space, and industry needs to make commercialization achievable. The results will probably vary considerably from one "Area of Opportunity" to another, and from one company to another.

As we follow the study strategy outlined above, a clearer picture of commercialization opportunities should begin to emerge. We will consult with NASA and the SCEP for their views to create the best possible recommendations. The Institute will submit a final report which contains our insights and conclusions. The intent is to provide constructive recommendations which will be embraced and enacted to further the fullest commercial use of space.

ISSC Study

Study Objectives. Two purposes are addressed by the ISSC study. These are reflected in the major issues to follow.

1. Determine the viability of commercialization of space through the ISS.

2. Define terms and conditions under which NASA and industry can enable the initiation and sustainment of profitable commercial activities in space through the ISS.

Major Issues. In order to understand the viability of potential commercial opportunities identified in the study, a series of major issues must be addressed from both a collective (Areas of Opportunity) and an individual (specific companies and products) basis. These major issues are at the core of the determination of plausibility for each proposed commercial strategy.

1. What is the national intent in encouraging space commercialization? Is there a commensurate strategy, policy, organization, and implementation plan aimed at realizing that intent?
2. What are the "Areas of Opportunity" for commercialization?
   a) What are the technological and production potentials and challenges for each area and affiliated products?
   b) What are the commercial potentials and challenges for each area and affiliated products?
   c) What circumstances are necessary for their success?
1. What should the government intent be, and how should it be facilitated through strategy, policy, organization, and implementation planning?

The process described above will be pursued through the five overlapping phases listed in Table 1, below. These phases are explained in the next section, which also provides a summary of progress made thus far.

PHASE	TASK
I.	**Formulation of Study Strategy** · Define study goals · Define major issues · Establish criteria for acceptable answers · Define study approach · Define final product
II.	**Pre-Study Investigation** · Identify and gain access to study resources · Define areas of opportunity for commercialization of space · Identify appropriate companies, CEO's, and contacts • Begin to identify and define study products
III.	**Data Collection/Analysis/Conclusions** · Examine and process background information · Perform selected Case Studies · Perform Technology Assessments
IV.	**Consultation of Interim Findings and Recommendations**
V.	**Final Report**

Table 1. ISSC Study Phases

Terms of Reference of the SCEP

The Space Commercialization Experts Panel (SCEP, or Panel), will advise the Potomac Institute for Policy Studies on commercialization through manned space, using the International Space Station as a pathfinder. Specific terms of reference are summarized below. They are meant to be suggestive of the questions the study seeks to address, and the level of detail desired. However, they are not meant to constrain the SCEP from additional or alternative valuable insights.

1. Provide guidance on conduct of the study and assist in identifying useful data sources.
2. Review, assess, and extend data and analyses presented by ISSC Study Team.
3. Define Space Commercialization with rationale.
4. Identify ways that NASA could encourage commercialization of the International Space Station:
    a) For policy recommendations, suggest useful models that have worked in the past, or justifications in the law and elsewhere;

b) For hardware recommendations, identify successful commerce examples and opportunities; and

c) For management recommendations, estimate any potential cost savings and the projected results of these cost reductions on commercialization.

1. Comment on the effectiveness of NASA organization for commercialization (e.g., Commercialization Centers, Space Technology Enterprise), and ways to improve.

2. Evaluate Areas of Opportunity identified by the Study Team and comment on which may be commercialized through the utilization of manned space:

e) Products, processes, and technologies under each area;

f) Companies working in these areas;

g) Business opportunities for each area;

h) Technological risks for each area; and

i) Reasons that space access is required.

1. Discuss technical features of the ISS that may impact commercialization, e.g., microgravity environments, vibrations, vacuum conditions, orbit parameters, equipment/facility availability. Given that the ISS design is all but set, are there any workarounds that are indicated?

2. Suggestions for pricing policy for commercial payloads for ISS? Allocation of time aboard and utilization of NASA resources? Liability?

3. Review and contribute to the Final Report.

4. Assist in disseminating the study findings to appropriate decision makers, as determined by Study sponsors.

Operation of the Panel

The Potomac Institute for Policy Studies (PIPS), as part of its task with NASA to manage the International Space Station Commercialization Study, has established the SCEP. The Panel will be composed of experts in space, technology and business matters relevant to commercialization of space. At least two Panel meetings will be held during the study to brief and consolidate the views of the Panel. Individual tasks will be assigned for the intervals between meetings.

Anticipated Schedule

The Space Commercialization Panel deliberations and reporting will extend over a five month period (1 October 1996 to 1 March 1997), with extensions if needed.

ANNEX C. A SUMMARY OF DISCUSSIONS AND CASE STUDIES

ISSC DISCUSSIONS AND CASE STUDIES

Case Studies focus on individual companies to determine their perspectives on the viability of commercialization of their product or process through the ISS and on conditions which must exist to realize successful commercialization in space. Companies reached for discussion or case studies are listed below.

I. A Partial List of Personnel and Organizations Contacted

Companies:

ITA: John Cassantos (President), Michael Bem (Director for International Operation)
SHOT: Mark Deuser (President)
VIVO RX : Dr. Glenn Spaulding (Vice President)
Boeing: John Winch (Vice President, Huntsville Plant Manager), J. Jeffrey Irons (Manager, Civil Space Business Development), Dr. T. K. Jones (Vice President), Jeffrey Trauberman (Senior Representative, Space Programs)
McDonnell Douglas: Charles Walker (Senior Specialist, Program Development, Advanced Systems), Dr. Peter Kurzhals (Director, Advanced Space Programs, Space Flight Division)
Lockheed Martin Missile Systems: T.K. Mattingly (Vice President RLV Programs, Aeronautics Sector)
SPACEHAB: Nick Fuhrman (Director, Government Relations)
LunaCorp: David Gump (President), James Dunstan (Executive Vice President)
Johnson & Johnson: Dr. Robert Gussin (Corporate Vice President, Science and Technology)
X PRISE: Dr. Peter Diamandis (Chairman/President)
Aerospatiale: Benoit Lefebre (Director of Space and Defense Programs)
Novespace: Jean Pierre Foquet (President)
GDE Systems, Inc.: Dr. Terry Straeter (President and CEO)
Walt Disney Imagineering: Dr. Eric Hazeltine (Vice President and Chief Scientist, Creative Technology)
Calspan SRL: Dr. Joseph Allen (Chairman)
Thiokol: Donald R. Sauvageau
Rockwell/Rocketdyne: Kate Kronmiller (Director, Rocketdyne Division), Shep Hill (Vice President, Government Affairs)
Tandy Corp: Steve Leininger (Technologist)
ADM: Carla Miller (Corporate Spokesperson)
Eaton Corp: Dr. Stanley Jaskolski (Vice President, Technology Management)
Warner Bros: Karl Samrock (Theatrical Publicity)
Multimedia Medical Systems: Michael Kerouac (President)
Bankers Trust & Co: Wolfgang Demish (Partner)
SEMATECH: Terry Romig (Program Manager For Ion Implantation)
Air Products & Chemicals: Phil Winkler (Manager, Government Systems)

Arvin Industries: James Baker (Chairman of Board)
Henry J. Kaufman & Assoc.: Mike Carberry (CEO)
CARMA: Albert J Barr, (President)
Northrup Grumman: Jim Littig (Vice President, Government Relations)
Peregrine Properties, Ltd.: Charles Lauer (President)

Universities:

UAH Dr. Charles Lundquist (Director, CMD), Dr. Francis Wessling (Associate Director CMD), Dr. Robert Naumann, Dr. Marian Lewis
UAB: Dr. Lawrence DeLucas (Director, Macromolecular Crystallography Center)
Vanderbilt: Dr. Taylor Wang (Director, Microencapsulation Center)
Auburn: Dr. Tony Overfelt (Director, Center for Casting), Dr. Henry Brandhorst (Director, Space Power Institute)
Worcester Polytechnic Institute: Dr. Albert Sacco, Jr. (Professor and Department Head, Chemical Engineering)

Government:

NASA: Wilbur Trafton (Associate Administrator, Code M), Albert Dimarcantonio, Leonard Sirota, Dr. Ray Askew, Edward Gabris, Candace Livingston, Ray Whitten, Donna Fortunas, Harold Nelson, Eve Lyon, Dr. Don Frasier, Bruce Luna
DOC: Dr. Mary Good (Undersecretary for Technology), Keith Calhoun-Senghour (Director, Office of Air & Space Commercialization)
DoD: Rick Dunn (DARPA General Counsel), John Jennings (DARPA Manager, TRP)

Associations, Foundations:

U.S. Space Foundation: Richard Macleod (President)
CSTA: Ray Deutsch (President)
Space Transportation Association: Thomas Rogers (President)

Advisory Committee for the ISS:

Thomas Young, Dr. Joseph Allen, BG Charles Bolden, Jay Chabrow, Barbara Corn, Dr. Lyle Cox, Dr. Lawrence DeLucas, Dr. Eilene Galloway, Dr. Robert Gussin, Dr. Eric Hazeltine, Dr. Albert Narath, Diane Weston

Selected Quotes From Discussions

"Been there, done that (PROSHARE used on Shuttle)!"

"The banking sector is the closest friend to companies who are looking toward industry in space … bankers are making generous financial terms available …. look for a long turn around time."

Excited about ISS because it will significantly reduce the price of diamond thin film R&D, and make it more commercially viable."

"Commercialization crew at NASA is fairly naïve - they are missing out on the opportunity in telemedicine for the large sector."

"Space is not even an issue - it is so far beyond what we do, we are definitely not interested."

No interest, feels that it is something that has come and gone - early work was not producing results.

"Cost is a big impediment, as a result, R&D (in Space) is not on our radar screen, it is too far in the future."

"We need a home run to get more interest in space commercialization."

"We do a number of sensors in the black world. We got out of the commercialization market because of the Conestoga disaster, and we are delighted to be out of it."

"Government wants to get commercialization out into private hands, but they don't want business to have it. It is critical for NASA to privatize,.."

Summary of Case Studies Results

This section provides some information on the case studies performed. A report covering the specifics of the cases studies and principal discussions has been published (see [5]). Studies were performed on twelve projects.

Case Study 1. Space Hardware Optimization Technology (SHOT)
Case Study 2. Boeing: Mir Experience
Case Study 3. Microencapsulation. (Vanderbilt U, VIVO-RX)
Case Study 4. Macromolecular Crystallography. (University of Alabama in Birmingham)
Case Study 5. NASA Space Sciences Laboratory (Marshall Space Flight Center)
Case Study 6. Centers for Casting and Power & Advanced Electronics (Auburn University)
Case Study 7. New York City Economic Development Corporation
Case Study 8. Zeolites (Worcester Polytechnic Institute)
Case Study 9. Virtual Presence (LunaCorp)
Case Study 10. Gallium Arsenide (Space Vacuum Epitaxy Center & Space Industries, Inc.)
Case Study 11. X-Ray Device (University of Alabama in Birmingham)
Case Study 12. Education Programming (Walt Disney Imagineering)

Case Study 1. Space Hardware Optimization Technology (SHOT)

SHOT was founded in 1988. They have seven full time employees, and three part time, but also use the services of approximately 50 consultants and manufacturers. The company is privately held, and the core activity is R&D engineering, with additional business being derived from spin-off products. SHOT's programs are all directed towards designing and building equipment for conducting life science and biology experiments in space. Their major programs are:

- Separation Devices (ADSEP - Advanced Separation) for organic cellular material, but with potential for wider biomedical application. This device is also planned for use on ISS
- Developing custom built incubators for chicken, quail, and reptilian eggs.
- Thermally controlled transporter designed for transporting, storing, and processing biological materials in space.

The first two programs will be the basis for services to clients, whereby they will deliver the scientific materials to SHOT, while the Thermally Controlled Transporter will be offered for sale or lease to both NASA and private companies requiring such a device.

Inception: When SHOT first approached NASA they had no design for ADSEP. Through Dr. Lundquist, at the Center for Material Development in Space (CMDS), SHOT was asked to submit a proposal and subsequently received a small contract to provide engineering support on the University's Organic Separator (ORSEP). Additional sub contracts were awarded by the University, and SHOT continued to provide engineering design services until the University built a lab unit prototype of ORSEP in 1991. Based on the success of this prototype, SHOT was contracted to design a flight unit, which the University built in 1992, to be flown on SPACEHAB 1 and 2. Throughout this process SHOT was a sub contractor, and the principal investigator came from the University.

ADSEP Experience: Shortly after the SPACEHAB 2 experiment, SHOT took on more responsibility for the design and building of an advanced model of ORSEP (which became ADSEP). SHOT received an SBIR grant in 1992 for the design and construction of the first ADSEP. They agreed that NASA would own the prototype separator which was to be built, but SHOT would retain all the rights to the intellectual property, and hence the right to commercialize ADSEP. Under the SBIR grant, SHOT developed and built a prototype, which was fully functional, but not flight qualified. This phase of development being completed, SHOT used their own funds to build a flight version of ADSEP, eventually flying on SPACEHAB 4 in May 1996. It is SHOT's intention to continue to make applications to fly ADSEP (and the incubator) on future shuttle missions, as well as ISS.

At the beginning of the process, SHOT worked with Code U in order to obtain space on shuttle missions. Although the SHOT equipment was part of an experiment, the choice of hardware (SHOT products) was made by NASA Code U as opposed to the principal investigator.

In order to attract paying customers, SHOT needs flight opportunities; however, NASA first wants SHOT to have paying customers. Unfortunately, SHOT must be able to provide hard information on scheduling, and pricing in order to obtain customers. NASA was unable to provide this information. To date, this has not been fully resolved, but Code X approved ADSEP for the May 1996 flight.

Clients: In order to offer a viable service, SHOT needs to offer customers a fast and reliable turn around (e.g., one month between receiving the experimental material and returning to the customer after processing on ISS). Eventually, it is hoped that the elapsed time between the customer request and material delivery can be reduced to two to three months.

Originally SHOT had prepared a 5 year business plan starting in 1990, with commercial revenue predicted for 1995. Experience has caused them to modify this to a 10 year plan, with revenue expected in year 2,000.

Cost: At this time, the costs of dealing with NASA can only be quoted on the basis of one flight, and one set of applications. The costs of compliance to certification demands do not include any engineering, design or production. The Flight integration and support costs SHOT expended were approximately $250k. These were personnel, consultant and travel expenses associated with the process. It is expected, under the current format, that the costs for each future flight would be similar. It is estimated that the cost to SHOT to support the ADSEP program for the last 6 years was approximately $750K. Therefore, although the actual flight was free, the cost of getting onto the Shuttle was on the order of one million dollars.

Case Study 2. BOEING

The focus of our discussions with Boeing, in Huntsville, was the Mir Space Station Payload Service, a Mir-based commercial venture being developed by Boeing in cooperation with Energia and Honeywell.

The payload venture is intended to provide an affordable, turn-key capability to place and operate payloads on Mir, with near-term access to space in early 1997. As the word “turn-key” implies, Boeing and their partners are offering integration, launch and operations services for experiments on Spektr. The service is for external payloads only. Mir has few internal experiment opportunities available and Boeing tries to avoid competition with the Shuttle and SPACEHAB. Boeing does not intend this project to compete with NASA, rather it is to act as a market test and pathfinder for eventual ISS and Boeing services. The project success factors also included a return on investment (ROI) to Boeing, however this data is proprietary.

Boeing was not willing to divulge the names of the potential customers approached, but between 75 and 100 companies have been contacted, all were selected for having shown prior interest in flying on the Shuttle, and more than 50% of these customers can trace original funding for the applicable experiments back to NASA. While only 2 customers gave a definite “no interest” response to the approach, none have signed up to fly, but the rest remain interested. Finally, all customers are American companies. The choice not to approach foreign entities was based on the cost of marketing[33].

Boeing described their service as affordable and simple, being open to a wide variety of industry, government and international scientific and revenue producing applications. The payload accommodations are:

- Payload dimension - up to 1.0 meter length X .65 meter diameter (cylindrical)
- Payload power - 28 volts up to 200 watts
- Weight up to 100 kg
- View perspective - Nadir (30-60 orbits per month); selected stellar, limb and solar views also possible
- Data downlink - up to 5 MB/day
- Orbit duration - up to 3 years
- Access to space - up to 5 times per year
- Standard Data Interface - MIL STD 1553B, EIA RS-422, Ethernet.

First flights were scheduled for March 1997.

The service was priced at $7M per mission with a lead time into space of 12 to 15 months. The vehicle to be used is Energia's Progress resupply vehicle, which has a 100% launch reliability record. The market testing aspects of the project have lead Boeing to some interesting findings:

- A price of $7M is too expensive. The probable acceptable range of burdened cost for this service is $3-5M.[34]
- Industry requires shorter lead times. Seven to eight months would probably be acceptable.
- Proprietary customer information was perceived as being at risk on a Mir mission.

Case Study 3. Microencapsulation Systems (VIVO RX and Vanderbilt) VIVO RX, a small company in Santa Monica, California, is developing materials for cell-based therapies for treatment of disease, such as wound dressing (using skin cells) and kidney or liver failure. VIVO RX was drawn to space because, in their opinion, sufficient quantities cannot presently be grown through conventional earth-based processes. There are basically two ways to obtain tissue. One is to use animal tissue (e.g., porcine) and the other is to grow cells from humans in a bioreactor. The latter is preferred but requires microgravity for effectiveness.

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[33] The "Marketing" of this service did not involve advertising and promotion beyond some basic Internet announcements.

[34] Pegasus appears to offer a cheaper alternative to the Boeing service. However, the Pegasus charges do not include the integration and operations services, as does Boeing's service.

Both VIVO RX and Vanderbilt conduct research into the encapsulation of materials in microspheres in order to protect the materials from antibody assault, and to time-release drugs into the system. For example, by protecting islet cells inside a microshell, diabetes patients can receive injections of insulin-generating cells, rather than insulin itself. The largest benefit is to reduce the high levels of insulin which occur in the body just after injection, to be followed by diminishing levels which quickly become too low to support the bodies need. These cycles cause the devastating side effects, such as blindness and heart failure, that so often occur with diabetes. Microencapsulation materials must have carefully tailored and optimized properties in order to withstand assaults by the body's immune system, to minimize this rejection, to maintain optimum permeability to allow passage of sustenance and drugs (while barring anti-bodies), and to provide close contact with the body's distribution systems. So, for diabetes treatment, the islet cells must be surrounded by a shell with great strength and permeability.

Vanderbilt has been supporting NASA commercial programs for the past four years. Its Director, Dr. Taylor Wang, is in the process of forming a commercial venture. He has produced a business plan, with the help of the Vanderbilt Business School, and has submitted it to the venture capitalist community for funding.[35] He is quite confident that they will respond favorably and his market estimates support that optimism (diabetes constitutes one-seventh of all health cases). There are two principal differences between the product being pursued by Dr. Wang and those developed by others working in the field. The first is the use of many material components in the shell, rather than the binary compounds used by others, allowing a greater ability to tailor the shell to meet the numerous requirements for the encapsulated cells. Second is the production of larger spheres, enabling laproscopic removal if necessary. The latter may open the market of microencapsulated drugs to less seriously ill (thus more risk-averse) patients -- Type 2 diabetics, for example. So, the addressable market will be much larger. The difficulty is that it is possible that these large microspheres can only be produced in space. If this is the case, due to the current reduction in commercial space flights, it may be impossible to have them ready when clinical trials begin in 3 - 5 years. Further, the multi-component spheres require longer-term production processes; thus, they need the stability and time inherent in the ISS or a free flyer.

Case Study 4. Macromolecular Crystallography Investigations (University of Alabama in Birmingham). The Macromolecular Crystallography Center is developing and growing protein crystals in space in order to better understand their structure, as well as investigate their utility for a number of medical applications, such as a time-release vehicle for drugs (e.g., insulin and interferon). Space is necessary because it allows larger and more perfect crystals to be grown, due to the lack of interfering or distorting forces, such as those imposed by convection flows. Once a crystal is formed, its structure and its application can be studied on earth. The Center has produced 25 or 30 crystals in space. Although none are ready for the market, several are undergoing clinical testing.

The future of protein crystal research under microgravity conditions looks good. There are around 100,000 protein crystals in the human body. Thus far, 2,000 structures have been defined. Importantly, new knowledge and techniques are increasing the effectiveness of protein crystallography through DNA studies and a number of related research efforts. Although it is certainly true that not all protein crystals are of interest, and perhaps there are some which will resist crystallization, it seems there will be a need for space-based research for a good while.

[35] Dr. Wang has also incorporated the support of the medical school at Vanderbilt.

Because protein crystals are up to 80% liquid, they can be used as a "sponge" to soak up drugs. After these crystals are injected into a patient, the drugs they embrace are released at a fairly constant rate as the crystal dissolves. This both extends the life of a single injection and eliminates or reduces the peaks and valleys of drug introduction, so harmful to those now undergoing drug treatment for diabetes and hepatitis.

Case Study 5. NASA Space Sciences Laboratory at Marshall Space Flight Center

This NASA research group has performed research in polymers for a number of years. During the past year they have begun to develop relationships with industry to commercialize some of the emerging organic polymers through space-based research in the following areas:

1. Nonlinear Optics. Organic polymers are well suited to uses demanding controllable optical nonlinearities and other unique properties. Optoelectronic devices, which are increasingly important to the information and communication revolution, represent an important class of employment. Space provides research advantages in the development of these polymers through containerless processing, property measurements, and measurement of diffusion coefficients (by mitigating the distorting effects of convection).

2. Aerogels. The study and formation of this solid gel have application in exploiting its light weight and insulating properties.

Case Study 6. Centers for Casting and Power and Advanced Electronics (Auburn University)

Auburn University manages two centers.

1. Center for Commercial Development of Space Power and Advanced Electronics. This center, led by Dr. Henry Brandhorst is developing advanced space power systems to decrease power costs in space while increasing power levels. This effort includes power conditioning, distribution, and management. It demands improvements in the performance or integration of sensors and new materials, as well as dramatic increases in system reliability (without resort to redundant componentry). A major effort being pursued is the employment of Silicon Carbide to increase high temperature tolerances for electronics components. An extremely efficient power converter was developed for both space and terrestrial use. Over 900 power converters were sold after the prototype developed by the Center and its industrial affiliates was transitioned into industrial manufacturing.

2. Center for Solidification Design. Under the direction of Dr. Overfelt, this center has focused on measuring and controlling the thermophysical properties of casting alloys. The approach used is to produce small containerless melts in space of alloys of interest, by suspending the molten metal in microgravity. Through this approach they eliminate container contamination and improve measurements by looking directly into the metallic melt. Computer models developed or improved under this effort are projected to save up to two years from a four year casting design process. Progress has been sufficiently good to attract industry participation, even though they have only flown on parabolic arc aircraft flights. Shuttle or Space Station facilities will give them the time and stability needed to improve their observations considerably. This is another example of space research done to improve products or processes on earth. It is difficult to

imagine how this research could be done without microgravity. The direct product of this research is the improvement of computer models of the casting process, making them sufficiently accurate to reduce trial castings, thereby reducing the time to delivery of a production casting. New alloys will continue to present themselves, requiring this sort of characterization for years to come.[36]

Case Study 7. New York City Economic Development Corporation (EDC)

In the 1970s New York experienced a financial crisis. The city was all but bankrupt, services were declining, infrastructure was decaying, and businesses were leaving, further eroding the tax base, and exacerbating the problem. New York was no longer perceived as a place to do business. As communications improved, companies could move their operations from the City, and many did.

The City appointed a Deputy Mayor for Economic Development, with a support infrastructure designed to manage the city's commercial real estate.[37] As with the Shuttle and ISS, the city was faced by the need to find commercial tenants for these properties.

In 1992, after a number of years of moderate success, the EDC was formed as a quasi government/private organization to manage the entire process, and although the Mayor's Office of Economic Development remains, the EDC is the heart of the business activity. The initial funding was to be New York City taxes, however, the EDC has since become self-supporting. The EDC incorporated the Industrial Development Authority (IDA) and the old city Department of Ports and Terminals (previously Markets).[38] The Chair of the EDC cannot be a public official. As a separate corporation the EDC has more opportunities for providing financing mechanisms, however it still responds to the Mayor, and works closely with the City agencies. It is considered the Mayor's primary vehicle for economic development, assisting businesses to become more competitive, more productive, more profitable.

To further economic growth the EDC:

- Recruits and retains companies interested in operating in New York City by helping them take advantage of services and programs available through the EDC and other entities,
- Expands economic activity through programs that provide small and growing companies with access to financial and tax incentives which lower the cost of doing business,
- Improves, leases and sells real estate for commercial and industrial use,
- Develops, manages and improves New York city's aviation, maritime and rail freight facilities,
- Assists projects in obtaining necessary governmental approvals, and
- Conducts planning and feasibility studies on behalf of New York City.

Annually, the EDC directs and monitors the expenditure of more than $200 million of the city's capital budget programs for projects and properties promoted, managed or developed by the EDC.

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[36] The National Research Council designated this as an area of potential high payoff [1].

[37] Through tax forfeitures and other actions the City accumulated industrial, commercial and residential real estate.

[38] The IDA, Ports and Terminals and other departments and corporations addressed specific markets, and through incorporating them into the EDC, their scope, and hence ability to provide a broad and effective service has been enhanced.

The EDC role in capital program projects varies from providing support, both financial and advisory, to private developers for commercial and industrial development, to enhancing the city's ports and transportation facilities, to improving public wholesale markets, to revitalizing neighborhoods through street and access improvements.

To do this the EDC employs a staff of engineers, economists, architects, lawyers, real estate experts, banking professionals, public relations staff and marketers. All are employees of the EDC, and report to the President of the EDC. Salaries are set by the EDC, and are independent from the city scale.

The atmosphere has become similar to that of banking and business rather than welfare or other state functions. Certainly mistakes are still made, and the EDC is always under the scrutiny of the press, however business is now coming to New York, and the city is benefiting.

The EDC's definition of commercial is broad. From the point of view of this study, it is worth noting that its current focus is technology. Again the application of the term is broad. One "technology" business provides high-tech entertainment based in the Empire State Building (a parallel may be drawn with LunaCorp.). The EDC was criticized for this action, however they point out that jobs have been created, and that the return to the EDC and investors has been excellent.

The EDC does not lead efforts to privatize city activities; however, they do sometimes become involved. For example, the city is now seeking to privatize the city owned hospitals (such as Bellevue). The city is taking the lead, but the EDC is playing an advisory role.

Funding Provided:

In order to attract business, EDC has had to offer more than the ability to cut bureaucratic red tape, and good public relations. Companies required incentives, particularly when other state and local governments were rolling out gold trimmed red carpets.

The EDC provides conventional tax incentive programs to companies, which are calculated on a pay-back rate to the city using economic models. If a company does not meet promised goals, the incentives are reduced, and if a company reneges entirely, all moneys must be paid back with penalties. The other funding programs are of greater relevance to NASA:

- The Industrial Development Authority (IDA) Equipment Financing Program, which enables manufacturers to purchase the latest in production equipment and machinery through tax exempt financing.
- The IDA Straight Lease Program, which allows industrial companies to benefit from a variety of tax exemptions on newly acquired properties.
- The New York City Discovery Fund, a venture capital fund, which can provide companies with capital if they specialize in advanced technology and meet certain financial criteria. This fund is capitalized at $135 million, and will invest up to $10 million per project. The fund was initially seeded by EDC, Con Edison, Brooklyn Union Gas and other local companies. Using Federal matching programs and other vehicles, the fund was increased to the current level. Investments are made on normal venture capital terms, and the fund is administered by an outside company.
- The Small Business Reserve Fund, which assists banks in making loans to companies which may not otherwise have qualified. The reserve is an insurance pool, to which the EDC contributes 7%, the borrower 5% and a consortium of banks the remainder. The EDC is not involved in the loan process, having learned that banks are best suited to this work.

All deals are negotiated on a case-by-case basis, and there are no set parameters. It is possible that applicants with identical situations will receive different "deals". Negotiation is the key. In certain cases, there are programs where the rights are established under the law and the parameters clearly set, and the terms non-negotiable. In most of those cases the EDC does not get involved. In fact, their goal is to work themselves out of business, by having all necessary aid based on law, and for the city to have been made a good place for business.

Relationship with City Government:

The EDC assists companies in their dealings with the city, not only at the time of the initial action, but whenever an old client calls with a problem. The EDC maintains a relationship with the Mayor and Commissioners as well as other civil servants. There are instances when the EDC president is called upon to intervene. There is no formal arbitrator, however depending upon the issue, it may be acted upon by entities such as the City Council.

The EDC plays a significant role in suggesting new legislation, principally State and City, and changes to existing legislation in order to further their mission. One of the intents is that special programs which they have run with success, should be passed into law, and be administered by the City as rights for qualified companies.

Neither the EDC, nor the city will ever enter into an agreement where they would be the "anchor tenant" for a project.[39] It is possible that they may become a tenant or a customer of a recruit company, but that would happen on merit, after the project is completed. Any recruit must satisfy the EDC, or the banks, that their business plan will stand on its commercial merits.

Outreach:

Until recently the EDC performed very little outreach. The reason was that they were concentrating on retaining business, as opposed to bringing in new recruits. Several brochures were produced, and there was a significant amount of attention paid to their program, and businesses were aware of their existence. With their current goals to attract recruits they are launching a more proactive program. However, there are staff whose role is to travel and sell the concept of locating business in New York.

Interviewer's Observations:

The EDC behaves like a business, as opposed to an arm of the government. Some of the funding tools, such as the Discovery Fund, are managed in the same way as any private sector fund. Where practical, the EDC has removed itself from the rolls normally played by bankers. To do this they created programs and support vehicles, then passed the day-to-day activities over to the private sector. In this regard, their philosophy is that banks will do a better job at banking than they would.

It is interesting to note that the EDC has changed from a public service depending on tax money for funding to a self-funded entity. Some of their internal activities, including providing bonuses for employees, reflect private practices rather than government. Although their role of supporting job creation in a city differs from NASA's need to commercialize space, their philosophy, some of the funding vehicles, and goals are directly transferable to NASA's situation.

The fact that they started as an internal government office is normal. And it is worth noting that the Mayor's Office For Economic Development remains in existence. However, it is clear that the EDC could not have functioned in the way that it does, if it had not been formed as a Not-for-Profit, Local Development Corporation.

Case Study 8. Zeolites (Worcester Polytechnic Institute)

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[39] NASA's role, in fostering commercialization of piloted space, should include acting as an anchor tenant on occasion, since circumstances and stage of life of the SEDC are different.

During Dr. Albert Sacco's involvement with NASA, he has gained unique insights through serving as a scientist, astronaut, and commercial entrepreneur at the same time. Because of this combination of roles, and the good working relationship he established with James Rose (then at NASA), the Zeolite program was a success, in that it flew and completed valuable research, yielding Zeolite crystals that are superior to those grown on earth.

However, the eventual commercial outcome of the Zeolite experiments was not as dependent on the quality as it was on the relative cost and availability of Zeolites produced on Earth, and the business relationship of the backers of the program. At this point, the terrestrial production of Zeolites are of adequate quality for commercial uses, and their price and availability are better than those products in microgravity. Furthermore, current oil industry cracking equipment is designed for the existing Zeolites, and the industry would be faced with large costs to convert to the use of the ones produced in microgravity. However, one potential customer expressed that should the need arise for microgravity production, they would not hesitate to invest the money required to facilitate production in space.

Beyond the subject of Zeolites, Dr. Sacco gave additional insight which supported many of the previous case study findings, but also clarified some of the issues:

Commercialization Criteria: Dr. Sacco stated that commercialization in space should not be measured against the criteria used on Earth. On Earth, a company may have as many as 10,000 potential products in R&D, with experiments performed 24 hours a day. Of these 10,000, the vast majority will generally be canceled for one reason or another before reaching production and market. However, a vast number of experiments and samples will have been processed to bring the successful products to term. By comparison, space offers few opportunities to experiment (38 samples in the case of Zeolites) and offers sporadic access to the "lab" as opposed to round the clock availability.

For commercial activity in space, the products must be carefully chosen, and the advantages of microgravity exploited to the full. In the case of Zeolite production, the principal advantage is that microgravity speeds the research process by suppressing gravity-related fluid motion. By using the "pure" data gathered in the microgravity lab, terrestrial research can leapfrog several years of investigation.

Peer Review & Science versus Commerce: Dr. Sacco feels that the peer review as practiced by NASA has restricted the scope of science accepted for flight. The reviews are often from the previous NASA review teams and thus often reflect what NASA has funded in the past; consequently they often "miss" the future. The dependence on modeling, for an apparent good reason of testing before flight to save money, has put these engineers and mathematicians in the position of making judgments on which science will benefit from the microgravity environment. The problem here is they are often ignorant of that science (such as zeolite crystal growth, protein crystal growth, fullerines, etc.) and incorrectly assume enough is known to accurately model the phenomenon. Thus they make erroneous conclusions which then take time and money to disprove. This has resulted in NASA missing the "wave" of new possibilities in discovery and potential market advantages for American industry. There must be a better balance in the way peer review is done in the future if NASA hopes to help academics and industry develop **relevant high-quality** science.

There is also the problem of weighing commercial value against scientific value. Dr. Sacco suggests that this is not a necessary or even valid comparison. In fact, the majority of science ends up having some commercial value. The Space Act provides that NASA's efforts should promote the greater good through science, as well as American competitiveness. Commercial science, and basic science can be measured against these criteria, on an equal footing.

A point of divergence is reached, when a course of experiments is moving from basic science towards applied science, and then the final "product." At this point it is probable that there will already be a history established for this effort within NASA, and criteria should always promote bringing existing, successful ventures to closure.

Scientist in Space: The success of virtually any venture, business or science, depends on the staff. It is generally accepted that scientists are better at running experiments than non-scientists. No amount of instruction manuals, expert systems and communications can replace the "gut feel" and experience of a scientist. At present there are approximately 40 scientists with the training and qualifications to go into space. Dr. Sacco believes that the performance of ISS and Shuttle experiments would be greatly enhanced if there were always a scientist on the flight crew, or at the very least available as a visiting consultant during crew change-overs on ISS.

Procedural Red Tape: Every case study has highlighted the burden of excessive paper work. Not only are the application processes complicated, they often need to be fully re-filed for each flight. In fact, the Zeolite flights were all "Grandfathered" after the first flight, however this remains the exception rather than the rule.

The entire process should be reviewed, with particular emphasis on duplication of activities, old procedures or criteria which are no longer relevant, repeat applications, and review committee size and experience.

To the uninitiated (or even the experienced) the flight application and certification process can be a mine field of inconsistencies, inter-Code battles, luck and unforeseen delays. None of these characteristics are attractive to business. A single Business Development Office is required, with the ability and authority to champion an applicant through the process, and protect the applicant from the effects of NASA's internal activities.

[Interviewer's comment: This supports the study draft finding that a properly chartered Business Development Office is required for commercialization to succeed.]

Pricing and Schedule: The interview with Dr. Sacco confirmed that price and schedule remain two of the most important factors in determining the commercial viability of ISS and Shuttle. "Fly early, fly often" is the basic request of any organization wishing to work in space. There is also a willingness to pay a "fair price" for the service, which can best be defined as either marginal cost, or direct cost.

Marginal Cost is the additional cost of flying an experiment on a particular mission. This will be variable but, in the case of a flight which is due to be launched with room on the manifest, the marginal cost is approximately zero. The cost of launching additional weight is probably inconsequential in terms of overall fuel cost.[40] The crew costs will be identical, and there is no opportunity cost.

Direct Cost is applicable to the cost of a dedicated flight. In this case the commercial interest would be that NASA does not apply fixed overhead to the flight, but only charges for expenses directly attributable to the flight. This would include fuel, boosters, turn around, et cetera. This figure has not been accurately calculated, but it is estimated to be less than $100 million.

NASA must also recognize the cost of preparation and compliance, and do everything to reduce these costs without compromising safety.

Scheduling is affected by the current hiatus due to ISS construction. A combination of appealing options have been discussed within the study. One is the use of Mir, and the other is additional Shuttle flights, dedicated to science with a commercial purpose. The ideal mission length would be 28-30 days, since this time is adequate for performing a meaningful series of experiments, and is at the maximum limit of the Shuttle. The greater the time spent in space, the more certain costs are spread, and the lower the per day rate, hence the lower the cost of individual experiments, so the ISS would greatly improve prospects for successful and affordable experiments.

Case Study 9. Virtual Presence (LunaCorp). LunaCorp, founded seven years ago, wishes to place two teleoperated rovers on the Moon before the turn of the century. The concept is to traverse over 1,000 km across the Moon's Sea of Tranquillity with teleoperated rovers, visiting five historic sites. The rovers have a mass of 250 kg each and a survivability of two years. They will travel in tandem, and are to be equipped with 360° panospheric cameras. Mission control will be placed at a public space attraction, and visitors to the attraction will lead the expedition, and will at times drive the explorers themselves. The visitors, both drivers and passengers, will sit on "ride along" motion platforms, where they will view the panorama of lunar terrain as well as feeling the motion of the rovers as they traverse the surface.

The revenues for the program are anticipated to be $365 million. It will be a long payback, and a hard sell for a provider, but data is by far the cheapest product to return to earth, involving the least transportation risk.[41] (The theme park and TV activities are based on the use of the base data product.) LunaCorp attributes their potential for success to four primary factors: understanding the market; having a product with delivery dates and prices; having an active sales force; and that the cost of their product is low compared to competitive products. They also believe that as a non-government entity, they are free to assemble the most cost effective program. The baseline space vehicle is the Russian Proton, a second choice was the Japanese launch service, and a third possibility is the Space Shuttle, but it was never actively pursued. LunaCorp has no business relationship with NASA but, have had ongoing contact with them on a number of issues. They will continue to work with NASA, however they will not put NASA on

[40] Dr. Sacco said that the Shuttle normally flies with a 20% fuel reserve

[41] It is worth of note that the Boeing Mir project is also based on returning a data product to earth.

the critical path for their activities, simply because they perceive that such a move would cause unacceptable delays, increase costs, and in fact jeopardize their business success.

Case Study 10. Gallium Arsenide Thin Film/Wakeshield (Space Industries, Inc., Space Vacuum Epitaxy Center). Wakeshield is a free flying facility that was developed and operated by Space Industries, Inc., under the sponsorship of the Space Vacuum Epitaxy Center (a CSC located in Houston, Texas). It flies in low earth orbit behind the Space Shuttle to create a vacuum in its wake more than one million times greater than the surrounding atmosphere. The facility is being used to produce semiconductors through an epitaxy process that, by virtue of the lack of contaminants under these vacuum conditions, should allow the fabrication of faster and more powerful computers.

Three missions have been flown, the last of which was early this year. The first flight proved the concept, using the Shuttle's Remote Manipulator System. On the second flight, Aluminum Galium Arsenide semiconductor material was produced with the greatest purity on record. The latest flight produced actual thin film semiconductors which are being turned into integrated chips (ICs). The testing of these devices will complete the proof of principal.

Case Study 11. X-Ray Device (University of Alabama in Birmingham). A major proposal before NASA by Dr. Lawrence DeLucas, is the development of a dual use x-ray machine for space that would be small, lightweight, and low power (100 W Vs 7 KW normally required). Along with this design task will be significant advancements in robotic handling to allow much of the work to be done remotely from earth. This machine will analyze crystal samples but, through frequency selection it will also allow in-situ bone-scanning of monkeys for Calcium-loss (rather than returning them at intervals) and other missions. NASA's initial response to this proposal was favorable, but it demanded funding from industry. Dr. DeLucas was able to get participating companies to contribute $25M to the task with the agreement that NASA would use their equipment after the successful completion of the development, with 20% of their utilization free (for flight pay-back). NASA's response was that such a payback agreement would need Congressional authorization.

Case Study 12. Education Programming (Walt Disney Imagineering). We met with Dr. Eric Hazeltine, Vice President of Walt Disney Imagineering, the technological arm of Walt Disney Enterprises. Dr. Hazeltine is interested in applying media and technological skills to the production of educational and entertainment programs from space. For example, these programs could employ a camera positioned to view both inside and outside the ISS module, with remote control from the earth. Programming would combine science projects, earth and space views, and the human drama of the crew.

The following statements represent consensus reached during the case studies. These and other conclusions are referenced in the report.

Some Consensus From the Case Studies

Although there is much interest and enthusiasm, no venture is sufficiently robust to privately fund space access at this time - government support is needed.

NASA is not easy to deal with and does not appear very interested in true commercialization.

- Particularly true for promotion, entertainment, tourism
- When science and R&D is the key to commercialization, NASA is much more interested and helpful, but….
- NASA support for Science or the CSC technology program is not carried to commercialization phase
- NASA review processes are extremely time and resource consuming

Government is reluctant to accept investment risk for later payoff

Infrastructure providers complained that NASA in-house products compete unfairly with their products

Consensus on list of impediments

ANNEX D. BIBLIOGRAPHY

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