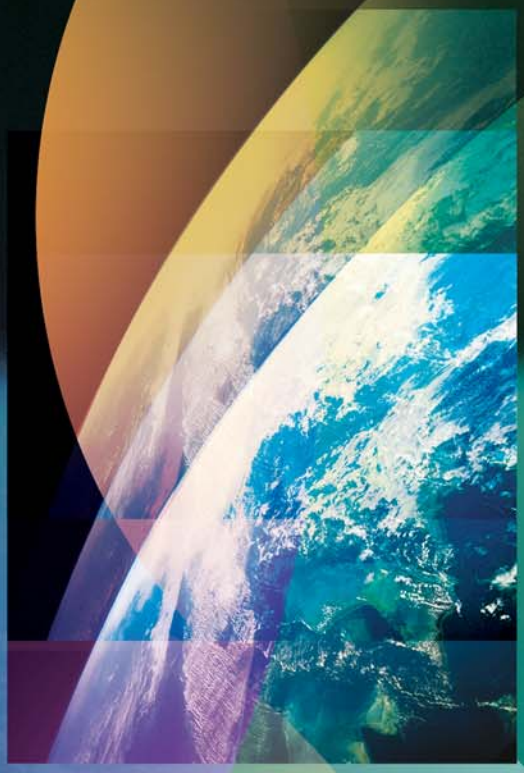
Market Opportunities in Space:

The Near-Term Roadmap

December 2002



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DFI INTERNATIONAL

Prepared for
U.S. DEPARTMENT OF COMMERCE
Office of Space Commercialization

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PREFACE

On November 7, 2001 the U.S. Department of Commerce, Office of Space Commercialization, co-sponsored a workshop titled Market Opportunities in Space: The Near-Term Roadmap, in collaboration with the Space Transportation Association and the Space Enterprise Council administered by the U.S. Chamber of Commerce. The Office of Space Commercialization retained DFI International to provide assistance in drafting workshop-related documents, as well as to provide support in organizing panels and managing the event itself. Workshop participation was by invitation only, in order to bring together a small group of traditional and non-traditional market participants with government decision makers, financiers and academics to discuss ways to facilitate emerging space markets.

In order to provide background for workshop panel presenters and participants, DFI prepared a document describing history and issues relevant to emerging market development. Subsequent to the workshop, DFI also drafted a brief summary of workshop presentations and discussion. Although not intended to constitute detailed proceedings, this summary was designed to capture key themes evident during the event. The purpose of the following document is to make available to the space community this workshop background information and workshop summary. Resources were not available to update the background material to reflect the full range of rapidly-occurring developments between the November 2001 workshop event and the October 2002 publication of this workshop report. However, effort has been made to acknowledge a limited number of significant post-workshop events.

The viewpoints presented in this report are not necessarily endorsed by the Office of Space Commercialization, the Space Transportation Association, the Space Enterprise Council, or any other organizations involved in sponsoring or hosting the November 7 conference. Also, the thematic overviews contained in the summary material were prepared by DFI International and should not in any sense be treated as though they constituted definitive statements prepared by the presenters themselves. Similarly, there is no intent to imply that panelists participating in discussions were in full agreement as to specific conclusions or potential future actions.

Recommendations drawing in part on information presented in this report, and directed toward facilitation of market growth, will be prepared separately by the Office of Space Commercialization for use in appropriate contexts.

FOREWORD

Visionaries have long enticed us with their promises about humanity's future in space. They have described in glowing terms how opening up the new frontier will not only enrich scientific knowledge and uplift the human spirit, but also provide tangible benefits and financial rewards to everyone with a stake in the enterprises that thrive there. Some envision a day when space will be a place for tourism, complete with hotels and cruise ships, and industries will also thrive in orbit, with research labs and manufacturing plants taking advantage of the microgravity environment. In such a future vision, movies will be filmed in space; unimagined sporting events will be played there; advertisers will flood the new environment with their messages; and space platforms will generate energy for people on Earth. But if this inspiring vision is to become reality at some point in the future, practical challenges must be faced and overcome in the near term.

In the mid-1980s, market analysts projected that within a decade new commercial in-space activities, outside the realms of satellite communications and remote sensing, would generate more than $50 billion in annual revenue. The world now stands six years beyond the horizon of these predictions and the stark reality is that such new activities still contribute nothing to the gross national product of the United States. However, progress has been made. Industry, government, and international organizations have made significant strides toward opening the space frontier to commercial endeavor. Despite the difficulties encountered in achieving profitability with new low-Earth orbit communications satellite constellations, traditional satellite communications markets continue to thrive. Commercial satellite navigation services are expanding, and commercial remote sensing services still hold great promise. Several new space markets also appear poised to emerge, if provided the proper resources and nurturing environment.

It is, of course, impossible to overlook the fact that the global mood remains somber in the aftermath of the September 11th terrorist attacks on the United States. Yet the promise of space is by no means diminished by recent events. There has long been a close relationship among military, civilian and commercial users of space, and the three segments will likely coordinate more closely than ever, sharing capabilities, technologies and resources. The current environment and refocused priorities will likely lead to expanded and improved U.S. national security assets in space. Just as the Cold War competition with the Soviet Union led to successful U.S. development of the Apollo program, as well as communications and remote sensing satellites, the current heightened security environment can also benefit both traditional and emerging commercial space activities.

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ISSUES IN SPACE COMMERCE

INTRODUCTION

For nearly 50 years, space was the domain of nation states. What began as a quest to assert national pride in the 1950s quickly became a race between nations to gain the "true high ground" and exert national superiority. This effort spoke to a generation that embraced the challenge and excitement of exploring a new frontier, yet the new frontier was to be dominated throughout the 20th century by governments.

At the dawn of the 21st century the world is witnessing a new reality – a reality where commercial uses of space far outpace military uses and are close to surpassing all government space activities. It is also a reality in which commercial product offerings increasingly equal or exceed the capabilities of many government systems and where nations, companies and individuals are increasingly dependent on space assets for the most basic of infrastructure services. The world is at a crossroads where the government use of space will increasingly pale in comparison with commercial investment and services. Yet the government still has a key role to play in facilitating emerging commercial space markets.

Space commercialization has always been a topic of interest to policy analysts and industry insiders. However, non-aerospace communities, innovators, and entrepreneurs have largely remained on the fringes of serious discussion, with conferences and analyses focused and refocused on familiar territory: space transportation, satellite communications, satellite navigation, and remote sensing. The flights of Dennis Tito and Mark Shuttleworth to the International Space Station (ISS) have changed this discourse by expanding the realm of possibility for the space community. Public support for Tito's flight arguably also catalyzed NASA, and the space agency subsequently played a more integrated role in Mr. Shuttleworth's mission. Events are rapidly overtaking policy in the realm of space commercialization, creating both a challenge and an opportunity for the U.S. government.

The first part of this examination of space commerce issues provides a brief overview of the current state of the aerospace industry and space commercialization efforts in general. Subsequent sections explore in greater detail the commercialization efforts specifically addressed by each of the panels convened at the November 7, 2001, market opportunities workshop.

The 1990s – A Decade of Challenges

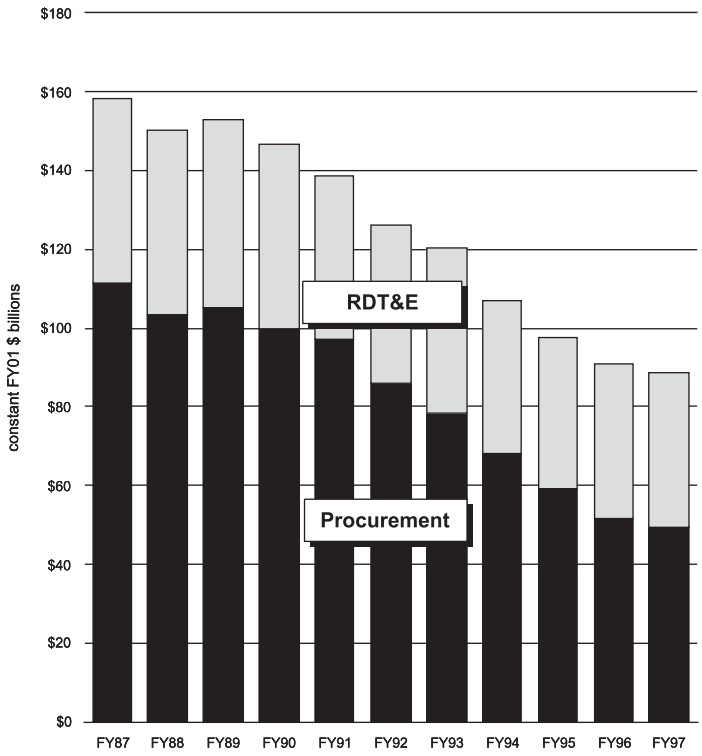
While a number of innovative satellite communications and launch services ventures have sprung up over the last 10 years, the story of the aerospace industry to a large extent is still that of more traditional commercial and defense markets. It is difficult to separate the story of the space industry from that of the large aerospace and defense contractors that dominate the competitive landscape. The two largest among these—Boeing and Lockheed Martin—constituted a majority of space industry revenues.

The 1990s were a difficult period for these aerospace giants. Severe budget cutbacks throughout most of the decade, combined with a global recession at the outset, led to mass layoffs, consolidation, reorganizations and a refocusing of priorities. On the positive side, the restructuring has left the surviving industry participants in fairly strong shape and more focused on commercial activities, perhaps making them better poised to grasp emerging opportunities as they become economically attractive.

As Cold War tensions began to ease in the 1980s and drew to a close in the 1990s, defense budgets declined sharply[1], and budget outlays fell more than 30 percent between 1987 and 1997. Expenditures on procurement and for research, development, testing and evaluation (RDT&E), which aerospace contractors depended on the most, fell almost 50 percent (see Figure 1).

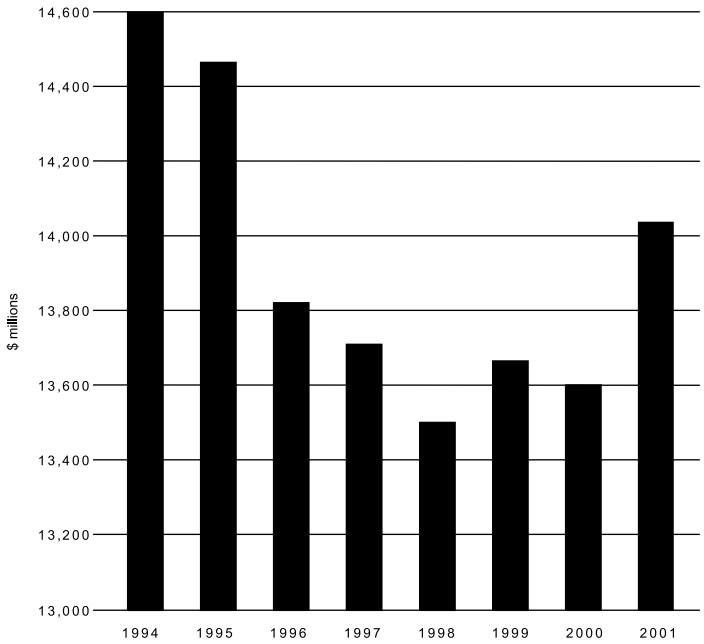
[1] All budget data are taken from the U.S. Department of Defense's 2000 budget document.

Figure 1. Declining Defense Investment, FY 1987 to FY 1997



NASA also faced a decade of declining budgets as the overall government atmosphere became one of severe fiscal constraint. NASA's budget reached a high point of $14.6 billion in 1994 and shrank steadily thereafter (see Figure 2).

Figure 2. NASA budget, 1994-2001 (adjusted)

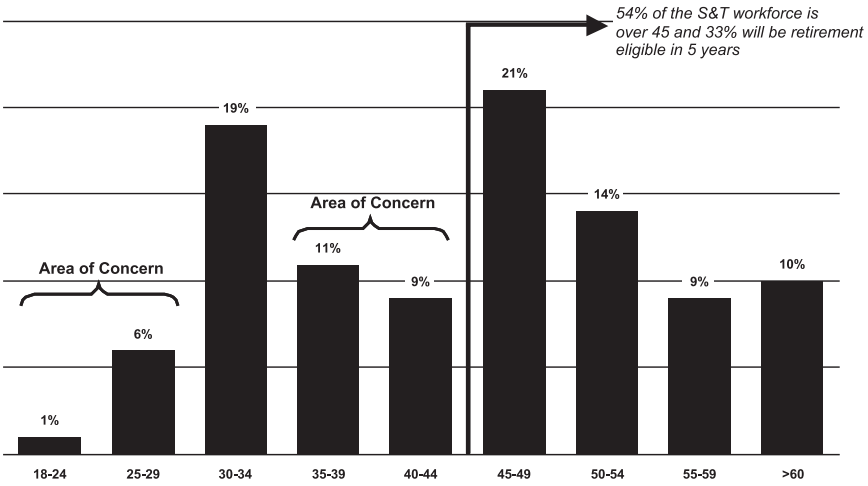


In addition to the substantial decrease in government spending, the industry also had to cope with a worldwide economic downturn that ratcheted the financial problems to near-crisis levels. The early 1990s witnessed a severe slump in commercial aircraft sales both the Gulf War and various recessions in the United States, Japan, and much of Europe significantly reduced tourism and airline travel, resulting in plummeting demand for aircraft. Ultimately, revenues and shipments dropped by almost 50% between 1991 and 1995.

Extreme fiscal pressures prompted unprecedented reorganization and an enormous number of mergers and acquisitions in the industry. Whereas there had been almost 50 independent companies in 1990, there are today only six. Companies looked to streamline their operations and eliminate overhead with the encouragement and cooperation of the Department of Defense. Part of the consolidation was also an effort to expand into commercial markets through acquisition of commercial firms or lines of business.

The merger and acquisition activity was especially hard on employees, as payrolls were slashed and aerospace employment fell drastically. Almost 1.5 million jobs were lost in the defense and aerospace industries in the 1990s. The workforce that remains is unbalanced: dominated by older engineers with tremendous experience, but lacking a sufficiently large younger group who will step in to manage the programs of the future (see Figure 3). The imminent retirement of a large part of the industry's knowledge base is a challenge that will need to be addressed in the coming decade.

Figure 3. Average Space Industry Science & Engineering Workforce Age Distribution



Source: Booz Allen & Hamilton (1999)

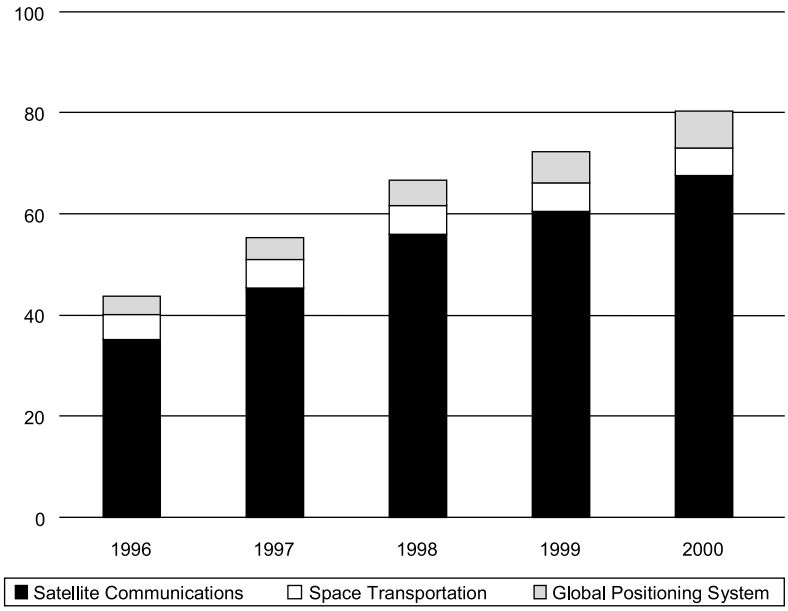
Government budget cutbacks left aerospace companies with excess manufacturing capacity, and capital investment consequently declined by more than 50 percent during the last decade. Facilities are now older and growing obsolete. Research and development also suffered, as the industry cut its investment in such activities from 4.5 percent of sales in 1990 to 2.2 percent by 1995. Even the rosier outlook by the end of the decade only spurred these companies to increase R&D expenditures to 2.9% of sales by 1999, far below the levels of 10 years earlier.

The upheaval to the aerospace industry in the 1990s has left most companies leaner and saddled with heavy debt burdens and excess capacity. Yet there is also greater recognition of the benefits of diversification and a strategic emphasis on expanding into commercial sectors that are not dependent on low-margin, cost-plus government contracts for success. Much of the restructuring among the larger aerospace companies, including the layoffs of large numbers of employees, has helped lay the foundation for a plethora of aerospace start-up companies. And many of these smaller players are exploring new launch technologies, remote sensing concepts, and opportunities that involve the emerging market areas of space tourism and space manufacturing.

Continued Commercial Space Success

One of the clear economic successes of the 1990s was the continued growth of more traditional commercial space activities, which helped partly to offset declines in military spending and civil aircraft sales. As Figure 4 indicates, overall commercial space enjoyed significant annual growth from 1996 through 2000. The traditional areas of space launch services and satellite communications boomed as overall demand for communications bandwidth soared worldwide. Services using the Global Positioning System (GPS) also grew rapidly, as entrepreneurial firms began to exploit the signal for a multitude of uses. In addition, high-resolution remote sensing satellite services made their commercial debut at the end of the decade. Although the economic scope of remote sensing was not yet large enough to be visibly represented in comparison to the other three sectors depicted in Figure 4, this new sector experienced growth sufficient to constitute a fourth revenue base for traditional space commerce.

Figure 4. World Revenue for Space Industry Segments, in U.S. $ billions, 1996-2000[2]



Together, these four commercial space segments—space transportation, satellite communications, GPS, and remote sensing—contributed $80.47 billion to the global economy in the year 2000, involving more than 500,000 jobs in the United States alone. Each of these segments is in a different stage of maturity.

Satellite communications is the largest and still the fastest growing segment of commercial space activity, with revenues of more than $67 billion in 2000 and a compound annual growth rate of 17 percent. Growth in this industry is being driven by increasing demand for communication bandwidth, thanks to the advent of the Internet and surging demand in developing areas of the world. Despite the severe financial problems facing most low-Earth orbit satellite constellations (e.g., Iridium, ICO, Globalstar) , the industry has seen the success of direct-to-home television systems and the introduction of digital radio services. Worldwide, healthy continued expansion is projected for the foreseeable future, although within the United States there are challenges ahead, especially for manufacturers. For example, international competitors are gaining market share as their technologies and production capabilities improve.

Despite annual fluctuations due to failures and stand-downs, demand for launch services generally grew during the 1990s, amounting to more than $5 billion most years. Unfortunately, the current decade has dawned with a steep decline in launch demand, primarily as a result of the economic failure of low Earth orbit constellations, which were

[2] Office of Space Commercialization, U.S. Department of Commerce, "Trends in Space Commerce", 2001, prepared by Futron Corporation.

anticipated to account for a robust number of launches. No near-term recovery for the industry is anticipated. The United States has faced continued competition from Europe's Arianespace, which launches more than 50 percent of all commercial spacecraft. The decade of the 1990s also saw vehicles from China, Russia, and Ukraine enter the commercial marketplace as the U.S. government established trade agreements with those nations allowing wider competition. New U.S. vehicles such as the Delta 4 and Atlas 5, both partly funded by the U.S. government's Evolved Expendable Launch Vehicle Program, should augment U.S. commercial competitiveness in the future.

In the area of satellite navigation, the commercial market has experienced robust growth thanks to the 1996 U.S. policy to provide GPS services free of charge and to actively promote GPS use around the world. Global revenues in this area exceeded $7 billion in 2000, with an annual growth rate of more than 19 percent. The development of GPS receivers as consumer electronic devices and the introduction of GPS chip sets into multifunction products are two emerging trends in this industry. Demand for these new services coupled with steady growth in traditional tracking and navigation use ensure continued market expansion for the GPS industry.

In 1994 the United States issued a new policy allowing commercial firms to collect and sell high-resolution images of the Earth from space. Within a few years, the first one-meter imaging satellite was operating in orbit. The commercial satellite remote sensing industry (i.e., pre-value-added raw imagery) saw $173 million in revenue in 2000, reflecting a growth rate of 14 percent. Many start-up services are in the process of developing systems for launch. New services online or projected to enter service in the near future include high-resolution visible systems, radar imagery systems, and low-resolution multispectral systems. The industry faces a number of challenges, particularly education — many users are unfamiliar with the value of satellite imagery or are untrained in how to interpret the data. Yet most analysts project that growth rates should accelerate in the near future, once less expensive services become available.

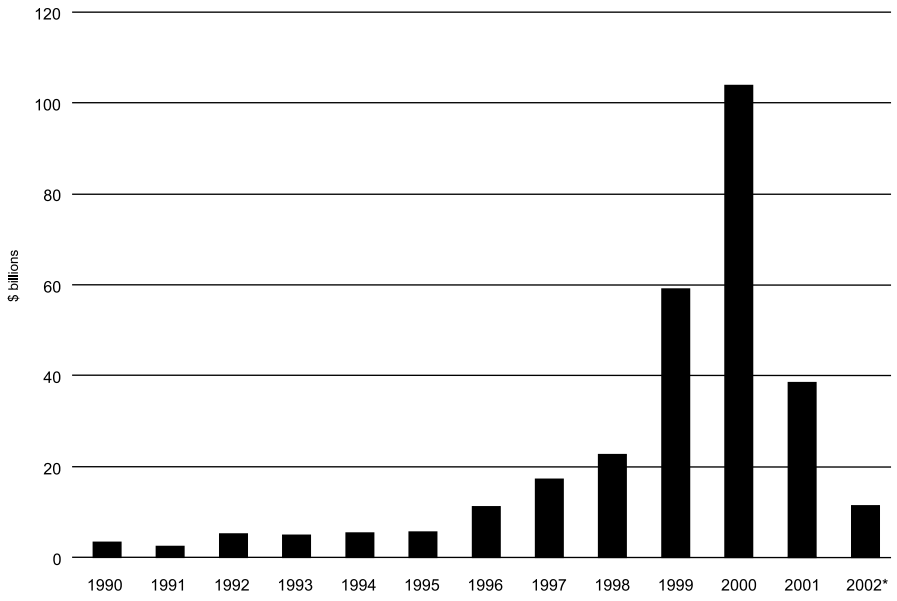
The continued growth and profitability in traditional space markets illustrate both the untapped opportunity that may lie in emerging commercial space activities and the potential role of government involvement. In all four areas — satellite communications, launch services, GPS, and remote sensing — the U.S. government took the lead in developing technologies and fostering commercial uses before passing the technologies off to private industry. Commercial space has become increasingly important to the aerospace industry and the global economy over the past decade, as its uses have significantly outpaced government uses of space. The government is likely to purchase increasing amounts of commercial services, further fueling the economic viability of many space sectors and creating a kind of virtuous economic cycle in the aerospace industry and beyond.

Current Investment Climate

A major obstacle facing emerging space industries is a lack of financial capital. Venture capitalists typically shy away from the risks inherent in cutting-edge space activities. Lockheed Martin, for example, was unable to find private backing for its VentureStar launch program, and many smaller firms have faced the same difficulty in securing adequate investment.

Despite caution about investing in aerospace, there is certainly no shortage of available capital. Figure 5 illustrates the investment climate of the past decade, in which, the legends go, ideas sketched out on the back of an envelope received hundreds of millions of dollars in financing. Total capital investments, which typically averaged $3 billion to $5 billion annually (and fell to a low of $2.5 billion in 1991 due to recession), rose to the astronomical height of $103.8 billion in 2000. Even in the wake of the Internet collapse, companies continue to receive financing at a historically aggressive rate. Venture capitalists disbursed $37.6 billion in 2001, and despite a continued decrease still financed $11.9 billion in the first half of 2002. These impressive figures would seem to suggest that the space industry's challenge is as much about the perception of risk and reward as it is about solid business plans.

Figure 5. U.S. Venture Capital Investments, 1990 to 2002(e)



Source: National Venture Capital Association **(2002 is first-half only)*

While many venture capitalists might not "understand" space, find it extremely risky, deem the returns too long to come to fruition, and consider the yields too low, in truth these characteristics are not exclusive to commercial space markets. The terrestrial power generation and biotechnology industries, for example, also require massive amounts of startup capital expenditures in order to achieve viability. For the biotech industry, which was the favored investment area of the mid-1980s and again in the mid-1990s, venture capitalists looked for liquidity of their capital in 5 to 7 years with promises of great wealth in the 7- to 10-year timeframe – not too different from space ventures of the last decade.

The growth of the Internet shortened the cycle significantly, and venture capitalists began to demand liquidity in 2 to 3 years, with promises of great wealth almost immediately following. The events of that period have skewed the investment climate for space ventures during the last several years. Few investors have been willing to wait the requisite 10 or more years for liquidity that is necessary when investing in the aerospace sector. That is not to say that capital markets have failed the space industry as a whole. In fact, as a number of observers[3] have pointed out, the last several years have proven the capacity of the private capital market to invest heavily in those facets of the space market deemed sufficiently attractive (see Figure 6).

[3] Macauley, Molly, Senior Fellow, Resources for the Future, "Prepared Statement delivered July 18, 2000 to the U.S. House of Representatives", Subcommittee on Space and Aeronautics, Committee on Science.

Figure 6. Major Commercial Space Investment, May 1999 – May 2000

Company	Amount Raised	Investors
Hughes	$1.5 billion	America Online
Spaceway	$1.4 billion	Hughes
Astrolink	$1.3 billion	Lockheed Martin, Telespazio Liberty Media and TRW
ICO Global Comm.	$1.2 billion	Eagle River Investments
Echostar	$1 billion	Private placement
XM Satellite Radio	$865 million	Debt offering, public stock offerings, General Motors, Clear Channel, DirecTV, Columbia Capital
Sirius Satellite Radio	$700 million	Blackstone Group, DaimlerChrysler, Apollo Management, convertible subordinated notes, common stock offerings
Thuraya	$600 million	Consortium of Banks
Gilat	$400 million	Private notes offering, Microsoft
Loral Space	$400 million	Private sale of stock
Sky	$250 million	Liberty Media and others
Earthwatch	$199 million	Subordinated discount rates
Globalstar	$150 million	Convertible preferred stock
Final Analysis	$130 million	General Dynamics, Raytheon
Teledesic	$121 million	Abu Dhabi Investment Co.
OrbImage	$75 million	Private notes placement

Source: Aviation Week and Space Technology, 3 July 2000, p. S22.

While venture capitalists and other investment organizations might not be experts on every industry, they do understand business models. The one entrepreneurial sector of aerospace that the markets had favorably supported was telecommunications. Iridium, GlobalStar, Teledesic and other constellations attracted billions of dollars in financing for what were perceived as relatively low-risk concepts. The first went bankrupt, costing investors approximately $5 billion in losses; the second is currently undergoing restructuring after defaulting on debt payments; and the third has an uncertain future. Satellite radio (DARS) ventures also had success with capital markets. These ventures required large initial investment and are incurring high operating losses, yet many analysts remain optimistic that they will soon achieve breakeven after only modest market penetration.

Despite all the elements stacked against space investing, the outlook for the investment climate might not be as bleak as expected. Many space ventures, especially the aforementioned communications constellations, involved a great deal of lead-time before deployment and are only now, or in the next several years, providing "returns" in the form of financial results and market data. That data will provide capital markets and private

industry alike with a critical ingredient — more information — needed for refining new ventures and business plans. Capital markets are cyclical and might in fact be poised to bounce back by mid-decade. For one thing, the last year has shown that the capital expenditure and development cycles of terrestrial telecommunications providers — especially those seeking to provide next-generation services — bear remarkable similarity to the space ventures of the early to mid-1990s.

Terrestrial networks have a unique and vitally important place in the future of the U.S. economy. However, the space industry can both be comforted by and learn from a certain amount of economic relativism. In both cases, time to deployment, heavy debt burden and overestimated demand were key issues. Ultimately, the realities of both terrestrial and space communications models require that the two segments think of themselves as part of a whole. Already, hybrid networks are beginning to become an important part of an overall infrastructure, supporting each other both in terms of geography and technology. Important new segments such as broadband multicast, digital cinema and route pioneering all reflect this realization.

Taken together, all of these trends suggest a number of lessons for market observers: first, that by definition pioneers blazing new trails may stumble along the way, and the smaller, leaner ventures that follow them should not be judged as inevitably condemned to repeat these initial missteps; second, and perhaps most important, that space should not be viewed as a self-contained unit but rather as an enabler for expansion of a wide range of consumer markets. In a hybrid network, for example, "orbital" and "underground" are simply mediums in a service delivery framework (in this case, data). Likewise, DARS satellites are a means to deliver services that have no economically viable terrestrial equivalent. Space activity could be viewed as an enabler of other industries and a key cog in an overall economic framework, and not as a pretext for selling satellites and launchers. This vision of space has a myriad of implications for commercial space ventures, involving capital acquisition, business partnerships, marketing, and even hiring strategies.

A few notably successful new space ventures would increase the pool of investors and expand the number of venture capitalists willing to accept the risks of such an investment. But the means to this end is the development of credible and convincing value propositions, not hype and obsolete technology. Clearly, a new dialogue is needed between capital markets and the space industry, for the mutual benefit of each party. From the perspective of the space industry, one way to accomplish this is to bring new, non-traditional private sector entities into the dialogue. Facilitating this process was one of the main goals of the *Market Opportunities in Space* workshop.

Globalization of financial markets, customer bases, telecommunications systems (most notably the rise of the Internet), and other basic economic infrastructure has forever altered the pace of information flow and technological progress. There has been a technology revolution that has profoundly altered the global economy and the place of

the aerospace industry within it. Global markets are increasingly vital for the aerospace industry, in terms of access to customers, capital, labor and technology.

Globalization has also changed the way companies do business and conceive of market opportunities. Companies are increasingly willing to look at unusual alliances and take on risks that would previously have been deemed unacceptable. For example, Boeing developed SeaLaunch with non-traditional partners (NPO Yuzhnoye in Ukraine, NPO Energia in Russia, and Kvaerner AG in Norway) as a commercial alternative to launches from U.S. government ranges; Lockheed Martin invested $357 million of its own funds in its attempt to build VentureStar, a reusable vehicle whose key design objective was the reduction of launch costs by a factor of 10; Kistler Aerospace found financing for its efforts in Saudi Arabia and Hong Kong; and Iridium developed a coalition of investors, manufacturers, and customers that spanned the globe. Although such new international business models do not ensure a space commerce venture's success, they do help enable space sector companies to pursue new projects as nimbly as companies in other technological markets. Commercial space activities are now held to the same standards – and have the same opportunities – as other emerging commercial industries.

Technical and Policy Challenges

Affordable, reliable access to space remains a critical obstacle to the commercialization of space. Meeting this challenge is increasingly important to a wide range of space-related initiatives, both government and commercial, and is critical to the development of emerging markets. Decision makers have also begun to realize that although government has a role in space science and exploration, sustainable space development will only exist where commercial interests are the driving factor. Commercial interests, once secondary considerations in forming space policy, have now risen to the forefront.

Lofting a payload into orbit uses basically the same technology today as at the beginning of the Space Age in the 1950s. Expendable rockets are burned up in the atmosphere after delivering their payloads at a cost of thousands of dollars per pound. Using the Space Shuttle allows most of the launch components to be reused, but at an enormous price – the cost of launching any payload on the shuttle costs up to $16,000 per pound. The best expendable rockets can only guarantee reliability in the neighborhood of 99 percent, and even the Shuttle's somewhat superior reliability is still far below that taken for granted in the world of aviation.

A 1997 Aerospace Corporation study on space launch provided a thorough analysis of launch requirements for near-term and long-term missions, including an in-depth

examination of emerging commercial markets.[4] The report outlined some of the precursors that must be in place before innovative space markets can exist:

- 86 percent of emerging commercial market applications will require at least 100X reduction in price before they are viable;
- 80 percent of emerging commercial market applications will require at least 100X improvement in safety and reliability;
- 66 percent of emerging commercial market applications will require a vehicle that can launch at least 100 times per year (53 percent of applications require a vehicle that can launch at least 300 times a year);
- 57 percent of emerging commercial market applications will require a vehicle that features a turnaround of less than one day.

Specific studies vary, but many appear to agree that launch costs will need to be reduced to a maximum of $500-$1,500 per kilogram to enable large-scale, long-term commercial activity. This does not mean, however, that incremental improvements would not have a marked impact on space commerce in the interim. Advocates of new commercial space markets maintain that even current launch infrastructure, employed at existing price points and levels of reliability, could provide near-term growth to commercial space markets, if some appropriate adjustments were made to government policies and incentives.

Most space analysts believe the key to growth lies in new launch technologies, and NASA's Space Launch Initiative (SLI) may sow the seeds of future success. SLI involves a long-term effort to explore and advance a variety of technologies that planners hope will prove suitable for eventual incorporation into at least two distinct vehicle architectures. It remains unclear, however, to what extent the initiative will satisfy the needs of an expanding commercial space industry. The Aerospace Industries Association has cautioned that the program's funding may be insufficient, noting that, "Measured in 2000 dollars, the U.S. government invested $50 billion to develop the Saturn V rocket that launched our astronauts to the Moon. Original federal funding for development of the Space Shuttle reached $40 billion. The budget currently projected for NASA's Space Launch Initiative to develop a replacement for the aging Space Shuttle is $5 billion. This small investment . . . will be inadequate to meet America's future launch needs."[5] It is also not clear to what extent SLI technologies, or vehicle architectures incorporating them, will be tailored to meet the specific demands of the emerging space marketplace. Clearly, facing the challenge of new vehicle development will require an intense national dialogue involving all stakeholders, as well as the creative inputs of a variety of industries considering expansion into space.

[4] *Future Spacelift Requirements Study*, The Aerospace Corporation, 1997.
[5] *Presidential Transition 2000 White Paper*, Aerospace Industries Association.

In an effort to play an appropriate role in promoting commercial activity in space, NASA has been carefully evaluating options for enhancing space commercialization. This effort reflects the recognition that contributing to an increase in the scale and diversity of commercial activity constitutes a significant aspect of the agency's mission.

The 2000s – A Decade of Opportunity

The United States now has the opportunity to make significant progress in commercial space development: increasing numbers of public and private sector leaders are recognizing the economic potential of space business activity; there is growing support for development of better and cheaper launch technologies; industry, although still facing some challenges left over from the lean decade just concluded, is better poised than ever to pursue commercial opportunities; and the United States has a new administration committed to expanded use of space.

But for real progress to occur, the nation will need more than just another speculative vision of an idealized, and very distant, future. By bringing together decision makers from a variety of public and private sectors, including both traditional and non-traditional market participants, the workshop, *Market Opportunities in Space: The Near-Term Roadmap,* sought to stimulate a new dialogue concerning creative approaches to achievement of practical, near-term progress. The workshop was designed to encourage established and prospective market participants to share opinions and perspectives on requirements for accelerated business development in space.

The following sections of this report provide background information on the subject areas that were addressed by the panels comprising the workshop. Preliminary versions of these topical overviews were made available to panel members prior to the workshop, as an aid in preparing their remarks.

PEOPLE AND PACKAGES: SPACE TOURISM AND CARGO DELIVERY

Space Tourism

Expensive, risky adventure travel is a serious and lucrative business on Earth, attracting more than 100,000 people per year. Tourists are exploring the Amazon, diving to the wreckage of the Titanic, and scaling the world's tallest mountains in ever increasing numbers. There is even an annual marathon at the South Pole. Treks to the top of Mt. Everest are probably the best known example of terrestrial adventure travel—with license costs alone reaching $50,000, and a six-year wait to climb. Despite the danger and expense, people are willing to go to extreme lengths to live adventures that push the experiential envelope to its limits.

The concept of space tourism has been around for ages but never at the forefront of serious space dialogue. The excursions of Dennis Tito and Mark Shuttleworth to the ISS in the past 18 months have changed all that. The Tito flight, whatever its positive or negative connotations, undoubtedly went a long way toward legitimizing the space tourism concept. In fact, according to one study, there were more than $140 million in space tourism commitments in 2000.[6] To date, these commitments—which have largely consisted of somewhat vague agreements to travel on Russian launch vehicles—do not constitute an "industry" in a traditional economic sense; however, they do serve as clear evidence that the Tito and Shuttleworth flights were powerful steps in raising public awareness and validating market demand. The latter, especially, is an area the industry is only beginning to understand.

Gauging the Demand

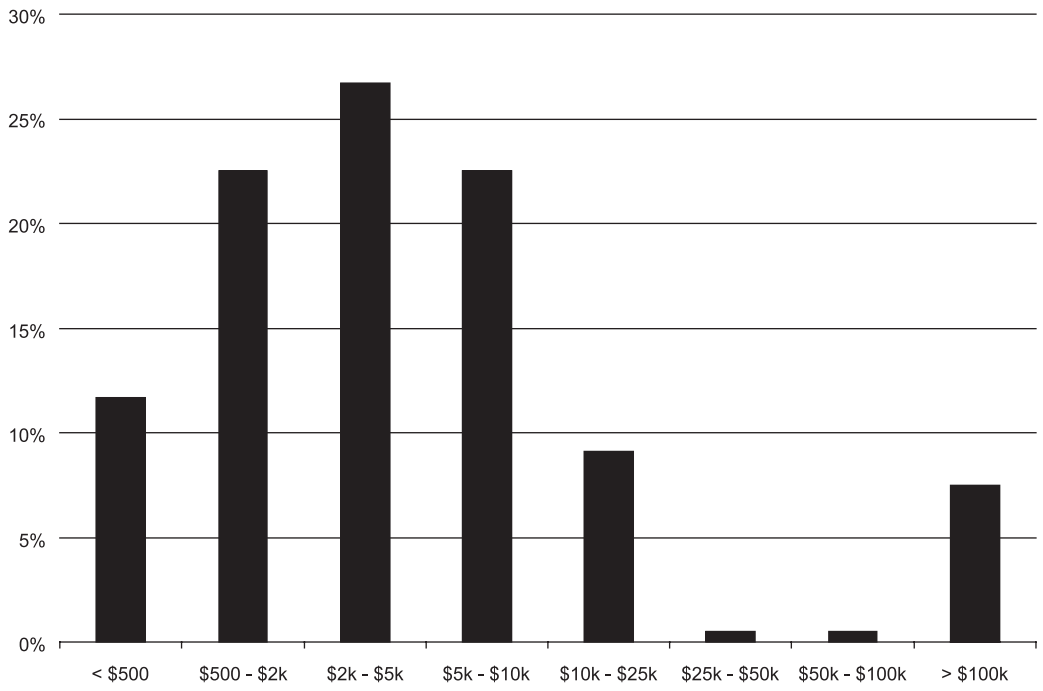
Analysts have been trying to forecast the potential size of the space tourism market for more than a decade, and they have arrived at an array of encouraging numbers. The 1994 Commercial Space Transportation Study used conservative metrics to determine that at

[6] *Future Space Transportation Study*, Andrews Space and Technology under NASA NRA 8-27, 2001.

$250,000 per trip there would be demand from about 600 passengers annually.[7] Other studies have shown that at a price of $50,000, worldwide demand would exceed 70,000 passengers each year.[8] A 1997 study conducted jointly by the Space Transportation Association and NASA found that 7.5 percent of 1,500 families surveyed would be willing to pay $100,000 or more for a chance to spend a two-week vacation aboard the Space Shuttle.[9] In the same survey, 33.9 percent of respondents said they would opt for a Shuttle vacation if available, but most people (perhaps not unexpectedly) would be unwilling to spend more than a few thousand dollars on the trip (see Figure 7).

Figure 7. Space Transportation/NASA Survey Results:

If you would be interested in taking a two-week vacation aboard the space shuttle, how much would you be willing to pay?



These demand-side studies of space tourism have been based on different methodologies and, accordingly, have contributed a range of different types of results. During the last several years, and increasingly now in the wake of the Tito and Shuttleworth flights, a general consensus has emerged that more integrated feasibility studies, combining market

[7] *Commercial Space Transportation Study*, published by the CSTS Alliance: Boeing, General Dynamics, Lockheed, Martin Marietta, McDonnell Douglas and Rockwell, 1994.
[8] Bekey, Ivan, "Economically Viable Public Space Travel," 1998.
[9] O'Neil et al, "General Public Space Travel and Tourism - Volume 1 Executive Summary," NASA/STA, NP-1998-03-11- MSFC, 1998.

research, architecture and concept definition, and business modeling are needed to help quantify demand.

One recent study conducted for NASA under the Space Launch Initiative (SLI) program took steps in this direction. The study examined the business process of a number of emerging space markets, including LEO travel, and surveyed industry players to size the market and define the necessary operational characteristics for a reusable launch vehicle (RLV).[10] The NASA study concluded that at a price of $400,000 a ticket, 10,000 passengers a year would purchase a trip to space, a number that signifies a $4 billion annual market.

Many studies have in the past been criticized for presenting hypothetical consumer choices without the reality of having to face economic trade-offs. Yet there has been increasing sophistication in the science of Choice Modeling, which uses studies of consumer choices to determine likely behavior.[11] The studies are used to determine consumer interest in innovative products for which traditional market research would be impossible. With proper survey techniques, a more conclusive estimate of consumer interest in space tourism could be ascertained. Such surveys would likely consider a number of important factors in addition to general interest and price. The recent NASA study took a first cut at some of the vehicle requirements, when its findings suggested a launch vehicle with the following characteristics:

- 6-hour payload processing;
- 1 week booking time desired, 3 month maximum;
- On-time reliability of 98%;
- Catastrophic failures of less than 1 in 10,000;
- $500-$1,000/lb for passengers;
- $1,750 - $3,000/lb for cargo.

In addition to vehicle requirements, however, more precise studies will in the future have to measure public perception of risk, tolerance for risk, type of activities desired, level of comfort expected and/or required, and duration of the journey, as well as other issues. All of these will have a substantial impact on the type and number of people who would actually pay for a space journey.

[10] *Future Space Transportation Study*, Andrews Space and Technology under NASA NRA 8-27, 2001.
[11] Crouch, Geoffrey, *Researching the Space Tourism Market*, La Trobe University of Australia, 2001. Crouch cites the pioneering work of James Heckman and Daniel McFadden, who won the Nobel Prize in economics for their work on choice modeling.

In 2002, additional SLI-funded market research is under way. Recent reports of research results suggest that, in a space tourism market of the year 2021, the orbital segment might involve 60 passengers annually, yielding revenues exceeding $300 million. In addition, the suborbital segment might attract as many as 15,000 passengers per annum, representing revenues in excess of $700 million.[12]

Positive Signs

Surveys are not the only means of measuring a potentially lucrative market in space tourism – some indicators are more down to Earth, and already evident. Each year in the United States alone 8 million people visit the Smithsonian's Air & Space Museum in Washington and 2.8 million tour the Kennedy Space Center in Florida. A more important indicator is the success to date of Space Adventures, a private Virginia company. The company offers tourists visits to Russian space facilities, rides on Russia's parabolic, microgravity aircraft, and trips on a MiG 25 up to an altitude of 80,000 feet. The deluxe package costs $12,595 and has attracted almost 1,000 customers. Space Adventures also plans to offer suborbital flights to an altitude of 62 miles sometime in the near future, enabling passengers to experience several minutes of microgravity as they arc into space and return immediately to Earth. Although flights have not yet commenced, Space Adventures has already received 140 deposits of $6,000 each toward the $90,000 cost of the trip.

A number of companies in addition to Space Adventures are working to get the space tourism industry off the ground. One organization that is committed to fostering growth in the industry is the X Prize Foundation, a non-profit group that has offered a $10 million prize to the first company able to launch three adults on a suborbital trajectory of 62 miles on two consecutive flights no more than two weeks apart. According to X Prize sources, 17 companies from around the world have entered the competition. Suborbital flights, although not as fulfilling as actual trips to Earth orbit, are a much easier technical challenge and put far less stress on the passengers—they are only subjected to pressures of a vehicle traveling Mach 3 to Mach 5 as opposed to one traveling at Mach 25 for an orbital space launch.

It is also possible that there may be many more tourists who book the expensive trip to the ISS. In 2002 the Russians have been in serious negotiations with "astromom" Lori Garver and popstar Lance Bass from the band N*SYNC. The latter even spent several weeks training for a flight and may yet be lofted to orbit. A host of wealthy individuals (including *Titanic* director James Cameron and Aerosmith's Steven Tyler) have also expressed interest in such a flight, pegged at close to $20 million per person. As of the end of 2000 there were 7.2 million individuals worldwide with liquid assets of more than $1 million, accounting for

[12]"Futron Releases New Space Tourism Publications" (Press Release). Futron Corporation, October 7, 2002.

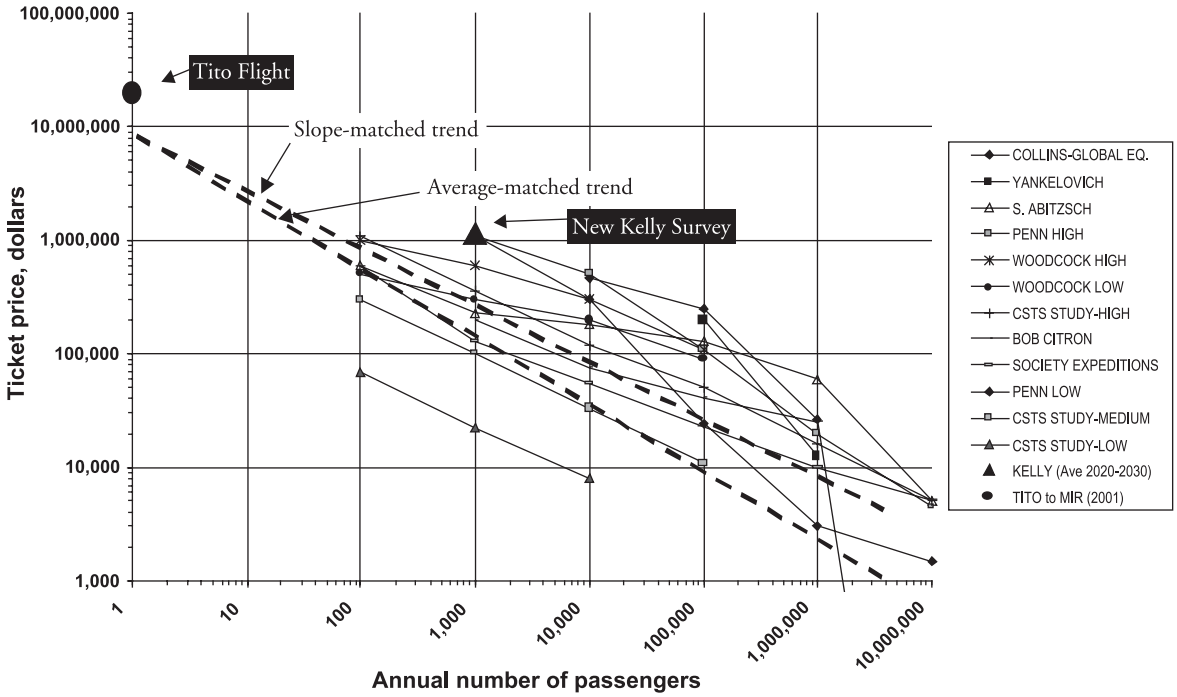
$27 trillion in total. Of these, 2.5 million live in the United States and Canada.[13] A number of market studies have shown that the appeal of space travel is widespread across all income demographics. It is certainly possible that the very wealthy will lead the way in opening up the new frontier, to be followed by the general public when the price of space travel declines.

Hurdles and Concerns

Of all the factors that affect the future of a robust space tourism market, the most critical one will clearly be price. Although safety concerns are important, there will always be a number of participants willing to take the chance despite high risks. A study conducted by Andrews Space & Technology suggests that the demand for spaceflight is inelastic above $600 per pound, meaning that not until the price is dropped below that level will people sitting on the fence be swayed to change their minds. While demand-side studies have varied, it appears to be clear that at ticket prices of $1,000,000, about 100 persons would go to space annually, and at prices of $10,000-$20,000 the market could be as large as 1,000,000 passengers (see Figure 8).[14] The latter represents a market potential in the billions.

[13] *World Wealth Report 2001*, Merrill Lynch / Cap Gemini Ernst & Young.
[14] Bekey, Ivan, "Economically Viable Public Space Travel," 1998.

Figure 8. Price Elasticity: A Market Research Comparison[15]



The hurdles to building a space tourism industry are not just technical. There are regulatory, legal, insurance, and of course financial challenges as well. Any passenger launch vehicle would have to receive government certification. Prior to certifying Boeing's 777 aircraft, the Federal Aviation Administration required 150 test flights and more than 1,500 flight simulations. It will be important to craft standards for flight testing that provide adequate protection of public safety while also taking into account the economic and technical challenges of new vehicle development.

In addition to certifying the vehicle for safety, there is the need to certify the flight path of a vehicle. An errant launch vehicle could crash into the ground hundreds of miles from the point of departure. Orbital launches today are conducted from sites that typically launch over oceans (e.g., Kennedy Space Center, Vandenberg Air Force Base, Wallops Spaceport, Guyana Space Centre, Tanegashima) or mostly uninhabited regions (e.g., Baikonur, Plesetsk), a solution that may not be practical in the long run for a more robust tourist industry. The Federal Aviation Administration's Office of Commercial Space Transportation

[15] The chart was created by Ivan Bekey for his report, "Economically Viable Public Space Travel," 1998. It summarizes the demand for space tourism based on various price points. Studies represented include: "Economical Feasibility of Space Tourism—A Global Market Scenario," by S. Abitzsch, October 1997; "Requirements and Approach for Space Tourism Launch Systems," by J. P. Penn and C. A. Lindley, 1997; Commercial Space Transportation Study (CSTS), with participation of U.S. aerospace companies, 1994; survey by Yankelovich Partners and Yesiawich, Pepperdine and Brown, included in the NASA and Space Transportation Association report, "General Public Space Travel and Tourism," March 1998; the Gordon Woodcock study; a survey by Society Expeditions, 1985; Bob Citron study, Collins-Global Eq study.

has already begun examining the issue of overflight in an attempt to determine what population density poses an acceptable public risk. Emergency landings and other unplanned scenarios will also have to be considered in this analysis, as will the issue of how space launches will interact with national and international air traffic control.

Insurance concerns loom large as well. Currently, the United Nations Outer Space Treaty holds nations liable for any damages wrought by their space activities. At today's level of activity, especially as the majority of launches are still conducted from government sites, this legal regime makes sense. Yet once a vibrant commercial launch business develops, companies will have to take responsibility, just as airlines are expected to do. The potential financial liability is enormous, however, and insurance may be prohibitively expensive or entirely unavailable. Some analysts have suggested that the U.S. government underwrite space launch insurance in the formative years of the industry, although this might carry with it considerable oversight and regulatory burdens.

Liability is not the only legal issue. Matters of jurisdiction in orbit, responsibility for environmental impact (such as orbital debris) and a host of other concerns also arise when one talks about a space tourism industry.

The final and arguably most important concern is financial. No industry can ignite without significant financial support, and signs from the financial community have been lackluster at best. The fact is that space activities are very expensive, very risky, and not very well understood. The regulatory, legal and insurance complexities only add to this perception.

Lockheed Martin unsuccessfully sought private capital for VentureStar, a reusable launch vehicle it had under development from 1996 until 2001. Despite a conservative business plan that projected profitability based on today's launch market and an evolution into emerging commercial markets only after several years of proven reliability, the vehicle had to be funded entirely by NASA ($912 million) and Lockheed Martin itself ($357 million). An operational vehicle would have cost at least $4 billion additional, an amount far beyond the reach of a single company to fund. There were suggestions of securing a government-backed loan that would guarantee the investment and minimize the risk to lenders, yet this raises the concern of propping up development of a vehicle that may not be the best technical solution and that may not sufficiently reduce launch costs. The benefit of a market-driven product is that it must be competitive to succeed. Yet when financial markets fail an industry because the costs are too high and the risks too great, it becomes exceedingly difficult to simulate market forces using government funds.

Proponents have suggested a variety of mechanisms that would enable the federal government to mitigate financial challenges that space start-up companies face. Some of the initiatives that have been explored include:

- Subsidized loans at below-market rates;
- Federal loan guarantees to commercial lenders;
- Tax credits and holidays;
- Anchor tenancy agreements;
- Direct development subsidies.

Most of the concepts are aimed at reducing the high-cost, high-risk paradigm that dissuades commercial lenders and venture capitalists from participating in space activities. Although there are compelling reasons for developing a space tourism industry commercially, the government can play an important role in easing the technical and market risks and enabling a true commercial industry.

The recent VentureStar experience, including the difficulties and delays encountered in developing some of the component technologies, is illustrative of the problems confronting developers of potential new launch vehicles. Private investors viewed the project as too risky from a technology and market perspective, and despite the technical success of some aspects of the project, unresolved technical challenges in other key areas acted to reinforce investor doubts. Ultimately, Lockheed Martin itself came to view the project as too expensive and risky to fund internally, but only after the company had already spent over $350 million developing the X-33, which was only a flight demonstration model. The government deemed it risky to commit to an architecture before all the technological risks were understood, and there was also criticism from some outsiders that continued government support of the X-33 project would amount to choosing a "winner," at the expense of other nascent technologies and launch system designs.

In an effort to learn from the difficulties encountered in the X-33 program, many analysts are now advocating a technology-driven development effort that does not commit to an architecture until the component technologies are better understood. NASA's $4.5 billion Space Launch Initiative (SLI) reflects this new direction, calling for exploration of technologies to enable eventual development of viable reusable launch vehicles. SLI, managed out of the Marshall Space Flight Center, hopes to direct the results of basic research toward vehicle architecture integration by 2006, with plans for an operational vehicle around 2012. Notwithstanding the considerable long-term potential of the program to achieve major breakthroughs in new launch vehicle technologies, the program is not designed to address the challenge of integrating *existing* technologies to produce improved launch vehicles well *before* the end of the current decade. And, as noted earlier, the ultimate applicability of SLI-developed technologies to specific commercial market needs remains an open question.

Outside the framework of SLI, several entrepreneurial companies have been developing commercial approaches that focus initially on suborbital vehicles. These vehicles could serve to some extent as prototypes to test technologies without the technical demands of an orbital vehicle, thereby reducing some of the technical risk at a lower cost than orbital designs would require. They could also open up markets in their own right, as demonstrated by the extensive waiting list for suborbital flights booked through Space Adventures. Suborbital voyages would undoubtedly increase public awareness about space tourism and, assuming continued demand for the service, help reduce the perceived market risk for the industry. Because the costs are lower, the risks reduced, and the potential financial returns quicker, a suborbital space tourism industry seems likely to develop prior to an orbital one. Just as the first public airplane excursions were rides with barnstormers, the first space trips affordable to the general public are likely to be suborbital jaunts taken for the thrill and the view.

Orbital space tourism began in 2001 with Dennis Tito's Soyuz launch. Suborbital tourism seems likely to begin sometime in the near future, once a suborbital vehicle is developed that is suitable for Space Adventures' pre-booked manifest of passengers—in fact, one may result from efforts of the several competitors vying for the X-Prize. And these activities may be only opening the gateway to a large and profitable extension of what is already a more than one trillion dollar tourism industry here on Earth.

Yet there are still a number of challenges to address and hurdles to overcome. Technologies need to be improved, operational regimes developed, financial decision makers convinced that the market is viable and worth the risks, regulatory and legal regimes created, and insurance issues addressed. Given the considerable potential benefit of space tourism to the U.S. economy, the government may choose to make use of options for accelerating industry growth, including additional R&D investments and refinement of regulatory regimes. The challenge for policymakers and industry participants is to determine the appropriate roles of the public and private sectors in helping this burgeoning industry succeed.

Cargo Delivery

A New Kind of Horse Race

In 1860 three businessmen launched the Pony Express, the fastest coast-to-coast delivery service to date. This innovative form of transport sliced delivery time in half to 13 days. Despite high costs, it was able to attract customers who needed to pass vital information along in a hurry. The Pony Express enjoyed a fledgling success and glowing press clippings, but it folded in just 19 months. A new technology wiped out the startup's customer base before it could make a profit: the transcontinental telegraph.

The story is a lesson in how quickly markets and technologies change. It applies as much to payload bays as saddlebags. Space transport is not an integral part of the mainstream transportation infrastructure. Unlike the more traditional modes of air, rail, waterways and highways, this capability sprang from a national security mandate and not from any market-driven enterprise. High operating costs and limited availability have kept it from competing successfully with the other modes. The result is an industry searching for customers.

The question before space entrepreneurs is whether to make the transition from space pioneer to transportation provider. The technology brings specific advantages to the latter proposition. No other mode can offer the same degree of speed and geographic coverage. But if that's all commercial spaceflight can bring to the table, it will not succeed even if the price is right.

Transportation is only one part of a chain of events that put a product on a shelf or an envelope in the hand. Whether it's called 'logistics' or 'supply chain management,' this sequence covers the lifecycle of a product, from the sourcing of raw materials to disposing of an obsolete or returned item. The business of managing transportation is increasingly about balancing the costs and efficiencies of producing, storing, and distributing the product. For these reasons, the advantages of speed and broad geographic coverage alone will not capture a new market. For space transport to do that it must link its advantages to the other elements in the chain.

Historically, the goal of transportation has been to increase the speed of delivery. With this rationale, the ability to circumnavigate the Earth in less than two hours is the logical next step in the evolution of transport technology. But it is not the next step in the transport

business. Improvements in air, ocean and surface transport in the last 25 years have replaced the imperative for speed with something wholly different: timely delivery. "As soon as possible" has given way to meeting specific time windows defined in hours or days. When inventory management and cost controls are key, too early is as great a sin as too late.

The trend is evident in the airfreight market. Air is the closest modal competitor to spaceflight in speed and coverage. Air transit is best suited for important documents and high-value, small-volume shipments that must be delivered shortly after manufacture. Semiconductors, electronic components and certain pharmaceuticals are examples.

U.S. organizations spend $91 billion annually for time-definite or "expedited" delivery. More than half of this market is for "time-deferred" service of two and three-day windows. The time lag permits adequate planning but is short enough to help defray the cost of carrying inventory. More significantly, two-thirds of these hauls are 700 miles or less, leading to a greater demand for truck transport instead of air.

Down the Stretch

Time-definite service has upended the traditional transport imperative of faster delivery just as the telegraph outpaced the mustangs that ran for the Pony Express. Time-definite is the product of a decades-long transformation in how products are manufactured and delivered around the world. Specifically, the goal is to eliminate the cost of carrying inventory and obsolescence while ensuring a faster response to market preferences. For these reasons manufacturers have steadily moved their operations closer to the markets where the product will be assembled and sold. They are outsourcing the responsibilities of warehousing, consolidation, distribution and even some aspects of manufacturing to independent contractors. It is a demanding but lucrative strategy. In the United States alone, the total amount of money spent on logistics last year was more than $1 trillion.

The auto industry, for example, has off-loaded the bulk of its supply chain responsibilities to a hierarchy of suppliers, classified as "Tiers," who make and manage the components and subsystems. The arrangement allows the automakers to concentrate on a core business of designing and marketing vehicles—not making them.

If space transport is to become a new link in the supply chain, its purveyors will have to recognize that it is competing not only against the cost and capabilities of other transport modes, but of manufacturing, distribution and holding inventory. For example, a space transport company may position its competitive edge as a replacement for a new manufacturing plant or warehouse – instead of these capital investments, a company could procure almost instantaneous global delivery that is as flexible and scaleable as necessary.

Of course, once the shipments are on the ground they would need access to the appropriate Earthbound transport for delivery to the final destination, which is another challenge for space delivery systems. While orbital or suborbital space systems could provide extremely quick and efficient point-to-point delivery, any efficient system will require substantial ground infrastructure to ensure that shipments reach their intended destinations. The space delivery segment is only one piece (and not even the most complex piece) of the delivery chain. DHL could have the fastest planes in the world, but without a means to deliver packages to the consumers, it would have no customers. Space cargo systems could contract with third parties for local delivery, yet the efficiencies and benefits of space travel may be lost without spaceports in every city. For a space-based system to work well, client facilities would have to be located near spaceports, just as most important manufacturing facilities today are built with easy access to seaports or airports. This is the only way to maximize efficiency and reduce time lost to ground travel.

Developing a global space cargo industry will be extremely challenging and will likely require a major anchor tenant that requires near-instantaneous global delivery to provide any carriers with sufficient volume to justify the expense of building the infrastructure. The U.S. Postal Service kicked off the air cargo delivery industry by committing to commercial procurement of air mail services. Similarly, Federal Express got its start in the expedited delivery service business by landing the Federal Reserve Bank as its anchor tenant.

There are two requirements before a space cargo industry can arise. First, as with the tourism industry, less expensive, more efficient and more dependable launch systems will have to be developed. It may be that the technical and economic challenges of new vehicle development could be decreased somewhat through initial focus on suborbital capabilities. Yet, to successfully respond to market demand, even suborbital vehicles would have to provide technical and operational efficiency and reliability well beyond that available with current launch vehicles. A space cargo delivery company would have to fit into the existing global transportation network, taking into account such issues as tariffs, taxes, export controls, and import restrictions. Second, space delivery companies would have to demonstrate a clear commercial need and possibly also sign an anchor tenant to provide sufficient volume while the provider is working to establish a market presence.

As noted earlier, NASA's efforts in the Space Launch Initiative (SLI) are intended to lead to cheaper, more reliable launch systems that also feature more efficient ground processing and support systems. If successful, this program might eventually provide revolutionary advances in commercial space transportation, thereby benefiting all emerging commercial space markets, including cargo delivery. However, operational vehicles based on SLI-developed technologies are not expected to be available until early in the next decade. New space launch vehicles intended for use well before that time would have to based on existing technologies, or on new technologies derived from more near-term research efforts.

In addition to government-financed research and development, analysts have suggested a number of other possible government incentives that might be employed to stimulate a space cargo delivery market, including anchor tenancy arrangements and tax incentives for any industry that uses space delivery services. Whatever action government may take, however, the success of space cargo delivery market development will ultimately depend on the effectiveness of its proponents in identifying the commercial requirements for the service and satisfying the precise technical and logistical needs of future customers.

BRINGING INDUSTRY TO SPACE: BIOTECHNOLOGY, PHARMACEUTICALS, MATERIALS AND POWER

Of all the things that can be done and will be done in space, industry – including research and manufacturing as well as power generation — is the most difficult for which to predetermine a timeline. Decisions in industry are not clouded by the gee-whiz factor that is such a motivator for the general public. Industries will move into space when it is profitable for them to do so, and not before. Prognosticators have been anticipating industrial uses of space for decades, with little to show for their predictions to date. Thanks to research opportunities onboard the Space Shuttle, there have been some important advances in a variety of fields, including molecular biology, materials science, botany and protein crystallization. Yet the obstacles to making space attractive to industry remain large. Still, recent developments have shown that these dreams of the future may actually be closer to reality than many have believed.

Revealing Industrial Potential: The Space Shuttle and the ISS

The Space Shuttle, primarily during its Spacelab missions, enabled hundreds of investigations in a wide array of fields, as NASA researchers worked with teams from industry and academia to explore the unique properties of space. With the advent of the ISS, opportunities for sustained research will expand, and the potential for a breakthrough application will increase. Valuable research has demonstrated the unique properties of the microgravity environment and indicated some potentially important directions for future industrial applications.

For example, the microgravity conditions of space enable the growth of large, superior quality crystals that could be the predecessors to synthesized proteins for fighting disease. Materials have been developed without the structural flaws that often accompany their production on Earth. Cell growth and interaction can be better observed in a microgravity environment where there are fewer outside influences. Additional groundbreaking research is expanding knowledge in a variety of fields:

- Neurominidase inhibitors have been developed that could lessen the severity of influenza and eventually lead to a vaccine against the virus.
- The study of Respiratory Syncytial Virus antibodies could lead to synthesized proteins targeting a disease that affects 4 million people annually.
- Gene transfer among plants appears to be more successful when using a bacterial technique in a microgravity environment.
- Studies on the intercellular conditions of breast cancer tumors and healthy breast cells have led to better understanding of how these cells develop.
- Development of highly conductive, pure ZBLAN fiber optic fibers may lead to vast improvements in terrestrial communications.

Experience on the ISS is also helping to establish appropriate procedures to manage in-space environmental concerns. NASA has strict guidelines for research conducted on the Shuttle and the ISS. Unlike ground-based research, the microgravity environment has unusual properties that can cause concerns for human researchers. Some substances may not disperse harmlessly into air as they would on Earth, remaining in dangerous concentrations, while others that would normally fall to the floor remain suspended in midair, where they could have harmful consequences if accidentally ingested. Another environmental concern often voiced by the scientific community concerning the ISS is that of disruptive vibrations. The reason for conducting most experiments in space is the pristine environment of near-zero gravity that enables growth properties impossible on Earth. The presence of humans, no matter how careful they are, introduces microvibrations into the facility that compromise active research.

One means being used to deal with such environmental concerns is the establishment of standards that protect astronauts while maximizing opportunities for industrial activity. Concern about the health and well-being of astronauts justifies testing of experiments in advance of deployment, to make sure no outgassing or other potentially harmful side effects occur while conducting the experiment in orbit. To encourage industrial applications, more attention is now also being paid to the need for increased procedural flexibility and speed.

For maximum near-term progress, appropriate pricing is also needed. One option put forward is the auction of available research space onboard the ISS as a means of establishing pricing level. An auction might increase visibility of, and interest in, the program among the research community. An intriguing possibility is that participants involved in such auctions might be just as interested in the publicity of leasing space aboard the space station as they are in the use of the research facilities themselves. Of course, clear guidelines would be necessary to keep activities within an acceptable range.

Yet another option for dealing with concerns raised by human industrial activity in space is development of additional automated, small-scale, low-cost, and privately-funded orbital platforms that could significantly accelerate subsequent exploitation of the industrial potential of the microgravity environment. This possibility will also be explored below.

Cashing In: Expanded Private-Sector Industrial Activity

How can private-sector companies and investors begin to capitalize on the opportunities that the Shuttle and ISS have made possible? One thing is certain: although the private sector will be justified in moving into space whenever it is genuinely profitable for them to do so, decision makers must be *aware* that real opportunities exist. Consequently, a key challenge in moving industries into space is to confront and dispel the widespread lack of knowledge about the microgravity environment and its enabling characteristics. Most research directors at biotech companies, pharmaceutical companies and semiconductor manufacturers have little, if any, knowledge of microgravity and are unaware of potential benefits the space environment might impart to their research activities. Microgravity science is a small field with many cross disciplines, and the diffusion of information can be inconsistent and imprecise. Reaching appropriate researchers who may benefit from advances is accordingly difficult at best. However, through a focused and sustained public and private sector effort, the message of opportunities for research in space can be effectively delivered.

Instead of focusing on what cannot be done, the key to near-term industrial expansion into space is to concentrate on what *can* be done in space. As technical progress takes place, industrial growth can advance in gradual, incremental fashion. At each stage of incremental advance, investors and companies can limit the size and terms of their investments to match the return-on-investment scenario appropriate at a given level of market demand and technological capability. What follows is an effort to offer some thought-provoking observations to stimulate interest in the economic potential space may hold.

Potential Opportunity: Small Automated Space Platforms

Two industries posing both considerable obstacles and considerable potential for space-based activity are biotechnology and semiconductor manufacturing. Biotech is one of the fastest growing industries in America, accounting for more than $365 billion in annual

revenues. These companies are typically young, flexible and open to new ideas, and they spend an average of 10-15 percent of their revenues on research and development. With the proper educational outreach, there would undoubtedly be a number of biotech enterprises interested in probing the potential of microgravity research.

The demand for accelerated biotechnology development has never been greater. In this new era of heightened security concerns, the United States and other nations will undoubtedly need to increase research into biological warfare so as to discover methods for effective response to biological attack. Specialized space facilities could in the relatively near future serve as secure testbeds for such research, because the risk of inadvertent contamination by research organisms, which is always a serious concern with Earth-based bioweapons research, would be dramatically reduced.

Semiconductor companies, overlooking a temporary downturn that is afflicting the entire technology sector, comprise one of the most profitable and dependable sectors of the U.S. economy. Intel, the largest of these companies, enjoyed after-tax profits of $6.1 billion, $7.3 billion, and $10.5 billion in each of the last three years. Companies in this sector are used to spending billions of dollars on R&D and factory construction — Intel alone spent $3.9 billion on R&D in 2000. Given industry's demonstrated willingness to commit such large amounts of money to Earth-based R&D, the stage is set for expanding this activity into space. Although advances in holographic data storage and optical microchips are rapidly increasing Earth-based research capabilities, specialized research into new data storage or processor concepts might be greatly facilitated by space-based activities.

Unlocking the potential of biotechnology and semiconductor activity in space requires tailoring research platform design to the specific needs of these industries. Success in the biotech industry comes out of its laboratories, where scientists must perform thousands of identical assays to determine the validity of investigative directions. For scientists who must measure results rapidly and make consequent incremental changes to test parameters, the ability to modify the characteristics of orbiting materials is critical. Similarly, in the semiconductor industry, with new product cycles lasting only 18 to 36 months, manufacturing facilities must be retooled rapidly to respond to new technologies and market requirements.

Given these industry requirements, it may be that some in-space activities requiring direct human access on a regular basis will have to be delayed until development of new launch vehicles with high flight rates and short turnaround times between flights. Even before such vehicles become available, however, advances in robotics and remote control of high-precision movements may render automated or remote controlled platforms feasible. If surgery will soon be performable by a surgeon miles away from the patient, can remote control of in-space industrial modules be far away?

Potential Opportunity: Space-to-Space Solar Power

Solar power generation is another area in which industrial activity might prove worthwhile. Terrestrially collected solar power has not become popular on a large scale for several reasons, most notably because weather and Earth's natural day/night cycle make systems inefficient. By contrast, putting a solar array in high Earth orbit would give it constant exposure to the sun, enabling it to work 24 hours a day, 365 days a year. The collected energy could then be beamed to microwave receivers on Earth for use by terrestrial customers. With global energy demand projected to increase by 100 gigawatts annually over the next 20 years, a clean and inexpensive source of power would seem to be an attractive alternative. Also, today's national security environment exposes the potential risks from relying on foreign sources of energy, and a U.S.-developed and controlled alternative may become attractive in the future for other than purely economic reasons.

To make space solar power economically advisable, however, market demand must be robust. Today, the technology available for generating power in space and beaming it to Earth is not sufficient to lower the cost to a point where space-generated power can compete with Earth-based alternatives. This is illustrated by the relatively prompt resolution of well-publicized power shortages in California, which at one point led many people to believe there was an acute energy shortage in the United States. The real problem, however, was one of distribution rather than scarcity. With the construction of new, efficient power plants and better managed distribution systems, shortages such as that one are unlikely to be repeated on such a scale. Between 2000 and 2005, for example, forecasts anticipate construction of new power plants generating 262 gigawatts of energy in the United States alone, providing excess capacity for the near term. New drilling technologies and exploration techniques have greatly expanded supplies of oil and natural gas. New power generation technologies, especially advanced turbine systems using natural gas, have substantially increased the efficiency and lowered the cost of creating electricity. Economists project that power costs are likely to be even lower in 2020 than they are today. The fact is, energy for the foreseeable future is abundant and inexpensive, although the United States alone is projected to need 45 percent more power by 2020. Yet, as solar power generation technology advances, this state of affairs may significantly change.

Near-term investment opportunities may more legitimately focus on use of solar power generation satellites to meet the demands of a different, but potentially very lucrative market — providing power for in-space activities. Freeing satellites of the necessity of having their own integrated power sources could open up a host of new space applications. For example, in order to reduce the obstacle posed by high launch costs, a cluster of microsatellites could be launched on one vehicle, while a much larger and heavier power generation satellite could be launched on a separate vehicle. In space the orbits of the

feeder satellite and receiver satellites could later be appropriately synchronized. Investment in power-generating satellites could be coupled with investment in less expensive receptor satellites, creating a potent and profitable combination.

Another possible application of space-to-space solar power might be to facilitate exploitation of higher radio frequencies for space-to-earth communications. Higher frequencies generally require a greater level of power consumption than would currently be cost-effective in space. However, with the availability of cheap and abundant solar power generated in space, use of higher frequencies might become economically attractive. Given the current pressure to make maximum use of all available radio spectrum, exploitation of this potential market opportunity might be well worth near-term consideration.

Thus, although reduced launch cost is a critically important need, today's relatively high launch cost need not be seen as an insurmountable barrier to near-term development of carefully selected facets of space solar power.

BRINGING OUT THE STARS: MEDIA, ADVERTISING AND SPONSORSHIP

Media is everywhere. No matter where one travels or what one does, advertising, logos and information are sure to be present to convey specific messages to whoever happens to be watching or listening. It is inevitable that in this Information Age media would travel with humans into space. In fact, it has already done so in numerous ways, although there has been no concerted and coordinated effort to form a mutually beneficial relationship — where media benefits from space and space activities benefit from the media. From movies to advertising to branding, there are a multitude of opportunities to harness media's ubiquitous message.

Movies

Space is a dynamic setting for movies. According to the IMAX Corporation, the large format space trilogy (*The Dream is Alive, Blue Planet*, and *Destiny in Space*) has grossed more than $250 million and has been seen by more than 70 million people worldwide. There are at least seven other large format films that deal directly with spaceflight or space science, some of which include footage shot in space from the Shuttle, *Mir*, the ISS and various space probes. The relationship between NASA and IMAX is clearly mutually beneficial – IMAX receives a popular product and NASA engenders positive publicity about its activities.

In addition to these documentaries, there are countless feature films about space, yet Hollywood has yet to shoot a feature film in orbit. Directors either simulate the microgravity environment or bypass it all together. With recent advents in computer technology, special effects can sometimes make simulated space seem more realistic than the real thing. Yet there are some directors who are not satisfied with computer-generated substitutes, as they recognize there are subtle properties to microgravity (and human reactions to them) that are not faithfully reproduced by computer graphics. Ron Howard used NASA's KC-135 (the parabolic "vomit comet" airplane that can achieve microgravity for periods of about 25 seconds at a time) in filming *Apollo 13*, for example. The microgravity effects in his movie are real, albeit not filmed in space. Russian film director

Yuri Kara long sought the opportunity to set a movie on *Mir* about a rogue cosmonaut who refused to leave the facility, and U.S. director James Cameron recently broached the idea of filming part of a movie on the ISS.

Interest from Hollywood is certainly there; if NASA were to open up the ISS to film crews, it is likely at least one producer would pursue a project. The costs would be high, but Hollywood is not averse to big budget projects. Directors and any actors would have to endure special training, be flexible with filming schedules, make do without large film crews, and cope with space sickness, yet all these challenges could be overcome. The opportunity to film in space might well justify the investment needed to meet these challenges.

The more serious hurdle is conflict with scientific activities aboard the ISS, which would probably prevent any significant use of the facility for commercial filmmaking purposes. A real in-space moviemaking industry will not likely evolve unless a dedicated studio, designed for the needs of film crews, is launched. Such a facility has been proposed as an addition to the ISS, to be built by Spacehab.

Despite potential complexities and expense, there may be considerable benefit to allowing a film crew in orbit. Allowing the public to see the program through the eyes of someone other than a scientist or engineer could boost public perception of the space program and NASA itself. That said, NASA would clearly want to approve the script in advance. NASA has established procedures for such action by their involvement in previous films such as *Apollo 13* and *Space Cowboys*. Presuming interest, funding, and a worthwhile script, NASA participation in a feature film effort could be the equivalent of a tourist trip for 100 million taxpayers.

Television

Producers from the small screen have also shown an interest in taking their business to space, although the types of requests are more varied. Some people consider the first space tourist to have been Toyohiro Akiyama, a Japanese television journalist who spent 8 days on *Mir* in December 1990. Despite severe space sickness, the news anchor made daily broadcasts from the Russian space station. The cost of his flight was pegged at between $20 million and $28 million. In February 1998 Russian cosmonauts hawked Fisher space pens from orbit on QVC, the home shopping network. Also in the late 1990s CNN unsuccessfully negotiated with Russia to allow journalist John Holliman a trip to Mir for up to $15 million. The producer of the game show Survivor had partnered with MirCorp and NBC to offer *Survivor: Destination Mir*, where contestants train in Star City and the winner received a ride to Mir on a Soyuz. With the demise of *Mir*, the destination may become ISS, if the international partners can agree on guidelines.

Prior to the Challenger accident in 1986, NASA was considering a journalist-in-space effort. Journalists are paid to describe events and issues to the public, so they would make excellent candidates to explain the experience of space to those on the ground. In addition to pursuing novel, short-term space flight opportunities, news organizations may also have an interest in maintaining long-term television capabilities in space to support their daily operations. Many media outlets are already paying thousands of dollars to purchase high-resolution satellite imagery from companies like Space Imaging and Digital Globe in order to illustrate or investigate major developments around the world. News organizations also expend significant resources to dispatch and station reporters in remote areas where such events are unfolding. It seems reasonable to suggest that some news media interests may wish to establish continuous broadcasting capabilities in space — either manned or unmanned — to exploit the unique vantage point of earth orbit.

Other television production possibilities include educational programming. Educational television is also likely to stimulate strong interest by the viewing public, which would be particularly beneficial at a time when NASA is trying to raise the level of interest in science and engineering careers in the U.S. Currently, flights that could be listed as raising public awareness (the flight of two U.S. congressmen, the teacher in space program, IMAX films, and John Glenn's recent Shuttle trip) were done pro-bono, as they helped fulfill NASA's educational mission. Some have argued that in the future, NASA should be allowed to fly non-mission critical individuals on the Space Shuttle, and to collect payments for such flights. One way to do this might be to auction a flight, enabling the market to establish a reasonable price. As with filmmaking, NASA would clearly have a role in qualifying the candidate(s) and ensuring that their activities do not conflict with the space agency's mission.

Advertising

One of the more contentious opportunities in space is advertising. To date, only the Russian government has allowed its space program to participate in commercial activities. In the most prominent spots, Pepsi and an Israeli milk company filmed television commercials onboard Mir. In 2001 Radio Shack filmed a commercial onboard the ISS with Expedition Two's Russian commander. Pizza Hut placed its logo on the Proton rocket carrying the Zvezda service module to the ISS. Part of that deal, which reportedly cost Pizza Hut one million dollars, was delivering a pizza to the ISS. While no one expects them to begin regular delivery runs to space soon, the claim that Pizza Hut was the first to deliver pizza to outer space outweighed the cost. In October 2001, during an ISS spacewalk, the Russian crew was paid to install a Kodak logo on the exterior of one of its modules.

Several years ago a Hollywood studio paid $500,000 to paint a billboard of an upcoming Arnold Schwarzenegger movie on the side of a Conestoga rocket. Unfortunately, the

launch was delayed until after the release date of the movie, so the contract was cancelled. Prior to the 1996 Olympics in Atlanta, Coca Cola investigated the possibility of launching a low-Earth orbit "billboard" in space that would be visible over the Olympics and to everyone on Earth along that trajectory, yet there were concerns that the sky pollution would cause a backlash of bad publicity for the firm.

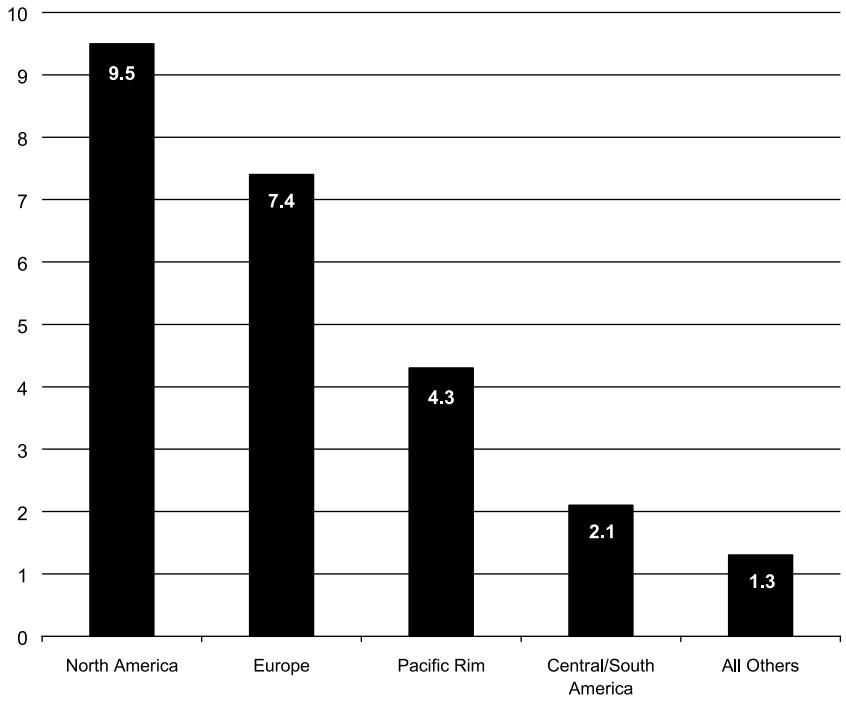
The concepts just considered (including the QVC sales of Fisher pens aboard *Mir*, noted above) illustrate the wide variety of creative ways facilities and activities in space can be exploited to promote different products. Some of these, such as a billboard on the side of a commercial rocket, appear likely to develop without government involvement. There may also be room, however, for commercial messages in government programs. It has been suggested that advertising onboard the ISS could offset program costs in a way that would be publicly acceptable. Appropriate price setting would require creativity. NASA and its international partners would have to review such requests on a case-by-case basis.

Branding and Sponsorship

Corporate branding of facilities and sponsorship of events has become an increasingly popular form of marketing—on Earth. Most often branding has been associated with sports. Federal Express paid $200 million for the rights to name FedEx Field, where the Washington Redskins play. Similarly, CMGi paid $114 million for the same privilege with the new stadium being built for the New England Patriots. Golf tournaments, auto races and college football games all typically have corporate sponsors. Out of 22 college bowl games, 17 have corporate sponsorships in their names. More companies are choosing to use sponsorship opportunities to connect with a particular image, instead of using it as substitute advertising. They use sponsorship to target a particular audience or convey a certain message. One company might support the symphony to communicate an appreciation of life's finer things, while another might sponsor an event at the zoo in order to reach families with young children. The sponsorship market, which is expected to reach $25 billion globally in 2001, could clearly be an important source of publicity and funding for emerging space markets (see Figure 9). While the majority of the market (nearly 70 percent) is dedicated to sporting events, the educational and arts sponsorship markets collectively constitute nearly $3 billion in revenues and suggest a robust market for sponsorships of "higher-purpose" types.[16]

[16] Chart and data courtesy of IEG, Inc.'s "Complete Guide to Sponsorship," 2001.

Figure 9. Global Sponsorship Spending, 2001



Source: IEG Sponsorship Report

One obvious target for sponsorship is the ISS, where there are large and small opportunities for sponsoring station components and events. While potentially controversial, pursuing such funding sources may be perceived as a first step toward commercializing the space station. It would send a signal that space, long perceived as a government milieu, is on a new playing field driven by commercial interests.

Sponsorships and branding may have secondary benefits worth considering. They would increase visibility for the facility and its projects, as any sponsor would want to get value from its investment by promoting the space station broadly. Sponsorships may also draw in valuable commercial interests that otherwise may be difficult to attract. For example, whereas NASA may have difficulty convincing the R&D department of Bristol Myers that it should conduct basic research on pharmaceuticals onboard the ISS, it may not have as difficult a time convincing corporate executives that a Bristol Myers Centrifuge onboard the facility would serve as an excellent promotional program for the company—and it would likely result in active research participation by the company as well.

Sponsorship could also take place in the form of services and supplies contributed to the ISS on an in-kind contribution basis. For example, if an apparel company were to be designated an official sponsor of the ISS, it might contribute crew outfits and footwear (both in space and during training) in return for the right to advertise their sponsorship and

perhaps sell the same "official space apparel" through retail channels. As another example, a food or beverage supplier could provide its products to the ISS in exchange for a similar marketing agreement.

Event sponsorship is not confined to the ISS. Shuttle missions have many of the same opportunities as the ISS. In addition, there are a plethora of deep space missions that could benefit from corporate sponsorship. LunaCorp, a Virginia-based company, is planning a lunar rover mission that is sponsored in part by Radio Shack. This partnership seeks to demonstrate that a profitable private venture can achieve the same goals as a government space mission. Government could create the same sort of public-private partnership by offering opportunities for commercial placement or use of cameras onboard planetary probes.

From movies to advertising, there are numerous ways for the government to help the space program move into the Information Age. Just as the government has supported aerospace markets through technology development, a public-private partnership with media participants could be beneficial to government and industry. The public continues to be fascinated by space activities, as evidenced by John Glenn's shuttle flight and the landing of the Mars Pathfinder. A careful approach to media activities might be embraced by the American public while providing a source of funds, publicity and increased utilization of assets. Such an arrangement could be a winning scenario for all concerned.

A NEAR-TERM WAY AHEAD

Clearly, the single most important technical need for accelerated growth of space commerce is the development of new vehicles that will increase the safety, reliability, flexibility, and affordability of access to space. But even before significant advances in space transportation take place, there are near-term opportunities for commercial activity involving space. As in other fields, the most important immediate need is not for a new *technology*; it is for a new *perspective*. Opportunities abound—for those who can see them.

WORKSHOP SUMMARY [17]

AGENDA OVERVIEW

Panel 1, Part 1: "People and Packages: Suborbital to Orbital Commercialization"

Ann Saccomano, Transportation Journalist (Moderator)
Debra N. Phillips, Executive Director, National Small Shipments Traffic Conference (NASSTRAC)
Charles Miller, CEO, Constellation Services International
Alan Ladwig, Vice President of Marketing, Team Encounter

Panel 1, Part 2: "People and Packages"

Ron Erdmann, Dep. Dir., Ofc. of Travel & Tourism Indus., Intl. Trade Admin., U.S. Dept. of Commerce (Mod.)
Professor Geoffrey Crouch, La Trobe University, Australia
Peter Diamandis, CEO and Chairman, Zero Gravity Corporation
Michael Lyon, Vice President of Corporate Development & General Counsel, Space Adventures

Panel 2: "Bringing Industry to Space: Biotechnology/Pharmaceuticals/Materials/Power"

Molly Macauley, Ph.D, Senior Fellow, Resources for the Future (Moderator)
Paul Silber, President and CEO, StelSys
Dr. Larry DeLucas, Director, Center for Biophysical Sciences and Engineering, University of Alabama
Dr. Louis Stodieck, Director, BioServe Space Technologies, University of Colorado-Boulder
Dr. Braja Mookherjee, Vice Pres. & Global Director of Natural Products Research, Intl. Flavors and Fragrances

Panel 3: "Bringing Out the Stars: Advertising/Sponsorship/Media"

Lon Rains, Editor, Space News (Moderator)
David P. Gump, President, LunaCorp
W. Clark Bunting, EVP and General Manager, Discovery Channel
George Pavlik, Director, Space Systems, L-3 Communications East

Panel 4: "Charting a New Course: Challenges for Government and Industry"

Lori Garver, Vice President, DFI International (Moderator)
Scott Pace, Assistant Director, Space and Aeronautics, Office of Science and Technology Policy
John Higginbotham, Chairman, SpaceVest
Jean Toal Eisen, Professional Staff Member, Senate Committee on Commerce, Science, and Transportation

[17] Panelists' positions are those held at the time of their participation in the workshop.

WORKSHOP PANEL THEMES

DFI International prepared the following paragraphs as general characterizations of key issues addressed in presentations and discussions. Accordingly, these thematic overviews should not in any sense be treated as though they constituted definitive statements prepared by the presenters themselves. Similarly, there is no intent to imply that panelists participating in discussion were in full agreement as to specific conclusions or potential future action.

Panel 1, Part 1: People and Packages

Moderator: Ann Saccomano, Transportation Journalist

Debra N. Phillips, Executive Director, National Small Shipments Traffic Conference

Freight transportation is a vital industry and its requirements are the same whether shipping around the corner or around the universe: on-time delivery, undamaged product, accurate billing, easy access to product, prompt resolution of problems, and speed. In addition, shipping is like any industry in that it is not free; someone (a customer or company) has to pay for the service. Today, freight transportation is integrated across departmental and company lines. The focus is on integrating processes, people and information. To support this type of operation, complete visibility throughout the supply chain is necessary. Satellite technology has been an enabler of real-time information in this process. Satellites track inventory, provide real-time information, and provide security for products, drivers and customers. Storage space is an increasingly expensive terrestrial commodity. Accordingly, space has potential to provide storage capacity for excess product. The value proposition is even stronger in specific segments, such as safe storage or disposal sites for hazardous materials. A specific and structured dialogue between space and logistics industries will be critical to future growth of this potential segment.

Charles Miller, CEO, Constellation Services International

The development of standardized containers was a revolutionary innovation for terrestrial commerce - decreasing labor, time and cost of shipping. Standardized containers are a staple of air, ground and sea transportation, as well as new markets such as home storage. The same principle can be applied to the space cargo market. CSI is developing a standardized container that uses existing technology for ISS resupply. Today, 40,000 kilograms are delivered each year to ISS, at a cost to NASA of about $1 billion per year. A

standardized container, designed for ISS, could be expanded to future space platforms. The greatest challenges facing the commercial space industry are regulatory issues and the lack of market. Contrary to popular belief, technology is not the problem. Government should look at what its practices are for encouraging terrestrial industry and apply those ideas to the space industry. These roles include being a better customer – which helps enable private investment. Specific potential roles for the Department of Commerce (DOC), include: putting together a list of best practices for procurement and encouraging other agencies to follow those practices; advocating a market-based investment stimulus; and studying and encouraging venture capital investment in space markets. One potential model for the Department of Commerce, in terms of its encouragement of space markets, is the Small Business Investment Corporation, which uses U.S. Government funds to encourage privately-managed venture capital funds to invest in new types of businesses.

Alan Ladwig, Vice President of Marketing, Team Encounter

Personal involvement in space is vital to catalyzing new markets. Using space to entertain or to provide a service creates a direct connection with consumers. Team Encounter is focused on building markets based on "virtual participation." Given that direct participation in space is still hindered by space transportation, the first step is to reconnect individuals to space through creative programs and entertainment, in a way that builds demand for future markets. For Team Encounter's sister company Celestis, the service designed to make this connection is space burial. Often such activities are categorized by the "snicker factor" and not taken seriously within established space circles. This has the effect of de-legitimizing these emerging businesses. Government entities should take innovative proposals at face business value, setting an example for investors and potential customers to follow. Companies like Team Encounter are also constrained by the limited availability of space transportation (i.e., limited to occasional commercial missions on appropriately sized launch vehicles). NASA missions are much more numerous but are prohibited from launching commercial payloads. Easing these restrictions would make a difference to small businesses. In 2004, Team Encounter intends to launch the first interplanetary solar sail mission. This mission will bear messages from 4.5 million people. The business model for the project is based on product sales, corporate sponsorships, technology and data product sales. Space sponsorship is a growing market segment, and the government should avoid pursuing the same commercial sponsors that might be courted by private companies.

Panel discussion: The panel discussed the role of NASA, and the government in general, as a customer for developing markets. Historically, the government's role has been to explore the frontier and then let the commercial market step in and develop it. This is envisioned as a key role for NASA in encouraging developing space markets.

In terms of specific proposals, the Department of Commerce (DOC) should consider creating a program equivalent to the Small Business Investment Corporation, targeted on emerging

space industries. Accordingly, the DOC, or a private entity, should study and publish economic indicators on investment in the space market to inform entrepreneurs, investors and analysts of market trends.

Despite the government's important role as a customer, the commercial space industry is encouraged to work with the government to create a working partnership instead of just asking for more money. Finally, in order to facilitate new ideas, efforts should be made by all space industry stakeholders to enter a dialogue with non-traditional (including terrestrial) players for advice and collaboration on market development.

Panel 1, Part 2: People and Packages

Moderator: Ron Erdmann, Deputy Director, Office of Travel & Tourism Industries, International Trade Administration, U.S. Department of Commerce

Geoffrey Crouch, La Trobe University, Australia

Travel and tourism is the world's largest industry, with $4 trillion of gross global product, sustaining on the order of one in ten jobs worldwide. This industry grew rapidly during the second half of the 20th century and is likely to grow and evolve in new ways as consumers seek new experiences, and as new technologies and service processes enable new products. In this regard, space tourism could create a very important new market, contributing to a revolution in space transportation systems and catalyzing other fields of space commerce. In truth, space tourism already exists, as the success of air and space museums, rocket launches, space camps, theme parks and astronomical observation sites demonstrates. Due to Dennis Tito's flight, space travel for the general public is now a real and tangible idea. Even before Tito, several modest studies were conducted in various countries to gauge public demand at various price points. While this research illustrates positive demand trends, from study to study price data are spread across an order of magnitude – an uncomfortable spread for investment purposes, suggesting the need for additional research. In addition, due to their methodology, these market studies may only indicate interest and not predict action. Future market research should utilize choice modeling to identify, define and quantify the structure of the potential market by taking into account how potential customers might perceive, react to and choose among competing options. For example, survey respondents should be asked to trade off choice attributes, such as trip duration, living conditions, training requirements, available activities while on orbit, and other potential tourism options. This stated choice approach has been shown to have advantages when dealing with new products and consequently appears to be a credible basis for future market research in the space tourism arena.

Peter Diamandis, CEO and Chairman, Zero Gravity Corporation

It is important to give people a chance to experience space firsthand. Zero Gravity Corporation was formed to offer people innovative opportunities to experience microgravity here on Earth, on flights that simulate a reduced-gravity environment. The company has received FAA certification for flying a 727 and also received patent protection for converting Boeing products to parabolic flight. This enterprise will offer commercial services to clients in the scientific, media, advertising and tourism industries. The focus of Zero Gravity is to build expectations for public space travel by offering opportunities for public participation. Another venture in this spirit is the X-Prize, a $10 million competition offered to the first private sector team able to launch a vehicle able to carry three adults up to 100 kilometers, land safely and repeat this process within two weeks. There are currently 21 different teams competing for the prize. Near-term actions in the space market should be guided by long-term potential, especially where there is qualified understanding that the potential rewards outweigh the obstacles. The primary challenge is access to capital, which is not flowing into the market because the necessary level of vehicle performance has not yet been demonstrated—something that the X-Prize is seeking to alleviate. Suggested government actions include: R&D tax credits; additional market surveys; innovative procurement; and building appropriate regulatory regimes without pricing new ventures out of the market.

Michael Lyon, Vice President of Corporate Development & General Counsel, Space Adventures

Human drama is key to the space program. This drama was key to public interest in the space program during its first twenty years. However, despite numerous accomplishments, the last twenty years have seen a decline in national and public support, perhaps due in part to a lack of public connection to human drama. In this context, suborbital activities are an ideal prelude to orbital activities. In addition to the pure adventure of the experience, a suborbital flight could provide a qualification process for those expressing interest in subsequently taking an orbital trip. Suborbital and zero gravity activities also offer a less expensive way for people to have a space experience. Presently, many of these options are available only in Russia. Creation of a U.S. spaceport, another area in which Space Adventures is actively engaged, is key to providing a domestic base for these activities and stimulating additional demand. In terms of government support, tax credits and government bonds are extremely helpful for startups in this arena and are preferable to systems based on deferred taxation. Both large and small companies should be eligible to receive such incentives. The regulatory process, import-export actions, and liability issues are other areas where the government should offer support, rather than hindrance, to market growth.

Panel discussion: Russian and American government assets, including launch vehicles and the ISS, represent potential venues for different types of space tourism experiences and

different kinds of customers. While the industry is presently reliant on Russia, American assets may be available for limited use within a year.

The government is encouraged to avoid competition with the nascent space tourism industry. Government-sponsored flights for people who would have a social or cultural contribution (teachers, artists, etc.) are appropriate, as they would not be in competition with private companies for paying customers. At the same time, prizes have many successful precedents during the 20th century, and they could provide a mechanism for NASA to encourage market growth.

Compared to orbital alternatives, suborbital flights have a number of advantages, including: less vehicle fuel use and thus reduced vehicle weight; greater safety and physical comfort for passengers; no export regulations; and less complicated technology. Consumer perceptions of suborbital versus orbital flights are not as well understood and merit further research.

Finally, government, industry and financial markets are encouraged to keep in perspective that technical risk is part of the space business – and accidents happen. However, if people are informed and willing, they should not be prevented from taking part in ventures involving significant safety risk. Likewise, government policy and regulations should be designed with a realistic assessment of the industry's risk profile.

Panel 2: Bringing Industry to Space

Moderator: Molly Macauley, Senior Fellow, Resources for the Future

Paul Silber, President and CEO, StelSys

StelSys is a bioscience company focused on using NASA microgravity bioreactors to develop significant products and services to benefit human health. These bioreactors simulate the microgravity environment of space and are particularly useful for studies of cell growth because they maintain and sustain the cells for much longer than in a traditional research environment. By sustaining the cells of infectious diseases, for example, researchers have a better opportunity to study and potentially culture the cells, and perform critical research on antibodies and treatments. This effort arose through extensive and lengthy discussions with NASA. The length of the process is due in part to an absence of a central point of contact or decision-making at NASA for ventures of this kind. Lawyers, whose main focus is regulatory, appear to have more influence on much of the process than do people with business experience. Despite good intentions on all sides, obstacles to optimal functioning exist. Streamlining the commercial proposal process would be a valuable first step toward encouraging private sector participation in space markets.

Dr. Larry DeLucas, Director, Center for Biophysical Sciences & Engineering, University of Alabama

NASA Commercial Space Centers, located around the country, are focused on involving industry in space-related activities and engaging students by partnering industry with universities. The Centers are required to turn in a business plan and annual report, and are peer-reviewed both internally and externally, which forces them to take a strategic approach to operations. For industry, the Centers offer a less cumbersome partnership than would be involved in working directly with the government. All of these observations suggest that space-based research should be conceived of as "value-added," when considered alongside existing ground-based research. Biotechnology advances are going to dominate the next decade, building on the success of genomics during the last several years. In order to develop new pharmaceuticals, however, scientists will have to understand the behavior of target proteins in the human genome – a field known as proteomics. Crystallography will be a key part of this process, and space production of crystals – which show a higher yield of usable specimens – has the potential for economic impact on these markets. However, biotech companies need to be convinced there is an advantage in doing research in space. An infrastructure facilitating public-private interaction, marked by mutual trust, must be built before companies will pay for space research.

Dr. Louis Stodieck, Director, BioServe Space Technologies, University of Colorado-Boulder

In addition to their role as a point-of-contact and facilitator for private industry, NASA Commercial Space Centers play a critical role in providing frequent and productive access to space. While space-based research can bring great benefits, it is also a costly and time-consuming activity. Mission integration and operations, hardware development, and transportation are all significant expenses, which render space-based research economically prohibitive in comparison to similar terrestrial experiments. There is also an issue of time: the process of experiment approval, and then preparing and getting the experimental materials into space, is more expensive and takes longer than the subsequent performance of the research itself. Without subsidies of some kind, greater participation from biotechnology, pharmaceutical, and agricultural industries is unlikely for the foreseeable future. There are a number of methods, however, that could help control and distribute these costs. One strategy is to form research consortia. This approach, which brings together companies that might normally be competitors, can be especially useful in the costly and risky early stages of research. It is also helpful to maximize flight opportunities by putting as much as possible on the payload, and using generic hardware to decrease custom development costs. Research at this particular center is focused on fermentation processes for the biotechnology and pharmaceutical industries, lignen production in trees for the paper and pulp industry, porous biomaterials for bone and joint implants, and compounds to prevent bone loss and promote resorption.

Dr. Braja Mookherjee, Vice President & Global Director of Natural Products Research, International Flavors and Fragrances (IFF)

It is important for research to have direct human benefit. IFF used Space Shuttle-based plant research to create a proprietary fragrance designed to enhance consumer enjoyment. The experiment yielded data that the growth and composition, and thus also the aroma, of the rose were enhanced in a microgravity environment. Similarly, the three or four components of the rose that are the greatest contributors the rose's aesthetic fragrance were dramatically enhanced from zero-gravity growth. While the perfume was created for consumers, the same research methods could also be utilized to study retention of olfactory and taste capabilities during long-term Government space missions. Likewise, future studies of plant growth on orbit or in reduced gravity environments, such as Mars, could yield future insight into the mechanisms for perception of odors and the creation of new fragrances.

Panel discussion: Ground based research will pave the way for both space-based research and production in fields such as pharmaceuticals and biotech. The question is only at what point space-based manufacturing will actually begin. The interest is there, but launch costs and time issues prevent companies from proceeding past the early stage of exploratory research. The government is encouraged to play a role with regard to space access. For example, royalty arrangements, such as those used in the oil industry, could help alleviate the cost burden for launch. In addition to access, if "platform technologies," such as a protein crystallography facility, were easily accessible and commercially available, it would help attract commercial customers.

Time to deployment is also a major issue. The time to market for industries such as pharmaceuticals and biotech is short – for example, when a pharmaceutical company picks a protein as a target for studying cancer or any disease, failure to achieve significant results in eight months would result in the company dropping the effort. Given that it takes several years for projects even to get manifested on the Space Shuttle, there is not yet a compelling case for companies to perform anything but modest research.

In the context of deployment time, government regulations for flying experiments are also of concern. From the perspective of potential customers, there is too much paperwork and red tape involved.

Panel 3: Bringing Out the Stars
Moderator: Lon Rains, Editor, Space News

David P. Gump, President, LunaCorp

In the long-term, space sponsorship should add value, not just "re-label" the ISS or other entities. Building public participation is key to the sponsorship equation. LunaCorp has developed telepresence portals that allow virtual interaction with a space probe. In addition, the company has also worked on filming commercials aboard the ISS. Through these kinds of projects, sponsors can make space exploration a participatory experience and create a connection with the public. For example, people can control robots from thousands of miles away or virtually ride along with a rover in real-time. Another area the company is developing would change the way satellites are launched and deployed. Under this method, satellites would be packed in foam containers and shipped to the ISS on the Shuttle. Astronauts would assemble the satellite on orbit, test it, walk it out the airlock, and deploy it. The approach is designed to reduce risk as well as mission costs associated with preparing the satellite for the mechanical and acoustical vibration of a traditional launch.

W. Clark Bunting, EVP and General Manager, Discovery Channel

One way to provide a personal connection between space and consumers is through television programming. The Discovery mission is to entertain, enrich and enhance the lives of its viewers, through the highest quality real-world storytelling possible. By making science and space accessible to everyone, and by telling stories about real people, a relationship is created. Such a relationship sparks further interest. In the last several years, television programmers have had increasing competition from new entrants. In order to cut through the clutter of available programming, space-oriented television has to be engaging, innovative and popular. The highest rated space programming at Discovery has employed an integrated approach to engaging the viewer: innovative programming, cutting-edge animation, an online and broadband component, and close collaboration with NASA.

George Pavlik, Director, Space Systems, L-3 Communications East

The communications infrastructure on ISS is just as important as the media products it enables. This infrastructure is the transportation vehicle for the research and entertainment applications of the present and future. For many current commercial applications, however, this infrastructure does not have a sufficient amount of available bandwidth. These issues are caused by a variety of technical issues related to hardware, architecture and physical limitations. Technical challenges aside, it is very important for

current and potential users to quantify both "wants" and "needs" to NASA to provide a basis for improvements and augmentations. At the same time, "better" does not necessarily mean "good enough," and there may be limitations that cannot be overcome or requirements that cannot be met. Quick fixes could be implemented, but if they were not sufficient for commercial requirements, an entire new replacement system would subsequently need to be built at a much higher cost, which could be prohibitive to many users.

Panel discussion: Cost is a major factor in media participation in space activities. Due to prohibitive expense, media participation in space is focused on only a few opportunities. One method to lower cost is to distribute an opportunity among several different users.

To effectively connect the media programming with the public, space needs to be personalized; for example, the public generally do not know astronauts by name. If a story can be told through the eyes of a particular person, it is more accessible to the public and helps generate the viewers and economic incentive necessary for media companies to participate.

Sponsorship is a challenge for NASA because in dealing with a company in a specific category, there could potentially be complaints that others were not given a fair chance. If certain space assets were switched to private ownership, it would alleviate this challenge for the government. By and large, most sponsors are interested in maintaining the image of NASA's brand and using it to elevate their own image. Beyond this, the government should be a customer of services rather than an owner of infrastructure.

Panel 4: Charting a New Course

Moderator: Lori Garver, Vice President, DFI International

Scott Pace, Assistant Director, Space and Aeronautics, Office of Science and Technology Policy (OSTP)

The Space Policy Coordinating Committee is under the President's National Security Council (NSC) and is the primary venue by which OSTP works with other Executive Branch agencies to review space policy and related issues. OSTP also works directly with the Office of Management and Budget (OMB) on R&D spending priorities, including civil space activities. The Administration is committed to active involvement in the space sector, although limited to doing only what is absolutely necessary, thereby leaving maximum room for the private sector to operate. Some of the options for promoting the economic growth of space include: cutting taxes, removing regulatory burdens, and streamlining export controls. It is also necessary to strengthen and reform NASA, using such tools as the recommendations of the Young Commission. NASA is in a transitional period, and in addition to its own

important goals, will increasingly develop a role as an enabler for other private and public sector organizations to accomplish space-related goals. For example, federal agencies that need geospatial data could benefit from increased support from NASA.

John Higginbotham, Chairman, SpaceVest

In many ways, the global commercial space industry is only five years old. Despite its relative youth, it has grown to dwarf the government market. Many in the investment community have a low awareness of the space industry. Nevertheless, there is a growing awareness among the private equity community that well-run satellite ventures can be successful. Those in the space community need to spread the word to non-space industries about potentially lucrative space market opportunities. With respect to the role of government, it is vital to allow the private sector to create new value propositions by focusing R&D funding on critical new capabilities – as opposed to reinventing existing capabilities – as well as integrating commercial practices into government procurement. If these conditions are met, there is an opportunity for the space industry to strengthen the U.S. economy and help it enter a new growth phase.

Jean Toal Eisen, Professional Staff Member Senate Committee on Commerce, Science, and Transportation

Given the current global environment, there are many issues competing for the attention of Congress, and it is important to realistically assess which issues Congress can most effectively address. Commercial space has not been forgotten on Capitol Hill, but it is not the top priority. Congressional perspectives are evolving in response to developments both in the marketplace and in the public policy arena. Although NASA has often been viewed in the past as a primary funding source for new initiatives with significant possible commercial applications, many feel that private investment should also play a key role. In both the public and private sectors, focus should be on opportunities with the greatest economic potential.

Panel discussion: For a variety of reasons, including difficulties in the Internet and telecommunications sectors, it has become more challenging for the commercial space industry to attract private investment. Nevertheless, capital markets retain the capacity to fund sound space-related activities, where there is a solid and realistic value proposition. The space industry is maturing, and there is a better sense of business realities in current proposals.

New commercial space opportunities can be assessed in terms of their addressable markets and the total capital exposure required. At the present time, many potential space business ventures have large addressable markets but also require prohibitively high levels of capital. A number of smaller addressable markets tend to be overlooked, but such markets

could be entered with comparatively less investment. For example, NASA's work on space solar power, specifically in the space-to-space modality, could potentially be applied on a limited scale by nongovernmental organizations to projects carried out aboard the International Space Station.

Government can play a legitimate role as a facilitator of space commerce. That role is primarily to focus on the public good, which includes – but is not limited to – support of basic science that is not yet commercially relevant. Particularly important for both the public and private sectors are dual-use technologies (i.e., with both government and commercial applications). Such approaches are having a growing impact on the marketplace, especially in areas such as remote sensing and satellite navigation (GPS). With a renewed focus on national security, the commercial sector will have the opportunity to develop more dual-use space systems and to direct research efforts toward especially promising areas, such as biotechnology.

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