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“Space Commerce – Market Driven Opportunities for Future Space Commercialization”

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ABSTRACT

As we head into the 21st century, there has been a significant, on-going paradigm shift occurring in the space industry. The once secretive and often adversarial Cold-War relationships that have turned into Post Cold-War cooperation and partnerships have paved the way for market driven opportunities in Space Commerce. The space industry is slowly shifting away from governmental domination, fueled by Cold-War politics and national security fears, to one of open commercial markets most notably in the areas of launch services as well as telecommunications and navigation satellites. In addition, futuristic commercialization opportunities are possible in remote sensing, microgravity research, vacuum based material processing, space derived energy, and space tourism. This paper will focus on current hardware development programs, the commercial trends and future outlook in each of these areas. Private companies are exploiting these various markets by relying less on the government and more on competitive business models supported by market demand or partnerships to share cost, technology and risk.

INTRODUCTION

Since the start of the space age in 1957, there have been about 4,000 orbital launches for an average of about 100 launches per year. The launch services market is expected to experience growth and many changes over the next ten years in response to government and commercial customers' needs for less expensive and more reliable access to space. The major aerospace companies are investing in new expendable launchers with government funding support. At the same time, commercial start-up companies are trying to obtain capital to develop new vehicles with dramatically lower launch costs to meet the demands of commercial customers who want to launch hundreds of communications and navigation satellites. However, current trends indicate there is likely to be a substantial oversupply of launch systems since launch service demand has been hurt by the bankruptcies of the Iridium and ICO Global satellite communications companies.

The demand for launch services in global markets and uncertainties in the space commercialization environment are closely coupled variables that determine the market size and growth rate. Thus, market characteristics contribute directly to the business success of launch service providers. Market uncertainties are important because they increase financial risk to the launch suppliers, so investors require a higher rate-of-return to compensate for the higher risk. This in turn increases launch costs, since adequate profits and insurance premiums must be built into the overall cost. Other significant drivers to market demand include the following items:

- New launch vehicle technologies and their success in reducing the cost to orbit
- Reliability of launch vehicles and the associated “tax” of insurance premiums to mitigate the risk of large financial losses as a result of launch failures
- Government incentives for new launch vehicle development,
- U.S. policy for controlling access to technology through technology export laws
- Need for human access to space and the competing architectural concepts for launching humans versus routine scientific and commercial payloads
- Dependability of launch vehicles to meet launch date commitments since launch delays directly translate to lost revenues if service dates slip
- Demand for global communications systems (voice, video, data) and technology choice between ground-based fiber optic systems and space-based Ka band systems
- Willingness of launch providers to offer long-term contract agreements with favorable pricing and manifesting flexibility
- Availability of “spaceports,” launch sites, and ranges that provide easy access and short lead-times

LAUNCH SERVICES

The market for launch services in the 21st century is likely to be very dynamic as a result of high uncertainty in demand for commercial space-based systems, an oversupply of launch system providers, conflicting federal government policy that encourages space commercialization while implementing regulations that stifle it, and uncertainty over which technological architectures will succeed in the long-term. None the less, market forces and commercialization will shape launch systems in the future. Abundant, low cost, highly reliable launch services enables dependable access to space that was once a significant barrier. Proven technologies enable cost reduction through shorter design life cycles, established mass production techniques, miniaturization, standardization and reduced operations cost.

The launch services market has a high level of uncertainty because there is a “Catch 22.” Low-cost launch vehicles are unlikely to be developed without a mature launch services market; however, launch costs must be reduced in order for a commercial market to mature. This market is driven by three key forces: (1) the government policy that establishes the rules under which government and commercial customers can obtain launch services, (2) the economics of supply and demand in the free market, and (3) the business firm’s need for profits to survive in the long-term. The most important variable is the market demand for launch services. Demand from commercial customers is driven by the cost of accessing space and competition between ground-based and space-based systems for communications, remote sensing, and materials processing. The second most important variable is the supply of launch service providers. We appear to be entering a period where there is a significant over supply of launch systems. Supply is also complicated by the way in which the federal government hinders commercial launch entrepreneurs by competing for research and development (R&D) investments and imposing stifling regulations.

The launch services market generated revenues of \$6.5 billion in 1997. The average price for a launch service was \$75.0 million, but prices vary from \$1.7 million to \$360 million depending on payload weight, volume, and complexity. The launch services market as defined in this section includes worldwide commercial, military, and science-related launches. Space shuttle launches are not included, although the shuttle consumes \$3 billion of NASA’s annual budget. In 1998, the market increased by 21 percent with revenues of \$7.9 billion. Figure 1 shows the number of launches and launch service revenue history from 1994 projected through 2004, as estimated by Frost & Sullivan, a market research firm. The compound annual growth rate from 1994 to 2004 is -4.6%. Data recently published in *Aviation Week & Space Technology* is similar and also references the Frost & Sullivan estimate. The negative growth rate can be attributed to three significant factors: 1) the Iridium bankruptcy, 2) bureaucratic space policy and, 3) restrictions in technology export. For example, in 1998, the U.S. government shifted the responsibility of satellite export licensing from the Commerce Department to the State Department. This has caused a dramatic slowdown of approvals for overseas launches using U.S. launch systems. Similarly, technology export issues have limited the participation of U.S. companies in international joint ventures since U.S. developed R&D cannot be shared.

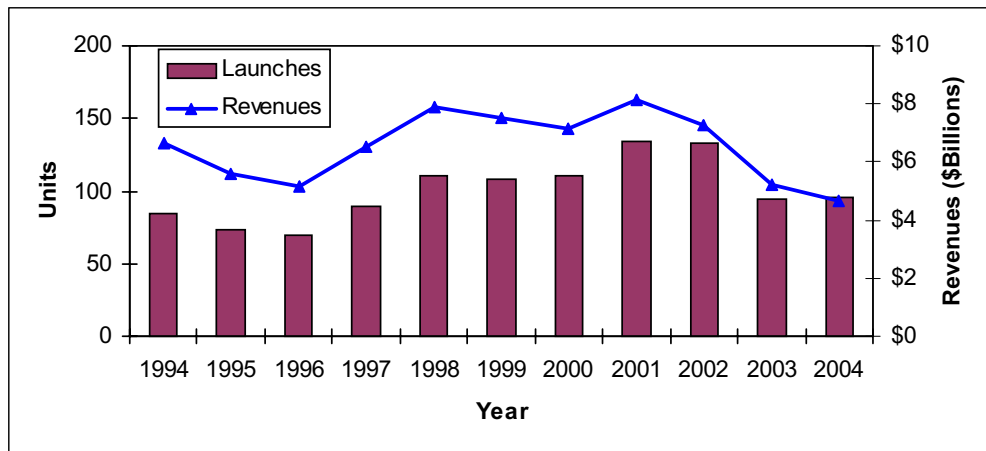


Figure 1 – Total Satellite Launch Vehicle Service Market

Other estimates of the launch services market exist. The FAA’s Associate Administrator for Commercial Space Transportation (FAA/AST) and the Commercial Space Transportation Advisory Committee (COMSTAC) have developed projections of global demand for commercial space launches for the next ten years. These estimates exclude government-sponsored launches for military, defense, and science. Figure 2 shows the payload projections for low Earth orbit (LEO) and geosynchronous (GSO) orbits. The LEO payloads peak in 2003 due to the contribution of commercial communications satellite constellations such as Teledesic. The total number of payloads for the 12-year period is 1,369 for an average of 114 per year. Figure 3 shows the launch projections for LEO small launchers, LEO medium-to-heavy launchers, and GSO medium-to-heavy launchers. The total number of launches is 610 over the 12-year period, for an average of 51 launches per year.

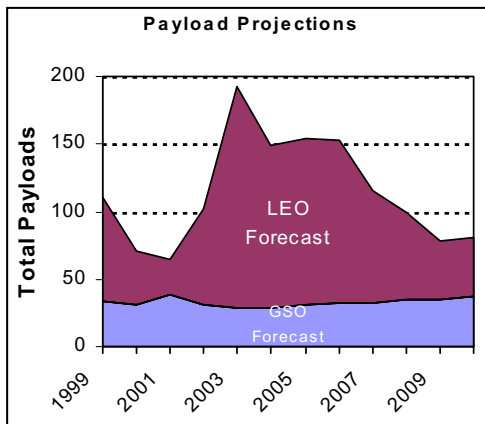


Figure 2 – Payload Projections

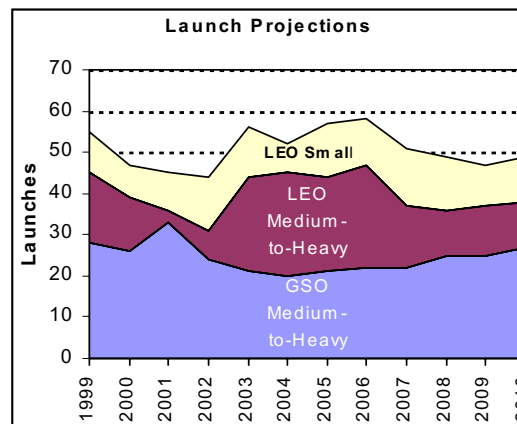


Figure 3 – Launch Demand Projections

Companies tend to compete in two main strategic groups 1) payload capability and, 2) technology level or reduced cost to orbit. As a result, they tend to utilize different business strategies to earn profits. For example, the evolved expendable launch vehicle (EELV) companies (Lockheed Martin and Boeing) offer a full-range set of launch services. Conversely, the “Light” payload companies focus on product niches where customers have a specialized range of interests. The “Low-Cost Entrepreneurial” firms are trying to differentiate themselves through low cost offerings. The “Modified Older Launchers” firms are using global alliances and other cooperative strategies to take advantage of proven, off-the-shelf launch systems that are readily available from international firms. One such program is Sea Launch, which was formed in April 1995 in response to increased market demand for a more affordable and reliable commercial launch service. Sea Launch combines proven launch systems with marine-based operations to provide heavy-lift launch services for commercial customers around the globe. With 19 launches sold to date, the Sea Launch partnership combines the best in aerospace and marine technologies as well as provides a complete launch service package from analytical integration, spacecraft encapsulation, vehicle integration and automated launch processing. In a short time span of five years, the Sea Launch partners of Boeing, RSC-Energia, Dnepropetrovsk-Ukraine and the Anglo-Norwegian Kvaerner Group, built the entire launch infrastructure and working launch system. The equatorial launch site provides the most direct route to orbit, offering maximum lift capacity for increased payload mass or extended spacecraft life. As a result, Sea Launch can afford to charge less than the competition when bidding on payload launch servicing, which is a significant competitive advantage.

Modeling of launch vehicle economics is performed for launch vehicle supply and demand to evaluate the potential impact that new launch vehicles will have on the market. This modeling looks at economic variables such as the cost of access to space (average \$ per kg), the percent of capacity manifested, the percent of market captured, payload size, and the price per launch. A RAND study by Garth Henning has concluded that the government’s objective to achieve lower launch prices by cost reduction is limited by economic principles. Launch firms will seek to price the newly developed vehicles to earn the highest profits possible while still maintaining a full manifest. If new EELVs and even reusable launch vehicles (RLVs) capture a small or moderate percentage of the global market, then the profit motive will be at odds with the government’s objectives. According to Henning: “As long as the new low-cost vehicles do not have enough capacity to meet demand by themselves, there will be some customers who must fly their payloads on more expensive launchers. This means there is little incentive to price the low-cost launchers more cheaply than the high-cost vehicles.” If the new launchers capture enough of the market to push the high-cost systems out, then the launch firms would be in a position to employ monopoly pricing.

The Teal Group, a market analysis firm, calculates that the world has been launching 115 payloads annually since the start of the space age in 1957. They also estimate that while there are 2,100 payloads proposed for launch between 1998 and 2008, only about 1,700 payloads will actually be launched, requiring about 800 launchers to reach orbit. This average of 170 payloads per year is a significant increase over the historical average. At the present time, there is a significant oversupply of launch capacity. Numerous launch vehicles are starved for orders, including Orbital Science's Taurus, Lockheed Martin's Athena, EER Systems' Conestoga, and many of the Russian, Ukrainian, and Chinese launchers. The healthy mainstream launchers, including Arianespace's Ariane, Boeing's Delta, International Launch Services' Proton, and Orbital's Pegasus, are waiting for the market expansion. A problem exists in which dozens of new companies are in the process of developing new launch vehicles, creating a situation where the launch vehicle supply will greatly exceed the market demand. Assuming that only half of the proposed launch vehicles actually get built, there will be at least 30 launcher programs with some 60 available models to compete for a market of 80 launches per year. The present industry standard for the number of launches is set by the Ariane and Delta programs that average 10 to 12 launches per year.

The Teal Group estimates that market demand will not significantly increase as long as the payload cost to orbit remains between \$2,000 and \$8,000 per pound to LEO and between \$8,000 and \$15,000 to geosynchronous transfer orbit (GTO). Launch costs will have to be reduced to between \$100 and \$500 per pound to LOE and between \$1,000 and \$5,000 to GTO before the market demand will increase to 300 or more launchers per year. If prices could be lowered to \$100/lb to LEO, market projections would be doubled or tripled. The DOD funded EELV program has goals to reduce launch costs by 25 to 50%, but this is not considered enough to increase the market demand. Reductions on the order of 50 to 75% are thought to be significant enough to dramatically increase market demand. Achieving these reductions will require reusable technology and launch rates of 25-50 times per year. The commercial RLV pioneers striving to achieve these reductions include Kistler Aerospace's K-1, Kelly Space & Technology's Eclipse Astroliner, Rotary Rocket's Roton, Pioneer Rocketplane's Pathfinder, Space Access's SA-1, and Universal Space Lines' SpaceClipper. The leading contender technically has been the Kistler K-1, but program development was halted in mid 1999 due to a lack of financial capital.

REUSABLE LAUNCH VEHICLES

NASA has established a goal of providing low-cost reliable access to space. While this goal has been around for many years, it received a major impetus when the U.S Congress mandated the Access-to-Space study in 1993. This study concluded that a rocket powered single-stage-to-orbit vehicle offered the best opportunity for low-cost reliable space transportation by close of the first decade of the new millennium. This required a focused technology development program before such a vehicle could be built. NASA recognized that no commercial entity would commit to the development of a single-stage-to-orbit vehicle without the U.S. Government's participation. To this end, NASA entered into a cooperative agreement with industry to develop the required technologies. This effort includes the development of an experimental subscale-vehicle known as the X-33, an extensive ground-based program to provide the required additional technology development, as well as the preliminary design, production and operation of a reusable launch vehicle. The 1994 National Space Transportation Policy directed NASA and the DOD to develop next generation launch vehicle technology in partnership with industry. NASA has been investigating reusable launch vehicle (RLV) technology through the X-33 and X-34 sub-scale demonstration vehicles. A technological extension of RLV vehicles is the single-stage-to-orbit (SSTO) spacecraft that represent the long-term vision. The DOD has been pursuing expendable launchers through the Evolved Expendable Launch Vehicle (EELV) program. In 1997, the Air Force decided to continue to fund both Lockheed Martin's Atlas V and the Boeing Company's Delta IV launchers so it would have a broader portfolio of launch options. Boeing offers a portfolio of five Delta IV models to cover payloads of 9,200 lb to 29,100 lb to GTO, and Lockheed offers three Atlas V models. In 1998, DOD announced that Boeing won 19 EELV missions compared to nine for Lockheed Martin.

NASA is cooperating with the aerospace industry to develop a space transportation system that provides reliable access-to-space at a much lower cost than is possible with today's launch vehicles. While this quest has been on-going for many years it received a major impetus when the U.S. Congress mandated as part of the 1993 NASA appropriations bill that: "In view of budget difficulties, present and future...the National Aeronautics and Space Administration shall recommend improvements in space transportation." This led to the "Access-to-Space" study (Access-to-Space, 1994) which concluded that the best opportunity to reduce launch costs, and improve safety and reliability was to develop a fully reusable single-stage-to-orbit vehicle capable of delivering 25,000 lb to the International Space Station. The study also identified many technologies that had to be matured before a commitment could be made to build such a vehicle. NASA accepted the recommendation and the need for new technology as the key to low-cost, reliable space transportation. In addition, a decision was also made by NASA that it should purchase future launch services and no longer operate a Space Transportation System.

NASA's Advanced Space Transportation Program (ASTP)

Today's high cost of space access is a tremendous limitation to scientific research and space commercialization. The government can sponsor only the highest priority military and civil space activities, and many missions require advancing spacecraft technology in order to achieve low launch costs by placing the satellites on the smallest available launch system. To achieve a profit, the value of commercial vehicles must literally exceed their weight in gold. The National Space Policy, signed in 1996, reaffirmed these goals for NASA and subsequently initiated longer-term technology investments that would assure U.S. leadership for decades to come. NASA formally announced investment objectives in the following goal statement: *“Reduce the payload cost to low Earth orbit from \$10,000 per pound to \$1000 per pound within 10 years, to \$100 per pound within 25 years, and to tens of dollars per pound within 40 years.”* Figure 4 illustrates this goal.

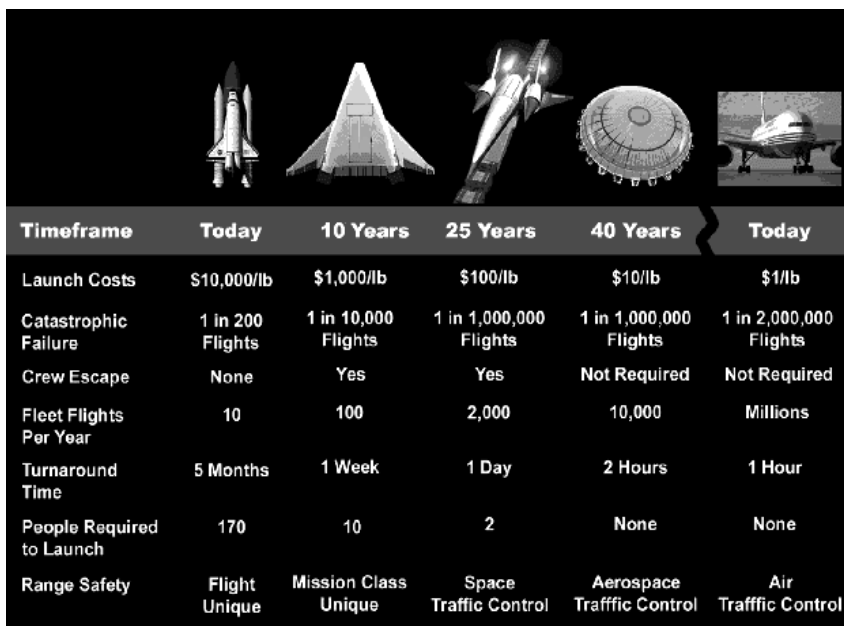


Figure 4 RLV's, Present and Future

In order to meet these aggressive but attainable goals, NASA must focus on new, advanced technologies that U.S. industry can use to regain market share and create new business opportunities in space. In turn, NASA will realize a reduction in launch costs that currently absorb 25% of the Agency's annual budget of \$14 billion. Future, low cost systems must also be far more reliable and safe to operate than current expendable rockets and must focus on performance and simplicity through the invention of new technologies. Some U.S. and foreign rockets used today fail between 1 and 10% of the time. NASA is working to reduce that to far less than 0.1% and strives to reduce chances of failure to one flight in a million within 25 years.

The RLV program was established to be a cooperative effort between NASA and several aerospace companies, and marks a huge paradigm shift from the way NASA currently implements programs. In this cooperative agreement NASA and the selected contractor(s) each provide part of the funding required. In addition, the selected contractor(s) hire NASA centers to perform specific tasks. These cooperative agreements put the decision authority in the hands of the contractors, not NASA. NASA is assisting industry with the development of the "high-risk technologies that industry cannot afford." said Dan Goldin, the NASA Administrator. He also added that "NASA won't build the vehicle, industry will and NASA will be a user, not an operator." The RLV will lead to a commercialization of space access with more airplane-like operations, such that the cost of delivering payload to orbit is significantly reduced. The goal is to decrease the cost to deliver pay-load to low earth orbit LEO from the current estimated \$10,000 per pound to \$1,000 dollars per pound. New launch vehicle technologies are necessary to provide more affordable access to space. Increases to technical performance are required in the areas of advanced materials to reduce structural weight and advanced propulsion systems to provide higher specific impulse. With improved mass fractions and higher propulsive efficiency, the cost to orbit can be reduced.

Reusable Launch Vehicles (RLVs) can further reduce costs by implementing more robust and maintainable launch vehicle systems and processing concepts that can turnaround and re-fly in days rather than months, achieving airline type operations. Single-Stage-to-Orbit (SSTO) concepts require even more exotic structural and propulsive technologies with the potential for even lower cost than RLVs.

Federal Government Incentives for New Launch Vehicles

Providing more affordable access to space is a federal policy goal that cuts across numerous departments and agencies, including the DOD, NASA, FAA, and Department of Commerce. New commercial space markets are too immature and uncertain to motivate aerospace companies to undertake large R&D investments with significant technical and business risk. However, there are a number of incentives the government can implement to stimulate companies to make the necessary investments. These incentives include the following:

- Advance purchase agreements that guarantee a sufficient number of launches required to achieve profitability
- Tax incentives such as extending the R&D tax credit and/or allowing for tax rebates
- Loan incentives with government subsidies
- Government reimbursement of the developer's R&D cost, as in EELV
- Regulatory control of pricing structures charged government and commercial customers

SATELLITES

Investors have used the examples of Iridium and ICO Global's near simultaneous bankruptcies to prove there's no serious market for satellite communication systems. Additionally, they jauntily point out that the explosive growth of terrestrial cell phone systems mostly obliterated the need for "sat-phones". What they fail to recognize is the deployment of successful satellite communications systems such as PanAmSat. None the less, this leaves many wondering why cell phone system billionaire Craig McCaw decided to bail out the ICO group and add it to his, Boeing's and Bill Gates' (among others) Teledesic operation, which is planning to roll out voice and data services in three to four years. In addition, they've reportedly raised over one billion dollars in new money to finance this endeavor. Quite frankly, they are doing this because they see a business opportunity to make money. Perhaps they recognize that Iridium and the original design for the ICO Group used data unfriendly and capacity constrained Time Division Multiple Access (TDMA) technology, which coincidentally is the foundation for the currently dominant terrestrial cellular Global System for Mobile (GSM) communication systems. Instead, they intend to utilize data-friendly, high user-capacity Code Division Multiple Access (CDMA) technology, which is part of the new high capacity broadband technology. An example of this application would be the In-Flight Network to provide high-speed Internet and email service to airline passengers. In addition to this, Boeing's newly developed Connexion Service provides live television, Internet and other information services to customers on the move. This new broadband telecommunications service from Boeing will offer real-time, high-speed, two-way connectivity for commercial airlines and their passengers, private business jets, and U.S. government customers worldwide. Even while flying at 40,000 feet or visiting remote locations, travelers will be able to stay in touch with home, work, and the world.

Although terrestrial cellular systems have grown like wildfire, once outside the populated areas and off the major highways, there are large holes in covering the U.S. not to mention the whole world. This is where the real satellite communication opportunities lie in terms of growth and commercialization. The wireless Internet market is projected to explode once operators begin delivering streaming media at reasonable prices. A recent research study shows that Code Division Multiple Access (CDMA)-based air interfaces will "get there first," said Ira Brodsky, President of Datacomm Research and principal author of the research report. He further added that "the ten million people in Japan accessing the Internet from wireless phones today represent just one drop in a sea of potential users." The report describes many of the new products, services, and business models enabled by CDMA. New consumer products will include Internet radios that download music on-demand, wireless cameras that print to the Web, personal navigators providing turn-by-turn driving directions, and electronic wallets offering the convenience of cash with guaranteed security and privacy. The report also examines how Internet-based business models will essentially transform the mobile telephone industry.

The Iridium system, which launched commercial service in 1998, was the first-generation low earth orbit (LEO) satellite system. It was designed to communicate with hand-held wireless telephones worldwide. The telephone was to be capable of communicating directly with the system constellation of 66 interconnected low Earth Orbit (LEO) satellites. Designed by Motorola, using time-tested and proven technologies, the Iridium system was to deliver voice, data, facsimile, and paging services to hand-held telephones located virtually anywhere on the surface of the Earth. Unfortunately, Iridium has discontinued service due to expensive service and limited capability, leaving customers stranded with useless \$3,000 handsets and a lot of skepticism about migrating to

Globalstar as the only available alternative. Globalstar, which has launched services in 25 countries, will be well positioned to make a play for Iridium's customer base and offshore distribution partners. The failed Iridium venture has distributor licensees in close to 140 countries. However, Globalstar now has a small window of opportunity to regain the confidence of investors and convince corporate customers that its service offer is more desirable than Iridium's proved to be in terms of cost, capability and ease of use. If it disappoints, investors should expect companies such as ICO and the Gates-McCaw Teledesic project to be delayed or even abandoned.

One of Globalstar's chief competitors is Teledesic, which is a private company based in Bellevue, Washington that is building a global, broadband Internet-in-the-Sky™ network. Using advanced satellite technology, Teledesic and its partners are creating the world's first network to provide *affordable*, worldwide, "fiber-like" access to telecommunications services such as computer networking, broadband Internet access, interactive multimedia and high-quality voice. Once operational, Teledesic will enable broadband connectivity for businesses, schools and individuals everywhere on the planet. They intend to build alliances with service providers in countries worldwide, enabling service providers to extend their networks, both in terms of geographic scope and in the kinds of services they can offer. In addition, they will also market service directly to select customers. The Teledesic Network will accelerate the spread of knowledge throughout the world and facilitate improvements in education, health care and other crucial global issues.

OTHER AREAS OF SPACE COMMERCIALIZATION

Remote Sensing

The numerous applications of remote sensing lends itself to a wide variety of customers and potential commercial markets. Although remote sensing is primarily focused on terrestrial uses, it also includes all the bodies of the solar system and deep space. The terrestrial uses of remote sensing include land use/cover mapping, geologic and soil mapping, environmental and climatology assessment, landform identification, and applications for agriculture, forestry, rangeland, biomass, water resources, urban and regional planning, wetland mapping, wildlife ecology, archaeology, and meteorology. Military planners use remote sensing for intelligence gathering as well as tactical and operational planning. Astronomers use remote sensing to study the makeup of the moons, planets, stars, galaxies, and other forms of matter and energy found throughout the universe. This area of space commercialization continues to expand based on the successful history of remote sensing satellite systems, such as LandSat, the French SPOT Earth Observation satellites and the European Remote Sensing Satellites such as (ERS-1). Numerous other countries such as Canada, China, Japan, Brazil, India and others have remote sensing satellites they intend to commercially operate in the near future.

Space Based Energy

As the population of the Earth increases, so does its energy needs. The prime source of energy consumed by humans now comes from the fossil fuels: coal, oil, and natural gas. But, they are not in-exhaustable and will eventually run out. Even nuclear energy is not an unlimited source of power. An additional factor associated with nuclear power is the strong public concern over how to dispose of the radioactive waste or how to prevent catastrophic disasters like Chernobyl. One practically endless source of nonpolluting energy is the Sun, which will continue energy production for another 5.5 billion years. The problem has been finding an efficient and economical way to harness this power. Perhaps advances in technology coupled with lower design, launch and operations cost could make space energy satellites a feasible commercial business opportunity. Another potential area of future commercialization is mining Helium-3 (He^3) from the moon or passing asteroid. It has been estimated that the Moon has at least a million tons of He^3 . Theoretically, a ton of He^3 can produce 10,000 megawatts of electricity for a year, enough for a city with a population of 10 million; 25 tons would produce a year's supply of electricity for the entire United States. This could be a very profitable venture considering many researchers expect eventual breakthroughs and predict that nuclear fusion will be the major energy source of the 21st century.

Microgravity Research

Proteins are complex compounds contained in all living cells. They provide structural support for cell walls, transport materials from place to place, promote chemical reactions, contract muscles, regulate metabolism, and do a host of other functions. Because they float immersed in body fluids, protein cells growing inside a body are nearly weightless. Similar cells growing outside the body in a laboratory are usually deformed because of gravity. However, in the weightless environment of space, the cells can grow perfectly in three dimensions as they would inside a body. This represents a tremendous opportunity for pharmaceutical companies developing drugs and medications for many ailments, cancers and diseases. Examples of protein crystals already grown in space include an antibiotic for treating infections; an antibody and a drug related to AIDS; a protein used to treat diabetes; an iron-containing

enzyme associated with liver function; and dozens of others. Cultures of cancerous tumors, such as breast and ovarian tumors, grown in space can be used to learn how they form and grow, perhaps leading to treatment methods.

Vacuum Based Material Processing

Manufacturing items such as high quality metals, fiber optic cables and even semi-conductor materials may become a viable commercial opportunity in the future. For example, a large percentage of the silicon crystals grown on Earth for computer chips must be thrown out because of imperfection resulting from gravity gradients. Gallium arsenide chips are faster and more powerful than silicon chips, but are even more difficult to manufacture. In weightlessness, crystals can be processed without a container, eliminating the impurity problem, and can be grown much larger with a near perfect molecular structure. In spite of the high cost of transportation, it may become profitable in the future to manufacture such crystals in space. Finally, microgravity research on the International Space Station, may one day lead to the development of manufacturing processes capable utilizing mass production techniques, which lend themselves well to commercialization opportunities.

Space Tourism

There most intriguing commercialization opportunity might be space tourism. Today, MirCorp is using private funding to initiate commercial operations on the Russian Space Station Mir. Their vision of the future is to open space enterprise to private industry via commercialization. With the market free to determine the use of an operational space station, the opportunities are almost unlimited. Although Mir is at the end of its design life and it's future unknown, space tourism could become a reality for the first time. Another such program designed to encourage the commercialization of space and possible space tourism, is the St. Louis-based X-Prize Foundation. They recently welcomed the 21st team into the \$10 million international competition. To win the X-Prize, spacecraft must be privately financed and constructed, and capable of flying three people to the edge of space (100 km) and back. Entrants must also demonstrate reusability of the vehicle by flying twice within a two-week period. The X-Prize competition, the first space-based incentive competition, follows in the footsteps of more than 100 aviation incentive prizes offered early last century, which created today's \$300 billion commercial air transport industry. The most significant of these prizes was the Orteig Prize, won by Charles Lindbergh for his 1927 historic flight from New York to Paris. It is competitions like X-Prize that provide the necessary shot in the arm to finally develop the first commercial spaceship.

CONCLUSIONS

Although there are numerous opportunities, one of the biggest keys to the successful commercialization of space is market demand. This factor combined with reductions in launch service, vehicle design and operations cost will encourage investors and entrepreneurs to take the huge financial and technical risk associated with spaceflight and operations. Although the risks are high, so are the potential rewards in a multitude of areas. The tradeoffs between the competing technical architectures are highly complex and it is impossible to forecast which will ultimately win in the marketplace. ELVs, RLVs, and SSTOs each have a complex set of economic advantages and disadvantages to consider. If the launch service and spacecraft design market can be put in a proper framework of government policy that transcends national boundaries, it has the potential of playing a larger and more significant role in the global economy.

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