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Industry Study

Final Report
The Space Industry

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SPACE INDUSTRY STUDY 2007

ABSTRACT: U.S. space domination is far from guaranteed as the number of space-faring nations increases. The U.S. space industry remains a critical element in providing capabilities essential to national security and economic prosperity. The ability to access space for communications, monitoring, research, and exploration is vital. To ensure these, U.S. policy should encourage more commercial activity in space, emphasize a more globally cooperative environment, change acquisition methods to emphasize cost control over performance at any cost, and focus government investments on technologies having the greatest impact on the space industry.

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PLACES VISITED

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National Security Space Office, Washington, DC
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Introduction

In 1924, noted industrialist Bernard Baruch commented, "the military minded man who has to devise the machines of destruction should keep in touch with the man of industry" (Thompson, 2006, p. xi). No industry exemplifies this better than space, where industry and government are fused to a common goal of space leadership as a means to ensure the continuation of American prosperity and guarantee its strategic, political, scientific, and economic leadership. The U.S. space industry serves as the basis for American primacy in space and provides the foundation for a distinct technological advantage. But the solar winds of change are blowing. America's dominance in this important domain can no longer be taken for granted.

Space represents an asymmetrical advantage for those countries that have both the technological ability to pursue national interests in space and the financial power to overcome significant industry costs. The U.S. and other space-faring nations clearly understand the security advantages that accrue from the ability to exploit the space domain and, accordingly, have created national policies that emphasize the development and preservation of such abilities. As a result, national policies focus on developing indigenous assets to assure access to space, often independent of cost.

At the strategic level, assured access to space describes the development of achievable national policies that foster the use and exploitation of space and the development of the requisite industrial and technological base to implement those polices. At the operational level, it translates into a need to develop and maintain a launch booster for reliable placement of high value, national assets in orbit, and the ability to control those assets once in place. A review of the industry illustrates that many developing nations see a need to build assured access to space through the use of national programs that will establish and preserve their ability to independently use and exploit the space domain.

The requirement to maintain an organic space capability at a national level creates a symbiotic relationship between industry and government. Governments see the need to preserve robust and reliable capabilities within the industry to guarantee the ability to use space in ways that support national objectives. In return, industry depends heavily on government orders and subsidies to ensure their production capabilities remain intact.

The space industry has matured greatly from its birth nearly fifty years ago. Today it is characterized by an emphasis on production efficiencies, upgrades to existing systems, and product maintenance, or retirement. In this phase, the process receives re-engineering attention while the product remains stagnant. Nowhere is this more obvious than in propulsion systems, where the Boeing/Rocketdyne RS-68 engine is the first new U.S. liquid-fueled rocket engine developed in the last 25 years (Boeing, 2007). Since then, only SpaceX developed and tested another new rocket engine. As a result, space policy and the space industry seem caught in a loop of repeating successes with current technologies and relying on small, iterative improvements, rather than fostering innovation and developing new technologies. This condition reflects an environment of risk intolerance.

The Industry Defined

The space industry is segmented into three distinct areas: space, control, and user. The space segment deals with launch and platform components, usually a satellite or scientific experiment. The control segment addresses infrastructure required to operate platforms, while the user segment enables the user to access the platform for the designed capability, such as television or telephone signals. To address these segments, the industry deals with two primary markets and one secondary market.

Satellite production/manufacturing and launch services, including booster development and infrastructure, represent the two primary markets. These markets are organized in terms of support for commercial, civil, and military (including intelligence) clients. A Cold War acquisition mentality, where schedule and cost are tradeoffs to performance, still permeates the space industry. Rapidly changing technology, coupled with a desire to produce decisively superior capability, has led to large cost overruns and unacceptable delays in system fielding. As payloads get larger, more capable, and significantly more expensive, launch vehicle performance has become paramount and economic aspects are ignored in favor of reliability.

The primary markets for satellite production services are concentrated within a narrow range of companies producing a majority of the systems and services in these markets. Satellite production is centered on Lockheed Martin, Boeing, Northrop Grumman, Space Systems/Loral, Alcatel Alenia, and EADS Astrium Space Systems.

Launch is likewise concentrated. Booster production is focused on United Launch Alliance (ULA), which combines the Boeing and Lockheed Martin Evolved Expendable Launch Vehicles (EELV) under a single management structure. Arianespace produces the Ariane 5 booster. Sea Launch is a joint venture between Boeing, Energia, Aker Kvaerner, and SDO Yuzhnoye/PO Yuzhmash. The Ukranian Zenit booster, a former ICBM and the Soyuz rocket are also strong competitors in launch, as well. SpaceX, a new entrant to the launch market, was founded as an alternative to higher cost launch. SpaceX is taking an innovative approach to the design and production of an entirely new booster vehicle.

The secondary market for ground services and infrastructure is more difficult to define. Aspects of this market, such as launch facilities and range control represent a direct tie to the use of space. Major launch control and ranges in the U.S. are Kennedy Space Center and the Cape Canaveral Air Force Station in Florida, along with Vandenberg Air Force Base (AFB) in California. Arianespace, the marketing commercial launch component of the European Ariane rocket, is located in French Guiana, South America. The Russian component launches from the aging Baikonur Cosmodrome in Kazakhstan. Sea Launch, an international consortium, modified a mobile oil platform to launch rockets from an equatorial location in the Central Pacific.

The ground control segment is fairly robust, with major facilities for communications at Intelsat in the U.S. and the European Space Operations Center at Darmstadt. Governments with robust space programs generally provide control for their own assets on orbit. The United States controls its military and intelligence assets through the U.S. Air Force Satellite Control Network, located at the 50th Space Wing at Shriever AFB, and in Cheyenne Mountain. U.S. Civil spacecraft are controlled through a number of different facilities across the country, including the Johnson Space Center which controls the space shuttle and the International Space Station.

Conditions in the Industry

Characterized as mature within the industry life cycle, the space industry experiences few emerging markets and little opportunity for growth. High barriers to entry include: (a) a significant capital investment to support land, plant, technology, and labor; (b) a highly skilled workforce that can provide both for current needs and also adapt to evolving technologies; (c) a reliance on government contracts and acquisition systems for the majority of industry revenues; (d) the use of governmental grants and subsidies, which provides an unfair advantage to incumbent producers; and (e) stringent regulations, such as the International Traffic in Arms Regulations (ITAR), which limit the ability of industry to compete in the global market.

These barriers support the large scale, vertical integration that characterizes the industry. Boeing's mergers with North American Rockwell, McDonnell Douglas, and Hughes Electronics, are representative of the consolidation throughout the industry. Similar industry consolidation took place on the other side of the Atlantic, resulting in the creation of European Aeronautic Defense and Space Corporation (EADS) from the merger of a number of European aerospace giants including Dassault, Aerospatiale, Fokker, Vereinigte Flugtechnische Werke, Messerschmitt Bölkow-Blohm, Construcciones Aeronauticas Sociedad Aónima, and Aeronautica Industrial SA. This merger was significant because it crossed a number of national borders to create a dominant regional company capable of competing with similarly realigned Lockheed Martin and Boeing.

The industry's heavy reliance on government contracts and support comes with some concern. When access to space is characterized as a national security issue, the industry becomes a fertile ground for governmental regulations. Barriers to trade, such as the ITAR, significantly reduce free and open exchanges of information, leading to diminished innovation and competition in the market. Heavy use of grants and subsidies distorts market conditions, increases government costs, and lowers competition by raising barriers for would-be entrants. This phenomenon exists both in the U.S. and abroad. For example, the U.S. provides government launch infrastructure to ULA for commercial launches. Similarly, the European Union taxed its members 960 million Euros to subsidize the Ariane 5 (de Selding, 2003).

The Global Industry

Currently, globalization within the space industry is low, but the projections for increased globalization are favorable (IBISWorld, p. 22). As more countries enter the market and costs of production decrease, the dominant role of government may give way to commercial enterprise, suggesting the likelihood of freer markets for suppliers throughout the world. India and Japan have joined Russia, China, the U.S. and Europe in gaining an independent means to access space (Defense Industry Daily, 2005). With the success of these programs, Brazil, North Korea, and Iran are emerging as next generation space-faring nations. While it is true that governments show a distinct predilection to purchase equipment from their own domestic sources, fewer new programs and higher budget deficits coupled with favorable incentives from foreign governments are driving space ventures abroad. Examples include U.S. satellite manufacturers using Ariane 5 boosters to orbit payloads for U.S. customers, and the use of the Russian Energia RD-180 engine in Lockheed Martin's Atlas V booster.

The Nature of the Market

The space industry as a whole is an oligopoly in which the top four producers in guided missile and space vehicle production hold a combined market share of 95% (Defense Industry Daily, 2005). The market is expected to include 118 establishments and 81 enterprises by the end of 2007. The average revenue per supplier in 2006 was $187 million. Projections for the next fiscal year include a decrease in revenue of 2.1% (IBISWorld, 2007, p. 11). Key players in satellite production are Lockheed Martin, Boeing Satellite Systems, Northrop Grumman, Space Systems/Loral, Alcatel Alenia and EADS Astrium. The Herfindahl-Hirschman Index, a measure of industry competitiveness, is 2,393 out of 10,000 for the space industry, indicating a high level of industry concentration.

Markets within the Sector

The two major markets within the space industry are satellite development/production and booster manufacturing/launch services. The North American Industry Classification System, or NAICS, defines these two sectors as 336414, Guided Missile and Space Vehicle Manufacturing and 334220, Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing. While these two sectors include the majority of the space industry, they do not include all of it. For example, booster propulsion falls under NAICS code 336415 and portions of the launch and manufacturing infrastructure falls under 336416. While a good deal of the space industry falls outside the two primary codes, several elements within these two codes are not related to space. As a consequence, accurate data relating specifically to the space industry is obfuscated, resulting in a chronic degree of uncertainty as to the industry's fiscal condition and developments. Since reliable economic data is required for complex budgeting processes, to provide valid cost estimates, to accurately account for research and development spending, and to better understand the role of government within the market, there is a need to improve the economic data analysis of the industry (Hertzfeld, 2002, p. 21).

Market Conditions

The satellite development and production market. The satellite manufacturing market is an oligopoly and oligopsony, with a limited number of suppliers and buyers. High barriers to entry such as the need for government contracts to survive, keep the number of suppliers low. The governmental market dominates with approximately 70% of total revenues. The commercial market represents the remaining 30% of total demand. Governmental orders are typically restricted to suppliers within the using nation, creating a market distortion.

While customers may generally desire faster production rates with higher degrees of reliability, satellite manufacturing is cyclical. Few satellite production runs comprise large numbers of satellites, so production times for most manufacturers vary significantly. The industry standard ranges from a low of 15 months with the Boeing Astra 3A to a high of 59 months with the Alcatel Astra 1K (Futron, 2004).

Worldwide satellite manufacturing revenue growth was 7.4% from 2004 to 2005, higher than the average growth from 2000 to 2005. In 2004, 55 satellites were launched, showing a slight increase from the downturn of 2002-2005, which experienced a significant decline in satellite orders (Caceres, 2005).

Commercial efforts, such as Direct to Home (DTH) television have shown strong growth. 2005 revenues were $52.8 billion, and represented 11.7% growth in subscriber levels over 2004. Current subscriber levels are approximately 80 million worldwide (SIA, 2006, p. 11). Similarly, North American satellite radio, specifically XM and Sirius, also shows growing subscriber levels, totaling over 14 million in 2005, an increase of 29% from 2004 (Ellis and LaMonica, 2007).

The space launch market. This market is also an oligopoly and an oligopsony, characterized by policy directives and government subsidies that make portions of the market appear monopolistic. The market has some odd traits. For example, the market for light- and medium-lift (less than 20 metric tons) exhibits elasticity, while the heavy-lift market (25 metric tons) is inelastic (Hertzfeld, 2005, p. 23). There are many global providers of light and medium lift, while there are only two commercial providers of heavy lift today, ULA and Arianespace.

The market presents a challenge for competition given the widespread government subsidies or national ownership in each launch-capable country. In the U.S., government launches are projected to account for 50% of the world launch demand through 2020, with the Department of Defense (DoD) responsible for 63% of those launches (Congressional Budget Office [CBO], 2006, p.4). In terms of heavy lifting for geosynchronous orbits (GEO) or geosynchronous transfer orbits (GTO), 81% of all launches use one of three government-sponsored boosters: Ariane, Atlas, and Delta (Futron, 2002, p. 5). Hardly by coincidence, both the Ariane under ESA in Europe and the Atlas/Delta team under ULA in the U.S., enjoy substantial government subsidies and national policy protection.

This highlights the need for a commercially developed heavy-lift booster that can compete against the government sponsored programs, but high barriers to entry, such as government certification, research and development costs, capital outlays well in advance of launch, and the requirement to provide alternatives for launch failures, provide a strong disincentive to new launch programs (CBO, 2006, p. 4). Thus the launch market is not driven by cost, but rather by reliability and schedule, and risk aversion becomes another barrier to entry. Since the government is the principal consumer of launch and since it is performance-oriented rather than cost-oriented, it tends to avoid alternatives like SpaceX in favor of providers with a demonstrated track record.

Market Segments

Segments define the market across three dimensions: Commercial, Civil Government and Military. Each segment is interdependent with substantial overlap in function and technology.

Commercial. The commercial segment is characterized by a rising demand in communications and satellite to home television services. Commercial insurance is included in our study of the commercial segment. Key players include Intelsat, Eutelsat, Echostar, DirecTV, Sirius, and XM satellite radio.

Civil Government. The civil segment principally includes science, exploration, and remote sensing. While the United States dominates the civil government segment, the French, German, Indian, Italian, Japanese, and Russian space agencies are also key players.

Military. Satellites are a cornerstone of the U.S. plan to ensure battlefield dominance and unparalleled communications reach-back from the battlefield to the U.S. The military space mission is central to battlefield success and includes such fundamental capabilities as surveillance, early warning, communications, and navigation. French, British, Russian, and Chinese activity in this segment is important, though small relative to the U.S.

Industry Outlook

U.S. national security is dependent upon space, and thus must be able to assure access to it as well as operate critical assets within it. Key space industry elements supporting these national security requirements are shown in the table below.

Assured access to space	▪ Satellite/spacecraft manufacturing
	▪ Launch vehicle production and launch services
	▪ Infrastructure – ranges (aging systems, single point of failure), launch control centers, ground stations world-wide (availability, physical security, redundancy)
Assured operation of space assets	▪ Satellite/spacecraft design and quality of manufacturing
	▪ Infrastructure – ranges (aging systems, single point of failure), space ops control centers, ground stations world-wide (availability, physical security, redundancy)
	▪ (Future) defensive systems

It has been widely reported that U.S. aerospace and defense companies underperform when compared with other high-tech industries. Overall, U.S. aerospace and defense companies showed profit margins of 4.2% and 5.2% in 2004 and 2005. The space prime contractors such as Boeing and Lockheed Martin performed worse, and space suppliers worse still. A number of factors are responsible for this performance, including limited government demand for large and technologically complex satellites, industry consolidation and divestiture of redundant business units, customers' push for lower prices, global competition, and the communication satellite market collapse in 2001. (DeFrank, 2006, pp. 1-2). There also has been a trend to push risk, and especially cost risk, down to the lowest possible level in the contracting chain, which has hurt subcontractors in particular.

These trends have the potential to prevent U.S. industry from meeting future national security requirements. At least one source suggests that half of the current space suppliers may not be in business by the end of the decade (DeFrank, 2006, p. 2). Further, long development times and the cyclical nature of the business may poorly position the U.S. space industry to meet a full-up surge requirement. U.S. national security interests would be met if the forecasts of space industry consultants Futron and Euroconsult pan out, and if U.S. industry, aided by the government, takes steps to assure its own competitiveness.

Short-Term Outlook

Industry observers predict launch demand will begin to pick up in the near term. The launch industry suffered from low margins as demand decreased in the early 2000s while increased competition drove prices down. Rebounding communication satellite and increasing Earth observation markets will help to boost demand appreciably in the next five years. Prices should increase as demand increases to meet supply (Euroconsult, 2005, p. 1; Forecast International, 2006, Analysis 2, p. 2).

The current overcapacity in the commercial communications satellite industry will lessen as further consolidation is likely, either through formal mergers and acquisitions or through strategic partnerships (Euroconsult, 2005, p. 2). The U.S. share of the commercial communications satellite (comsat) market continues to drop (41% in 2005), both in terms of satellite manufacturing as well as supply of components to foreign-built satellites, and the trend doesn't show signs changing (Forecast International, 2006, Analysis 3, p. 2). Demand in the comsat arena will be driven by digital video in the near-term with HD TV gaining a higher proportion over time. DTH continues to grow, with significant growth in China and India, while voice declines, remaining primarily to serve rural markets (Starzyk, 2006, pp. 1-10).

Long-Term Outlook

Satellite demand forecasts predict continued, long-term market growth. Euroconsult predicts 960 satellites will be launched between 2007 and 2016, while Forecast International projects over 800 between 2006 and 2015. In terms of 36MHz-equivalent transponders, Futron projects even larger numbers than Euroconsult (approximately 9000 in 2015 vs. about 6500 in 2016 respectively); both agree that voice demand is shrinking, but will still exist in the out-years, while video will be the largest and increasing segment of demand (Euroconsult, 2006; Starzyk, 2006).

Euroconsult forecasts increases in satellite weight, in market value, and in demand for launch services over the next ten years. Government customers will continue to dominate the space industry. Of the 616 government satellites projected to be launched from 2007 through 2016, two-thirds will be civil and one-third military. This represents a 32% increase in government satellites launched over the previous decade (Euroconsult, 2005).

The big growth area over the next decade will be Earth observations, representing 77 satellites to be launched in this period (The European Association of Remote Sensing Companies Newsletter, 2006/2007). Developing nations look to remote sensing as one way to jumpstart their space programs, and provide technology and economic development opportunities for their citizens. In fact, a number of space agencies were established in the last few years, including Malaysia, Thailand, the Czech Republic, and Colombia. Additional growth could result from new applications associated with the success of such ventures as Google Earth.

Political And Social Factors Impacting The Short- And Long-Term Outlooks

New entrants. The current projections do not include the impact of new entrants in the industry, particularly in the launch business. Should emerging companies, such as SpaceX, become successful in developing and delivering low-cost, reliable, human-rated launch vehicles, access to space could become more affordable and projections of commercial ventures such as tourism may occur more quickly than forecast.

U.S. space transportation policy. The industry outlook assumes the continuation of U.S. policy requiring government payloads to use U.S. launch vehicles. A change in U.S. policy allowing free trade in transportation services will force high cost U.S. launch providers to compete. Similarly, other nations have policies that assure their space systems are procured domestically. Should they open up their markets, U.S. launch providers would have a level playing field upon which to compete. As space commercialization increases, decisions premised on fiscal constraints will lead to more competition in space transportation.

Satellite cost. Satellites continue to grow in size, complexity, and cost. As a result, aggregate demand may fall. However, should demand for small, lower cost satellites increase, it could lower risk sensitivity in the launch market, driving down costs, increasing demand, and perhaps encouraging new entrants.

Technology. Major advances in launch technology in the next 20 years are unlikely. Chemical propulsion is constrained by physics, and more advanced concepts, such as the space elevator popularized by Arthur C. Clarke in the 1970s, remain just concepts. Given the risk aversion inherent to the market, very little technological change can be anticipated in the near-term.

U.S. Space Industry Position in the Global Marketplace

The U.S. currently leads the world in the space arena. It outspends the rest of the world both in its civil government and its military space budgets. Of the $50 billion spent by governments world-wide in 2006, $38 billion was spent by the U.S. government alone, and there is no near- to medium-term likelihood of this situation changing. Even though other states are increasing their military space budgets, as long as it is willing to continue to invest at current levels, the U.S. should maintain this edge for decades to come.

The EU is the next largest spender. Historically, the Europeans have viewed space more from a science and research perspective as evidenced by a predilection to use research ministers to lead national space programs. The new European Security and Defence Policy (ESDP), combined with a new European Space Policy, emphasizes competitiveness and the dual-use of space, and reflects an important evolution in the European approach to space towards a greater national security focus (Verheugen, 2007, p. 2). Asian nations, particularly India and China, are increasing their space investments and activities. As noted above, even much smaller nations are investing in remote sensing from space, particularly for environmental monitoring and technology development purposes.

While there may be no immediate danger of the U.S. losing its lead in space, the U.S. should not remain complacent about its position. Current trends in the U.S. space industry include decreasing market share, limited capacity, high cost, and restrictions on U.S. components in foreign space systems, and high barriers to entry. The U.S. has already lost its advantage in the launch and communications satellite markets. Should these trends continue, the U.S. is in danger of losing further market share, and perhaps as a result even its technological lead in space.

Space Industry Challenges

The success of the U.S. space industry enables critical military, civil, and commercial capabilities. Despite noteworthy challenges, it plays an essential role in maintaining American technological advantages in space-related products and services.

Export Control

One of the most significant defense trade export control regimes affecting the space industry is ITAR. There is an open debate among the State Department (DoS), the U.S. Congress, and the space industry concerning the harm that regulatory restrictions have caused for U.S. businesses and U.S. foreign policy. The DoS contends that ITAR has had limited negative effects while it has provided essential security benefits to the nation. The Congress concedes there may be room for improvement or revision but has consistently failed to act. U.S. companies argue ITAR is a significant trade barrier, stifling U.S. trade and weakening the ability of U.S. companies to compete in the global market. The U.S. government must re-examine current export control policies and procedures to seek a better balance between assuring national security and fostering a viable and innovative space industrial base.

Acquisition Reform

Poor acquisition decisions in past space programs have led to unrealistic cost forecasts and rampant requirements growth. Cost and schedule overruns in U.S. strategic military space programs continue to generate high political and financial costs in an environment of austere budgets. As a result, space programs are often fielded without intended capabilities despite substantial cost overruns and program delays. This becomes increasingly critical today insofar as upgrades are currently underway in every major military space mission—communications, navigation, weather, warning, and intelligence. Yet, the consistent and systemic underestimation of military space program costs impacts the health and viability of these and other important programs when inevitable budgetary refinements necessitate programmatic modifications. Thus, a failure in one program is measured not only in terms of waste or diminished capabilities, but in terms of opportunities lost elsewhere.

An Industry in Decline

Nascent industries are marked by growth, innovation, and competition among a large number of companies, which was representative of the space industry fifty years ago. Today the industry reflects little innovation, little competition, low capacity, and high cost. As U.S. reliance on space continues to increase, these industry conditions become cause for concern. It is certainly worth asking why newer technologies have not emerged in the last forty years. In part, this may be due to the very small market for space capabilities. Until new and different technologies are developed, which is not likely to occur without an interest and investment by government, the current dynamic will sustain a condition of limited innovation and capacity.

Government Goals & Roles

The U.S. government has long understood that access to space and space capabilities are essential to U.S. economic prosperity and national security. U.S. space policy from 1962 to 2006 served to ensure national leadership in space and governance of space activities, including science, exploration, and international cooperation. The current Administration has issued five space-specific policies to provide goals and objectives for the U.S. Space Program. In addition to the National Space Policy, these policies are Space Exploration; Commercial Remote Sensing; Space Transportation; and Space-Based Positioning, Navigation, and Timing. Each policy endeavors to maintain U.S. space supremacy, reserving the right to defend assets in space, and to continue to exploit space for national security and economic prosperity.

America's success in space is dependent on government involvement, motivation, and inspiration. It is significant that the Bush Administration has taken the time and effort to update all of the U.S. space policies. The consolidation of the major space industry players and a general down-turn in the commercial space market demand, coupled with export restrictions, has left the U.S. space industry reliant on the government for revenue and technology development.

Heretofore, the European Space Agency has focused exclusively on civil space. The imminent release of a new European Space Policy includes important provisions to conform to the ESDP, suggesting the potential for a larger economic and political role for space in Europe. The EU is also providing an important economic stimulus, not just in terms of funding for research and programs, but by increasingly using space as a tool in the implementation of its policy objectives, becoming a key institutional partner and customer.

The U.S. government's attempt to revitalize a declining space industry has met with some early success, but there are areas that need more attention. For example, the U.S. Space Policy on Commercial Remote Sensing Capabilities has been a catalyst to advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by enhancing the U.S. remote sensing industry. The Administration also revitalized the nation's interest in manned space to the Moon and Mars with the issuance of *The President's Vision for Space Exploration*. Although the extent of technological benefits America received from its first successful foray to the Moon four decades ago may not be realized under this plan given the extensive use of existing technology to achieve its aims, it remains a laudable effort to foster enthusiasm in the manned space program.

Several U.S. Space Policy initiatives fail to address key issues affecting the U.S. space industry. The newly-issued space policy documents generally share the common themes of maintaining space leadership, self-defense, and exploitation of space for national security and economic prosperity, but they all lack a cohesive and specific plan to invigorate the commercial space market. There are also key factors that challenge U.S. national security and economic prosperity with respect to its dependence on the space industry, and that should be addressed more fully by U.S. policy. These factors, as discussed below, include external threats to U.S. space access and internationalization of space.

External Threats to U.S. Space Access.

The Chinese test of a direct-ascent, kinetic kill anti-satellite (ASAT) weapon in January 2007, raised legal, ethical, and policy questions regarding the merits of 'weaponizing' space. This test forces the U.S. to confront the possibility of a challenge to its use of space. The 2006 U.S. Space Policy states the U.S. will "take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests" (p. *xx*). Now that the potential for such attacks is manifest, senior U.S. leadership must address the scope of a national response.

Internationalization of Space

The number of space-faring nations is on the rise. Without natural or imposed borders, space is a fertile ground for international cooperation or conflict. Therefore, global space governance is essential to prevent national conflicts from extending to space. With increased space use and exploration, a number of related challenges remain unsolved, such as the need to address space-based property rights, ownership and mining rights, or non-earth colonies. The U.S. Space Policy intends to pursue international cooperation but fails to address U.S. strategic goals for space relations with such countries as China or Russia, who have the potential to rival U.S. space capabilities.

To sustain its space-related advantages and ensure economic prosperity and national security, the U.S. must address the above-mentioned issues and challenges by revisiting its Space Policy. The essays that follow address these key issues and challenges.

ESSAYS

Export Control and U.S. Space Industry

One of the most significant defense trade export control regimes affecting the space industry is the ITAR. There is an open debate among the State Department (DoS), the U.S. Congress, and the space industry as to whether these regulatory restrictions are harmful for U.S. businesses and U.S. foreign policy. The DoS contends that ITAR has had limited negative effect while providing necessary security benefits to the nation. The Congress concedes there may be room for improvement or revision but has consistently failed to act. American-based companies argue ITAR is a significant trade barrier that acts as a substantial tariff, stifling U.S. trade and weakening the ability of U.S.-based space companies to compete. It is time to re-examine current export control policies and procedures, balancing the denial of access to critical U.S. technology with maintaining a viable and innovative space industrial base.

ITAR governs the export of arms and defense technologies including satellites. ITAR authorizes control of import and export of items on the U.S. Munitions List (USML). The dual-use nature of certain space technologies makes export controls like ITAR necessary, but also tends to make them more onerous when seen from the global commercial market perspective. The dilemma for the U.S. space industry is that space technologies have been classified under the USML since 1999. Prior to that date, space technology transfer was handled by the less cumbersome and more market-friendly Commerce Department.

The overarching goal of ITAR is to advance U.S. national strategic objectives and foreign policy via trade controls. The majority of space technologies targeted by ITAR are components rather than complete systems, because the theory is that complete systems are subject to tighter global scrutiny, are more expensive to acquire, and are more difficult to bring into production in all but a few highly industrialized countries.

ITAR has certainly limited the proliferation of U.S. controlled technologies, but has it done so at the expense of maintaining U.S. space industrial competitive advantage? Export control policies intended to protect U.S. security may not achieve their goal if they are outdated and overly bureaucratic. Complex ITAR rules force the providers and customers to wade through lengthy processes to obtain export approvals on many, globally available components. One of ITAR's most serious problems is that the USML is largely out of date, protecting nearly all technologies in mature global industries rather than focusing on cutting-edge technologies.

In 2000, significant ITAR revisions were proposed to help industry and allies—dubbed the Defense Trade Security Initiative (DTSI). DTSI proposals included allowing partners on major cooperative defense projects to perform work under one license, reconsideration of the USML, expedited licensing review for NATO countries, and extension of ITAR exemptions to qualified countries. These important improvements never gained traction as the events of September 11th, 2001, dampened much of the enthusiasm for easing export controls (Schinasi, 2005, p. 2).

ITAR Effects on U.S. Space Industry

ITAR regulations have negatively affected the U.S. space industry's ability to rapidly and cost-effectively compete in the high technology space arena, an arena that not only depends upon technological innovation but also requires speed of action. Barring the unlikely event that ITAR restrictions will be eliminated in the very near future, the single greatest industry impediment is the long delay to obtain U.S. government approval for licenses, thus degrading the ability of U.S. space industry companies to quickly enter into mutually supportive relationships.

As ITAR continues to provide downward pressure on the U.S. share of the international space market, it has not been adjusted to distinguish among a wide range of technologies. For example, simplistic, widely available, satellite solar arrays are treated the same as military-specific encrypted satellite transponders. Missed technology sharing opportunities, in a very competitive, capital-intensive, space technology market, have eroded the U.S. space industrial base and labor force. From a U.S. government standpoint (e.g., NASA), interoperability with foreign space agencies continues to be difficult, diminishing cost-sharing opportunities. Worse, still, the U.S. risks turning potential partners and customers into competitors.

ITAR may impact smaller businesses differently than the large firms. As the larger U.S. space firms move toward a lead systems integrator construct, technological innovation migrates to lower tier companies. The lower tier firms, however, experience ITAR-related barriers of entry as they try to recruit highly qualified workforce from bigger firms because they are restricted from hiring capable foreign workers. When viewed from this lower tier perspective, ITAR may be more about the loss of U.S. technical space capability than about profit and loss.

The Road Ahead

ITAR involves a delicate trade-off: the balance of national security interests, diplomatic opportunities, and economic policy interests. Export controls work best when they limit only the availability of specific technologies that cannot be obtained elsewhere in the global market. Fundamental ITAR reform will most likely be accomplished in incremental steps that sequentially appease the stakeholders as the reform process gains positive momentum. Several such solutions include:

Short-term solutions: (a) provide adequate resources (space-experienced people and money) to the State Department to improve the timeliness of their ITAR approval process, (b) ensure transparency and predictability in the ITAR approval process (early notification of "intent to deny"), and (c) conduct a comprehensive review and update of the USML related to space.

Mid-term solutions: (a) exempt our responsible trading partners (e.g., Canada, UK, Australia) from ITAR restrictions, (b) provide education and outreach from the space industry to the Administration & Congress, and (c) erect higher barriers on significantly fewer technologies.

Long-term solutions: (a) make ITAR reform part of the National Space Policy, (b) establish an NSC-level Export Control Lead for the Interagency, and (c) embark on complete ITAR overhaul with space export control returned to Commerce.

Conclusion

The ITAR export control regime retains the character of its Cold War origins. ITAR weakens the space-related sector of the U.S. economy by controlling exports of U.S. companies but not those of competing nations. That said, ITAR is not the cause of all the ills of the U.S. space industrial base, nor will "fixing" ITAR be the panacea for the industry. However, loosening restrictions on space-related exports could enable U.S. space companies to recapture some of its lost market share and attract new financing to be funneled into new research and development.

—Commander Brent Kyler, USN

Internationalization of Space

The future of peace and security in space largely depends on the legal regime the international community perceives as being in its mutual interest. As world-wide space-based technology advances and the number of space-faring nations increases, we must ask ourselves if the current legal regime is sufficient for maintaining peaceful uses of space. Another important question is: what role must the U.S. play in advancing the kind of global governance necessary to keep nations from carrying the conflicts of man into outer space, especially as access to and use of space becomes more essential to our global social and economic well-being, as well as to the security of each nation?

This essay reviews the current global space legal regime, how current U.S. space policies reflect engagement of the international community, and the methods the U.S. may choose to engage the international community in the future. As the current world leader in space use and exploration, the U.S. should take the lead in engaging the international community in serious discussions about the future of global space governance. By engaging the international community in development of a new legal regime, the U.S. can more effectively influence international agreements on space activities and more fully address its national security.

Current Space Legal Regime

The current space legal regime grew largely out of the Cold War (Gabrynowicz, 2004). As the space race began in the 1950s, "the United States and the Soviet Union agreed that no nation would claim sovereignty over space…however, they also created a powerful disincentive to engage in exploration: without sovereignty, jurisdiction cannot be imposed, laws cannot be applied, and investments cannot be secured" (Tobias, 2005, p. 299). Sovereign nations can make and enforce laws; however, international agreements and treaties, whether bilateral, multilateral, or collective through the UN, lack enforceability through any supra-national means. When it comes to international agreements and treaties, nations are expected to bind themselves to the agreements they sign.

This self-binding compliance is the nature of international law. Thus, currently, the legal regime for the use of space is covered by "treaties, bilateral agreements, customary international law, and national laws providing for the orderly regulation of national space activities as well as related national legislation" (U.S. Senate Committee on Commerce, Science, and Transportation [Committee on CS&T], 1990, p. 3). First among the space treaties and agreements is the UN's *Treaty on the principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies*, also known as the Outer Space Treaty (OST) (Committee on CS&T, 1990). The purpose of these treaties is to gain the cooperation of nations for the peaceful use of space "for the benefit of all peoples irrespective of the degree of their economic or scientific development" (UN Office for Outer Space Affairs [UNOOSA], 1994, p. 4). The problem, however, is that the advent of space use and exploration is becoming more and more pervasive. As the future of space leads to tourism and colonization of other celestial bodies there are myriad issues that these treaties and agreements are unable to address, such as property rights in colonizing space, ownership and mining rights of new raw materials discovered on other celestial bodies, or even a body of law to address the requirements of a non-Earth colony (Tobias, 2005). As futuristic as these possibilities sound, they are all enumerated in the President's current vision for space.

U.S. Space Policy and the International Community

A fundamental goal of the 2006 U.S. National Space Policy is to "encourage international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security, homeland security, and foreign policy objectives" (p. 2). However, one of the principles states, "the United States will oppose the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space" (p. 2). It is understandable that as the leading space-faring nation, the U.S. would be opposed to new legal regimes that restrict its access to space, but as Paul Tobias points out: "Space law makers have the unique motivation to avoid the extension of present national rivalries into this new field," and "To argue that our current state of American hegemony will continue is short-sighted" (2005, p. 4). Given the rate that technology is advancing, and at which more nations are becoming space-faring, these statements should be taken seriously. The U.S. policy opposing new legal regimes should be revised to give ample consideration to the manner in which space should be governed.

Space Legal Regime Alternatives

Three possible legal regimes the U.S. may pursue to ensure the peaceful use of space are: (a) maintain the current space legal regime, (b) establish a regime based on a unilateral or dominant power, or (c) establish an independent agency with sovereign powers.

Current legal regime. This alternative is a viable option and the path the U.S. is currently pursuing. In this alternative, each nation can rely on its own interpretation of the general principles within the UN treaties. Each nation negotiates with other states based on its own personal interests with the freedom to exploit space as they wish, but with the expectation that all nations will adhere to the OST principles. In supporting this alternative, essentially the U.S. takes the official position that the current legal regime is adequate and that any military plans the U.S. has for space pose no threat to the international community (Tannenwald, 2004).

Unilateral or dominant power. In this second alternative, the U.S., in its desire to maintain an asymmetrical advantage in space, could impose its own rules as hegemon. Its primary aim would be to use space to achieve its strategic objectives on earth. This alternative would essentially override the OST, rendering other space-related agreements irrelevant. Success would require the U.S. to weaponize space to deny access to other nations (Tannenwald, 2004). Although this alternative might seek to guarantee U.S. national security, it would also violate the fundamental values for which the U.S. stands.

Independent agency with sovereign powers. Paul Tobias offers a third alternative, which is "an independent agency…under the auspices of the United Nations…[which is] given sovereign control over space" (2005, p. 312). He suggests that this agency have legislative, executive, and judicial powers and be conducted in the spirit of OST. He further suggests some type of democratic system with geographical rather than national representation. Essentially, this organization would exercise sovereignty over outer space. Some ideas Tobias offers for this new agency are: gaining funds by taxing satellites; introducing a system of property rights to encourage investment and exploration of space; providing leases for mining celestial bodies; and creating regulations for such things as health, safety, and the environment.

Michel Bourbonniere, in his article on National-Security Law in Outer Space: The Interface of Exploration and Security, states, "It is important to realize that law never seeks to regulate technology, but rather aims to place order in the competing human interests that result from technology" (2005, p. 3). The premise here is that nations can pursue the greatest and grandest technologies they can imagine and the law should not impact that pursuit; rather, its impact should be on the sense of justice and fairness for all within the environment in which the technology is used. Space governance provides "a direct and enforceable management system for space resources, space activity off world, and people who reside in, tour into, or visit at venues in the territory of our solar system" (O'Donnell, 2002, p. 542).

The U.S. must take the lead in engaging the international community in serious discussions about the future of global space governance. The current space legal regime may work well for now, but likely will not serve very well in the not-too-distant future. The pace of technological change continues to increase. These advancements are encouraging many other developing nations to gain access to space as well. The U.S. must keep in perspective that an international competition for space will exist well into the future, but it must also look beyond the current technologies, political issues, and national boundaries to see how access to space can be managed, regulated, and adjudicated when space travel becomes more common.

In President Bush's cover letter to The National Security Strategy of the United States of America, he states, "We seek to shape the world, not merely be shaped by it; to influence events for the better instead of being at their mercy" (2006). The U.S. must begin the serious debate over the appropriateness of a supra-national agency to govern space, using the fundamentals of our own Constitution to shape the future space environment. If the U.S. begins to think seriously about this now, it will better preserve its national security interests by more effectively influencing international agreements on space activities.

—Mr. Bruce Cogossi, GS-15

External Threats to U.S. Space Access

On September 11, 2001, two aircraft impacted the World Trade Center, immediately ending thousands of lives and closing the United States' financial network for a week. Aside from the immediate losses, the financial impact grew to hundreds of billions of dollars. The U.S.'s increasing military and economic dependence on space-based systems has created a vulnerability that could result in a "Space 9-11." In July 2000, The Xinhua news agency reported that China's military is developing methods to defeat the U.S. military in a high-tech space-based future war. It notes, "For countries that could never win a war by using the method of tanks and planes, attacking the U.S. space system may be an irresistible and more tempting choice" (Wilson, 2001). As if to prove their point, earlier this year China successfully launched a direct-ascent, kinetic ASAT weapon. It appears that having weapons that can destroy satellites is part of China's unofficial doctrine of asymmetric warfare, which should serve as a wakeup call to the U.S. As a nation that is fundamentally reliant on space, serious debate must occur to fully evaluate the implications of that vulnerability; however, with most of the nation's attention focused on Iraq and Afghanistan, the U.S. may be blind to its adversaries' plans. This essay will identify both direct and indirect threats to U.S. space access using offensive counter-space operations and provide policy recommendations to better prepare for this threat.

Counterspace Operations

According to a recent DoD study, counter-space operations are designed to achieve five major purposes: deception, disruption, denial, degradation, and destruction. To accomplish these, four types of operations are used: denial and deception, attack or sabotage of ground segments, direct ASAT attacks on space assets, and electronic attack (Wilson, 2001). Examples of each of these four types of operations follow:

Denial and deception. State and non-state actors can defeat the advantages of U.S. satellites by obtaining information regarding a satellite's orbital and sensor characteristics. While ITAR restricts access to U.S. satellite sensor characteristics, orbital information is easy to obtain. According to Space Commission staff member Tom Wilson, denial and deception can be passive or active. Examples of passive denial and deception activities include camouflage, concealment, and decoys. In Desert Storm, there were numerous examples of decoy Scud missiles that were attacked based on satellite imagery. Active denial and deception activities include jamming and masking (Wilson, 2001).

Ground segment attacks or sabotage. Attacking a remote satellite ground station can have the same result as physically destroying a satellite. For example, the Global Positioning

System (GPS) has five fixed monitoring stations and four fixed ground antennas located throughout the world. Loss or degradation of these sites would significantly impact on-going worldwide military operations as well as every automobile, aircraft, ship, and banking system that relies on the GPS constellation to provide critical navigation and timing information. In 1999, the DoD reported 22,000 probes and scans against the U.S. Space Command's Computer Network System. In the first 11 months of 2000, the number had increased to 26,500 (Wilson, 2001). Other ground-based capabilities remain vulnerable as well. For example, recently, a liquid oxygen leak on a Delta IV rocket cracked the launch pad and rendered it unusable. While a mishap, it proves the point: any government satellite scheduled to launch on a Delta IV rocket is now grounded until that launch pad is repaired.

Direct ASAT attacks. With its ASAT demonstration last January, China became the third country to physically destroy a satellite in orbit. The ASAT test showed its ability to hit targets in Low-Earth Orbit (LEO) where most American reconnaissance assets are deployed. However, reports also suggest that the Chinese seek the ability to attack satellites in Medium- and High-Earth orbit, such as GPS (Kyl, 2007, p. 2). The direct-ascent interceptor that China used is just one type of ASAT weapon. The most dangerous type of ASAT weapon is a nuclear device. Several countries, including China, have the ability to put nuclear devices on missiles capable of reaching outer space. Because of the continued threat of nuclear weapons and long-range missile proliferation, this scenario must be considered. According to the Defense Threat Reduction Agency (DTRA) one low-yield nuclear device detonated at approximately 150 km could disable all unprotected LEO satellites within a few months. Additionally, replacement satellites launched within three months of the nuclear blast would become inoperable after just eight months (DTRA, 2001, p. 4).

The Sing Tao newspaper recently quoted Chinese sources claiming China is developing a parasitic satellite that can attach itself to an enemy's satellite and destroy itself and its host by command from a ground station. This cheap and very effective ASAT weapon costs only 1% that of a normal satellite and lasts significantly longer than a typical ASAT (Wilson, 2001). Other types of ASAT weapons include lasers, radio frequency, and particle beam weapons.

Electronic attack. All military and commercial satellites are susceptible to jamming under the right circumstances. For example, Russia currently markets a handheld GPS jammer that can deny access to receivers as far away as 50 miles. The jamming threat becomes clear when one considers that 80% of satellite communications used during Operation Iraqi Freedom were provided by the vulnerable commercial satellite sector (Satellite Industry Association, 2007, pp. 1-31).

Space debris. Space debris is increasingly a byproduct of man's activity in space. Particularly troublesome is the use of kinetic devices. America's Space Surveillance Network tracks approximately 14,000 pieces of debris greater than 10 cm across (Morring, 2007). According to Nicolas Johnson, NASA's chief scientist for orbital debris, China's recent ASAT weapon created thousands of pieces of debris, which were thrown into multiple orbits ranging from 200 km to 3,800 km. Johnson called it "…by far the worst satellite fragmentation in the history of the space age…" Currently, of the 2,792 payloads in space, two-thirds pass through the zone now affected by the debris from China's ASAT (Morring, 2007). Another major concern regarding debris is the cascade effect that occurs when orbital debris collides with other space objects, in turn creating new debris that causes ever more collisions (Taylor, 2006). Penetration of a critical satellite component by space debris, such as the flight computer or propellant tank, can disable or destroy it. In LEO, the average relative impact velocity is 21,600 mph. At this speed, an impact with an object only 10 cm long releases an amount of energy equal to 25 sticks of dynamite. NASA frequently replaces space shuttle windows damaged by objects as small as a flake of paint (Whitlock, 2004).

Recommendation

The world has watched U.S. capabilities in space grow over the last 15 years. While no country dominates space like the U.S., no other country is nearly as dependent upon space. This dependence heightens the likelihood that its enemies will employ technologies to diminish its advantage. The United States will undoubtedly confront the issue of counter-space weapons in the future. The issue may surface via one of two means. First, a dramatic surprise event of strategic importance that destroys or severely degrades a U.S. asset or that of a friendly state; or second, the development of a breakthrough technology that leads to the deployment of a space-based weapon, or even just the announcement of such a capability.

Therefore, policy makers should plan now for the weaponization of space. A frank debate must begin to review U.S. response options to a kinetic weapons strike upon its space assets; a computer attack upon its critical space networks; or the destruction of an essential capability by space debris. Additionally, policy makers must address ways to adequately protect the space assets our nation relies on daily for our national and economic security. Finally, our nation must determine the level of resource investment necessary to meet these challenges. Given the very slow rate at which the space industry can respond to crisis, and the nation's many competing fiscal priorities, the decisions the U.S. makes in the near future will determine how effectively prepared it is to deal with these emerging threats.

—Colonel Jeff Koch, USAF

The Space Industry in Decline

While the ability to operate in and exploit space has been an historic advantage for the United States, this advantage is beginning to erode. The principal cause of this erosion is a reduction in the U.S. industrial share of the global space market. Even though the U.S. National Space Policy claims "…space capabilities—including the ground and space segments and supporting links—[are] vital to [U.S.] national interests," government policy has failed to adequately deal with today's negative market conditions (OSTP, 2006, p. 1). Until and unless national policy corrects the current market conditions, this erosion of capability will continue, threatening the security and prosperity of the United States.

The Troubled Industry

The sectors of the space industry span the industry lifecycle, though the elements that most directly support the national security, launch and satellite manufacturing, have matured over the last 50 years and today reflect little innovation, little competition, low capacity, and high cost. U.S. policies governing the acquisition and export of space technologies have hastened the maturation, concentration, and decline of the industry by limiting the ability of foreign countries to purchase U.S. space technology or preventing foreign companies from competing for U.S. space contracts. One stark result, for example, is that of the 24 comsats ordered globally in 2005, U.S. companies secured only half (Lardier, 2006, p. 43). By comparison, U.S. companies provided 83% of the global commercial satellite market in 1999 (Zelnio, 2006). Should these trends continue, they will limit the ability of the U.S. to exploit the medium of space and may erode its asymmetric advantage. To sustain its space-related advantages, therefore, the U.S. must address these challenges by transforming the space industry through increased competition, and by so doing lower costs, increase capacity, and improve innovation.

Limited competition. In 1933 Congress passed the Buy American Act. While this policy, as amended in 1979, admits foreign competition for all government acquisition over $169,000, more practically the acquisition process is governed by the constituent interests of the Congress (Aaserud, n.d.). Accordingly, a de facto "Buy American" provision influences every major federal acquisition in the U.S. Since there are only five major satellite manufacturers worldwide and two are foreign, domestic political pressures limit the competitive arena by nearly half (Zelnio, 2006). A more explicitly troubling U.S. government policy is the International Traffic in Arms Regulations (ITAR). ITAR embodies the legislative restrictions on the export of certain U.S. munitions, including satellites. The logic for ITAR is to sustain a military advantage by preventing the spread of key, dual-use technologies to third parties. While the provision is meant to enhance the security of the nation, its implementation has limited the ability of U.S. manufacturers to compete in the global market (Zelnio, 2006). Collectively, natural barriers and governmental regulation have eroded U.S. market share and competitiveness in the industry, yielding, among other things, a lack of innovation.

Limited innovation. Though the space industry is one of the most advanced and technologically complex industries in the world, the developmental pathways along which launch vehicles and satellite manufacturing have progressed have changed little in the last 40 to 50 years (Furniss, 2001). The industry continues to use massive liquid fuel rockets that are extraordinarily expensive, costing approximately $90 million to $200 million each to deliver a payload of 6,000 to 13,000 kg to geosynchronous transfer orbit (GTO), or approximately $15,000 per kg, depending on the device (FIAG, 2006, pp. EELV-1-2 and p. Sea Launch-1). Further, a liquid fuel rocket is only about 1.6% efficient to GTO, insofar as it uses 98.4% of its thrust to propel itself along its ascent trajectory and into position to release its payload (FIAG, 2006, p. Atlas V-2). Additionally, the chemical reaction that generates the thrust necessary to accelerate the rocket and its payload to 11.2 kilometers per second is also prone to catastrophe nearly one time in ten (Newell, 1979, pp. 170-171).

Similarly, satellites have followed a developmental pathway that exploits the most advanced technologies. This pathway incurs a good bit of risk because immature technologies are more prone to fail. Cutting edge technologies are also quite expensive. Developmentally, they result in one-off devices or devices from a limited production run of two, three, or four in most cases (Mehuron, 2006, pp. 81-83). These risks and their attendant costs are understandable in light of the fact that a satellite cannot be upgraded on orbit. Still, the implications of this risk and the opportunities lost through unexpected expense are detailed in a series of General Accountability Office (GAO) investigations (Chaplain, 2006).

Limited capacity. There are only five companies that build the great majority of satellites today: Boeing, Loral, Lockheed Martin, Alcatel, and EADS-Astrium. Another nine companies participate in the market, though in a much smaller role (SIA, n.d., p. 9). While Futron reported in 2004 that the satellite manufacturing industry had overcapacity, the market dynamics actually reflected diminished demand as a function of price rather than oversupply (p. 15). The cost to produce a satellite is extraordinary, ranging between $200 million to $500 million, and is probably the single greatest barrier to companies or states as they consider exploiting the medium of space (Zelnio, 2006). This cost must then be evaluated in terms of the attendant risks to launch it into space. While risk may be managed to some extent through insurance, it is never eliminated.

The launch industry is smaller yet, wherein only Boeing and Lockheed Martin have a commercially viable launch capability in the U.S. China, the European Space Agency, France, Israel, Japan, Russia, and India each have governmental or commercial capabilities as well (Morring, 2007, p. 52). Space-X, a new U.S. company, is working hard to develop a launch capability that will offer lower costs relative to the two domestic majors. It recently tested its Falcon 1 launch vehicle, and while the second stage did not perform fully to specifications, the company claimed the launch as a success (Bergin and Lowe, 2007). This is an important development since Boeing and Lockheed Martin have merged their launch capabilities into a single company, the ULA, effectively eliminating any competition for government payloads within the U.S.

Recommendations

The industry shortcomings enumerated above are clearly interdependent, though the principal cause of current industry conditions is a lack of competition. Unfortunately, far from solving the structural problems in the space industry, the U.S. government's policies to date have made things worse. Successful policy in the space industry should be evaluated in terms of its ability to transform market conditions to increase the number of competitors, thereby increasing competition and innovation along a pathway that will produce essential capabilities with lower risks and costs and enhance the capacity of the U.S. to access and exploit space.

Option 1: Internationalize competition. ITAR and the current "Buy American" imperative artificially constrain the size of the industrial base. Economic theory argues that a reduction of competition introduces inefficiencies in the market, offering strong rationale against ITAR. The tension that opposes completely free trade is the potential it has to transfer key technologies to other countries. ITAR reform is necessary and should adhere broadly to the principle of the freest possible trade within the bounds of protecting U.S. national security. This approach would immediately internationalize the launch sector, and could internationalize much of the satellite-manufacturing sector. Internationalization would not only enable the U.S. government to award foreign contracts, it would enable U.S. companies to seek the same in a much more robust way than is practical today. The prospect of U.S. contracts being let globally would encourage new entrants to the market. Greater competition in the market would yield cost benefits to the U.S., encourage greater innovation, and through lower costs and greater product offerings, and induce a larger commercial market for space products.

Option 2: Competitions and prizes. History is replete with stories, now legend in some cases, of the heights to which man's creative energy can reach when inspired by a meaningful challenge and the potential for economic reward. Such challenges may also inspire a new generation of adventurers, scientists, and inventors to solve the pressing problems of our day. In that vein, NASA supports a series of space-related challenges today, though does so in an ancillary role through a vehicle called the Centennial Challenge. Unfortunately none of these prizes exceed $500 thousand (NASA, 2007). Further, these challenges, while interesting, are unlikely to usher in the changes necessary to transform the space industry from its current conditions of high cost, high risk, and limited innovation and competition, to one of many competitors creating reliable capabilities for many consumers at a fraction of the current expense. Therefore, a dedicated, government-sponsored effort offering substantial prize money is needed to stimulate the technological innovations that will foster the necessary change. The most critical opportunity would be a competition to replace the liquid fuel rocket as the principal means of accessing space with a low cost and lower risk alternative. Eliminating the liquid fuel rocket would transform the industry and set the conditions for broad commercialization of space.

Option 3: Focused research. NASA and the Department of Defense (DoD) use a number of different agencies and institutes to pursue research critical to the development of enabling technologies. Unfortunately research budgets are declining. In Fiscal Year (FY) 2007, NASA programmed $893.2 million for aeronautics research but reduced that amount by nearly 41% to $529.3 million in FY2008 (NASA Budget, n.d., p. 14). DoD has similarly reduced its spending on research (Spring, 2007). Given limited resources, a concerted research focus is needed to uncover the most critical technologies. A prioritization of the right areas should include efforts to discover materials with substantially higher strength to weight ratios to reduce the energy required to achieve escape velocity from earth; the development of improved chemical thrust options in order to increase the relative efficiency of chemical launch vehicles; and the development of modular, cooperative satellite architectures that offer both substantially enhanced survivability in space through redundancy and dispersion, and the ability to leverage the promise offered by on orbit refueling and modification capabilities such promised by Orbital Express or Kayser-Threde's proposed Orbital Recovery System (DARPA, 2007, pp. 1-2). Collectively these technologies will enable a much more cost effective and much larger competitive market.

Sustaining the Advantage

The promise of these recommendations is to fundamentally transform the space industry from one that is mature, high-cost, high-risk, and reflective of limited competition and limited innovation, into one that is full of competitors vying for a burgeoning commercial market, the richness and vibrancy of which we can only dimly fathom. The critical motivator for this decision is to preserve the U.S. advantage in space. By encouraging competition in the market place, the inevitable and predictable consequence is innovation. As costs come down and the market becomes adequately commercialized, the possibilities for greater technological achievements are limitless. The future may still be ours.

—LtCol Pete Yeager, USMC

Conclusion

The space industry remains a critical element of the U.S. industrial base, providing capabilities that are essential to national security and making ever-greater contributions to the gross domestic product. This condition of space dominance and space dependence is entering a period of flux due to factors both within the U.S. and outside of it. To date the U.S. government has prioritized the acquisition of space capabilities according to a Cold War model, treating cost as a subordinate consideration to performance and schedule. In fact, the GAO has provided a series of detailed civil and military space program reviews, consistently finding fault with the government's ability to predict program costs and manage technical risk. At the same time, industry consolidation has reduced competition and raised costs.

Outside the U.S., many nations have shown a growing interest and effort to create space-faring capabilities. Accordingly the U.S. can expect increasing challenges to its preeminent position in space. Further, the possibility of direct challenges to the U.S.'s ability to use space have manifested recently and emphasized the fragility of its space-based capabilities. Still, the U.S. is uniquely positioned to shape mankind's future use of space, thus guaranteeing its own continued and unimpeded benefit. The U.S. should use its current advantage to seek increased opportunities for international cooperation and collaboration in this important domain. The following recommendations are meant to address these emerging conditions.

Technical Solutions

Insofar as the intersection of industry and government most commonly occurs in the acquisition of space capabilities, the U.S. must revise its current acquisition methodologies. In a diminishing fiscal environment, the U.S. must find a way to gain greater benefit from each dollar expended. One important method to accomplish this aim is to reprioritize cost as a primary determinant of programmatic value and health. Simply put, the government must begin to more aggressively manage programmatic cost instead of solely performance.

Second, given that technological risk often derails acquisition efforts, technology development should be performed independently from systems development. The acquisition process needs a better gauge to determine the maturity and availability of technology before embarking upon a space program. This process should yield a more accurate cost model to better determine programmatic risk prior to initiation.

Third, because resources are increasingly scarce, the government must maximize each investment. To this end, the government's research investments should be spent explicitly on technologies that have the greatest impact on the conditions of the space industry, such as high cost and high risk. New technologies that hold promise for fundamental change in space include those designed to perform on-orbit life extension, repair, or performance improvements. These capabilities can only be maximized in a standards-based environment. Space capabilities such as satellites are often unique, complicating efforts to improve performance after launch. Therefore, development of standards in bus, payload, power use and provision, communications methods, and processing characteristics could set conditions for widespread use of on-orbit capabilities that could reduce lifetime costs and risk.

Policy Solutions

Given current trends, U.S. space dominance is far from guaranteed. The U.S. may consider that its security rests both in its ability to use space as well as its more prosaic terrestrial activities. Insofar as many nations are demonstrating increasing interest and attention in gaining access to space, the U.S. should evaluate the merits of using space not just as a critical national security and economic enabler, but also as a vehicle to accomplish broader geo-strategic goals through international cooperation. Several options for international cooperation exist.

While national security offers ample inducement to seek cooperative international ventures, fiscal effectiveness offers an additional benefit from collaborative action. The International Space Station is one example of successful cooperation that contains the benefits of international teamwork. Many additional possibilities exist, including seeking a framework for cooperative development of a common, space-based navigation system with the EU rather than redundant, separate systems such as GPS-3 and Galileo.

As noted earlier, a common thread in U.S. space policies is to induce a more active commercial market in space. Yet, to date the U.S. government continues to dominate the demand side of the market for space transportation, and remote sensing. If the U.S. truly seeks a sound commercial market for space, it must address and correct the inherent, structural elements of risk and cost within the industry. Additionally, it must take definitive steps to encourage new entrants into the space industry as the principal method by which innovation and competition will be generated in the near term. Despite rising costs and diminishing returns, the government appears content to limit both competition and new entrants within the market.

Finally, in recognition of space as a common domain benefiting all mankind, the U.S. should establish the legal and policy foundations necessary for peaceful space exploration through internationally binding agreements. This effort diminishes the likelihood of conflict in outer space, and contributes to a more energetic effort to extend the civilization of mankind beyond the earth. As such, it will serve as a fitting legacy for the greatest space-faring nation on the planet.

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