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SPACE
A Report on the Industry

Industry Study 5240-17

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SPACE

ABSTRACT

Americans take space system services for granted. But if the systems weren't available, the impact would jolt our nation's defenses and our daily way of life. While the US currently enjoys great advantages across the national security, civil, and commercial space sectors, foreign competition combined with self-imposed restrictions on the industry will likely challenge US space dominance in the coming years. Overcapacity since the late 1990s has also weakened the bulk of the industry.

Today, the country needs leaders who will take action. We need to provide qualified acquisition staffs for struggling national security space programs, rejuvenate the space industry's much-needed high-tech workforce, and allow our space companies to compete fairly worldwide. These are just a few of the recommendations presented in the following pages. The US space industry's health depends on US government leaders taking actions that strengthen the nation's competitive advantage in the industry.

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INTRODUCTION

Access to and freedom of action in space are critical to our way of life. Americans take space system services for granted, but if the systems weren't available, the immediate impact would jolt the nation's defenses and our daily way of life. In short, the space industry plays a vital role sustaining US national security.

The US currently enjoys great advantages across the national security, civil, and commercial space sectors. However, foreign competition combined with self-imposed restrictions on the industry will likely challenge US space dominance in the coming years. With this in mind, several important questions are worth investigating:

- Is the global space industry healthy?
- Is the US share of the industry healthy?
- What is the industry outlook, given today's policies and unfolding developments?
- What actions can our government leaders take to ensure the future health and competitiveness of the US space industry?

To answer these questions, this paper will define the industry, discuss its current state and outlook, briefly explore pressing challenges, advocate important recommendations to overcome these challenges, and offer four essays that further focus on specific space industry issues.

THE INDUSTRY DEFINED

Most US and many international citizens depend on the space industry to carry out daily activities, without recognizing how dependent they are on space-supported services. Examples include: global positioning systems, satellite radio, television signals, credit card transactions, communications, weather forecasts, and global remote sensing. Banking, internet transmission, environmental monitoring, and telemedicine are also space-reliant services.[1]

Sectors

The space industry consists of three overlapping sectors: civil, national security, and commercial. Events in any one frequently affect the others.

National Security Sector. This sector provides space system capabilities that directly support the military and intelligence communities. Capabilities include communication, navigation, weather, missile warning, and intelligence. In the US, the Air Force is designated as the lead agent for military space systems, while the National Reconnaissance Office (NRO) is accountable for the nation's intelligence space systems.

Civil Sector. The civil space sector conducts exploration, Earth science, scientific experiments, and other research and development (R&D) for non-military missions. In the United States, the National Aeronautics and Space Administration (NASA) oversees such efforts.

Commercial Sector. This sector builds satellites, rockets, and operations support systems, and provides services to government and commercial customers. The globally networked economy depends heavily on commercial space capabilities to enable economic growth (e.g. cell phones, satellite television, navigation, etc.). Although private companies are the main players in this sector, some governments subsidize commercial efforts.

Segments

Each sector above relies on three main space industry segments:

Launch Vehicles and Services. This segment includes the design, manufacturing, and services required to launch payloads into space. Three of the largest launch vehicle manufacturers are Boeing, Lockheed Martin, and the French manufacturer Arianespace. SpaceX is a recent start-up planning to compete for small satellite launch market share against Orbital Sciences Corporation's Pegasus air launch system. In addition to the US and Europe, other countries including Russia, China, India, and Japan have proven space launch capabilities. Launch segment health depends on the pull of satellite production and operational demand.[2]

Satellite Manufacturing. Satellite manufacturers design, build, and sometimes operate satellites for governments, militaries, and private corporations. Satellite production demands significant engineering expertise. This usually involves long-term design, test, and production cycles requiring extensive R&D and capital.

The satellite industry's production capability is currently underutilized, especially with respect to the demand for second and third tier subcontractor components.[3] In some cases, "domestic capabilities required to support payload and sensor development for national security are at risk."[4] According to a senior spacecraft analyst at the National Air and Space Intelligence Center, there isn't a large enough domestic market, and the international market is off limits due to export restrictions set forth in the US International Traffic in Arms Regulations (ITAR).[5] This is just one of the key space industry issues discussed in the Challenges section.

Operations and Satellite Services. Operations include networks of ground stations that ensure satellite system health and status. Satellite services include voice, video, and data communications, remote sensing, and global positioning, navigation, and timing.

Barriers to Entry

Barriers to space market entry are extremely high, including tremendous capital requirements, technical complexity, high risk, strict environmental standards, highly skilled and educated labor, high insurance costs, and rigid government regulations. Even though the US government mandates many regulations in the interest of national security, these same actions frequently cause difficulties (see Challenges section) for both US and international space competitors. Additionally, overcapacity has induced greater price competition, while government subsidizing of current players further hinders new entrants.

CURRENT INDUSTRY CONDITIONS

Two central themes characterize the industry today. The first theme is US space domination—the US enjoys advantages across all space sectors. However, successful European, Russian, and Chinese competition, facilitated by US-imposed export control impediments, could hinder future US advantage. The second theme is existing overcapacity in satellite services, manufacturing, and launch. Current overcapacity is a function of the 2001 economic recession and telcom bust, during which terrestrial-based service competitors captured part of the telecommunication services market.[6]

The Global Space Industry

National Security and Civil: The US invests almost six times as much on national security space applications as the next largest investor, the European Union (EU), and nearly three times as much on civil space.[7] These US investments currently provide the country with information superiority and the ultimate command of the commons.[8] Military power projection depends on space-based systems. Today, US military advantages play a vital role supporting international security and enable global trade and economic prosperity.

The 2004 total global investment across all space sectors was estimated at $50.8 billion, due mostly to US national security and civil space spending.[9] The US's $35.5 billion investment eclipsed the $6.6 billion European, and $1.5-2.4 billion Chinese investments.[10] US ambitions continue unabated, with a robust national security space program, recent US Air Force Counterspace Operations Doctrine, and a new civil exploration vision for NASA.[11] With technology mastery and brute economic power, the US claims unambiguous (but not unchallenged) space dominance. Europe and the UK are now strong competitors, while Russia's vigorous space program has become a most successful export. Last year, Russia launched 45 % of all spacecraft—more than any other nation and 50% more than the US.[12] Israeli, Japanese, and Indian programs are also maturing. Additionally, EU and Japanese satellite makers claim technical advantage over the US, partly because of their government financial and regulatory support, in the midst of US export control hindrances to US competitors.[13] Finally, China is an emerging space entrant, placing a Taikonaut in space in 2003, launching six missions in 2004, recently signing a satellite agreement with Iran, and planning eight launches in 2005.[14] The playing field is changing.

Properly directed, civil space investment puts the US at the forefront of space exploration, engendering pride and energizing national will. In January 2004, President Bush announced a new National Space Policy that includes manned missions to the Moon by 2020 and Mars sometime later (likely 2030).[15] US leadership in space exploration should generate interest and needed commitment in math, science, and engineering careers. US leadership with egalitarian and participative roles for other nations may improve the country's status internationally. Additionally, dividends from space research and exploration provide economic and quality of life payoffs.[16]

Commercial: The commercial space industry is experiencing reduced demand, yet both Lockheed Martin and European Aeronautic Defense and Space Company (EADS) announced profits for 2004.[17] Global space revenues in 2003 reached almost $100 billion, with a five-year forecast of $560 billion, despite falling demand and slim profits.[18] When Burt Rutan won the $10 million Ansari X Prize in 2004 after his SpaceShipOne repeatedly transited to space, he generated refreshing excitement and interest in a potential commercial space market—space tourism.[19] Consequently, just hours after Rutan's success, Las Vegas hotel mogul and space entrepreneur Robert Bigelow announced the $50 million American Space Prize for anyone who could demonstrate a privately funded, commercial space passenger transportation capability.

Nature of the Market

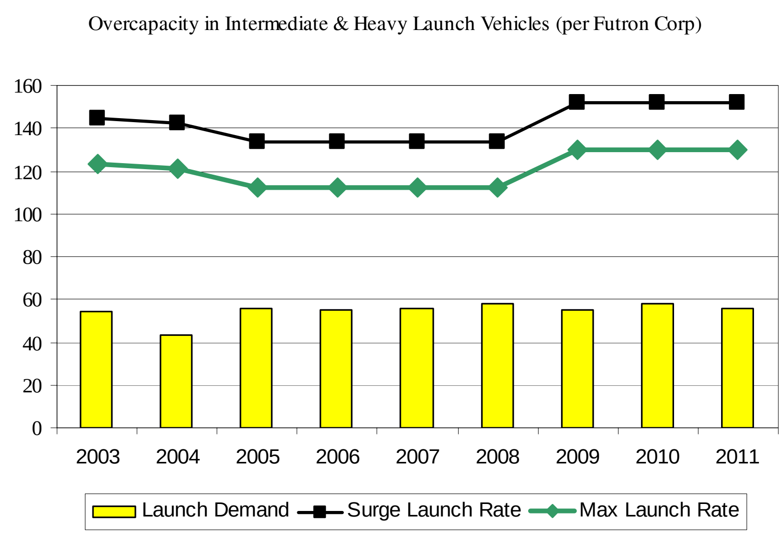
The space industry is an oligopoly-oligopsony relationship, with few suppliers and major buyers.[20] Oligopoly theory proposes that prices will fall between monopolistic and competitive models.[21] The US Evolved Expendable Launch Vehicle (EELV) market is an example at the monopoly end of the spectrum, with little competition, few buyers, two providers, and large government subsidies. EELV providers currently depend on subsidies to remain in the market.

These subsidies reduce the price of commercial launch for heavy payloads.[22] Lighter payload launch has more competitive pricing, with additional low cost providers. However, price flexibility is limited by the significant investment required to generate launch capabilities.

The satellite manufacturing segment is in the competitive end of the oligopoly-oligopsony economic spectrum. With diminished demand, low margins, idle capacity, high insurance costs, and restrictive export controls, satellite manufacturing companies are struggling to maintain profitability.[23]

Market conditions

A global industry downturn in demand for new satellites and launch services dominates the space industry, with a slow rebound for satellite communications (satcom) services—the primary commercial space revenue driver.[24] In the 1990's, satcom bellwethers devised aggressive plans, investing billions in satellites and distribution infrastructure based on strong predicted demand. With the previously mentioned 2001 telecom bust and economic recession, much of the anticipated satcom demand evaporated or was filled by terrestrial competitors, triggering provider bankruptcies.[25] By 2001, world launch revenues declined 41%, the US's declined 59%, world satellite manufacturing revenues declined 18%, and the US's declined 38%.[26] Four major mobile service providers (Globalstar, ICO, Iridium, and Orbcomm) filed for bankruptcy, and Teledesic's FCC licenses were cancelled. Past launch and satellite reliability issues plus rising insurance costs exacerbated the downturn.[27] The 1990s saw on average 91 launches per year.[28] With 63 global launches in 2003, 55 in 2004 (fewest since 1961), and an estimated 68 for 2005, 60-70 launches per year appears to be a new equilibrium.[29] The Futron Corporation chart shown here illustrates the excessive gap between capacity and demand for the larger launch vehicles.[30]



Revenue and Economic Contribution

The space industry doesn't directly generate a significant portion of the US economy.[31] In 2002, the US space industry produced $23.5 billion in employee earnings on activity of $95 billion, generating 576,000 jobs. For comparison, civil aviation produced ten times the earnings, and recreational fishing produced $6.6 billion *more* in earnings, on $116 billion in activity.

Examination of the industry economic contribution structure is illuminating. In 2002, contribution from highly visible launch services was 1%, distribution 1%, remote sensing less than 1%, satellite manufacturing 5%, and ground equipment 40%. The "cash king" clearly was satellite services at over 52%. Direct-to Home Television (DTH) provides 80% of this share.[32] Although revenues earned by satellite manufacturing and launch contributors are small, these providers supply *the* critical link that enables satellite services to generate profits.

INDUSTRY OUTLOOK

Support to National Security Resource Requirements

The US currently maintains the necessary space industry capabilities to effectively support US national security requirements: infrastructure, skilled high-tech labor, and capital resources. But there's more to the equation. When the market crashed as noted above, unrealized demand yielded unused capacities. The industry's ability to surge to support additional national security needs depends on available launch facilities and vehicles, satellite hardware, and manpower. While launch facilities and vehicles aren't limiters, satellite hardware and human capital are.

Senior leaders in US satellite manufacturing companies report surge limitations. One CEO noted vulnerabilities with second and third tier components suppliers.[33] He said maximizing dual use electronics that share non-space applications would increase available stock in times of rapid mobilization.[34] Another contractor stated his company was producing at 60-65% of capacity.[35] His surge limiter was technically competent employees.[36] The decreasing availability of this human capital is discussed further in the Challenges sections.

Near-term (2005-2010) Outlook

Industry insiders are confident that by 2008, demand will push satellite orders and total commercial US launches to about 20 per year for satellite fleet replenishment.[37] Yet several of the failing providers have recently been purchased by investors merely intent on wringing out profits. Highly leveraged private equity investors now finance Inmarsat, PanAmSat, Intelsat, and NewSkies Satellites.[38] With short-term profit motives, replacement of aging constellations may not occur as quickly as industry experts suggest.[39]

Even so, opportunities exist for struggling satellite manufacturers. "The importance of satellites with respect to military operations and homeland defense has never been greater."[40] On the commercial side, "There is no question that the space and satellite industry will remain a solution to the needs of many organizations for years to come."[41] Service market sub-segments such as direct broadcast satellite television (DIRECTV, Echostar, etc.) and satellite radio (XM Radio and Sirius) are growing rapidly. Additionally, commercial space passenger transportation and space port businesses could contribute over a billion dollars to industry revenues by 2021.[42] While the industry is mature in many respects, these areas show promise for further growth.

On the international civil government side, *Standard and Poor's (S&P)* pegs the industry's growth at 3 to 4% annually. *S&P* further notes that the International Space Business Council forecasts the space manufacturing growth rate through 2009 at 5.5% annually, but states 3% annual is more realistic, with profit margins of roughly 5 to 8%.[43] Noting with exception that there are areas with room for growth, we are convinced the above S&P numbers show that in broad terms, the industry is mature in its lifecycle.

Long-term (2010-2020) Outlook

Professional industry analysts do not forecast beyond 10 years. That said, *S&P's* latest data predicts a future decade without "huge defense spending hikes."[44] *S&P* reports the US military continues to become more reliant on space systems and "will help prop up [the] otherwise sluggish long-term demand for satellites…[with a] long-term average annual military space growth in the 5% to 7% range."[45] Long-term profit margins are expected to fall between 6 and 8%.[46] Per *Forecast International*, the US "will truly drive the international military satellite market in years to come…[while] Europe continues to develop systems through cost-sharing partnerships."[47]

Assuming defense acquisition does not change drastically, US military systems in development today will be on orbit in the next five to ten years, reducing the demand for additional huge outlays in the long-term. *If* the nation finds a way to fill the human capital gap, and *if* the nation musters the will to explore, industry support of space exploration will continue growing on a steady path. Commercially, constant demand for increased data quantity and speed may drive new telecom satellite demand. Disruptive, innovative technologies may also spur growth. Today's inspirations, including Burt Rutan's SpaceShipOne and Robert Bigelow's inflatable space habitats, may drive a burgeoning demand for space tourism. As a whole, space systems will continue to play vital roles in our way of life.

Political and Social Drivers

Several political and social factors impact the industry outlook. Two of note include the European Commission (EC) and US space control.

First, recent changes in the EU may impact the European space industry. The EC is getting more involved in Europe's space program. European Space Agency (ESA) leaders are concerned that the EC may want to assume responsibilities for which they don't have the necessary expertise. "Over the past years, the Commission Services have been increasingly playing an overarching role in policy and regulations to give orientation to the [European] space sector."[48] ESA leaders hope the EC will focus on organizing users versus getting involved in the technical side of programs—ESA's niche.[49] As all EU members are not ESA members, establishing a European Space Strategy (which ESA expects will be published by the end of this year) will be a significant challenge.[50]

Second, if the US decides to place offensive weapons in space, it will present a marked change to past US policy. In light of China's skepticism and mistrust for US policies, we expect that any move on the part of the US to place offensive weapons in space will be met by similar efforts on the part of the Chinese.[51] This risks an arms race and could increase the number and size of worldwide military contracts. Several other US political and social factors affect the industry outlook, including questionable national will, dwindling availability of high-tech human capital, and stringent export restrictions. These space industry challenges are discussed below.

CURRENT INDUSTRY CHALLENGES

The US space industry enables critical military, civil, and commercial capabilities and plays an essential role in ensuring the country's economic well being. The nation requires the industry to remain strong and competitive. However, the industry faces significant obstacles.

National Security

Human Capital. The US space industry is confronting a critical workforce crisis. The first is the scarcity of creative, highly skilled workers with advanced math, science, and engineering education entering the workforce. The second is the large demographic shift in western democracies, as the Baby Boomer Generation retires. The first essay (see Essays section) is devoted to this extremely serious issue.

Impacts of September 11th. While the attack on the nation did expedite an economic downturn, space companies had started a downward spiral earlier, in the late 1990s. Nevertheless, upgrades are currently underway in every major military space mission—communications, navigation, weather, warning, and intelligence. To support the global war on terrorism, the demand for space systems increased. "In the US, the military satellite market is booming, and there is a seemingly never-ending list of programs for which launches are planned during this decade and the next."[52] Acquiring these new programs prompts additional challenges.

Acquisition. Cost and schedule overruns in US strategic military space programs continue to generate high political costs in an environment of austere budgets and intense Congressional scrutiny. According to Thomas Young, the chairman of the 2004 Joint Task Force on the Acquisition of National Security Space Programs, bad acquisition decisions in some space programs led to "over-emphasis on cost rather than mission success, unrealistic budgeting and rampant requirements growth."[53] Several noted acquisition challenges still hold true today.

First, government competence in leading and managing acquisitions has seriously eroded, as program managers "lost authority to execute effectively."[54] They're often forced to lead programs without prudent budget or schedule margins.[55] Second, cost has replaced mission success as the primary driver for managing acquisitions, resulting in excessive technical and schedule risk. Third, the military's space acquisition system was strongly biased to meet unrealistically low cost estimates. "In source selections [during the 1990s], the incumbent had lost 90 percent of the time, often because the nonincumbent was not burdened by actual costs of the on-going program and could be far more optimistic."[56]

Weaponization. US military strategy depends more on its space assets than any other nation's. While our nation may not choose to pursue offensive space weapons, at a minimum it should assure the protection of our national security space systems. Secretary Rumsfeld testified to Congress that, "Our goal is not to bring war into space, but rather defend against those that would."[57] If we weaponize space, China will likely follow (see Essays section).

Civil

NASA's Exploration Vision. NASA accounts for the vast majority of the US civil space program. To achieve the President's exploration vision, NASA and the nation must overcome significant challenges. While most of the nation supported Kennedy's Apollo dream, recent polls indicate only 48% of Americans support the new vision.[58] The government and industry now face dwindling public support, lack of a NASA budget increase commensurate with this new and ambitious Moon-Mars exploration goals, and dependence on technology breakthroughs. These issues are detailed in two papers in the Essays section.

Commercial

According to the President's National Security in Telecommunications Advisory Committee, the "commercial satellite industry is critical to our national, economic, and homeland security."[59] The government continues to create major challenges for this sector.

Export Control. In 1999, the executive administration supported Congress's recommendation to move responsibility for satellite and satellite component exports from the Department of Commerce to the Department of State. [60] The policy classifies satellite components bound for export as weapons, without differentiating recipients as friend or foe. According to the Satellite Industry Association, America's share of the global satellite manufacturing market dropped from 64% in 1998 to 36% in 2002.[61] Admittedly, market share has since rebounded somewhat, but industry leaders question the long-term outlook.

Increased scrutiny of US space exports delays or prohibits delivery to overseas customers for whom time equals money. As these delays frustrate customers who demand quick responses, the Substitution Effect results—foreign customers switch to substitute suppliers to keep their costs from increasing.[62] In response to US restrictions, the EU initiated a European Component Initiative to develop space technology capabilities autonomous from the US. This program is geared at filling the strategic gaps in European technology. Today, the program funds two European suppliers to produce critical technology currently available only in the US.[63] ESA will extend these incentives to other European manufacturers to produce other "ITAR free" components currently only available from the US.[64]

US companies unable to maintain a diversified customer base, which must *include* international business, will be hard-pressed to remain solvent. "Five years from now, US component suppliers could well find themselves facing a flat or declining defense market and a commercial sector that, healthy or not, has limited interest in their wares."[65] Because of this concern and the other implications discussed above, the government should take immediate, specific actions to improve the situation, as recommended below in Government Goals and Role.

Overcapacity. Overcapacity of satellite manufacturing and launchers is also a serious concern. It has forced manufacturers to reduce prices and profits in order to entice consumers to buy their products.[66] Satellite overcapacity reduced overall demand for expendable launch vehicles (ELVs). "With major portions of the satellite launch market going bust in recent years, ELV makers are faced with the problem of promoting their products in a market where the number of launchers exceeds the satellites earmarked for launch."[67] Since the late 1990s, commercial demand for ELVs has dropped 50%, driving a 40% reduction in prices.[68] Such drastic reductions, while a boon for the customer, greatly reduced earnings below sustainable levels—according to a major launch company's senior executive, the situation is "not healthy."[69]

Private Equity Investors. As stated in the Industry Outlook section, highly leveraged private equity investors are focused on profit above all else—recapitalization is not on their radar. As a result, some aging constellations may not be replaced as quickly as is warranted.[70]

GOVERNMENT GOALS AND ROLE

In the global arena, US national security and civil space sector funding dominates. Given our country's ubiquitous dependence on the industry, on-going government funding and oversight is appropriate. However, there is *much* more the Executive, Congress, and DoD could do to provide improved leadership on the national security and civil side, while taking steps to facilitate improved competition and health within the commercial sector. The following recommendations will help resolve the concerns discussed previously in the Current Industry Challenges section.

National Security

- **Publish a contemporary National Space Policy**. Our nation's current overarching, Presidential-level space policy was published in 1996. The imminent release of a new, clearly stated national policy should inspire and encourage a collective national will.[71]

- **Revitalize human capital in Science, Technology, Engineering, and Mathematics (STEM).** Inspire the next generation to pursue careers in the space industry: accelerate and resource current initiatives while developing a collaborative and integrated national human capital strategy. The DoD's 18 October 2004 opening of the National Security Space Institute in Colorado is noteworthy.[72] The Institute will play a critical role in growing needed DoD space acquisition expertise.

- **Improve acquisition**. The DoD and Congress must continue pushing improvements:
  - Enforce the Defense Acquisition Workforce Improvement Act to provide program directors and managers with sufficiently sized and trained staffs.[73]
  - Separate and run development and production efforts in series—do not enter production until confidence is established in a good baseline design.
  - Ensure an adequate testing program to rigorously prove the developing system design.
  - Provide requisite *and predictable*, multi-year program budgets.

- **Debate weaponization policy**. Consider the ramifications of our action or inaction.
  - Strengthen non-offensive space use policy. The United States should leverage leadership in international institutions (e.g., the United Nations) to reinforce all countries' freedom of action in space—avoid risking a dangerous "space arms race."
  - Change the "Harmless Heavens" paradigm in hardware design. Establish mandates to protect DoD-used space system sensors from basic ground-based laser dazzling or radio frequency jamming.

- **Evaluate surge and mobilization capabilities.** As launch support is not currently a surge limiter, satellite producers introduce the most likely mobilization constraint.[74] As stated previously, changing export restrictions and rejuvenating interest in STEM will do much to rectify major surge challenges—limited component suppliers and waning human capital.

Civil

- **Promote NASA's Exploration Vision**.
  - Accelerate NASA's Mars timeline to better capture and hold the country's interest.
  - Fully fund an *adequate* NASA budget and then grant the agency freedom to benefit from Mr. Griffin's capable leadership.
  - Avoid a gap in US manned access. Shorten the Crewed Exploration Vehicle acquisition schedule.[75]
  - Re-grow the country's science and engineering workforce as detailed in Essays.

- **Increase technology investment**. Pass legislation to remove barriers and incentivize research in space technologies. Leverage the ideas and expertise in industry and our nation's universities—again, revitalize our nation's education system as previously discussed.

Commercial

- **Rewrite export control policy.** As we learned in ICAF Economics, "No…resource allocation decision should be undertaken in either public or private enterprise without knowledge of its cost consequences."[76]

- Move control back to the Department of Commerce! Update the export control policy to better balance the needs of national security and the US space industry. Our national security could soon be jeopardized if major US defense contractors divest their space system subsidiaries so the country becomes dependent on foreign space products. For non-sensitive, commercially available components, return approval authority to the Department of Commerce. The Department of State should retain authority for a selected set of high-tech systems whose export would directly benefit foreign weapons development. If near term politics prohibits an immediate shift back to the Department of Commerce:[77]
  - Congress should require the Department of State to streamline approvals of non-threatening space exports. Do not require process-delaying Congressional coordination for these systems.[78]
  - Establish blanket approvals for capabilities exported to close allies as well as for technologies that are widely available outside the US. Products bound for the UK should not require the same review processes as those planned for export to China.[79]

- **Monitor overcapacity in launch.** Carefully review Lockheed and Boeing's request to merge launch capabilities in the "United Launch Alliance," and closely evaluate how this will affect heavy lift reliability, availability, and affordability.[80] Contractor-provided launch pad and services with leaner business practices will draw down current overcapacity. But keep in mind, assured heavy lift access to space is still essential to US national security.[81]

- **Track private equity investors.** Evaluate health of government-used commercial satellites financed by private equity investors. If these investors are not recapitalizing or improving government-used commercial systems at a rate deemed appropriate, then seek out new vendors that better meet the government's needs.

ESSAYS

THE FUTURE OF OUR NATION'S SPACE INDUSTRY WORKFORCE

"The harsh fact is that the US need for the highest quality human capital in science, mathematics, and engineering is not being met . . . .In a knowledge-based future, only an America that remains at the cutting edge of science and technology will sustain its current world leadership."[82]

Introduction: There is a crisis looming in America's science, technology, engineering, and mathematics (STEM) workforce base that has serious implications for the future of America's space industry, and our nation's economic and national security. Today, trends indicate other nations are on the verge of passing the US in scientific excellence and technological innovation.[83] This comes at a time when the US is more dependent on its military, civil, and commercial-supporting space assets than any other nation. To maintain American preeminence in space, our nation must reinvigorate and inspire a new generation of STEM talent, as well as increase investments in research and development (R&D) and infrastructures.

Troubling Trends of STEM Education and the R&D Connection: The Council on Competitiveness found that innovation is the single most important factor in determining

America's success through the 21st century.[84] While the report recommends increased funding in R&D, the US government has reduced funding in national R&D over the past ten years, including cuts in the President's FY 2006 R&D budget. Studies link a strong correlation between reduced R&D funding to the decline in the number of graduates in the STEM subjects.[85] Over the past decade, our nation has lost more than 600,000 scientific and technical aerospace jobs which have also adversely impacted the number of students earning degrees in STEM. Meanwhile, nearly 30 percent of the aerospace workforce will be eligible to retire in 2008.[86] The current US educational system will not provide enough students with the needed STEM skills to fill the critical positions being vacated by the retiring baby-boomers.[87] Concurrently, other nations are building up their science and technology (S&T) infrastructures and capabilities.

A disturbing trend is the low performance of American students in the math and science subjects. Math and science achievement scores of US students fall below international averages.[88] The results of a recent international survey, conducted by the Program for International Student Assessment in the spring of 2003, indicate the learning gap between the US and its competitors in Europe and Asia is widening in basic math and science skills at the eighth through twelfth grade levels. This is alarming since technology and innovation in the space industry depends on high tech skills in the STEM subjects, yet this is precisely where the best US students are not excelling. Space science education gets taught within the Earth science curriculum in the grades K-9. This narrow focus on space science is dangerously small relative to our nation's reliance on space. A Department of Defense (DoD) senior official recently stated that the need for US citizens in defense work is critical and that the downturn in America's science and engineering workforce has become "an issue of national security."[89]

Solutions to Improve the National STEM Workforce: It is imperative our nation take action to ensure the scientific proficiency needed in our future workforce. There are numerous policy improvements and on-going initiatives the government should pursue to increase student interest in math and science in the formative years, and to widen the pipeline of scientists and engineers who drive innovation. The US government and industry are taking some steps in the right direction to address the issues discussed in the first two points below. However, our nation should act now to implement the recommendations stated in recommendations three through six.

First, the Federal government should develop a clear policy of sustaining long term research to encourage young people to enter careers in science, mathematics or engineering. Developing a top-notch space industry workforce requires a top-down vision by the President that reaches out to the nation and across the government as the inspirational basis necessary to develop and sustain a knowledgeable and skilled workforce. The Administration is addressing this need and has recently announced a five-year Mathematics and Science Initiative that will engage in a public campaign to highlight the importance of mathematics and science education, and to recruit, train and retain teachers with strong backgrounds in mathematics and science.

Second, early outreach programs are vital to developing and sustaining a knowledgeable workforce. The Council on Competitiveness notes that we lose our future scientists and engineers around the junior high school years.[90] Successful outreach initiatives which expose children to the STEM subjects can help to reverse this trend. DoD implements a Starbase program which provides students in K-12 with a week of math and science based simulations and experiments in space-related fields.[91] The National Aeronautics and Space Administration educational outreach program, "Inspiring the Next Generation of Explorers", influences youths to pursue science and engineering educational opportunities. The Boeing Company's Summer Science Camp has successfully led students to pursue careers in science and engineering.[92]

Third, the Federal government should lift the visa restrictions for foreign students applying to enter the US. Post 9/11 immigration controls have resulted in a 32 percent drop in the number of international student applications in 2004.[93] Foreign students graduating from US universities with degrees in science and engineering have been an important asset in our industry workforce and have contributed to basic science and new innovations. One-third of today's US workforce of scientists and engineers were born outside the US[94] The challenge regarding foreign students is to find a balance between scientific exploration and security.[95]

Fourth, Congress should resist R&D cuts proposed in the President's FY 2006 budget. Federally-funded research has long been a significant factor in US patent productivity and economic strength.[96] As the government tries to reduce its budget deficits, R&D programs in mathematics and engineering are being reduced.[97] There is a real disconnect between the Administration's plans for the new space exploration initiative, and the failure to fund basic R&D programs. These programs motivate STEM talent and lead to the innovation our space industry needs for competitive advantage. Congress should also assist entrepreneurs who have plans to build space components, but do not have the capital to go from concept to delivery.

Fifth, the nation desperately needs to create an educational system of S&T schools. At a minimum, we should be offering and requiring advanced Earth and space science courses at the middle and high school levels while helping students integrate learning into future careers.

Sixth, sufficient training for teachers is critical since they are the ones who inspire and motivate our nation's children to dream and learn. President Bush's Council of Advisors on Science and Technology recently released a report which recommends improving our country's K-12 education to ensure future innovation and improve the nation's STEM capabilities.[98]

In summary, there is an urgent need for all the stakeholders involved, including the government, academia, industry, and professional societies, to develop an integrated plan for education, training, and workforce development. At present, there is no central database for collaboration and sharing information at the national level. Although there is a lot of good coming from existing initiatives, more should be accomplished, and in an integrated approach.

Conclusion: STEM talent is the center of gravity in a knowledge-based economy that has raised the bar on innovation. America's economic progress depends on a continuing supply of STEM talent engaged in and funded across the R&D spectrum.[99] The nation's space industry, knowledge base, and economic prosperity requires an urgent response from the government to accelerate and resource current initiatives while developing a national human capital strategy and vision to inspire the next generation workforce. It is clear that a long term solution to developing a skilled space industry workforce begins with improved math and science education, from kindergarten through graduate school. Children, teachers, and educational and science and technology infrastructures are key to our nation's vitality and future security. We must take deliberate steps to nurture our nation's children in math and science in the formative years and attract and retain enthusiastic educators who will hand off the pride and the passion to the next generation. Just as President Kennedy inspired our nation in the race to the Moon, we must now inspire the nation's young people to create a new generation of innovators to protect our national interests in space across the military, civil and commercial sectors. The children we are educating today are the STEM workforce that will successfully lead the US in the 21st century.

--- Susan W. Pollack, GS-15, Missile Defense Agency

CHINA'S SPACE PROGRAM- IMPLICATIONS FOR THE UNITED STATES

With a great deal of awe (and some apprehension), we have all watched China's rise over the last decade as a major world power. China's increasing interest in space (backed up by capital investments in its space program) mirrors its growing economy and emergence as a major power – both regionally and globally.

Overview of China's Program. On October 15, 2003, the Chinese taikonaut Lieutenant Colonel Yang Liwei launched aboard the *Shenzhou V,* thus making China the newest member in a select group of countries with manned space programs (the US and Russia being the other two). This event fulfilled one of the key milestones set forth in China's 2000 White Paper for Space Activities – a document which stressed the importance of and the future ambitions and milestone for the Chinese space program. The White Paper is essentially the roadmap for China's space activities. Lieutenant Colonel Liwei's successful spaceflight embodies the vision set forth in the Paper – a vision that reflects the importance China places on the exploitation of space and the space program's role in protecting national interests.[100]

China's slow but steady progress in achieving success in space reflects drive and determination. The Chinese know where they want to go with their space program, and by all indications have the national will and state sponsorship to achieve their vision. The foundation of China's stable communist government lies in nationalism and steady economic growth -- a successful space program helps contribute to both as it lends credibility and legitimacy to the government and provides yet another possible area to commercially challenge the United States.[101] In updating the 2000 White Paper, Chinese officials added a space lab and an orbiting space station as part of their 3-step plan for manned spaceflight (having achieved step one with the launch of *Shenzhou V*). [102]

It is important to note that much of China's space program remains shrouded in secrecy – especially the degree to which the military is involved. While it is known that the military is heavily involved in the commercial launch industry (all of China's launch and tracking centers are run exclusively by the military), the extent to which the military is involved in other aspects of China's space program is largely unknown at the unclassified level. In trying to assess the status and makeup of China's space industry, a senior analyst within the Department of Defense admitted that much of what we know and try to draw conclusions from comes from open written media as well as on-line sources.[103] Our understanding (at the unclassified level) of future Chinese ambitions in space, weapons, launch capability, etc. is based on observations of actual events and interpretation of statements made by Chinese officials. Regardless, China's rise as a space power has raised many of the same questions, concerns, and issues faced during the Cold War space race with the Soviet Union.

Will China Weaponize Space?: One of the most hotly debated topics with regard to US national security is the issue of placing offensive weapons in space. As noted in the FY03 Annual Report to Congress on the Military Power of the People's Republic of China, China's official public stance on space weaponization is that they oppose the militarization of space. In private, however, Chinese officials probably consider the development of anti-satellite technology inevitable.[104] Is China's stated opposition to space weaponization rhetoric or genuine policy they intend to pursue? The former is probably closer to the truth since it is likely that the Chinese will react in kind to whatever path the US pursues. As noted by Hui Zhang, a research associate in the Belfer Center for Science and International Affairs at Harvard

University's John F. Kennedy School of Government, many in China believe the goal of space control (vis-à-vis the US) is to achieve space domination. In light of China's skepticism and mistrust for US policies, it should be expected that regardless of China's officially stated policy, any move by the US to place offensive weapons in space will be met by similar attempts by the Chinese. [105]

At the unclassified level, one word best describes the assessment of the military threat that China poses to the United States space program – speculative. Much of the unclassified literature deals with expected responses by the Chinese to US policy and developments in space. The suspected capabilities the Chinese possess (in the unclassified arena) are probably based on assessments and estimates of how China's known and potential technologies might be used to field offensive space capabilities to counter US systems. Estimates in classified literature are almost certain to be more specific, less speculative, and more accurate.

Anti-satellite technology is the one area that seems to garner the most attention and debate. In light of the preponderance of open-source information about US space systems, the Chinese probably have enough knowledge to field systems that could jam US communications and navigation (GPS) satellite systems.[106] In follow-up to the FY03 Annual Report to Congress on the Military Power of the People's Republic of China, the FY04 report noted a January 2001 Hong Kong newspaper article that said China had developed, ground-tested, and would soon space-test parasitic micro-satellite and nano-satellite technology that could be launched and detonated close to US satellites. In addition, the FY04 report noted China making progress in anti-satellite ground-based laser technology. The interest the Chinese have shown in such technology makes it feasible they could develop (if they do not already possess) the capacity to disrupt or destroy US space-based system.[107] There is sufficient reason to believe, therefore, that adversaries such as China can and will pursue technology capable of denying us the use of our own space systems – especially if we pursue a similar strategy of weaponizing space.

Can China Challenge the US in Commercial Launch?: The emergence of China as a space power also has ramifications for the United States in the commercial sector. Nowhere is this more true than in the launch industry. Futron Corporation, a space industry leader in forecasting trends in the space and telecommunications markets, referred to China as the "new kid on the block" in non-commercial launch technology. In their 2004 report on recent trends in the space launch industry, Futron noted that while the US and Russia are still the world leaders in total number of launches, China has made "…steady progress and has distinguished itself from the pack of other launching nations" with a "…firm place just behind the USA and Russia in terms of non-commercial launch capacity."[108] It is interesting that China was barely mentioned in Futron's 2003 report whereas the 2004 report essentially proclaimed China a new force to be reckoned with in non-commercial space launch activity. This is indicative of the rapid progress made by the Chinese in this area. Russia has been forced to prioritize its expenditures in space which may account for a recent downward trend in terms of the number of Russian launches. If that trend continues, it may not be long before China is second only to the US in non-commercial launch activity. In addition, China considers international cooperation an important part of its space industry and as such, the Chinese have signed cooperative space agreements with Russia, Brazil, and Europe. In view of China's progress in other areas of its space program, including participation in the Galileo navigation satellite system, it is reasonable to expect subsequent gains in the launch industry as well, even if US satellite export control restrictions continue.[109]

What does the Future Hold for the US and Chinese Space Program?: The development of the Chinese space program may depend to a large degree on the approach the US takes toward China as a whole – several possibilities have emerged. The first would be to continue with the status quo, essentially excluding China from any possible joint ventures (such as the ISS and future lunar/Mars exploration missions) that may contribute to cost-cutting and improved relations. Such an approach would likely cause China to continue on its own course in trying to achieve the vision of the updated 2000 White Paper. This approach could backfire on us if China partners with other countries at the exclusion of the US. The US would then bear a heavier financial burden for any programs it maintains in parallel with China (future Moon and Mars missions come to mind).

An even more unpredictable approach would be for the US to incite another space race by implementing tough, unilateral actions which isolate and threaten the Chinese and force them to match the US step for step in the militarization of space. Such an approach has the potential to severely stretch the US and Chinese economies to the detriment of both.

The approach with the most potential for mutual success (although admittedly the least politically feasible at this time) is a phased plan for US - China cooperative effort on projects of mutual scientific benefit (i.e. the ISS). The approach could also help take pressure off some of the US's allies by not forcing them to choose between the US and China in certain areas of the space industry. This last option has the most to offer in terms of gain but is probably the least likely to occur any time soon simply because of the tense nature of the relationship between the US and China. Regardless, the US cannot afford to take Chinese progress in space lightly – but the approach we take should be one that does not push our country down a path which further isolates us or incentivizes China and other countries to work together in space at the exclusion/detriment of the US.

--- Commander Jim Morgan, USN

A CHALLENGING US SPACE VISION

In May of 1961, President Kennedy turned our country's attention to the heavens when he proposed, "… that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth."[110] His speech to Congress that day suggested a challenging feat that would require the fully focused attention and resources of our nation. His words and vision led us towards a common goal and, sped by the urgency of a space race with the Russians, instilled a sense of pride and commitment that resulted in an American taking an historic walk on the Moon just eight years later.[111]

Recently, President Bush sought to recapture this commitment when he released his vision for space exploration, describing steps that may take us back to the Moon and then to Mars and beyond.[112] His vision is also challenging, but times have changed. Will it have the same effect as President Kennedy's? Surely, reaching back into space is a lofty goal, but is this too much to expect from a nation that is struggling with other challenges? Some question whether the National Aeronautics and Space Administration (NASA) has the resources to meet this vision, but perhaps it is more important to ask if we, as a nation, have the will.

An Overview of the President's Vision. The President's vision calls for a near-term goal of returning the Shuttle to flight followed by putting men on the Moon no later than 2020.[113] Expeditions to the Moon involving extended human habitation and exploration will help prepare our scientists and astronauts for similar missions on Mars as early as 2030.[114] Upon reading the President's vision, it strikes you with its simplicity as well as its breadth – for while it is only seven pages of well-spaced text, it promises to stimulate our nation's imagination and spur new growth in our space industry.[115] We expect it to lead us back into space, firmly establish our position as a world technological leader, and strengthen the US economy and security.[116]

Our nation has a long heritage of benefiting from its insatiable curiosity and desire to excel. The President's vision carries much promise for our country, but it also requires much of our political leadership and the American people. The President and NASA must marshal broad, continuing support in political and public forums if the vision is to succeed. They must work with Congress and the American people to build support that will last 25 years, if not longer. Without such support, the vision may not even be attainable, much less sustainable.

Our Political Will. The President's vision is one that must endure if it is to be successful. Unlike President Kennedy, who set a goal to reach the Moon within 10 years, we may not realize President Bush's vision of landing a man on Mars for 25 or longer.[117] This means that the President's vision must not only gain political support now, but also sustain it across three to five more administrations. Nevertheless, President Bush has enough to worry about during his own term of office. While there is support in the current Congress for the vision, there are also overriding concerns about its cost and impacts to other NASA programs.[118]

It did not aid the President's cause when he failed to mention the new space vision during his State of the Union addresses, but Congress is more concerned about the budget.[119] The Senate Commerce Committee emphasized this when it noted, "the only constant in space exploration initiatives is that the actual costs have always exceeded the initial estimates."[120] Congress sees the cost for this vision as too high when balanced against other domestic programs, especially with a budget deficit once projected to reach close to $500 billion by the end of 2005.[121]

But Congress does not help the situation when it cuts NASA's budget requests and then directs funding for other projects against the agency's wishes.[122] Although Congress approved about $16.2 billion for NASA in fiscal year 2005, appearances can be deceiving.[123] That budget also included almost 170 Congressional earmarks costing close to $430 million, many of which had nothing to do with space-related functions.[124] NASA requested none of the earmarked programs, nor needed them to fulfill the new vision. Earmarks and associated budget cuts resulted in an almost $1 billion deficit NASA must deal with to meet the President's vision.

The Public Will. The views of millions of Americans do much to influence our political will, as well. Congress is forever looking to its constituency to help gauge many of their decisions on Capitol Hill, and it is no different when dealing with the space program. Public support for funding will be of critical importance to the future of the President's space vision, as well as to NASA itself.[125] While the average person will show some interest in NASA's programs or the President's vision, most will prioritize space programs below other government programs.[126] Polls in early 2004 indicated that 55 percent of Americans feel we should be doing more for domestic programs like Medicare and Social Security, rather than space programs.[127] Additionally, 57 percent expressed strong opposition to plans for manned missions to the Moon or Mars.[128] While recent polls show a slight upturn in support for the President's vision, there is little doubt that the American public has other things on its mind.

The President and NASA simply haven't done much to convince the public that this vision will come to fruition, much less benefit them in some way. For many, a manned mission to Mars seems unlikely, and with such a high price tag and long timeline to get there, many people don't understand why we'd want to go. They look at NASA's multi-billion dollar budget and wonder how much Congress would cut their taxes if we shut NASA down altogether.[129] This lack of understanding in the American public is a bad omen for a program that requires long-term support. Something must be done to correct this situation, and soon. We have much work to do if we are to face the challenges of future space exploration. We must focus on strengthening our national will, both publicly and politically.

Energizing the National Will. The public needs to be convinced that this space vision is affordable and will benefit them. Simple acts like comparing the NASA budget (about $16 billion) to how much we spend on annual events like Halloween (which records the second highest expenditures for US holidays at almost $7 billion per year) might put the cost in perspective.[130] In addition, NASA and the President should remind the public of the benefits of space exploration. The American public sometimes forgets or does not recognize the connections between space exploration and the benefits we enjoy each day. Yet, it is difficult to identify an area of our everyday lives that has not profited from space in some fashion.

Our space programs have returned an average of $7 for every $1 invested.[131] Apollo Era space research brought us CAT Scans, MRIs, programmable pacemakers, and kidney dialysis machines.[132] It also brought us infrared cameras for fire fighters and infrared ear thermometers, not to mention the technology to make enriched baby food, scratch-resistant lenses, water purification systems, athletic shoes, golf balls that fly further, and portable coolers to keep our drinks cold or food warm.[133] Space program research and development (R&D) provides the public with many benefits, but unless people are informed, they may fail to make the connection.

It is important to remind the public that space research contributes to our national prosperity. R&D during the space race resulted in both innovation and prosperity for our business sector and economy.[134] Such innovation inevitably leads to increased business and industry growth…and more jobs. The public might see the wisdom of space exploration if explained in those terms. Therefore, the government should aggressively market the new space exploration vision, proving to the public that space exploration provides great return on investment and improves our daily lives.[135]

Gaining broad public support will also result in a similar gain in our nation's political will. Congress tends to follow the will of its constituency, so if the voters get behind the space program, many in Congress will do the same. If nothing else, it should elevate the level of national debate about the space program and its budget, much like Social Security and Medicare today. Such a debate will also help raise the level of awareness on the aims and benefits of the President's vision and may place a greater level of scrutiny on how Congress funds NASA in support of the President's vision. It will be more difficult for Congress to attach earmarks to the budget if it is at the expense of a popular or even well known space program's success.

Concluding Thoughts. It is in our nature to be inquisitive – to explore. "Exploration is the essence of the human spirit."[136] The President's Vision for Space Exploration should stir the imagination of our nation and spur new growth in our space industry, but there are obstacles.[137] NASA's budget is insufficient, forcing the agency to cut back on key programs, and our national will to support a new space program, both politically and publicly, is weak and faltering. This vision can lead our nation towards a lofty goal, but it requires a concerted effort by the President, Congress, and NASA. They must work to fund the space program, market it to ensure our national will supports it, and protect vital R&D resources. This will encourage growth in our science and engineering workforce who will provide, in turn, steady research for our space program. To succeed, we must take quick and decisive action to raise the level of debate about the exploration vision and, once again, turn our nation's attention to the Moon…and beyond.

--- Lt Col Scott Merrell, USAF

SPACE: TECHNOLOGIES TO TAKE US THERE AND BEYOND

On January 14, 2004, the President laid out a new vision for US space exploration. To achieve this vision, the National Aeronautics and Space Administration (NASA) must develop new technology capabilities that are critical to future space exploration.

Technology Focus Areas

Robotics. Each phase of NASA's space exploration roadmap relies heavily on robotic missions to pave the way for human exploration missions. NASA's Jet Propulsion Lab (JPL) is developing advances in terrain geometry estimation, local and planetary positioning, and sensing and surface analysis capabilities to allow autonomous robotic operations to grasp, transport, and place structures in natural terrain.[3] JPL is also conducting research to network families of robotic vehicles that will operate together and perform surface and subterranean exploration, and assembly of spacecraft in space.[4] Similarly, NASA's Johnson Space Center (JSC) is developing a humanoid robot called *Robonaut* that can perform functions equivalent to an astronaut during spacewalks, with the target goal of someday working side-by-side with or in place of humans to reduce our astronauts' risk or exposure to radiation.[5]

Biotechnology. But before we can establish a long-term presence in space, NASA must develop new capabilities to ensure the health of its astronauts during prolonged missions. At JSC, life support technologies are one of the top focus areas for space exploration.[6] Radiation exposure in space can greatly increase the risk of contracting cancer or damage to the central nervous system.[7] Current technology only permits crew members to participate in three 180-day missions aboard either the International Space Station (ISS) or long duration missions beyond Low Earth Orbit (LEO) without exceeding acceptable limits.[9] To reduce these risks, researchers simulate the effects of extended exposure to space radiation in laboratories on Earth. Researchers in the United Kingdom are developing genetically engineered radiation sensors that will produce a green fluorescent protein in response to DNA damage caused by radiation exposure.[8] Likewise, NASA's Institute for Advanced Concepts is developing an electrostatic shield system to protect astronauts so that we may safely extend the durations of our space missions.

Microgravity is another characteristic of space that causes bones to lose calcium, muscles to lose strength, nutritional requirements to change, and the immune, cardiovascular, and sensory-motor systems to change.[10] NASA's research strategy to combat these effects is centered around developing countermeasures that prevent or reduce these adverse changes. These include using pharmacological agents, dietary modifications, exercise, mechanical and electrical stimulation, and artificial gravity devices.[11] NASA evaluates various countermeasure strategies, which are then approved for validation on space flight missions.

Another challenge facing astronauts during prolonged spaceflight is that of medical care. Caring for crews during missions depends upon development of minimally invasive technologies that can diagnose and treat medical conditions, and even perform surgical procedures. To meet this challenge, researchers are developing autonomous medical care systems to monitor an astronaut's physiological and psychological status, and nano- or micro-surgical devices and smart sensors for biomedical sensing.[13] These technologies will not only permit crews to survive long-duration space flight, but will contribute to improved healthcare on Earth.

Propulsion. Greater exploration of the solar system will require new propulsion systems to eliminate the need for heavy, on-board fuel used by conventional chemical propulsion systems. Promising technologies under development at the Marshall Space Flight Center include aerocapture, fission propulsion, solar propulsion, and antimatter propulsion.[14]

Fission technology has been in development for over 45 years, but has never been used for space propulsion. In comparison to the liquid oxygen/hydrogen combustion used to power the space shuttle, applying fission to a soda can full of uranium could produce as much energy as 100 external space shuttle fuel tanks.[16] In 2003, NASA's JPL initiated Project Prometheus to develop a nuclear powered propulsion system and demonstrate that it can be operated safely and reliably in deep space.[17] For missions to Mars, NASA hopes that advanced forms of fission powered spacecraft can reduce the transit time to less than 3 months.

Solar Sail propulsion has been around since the 1970s, but advances in the design and construction of solar sails during the 1980s and 1990s have increased their viability. The technology uses solar photons, i.e. sunlight, which are reflected off giant mirror-like sails made of ultra-thin lightweight reflective material that is 40-100 times thinner than a piece of paper.[19] The continuous photonic pressure provides enough force to enable maneuvers that would require too much propellant for conventional chemical propulsion systems. Solar sail propulsion is a leading candidate for missions that require a spacecraft to make a large number of maneuvers.

Antimatter propulsion is more commonly known in science fiction movies as the means by which starships zip from one side of the universe to the other. Engineers at NASA's Marshall Space Flight Center are advancing technology that may make antimatter-powered spacecraft a reality. Antimatter propelled spacecraft may be capable of traversing the distance between Earth and Mars in a day.[20] A single gram of antimatter could generate as much potential energy as 1,000 space shuttle external fuel tanks.[21] However, to date annual worldwide production stands at only two billionths of a gram. Scientists at Penn State University and NASA have also been working on solutions to store antimatter.[22] Nevertheless; significant advancements are still required to support a functioning antimatter propulsion system.

There is no shortage of promising advanced propulsion designs for long duration space exploration missions. However, with little or no current commercial market seeking to go beyond LEO, the development of advanced propulsion systems will continue to rely on government funded research to provide the breakthroughs.

Information Technology. A revolution in information technology will be as important to space exploration as the development of new propulsion technologies. As we reach further into space, we will need high-bandwidth communications and data transfer systems to transmit large amounts of data back to Earth. Researchers at the Ball Aerospace and Technologies Corporation are teaming with researchers from Boeing Corporation to develop laser communication systems that provide much greater data transmission bandwidth. They hope to use the ISS as a test bed to validate laser communication in space.[25] Advances in communication and data transfer capabilities will enable those here on Earth to see other worlds as if they were there themselves.

Industry Incentives: To further the development of the US space industry, the federal government may implement various incentives for the advancement of technologies needed for space exploration. The President's Commission on Implementation of US Space Exploration Policy has "recommended prizes as large as $1 billion for placing humans on the surface of the Moon and sustaining them there for a given period of time."[29] This commission based their recommendations on calculations that as much as $400 million in private funds were spent on rocket technology to capture the $10 million X Prize. They also recommended tax breaks, regulatory relief, protection of intellectual property, and reconsideration of international treaty language that might otherwise discourage commercial space ventures. Bigelow Aerospace, a commercial company, is also sponsoring the $50 million "America's Space Prize" for the first team that can build a commercial spacecraft capable of sending 5 astronauts at a time into orbit and demonstrate the ability to dock with a space station.[31]

Conclusion: Achieving President Bush's space exploration vision will require advances in several technology areas. Developing these technologies requires the right mix of federal policies, funding resources, and human capital. The federal government must focus on passing legislation that will remove barriers inhibiting commercial development of space, and incentivize research in space technologies. Many of these technical challenges will require innovative solutions generated from industry and our nation's universities. Therefore, the government must also revitalize our nation's education system to develop the human capital needed to maintain our competitive edge in technology and innovation. With little or no current commercial demand to extend beyond LEO, the development of these technologies relies on government funded research. The technologies that will advance space exploration also underpin our nation's economy and national security, and may provide a catalyst for international cooperation, helping us to develop partnerships and share our values with other nations.

--- Paul Richard, NH-IV, Department of the Army

CONCLUSION

The major findings presented in this paper answer the questions posed in the Introduction:

- **Is the global space industry healthy?**

While the space industry is surviving, it is weaker than it was ten years ago. Today, the industry is dominated by falling global demand for new satellites and launch services, plus industry-wide overcapacity.

- **Is the US share of the industry healthy?**

Yes. US government financing of national security and civil space programs dominates the rest of the world's spending, and plays the overarching role in ensuring the US industry's viability.

- **What is the industry outlook, given today's policies and unfolding developments?**

If Congress adequately funds the President's space exploration vision, new NASA contracts will be a boon for the space industry. Additionally, Burt Rutan's SpaceShipOne and Robert Bigelow's space hotel concept offer glimpses of future expansion. However, as a whole, industry trends show minor growth. Export controls and waning human capital will continue to diminish current US strength unless actions are taken.

- **What actions can our government leaders take to ensure the future health and competitiveness of the US space industry?**

Many important actions will benefit the space industry. For one, US national security, civil, and commercial space industry leaders should revitalize the industry's workforce by growing a new generation of domestic science, technology, engineering, and mathematics professionals. In addition, the DoD and Congress should provide government space program managers with adequate staffs, plus requisite *and predictable*, multi-year program budgets. Third, Congress should move space system export control back to Commerce or at a minimum, streamline State's processes to enable domestic space companies to fairly compete internationally. These important actions are just a subset of several presented.

Final Thought

Acting on all the recommendations presented in this paper will help the US maintain a competitive technology edge, regenerate a healthy space industry labor pool, and foster an improved space industry to better resource the national security strategy. The US space industry's health now depends on US government leaders making appropriate decisions.

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