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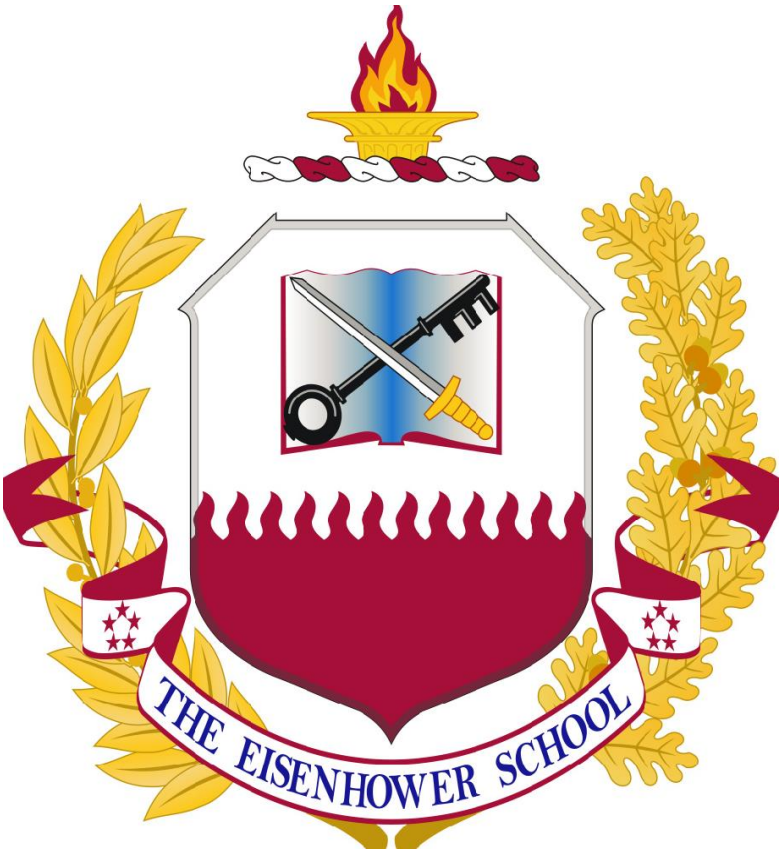
Industry Study

Final Report
Space Industry



The Eisenhower School for National Security Policy and Resource Strategy
National Defense University
Fort McNair, Washington, D.C. 20319-5062

SPACE 2014

ABSTRACT: The United States maintains a global advantage in key strategic measures of national power due in large measure to the utilization of satellites in military and intelligence applications, civil science missions, remote Earth sensing, weather forecasting, location services, commerce, and many other areas. The Space Industry Study Report examines the current state of the U.S. space industry, identifies challenges, provides an outlook for the near- and mid-term, and recommends actions to reinvigorate U.S. leadership in a domain that undergirds the nation's security and economic strength. The Eisenhower School Space Industry Seminar analyzed the domestic and international space industry -- the public organizations and private firms that design, develop, operate, and manufacture civil, commercial, and military satellite and launch systems. The Seminar concludes that the overall U.S. space industry is competitive, innovative, and enjoys certain comparative advantages in National Security Space, public services and mature commercial ventures, but it is losing ground to increasing foreign competition. A more developed legal framework for property rights in space, relief from certain regulatory constraints, and closer public-private collaboration would help to strengthen the industry. Innovation is strong in the launch and small satellite development sectors, with U.S. firms gaining momentum and market share in both areas. An uncertain fiscal environment will continue challenging the industry to develop and adopt new and more affordable options for utilizing and exploring space.

Ms. Jacqueline Albright, Dept of the Air Force
CDR John Alcorn, U.S. Navy
Mr. Douglas Apostol, Dept of State
CDR William "Murry" Carter, U.S. Navy
Lt Col Michael "Slick" Casey, U.S. Air Force
Mr. Shawn Flatt, Dept of State
Mr. Patrick Gould, Dept of the Air Force
Mr. Kevin Gulick, LMI
Lt Col John "Skip" Henley, U.S. Air Force
Lt Col Michael Johanek, U.S. Air Force
Lt Col David Lessick, U.S. Air Force Reserve
Lt Col Mark McDonald, U.S. Marine Corps Reserve
Mr. Steven Petras, Dept of Energy
CDR Virgle Reeves, U.S. Navy
Mrs. Debra Ward, Dept of Defense
Mr. Andre Woods, Dept of Defense

Col Kurt Kuntzelman, U.S. Air Force, Faculty Lead
Dr. Clark Groves, Faculty Lead

PLACES VISITED

Domestic:

50th Space Wing (Schriever Air Force Base, CO)
30th Space Wing (Vandenberg Air Force Base, CA)
26th Aggressor Squadron (Schriever Air Force Base, CO)
Alliant Techsystems, Inc. (ATK) (Washington, D.C.)
Arianespace (Washington D.C.)
Department of Defense Executive Agent for Space (The Pentagon)
Department of Homeland Security (Washington D.C.)
Goddard Space Flight Center (Greenbelt, MD)
JFCC-IMD (Schriever AFB, CO)
Missile Defense Agency (Vandenberg Air Force Base, CA)
National Aeronautics and Space Administration (NASA) Headquarters (Washington, D.C.)
National Coordination Office for Space-Based Position / Navigation / Timing (Washington, D.C.)
National Geo-Spatial Intelligence Agency (Fort Belvoir, VA)
National Reconnaissance Office (Fort Belvoir, VA)
National Security Staff (Washington, D.C.)
Office of the Secretary of Defense for Acquisition, Technology and Logistics (The Pentagon)
U.S. Naval Observatory (Washington, D.C.)
Naval Research Laboratory (Washington, D.C.)
O3-B (Washington D.C.)
Office of Science and Technology Policy, Executive Office of the President (Washington, D.C.)
Deputy Assistant Secretary of Defense for Space Policy (The Pentagon)
Aerojet Rocketdyne (Canoga Park, CA)
Ball Aerospace and Technologies Corporation (Boulder, CO)
Boeing Space and Intelligence Systems (Redondo Beach, CA)
Digital Globe Inc. (Longmont, CO)
DirecTV (Los Angeles, CA)
IntelSat LTD (Washington, D.C.)
Iridium Satellite Phone Communications (Tysons Corner, VA)
L-3 Communications Inc. (Washington, D.C.)
Lockheed Martin Space Systems (Sunnyvale, CA)
Masten Space Systems, Inc. (Mojave, CA)
Office of Management and Budget (Washington D.C.)
German Aerospace Center (Washington D.C.)
NASA Jet Propulsion Laboratory (Pasadena, CA)
Japanese Aerospace Exploration Agency, Japanese Embassy (Washington, D.C.)
Satellite Industry Association (SIA) (Rosslyn, VA)
Space Law, Space Policy Institute, George Washington University (Washington, D.C.)
Orbital Sciences Corporation (Sterling, VA)
SiriusXM Satellite Radio (Washington, D.C.)
Skybox Imaging (Mountain View, CA)
Space Systems Loral (Palo Alto, CA)
Space Exploration Technologies Corporation (SpaceX) (Hawthorne and Vandenberg AFB, CA)

Surrey Satellite Technology Ltd (Colorado Springs, CO)
United Kingdom Space Agency, British Embassy (Washington, D.C.)
United States Department of Commerce (Washington, D.C.)
The Spaceship Company (Mojave, CA)
Chinese Space Program, The Heritage Foundation (Washington, D.C.)
United Launch Alliance (ULA) (Washington, D.C. and Vandenberg AFB, CA)
XCOR Aerospace (Mojave, CA)

International:

Airbus Defence and Space (Toulouse, France; Paris, France; Stevenage, United Kingdom)
Arianespace (Paris, France)
Thales Alenia Space (Toulouse, France)
Centre National d'Etudes Spatiales (CNES) (Toulouse, France)
European Space Agency (ESA) Headquarters (Paris, France)
Surrey Satellite Technology Ltd. (Guildford, United Kingdom)

INTRODUCTION

To wage war, you need first of all money;
second, you need money;
and third, you also need money.[1]
– Prince Montecuccoli

Space, like war, requires vast resources. The opening quote succinctly describes the situation in which the United States finds itself today as the nation's reliance on costly civil, commercial, and exquisite military and intelligence systems continues to increase. Space systems provide the United States an historically unrivaled, asymmetric advantage in projecting national power. However, space systems are extremely expensive due to the rigors of operating in the harsh space environment and the need for extensive ground support facilities. Growing reliance on space systems coupled with their high cost presents a significant dilemma for the United States, especially in an era of constrained resources. How the nation can continue to assert leadership in space in this challenging fiscal and competitive environment is the central theme of this paper.

Today, the United States has reached a strategic inflection point. How can the nation maintain a robust civil, commercial and national security space capability in the current tight fiscal and politically divisive environment? The United States must cope with an escalating national debt of over $17 trillion, annual budget deficits in excess of $400 billion, and political divisions between the legislative and executive branches that preclude reasoned responses to the challenges facing the nation. As resources dwindle and Washington's politicians dawdle, other nations are investing heavily in space programs and developing their own organic manufacturing and launch capabilities, thereby challenging the United States' preeminence in space. For the United States to sustain its global leadership, it is critical that the nation continue to be the leading power in space.

This paper's contents and conclusions are based on a series of Eisenhower School Space Industry Study seminar meetings with a broad range of industry and government leaders and professionals in the Washington, D.C. area, Colorado, California, France, and the United Kingdom.

THE SPACE INDUSTRY DEFINED

The space industry consists of three basic segments: command and control ground stations, launch vehicles, and satellites. This tightly integrated system of systems delivers commercial, civil, and national security space capabilities to various global customers in the public and private sectors. The space industry environment may be described as highly competitive, extremely technical, and extraordinarily innovative.

The command and control ground station segment consists of a ground infrastructure that includes primary and backup power capability, secure and encrypted uplink and downlink antennas, and communication and data dissemination paths. Civil, commercial and national security space organizations around the globe own and operate these ground systems. This segment also includes talented professionals trained in maintaining satellite orbital and safety parameters for both near-earth and interplanetary space operations.

The launch segment consists of a limited number of U.S. rocket and engine manufacturers that provide the lift capability to place a satellite into its designated orbit or initiate its interplanetary mission. While the U.S. launch industry is relatively healthy, a major emerging concern is the United States' reliance on a Russian manufacturer for the RD-180 rocket engine that powers certain U.S. heavy launch vehicles.

Strained U.S.-Russian relations over events in Ukraine have prompted Congress to call on the Secretary of Defense to develop an alternative engine for U.S. launch vehicles by 2019.[2] United Launch Alliance, the firm which launches America's national security and other satellites, asserts that it holds at least a two-year inventory of RD-180 engines, but the potential engine shortage between 2016 and 2019 requires the U.S. national security leaders' concerted attention.

New entrants in the commercial launch market are putting financial pressure on established providers that will spur a more competitive launch market for civil, commercial, and national security space missions. U.S. government personnel and contractor support companies manage launch ranges on the East and West Coasts of the United States. Each range requires continued modernization that will compete for resources in an environment of conflicting national security priorities and fiscal constraints.

The satellite segment consists of a limited number of highly capable, established satellite manufacturers. Smaller, innovative companies are introducing new capabilities to the commercial and civil markets that should promote greater competition and expand the industrial base. Governmental organizations and private-sector companies rely on satellites for communications, precision navigation and timing, earth-observation (e.g., imagery, weather, and environmental monitoring) and other applications. Any disruption in this segment could have severe economic and security consequences on a global scale. Recognizing "the nation's growing reliance on commercial satellites to meet military, civil, and private sector requirements," the U.S. General Accounting Office added satellites to the United States' critical infrastructure protection strategy in 2002.[3]

Space industry customers include a wide variety of users in commercial firms and civil and national security agencies. Within the Department of Defense (DoD), the U.S. Air Force is responsible for developing, deploying, and operating military space programs in cooperation with the intelligence community. Air Force Space Command and the National Reconnaissance Office, which is staffed by personnel seconded from a variety of U.S. agencies, are the organizations primarily responsible for the acquisition and operation of national security space systems. With respect to civil/scientific space, the National Aeronautics and Space Administration (NASA) is responsible for the nation's non-military, manned and interplanetary space missions. NASA often cooperates with the space agencies of other nations and the European Union in the joint exploration of space; NASA's international activities include the International Space Station (ISS) and numerous planetary and non-planetary science missions.

CURRENT CONDITION OF THE INDUSTRY

The 2014 Space Industry Seminar concludes that the space industry today is healthy with regard to satellite manufacturing, launch services, new entrants to the commercial market, and skilled personnel. Industry development, NASA's public-private ventures, and technological evolution have spurred exciting new innovations in space launch, satellite manufacturing, and space tourism. However, the International Traffic in Arms Regulations (ITAR), which control exports of space products and technology, continue to hurt the competitiveness of U.S.

manufacturers. Easing ITAR restrictions will help strengthen the industrial base by allowing American firms to compete more robustly in the global market.

National Security Space

The United States enjoys a significant advantage in exquisite national security capabilities compared to other world space powers. Maintaining U.S. preeminence will be extremely challenging, however, if fiscal and budget constraints persist. Further budget reductions will complicate strategic-level planning decisions by commercial vendors upon which the DoD and the Intelligence Community (IC) depend for space system development. Based on our discussions with leading defense contractors, we conclude that the current state of the industrial base which manufactures these systems is healthy, but could be put at risk as the nation makes critical decisions about future space priorities. Declining government spending on space is putting financial pressure on some second- and third-tier suppliers, complicating efforts to address parts obsolescence and maintain effective supply-chain management.

One recent development that could increase resilience and reduce costs is "disaggregation," or dispersing national security payloads normally flown aboard large, expensive satellites onto larger numbers of less expensive satellites. The 2013 Space Industry Seminar explored the merits of disaggregation last year and noted both positive and negative aspects. Industry representatives were not convinced that disaggregation is the right course to pursue, especially with respect to national security payloads (though it should be noted that the manufacturers of large national security satellites stand to benefit from continuing the current approach to procurement).

Civil Space

This paper defines civil space as all government, academic, and private space activities not directly intended for national security (including intelligence) or profit-driven commercial activities. Space activities undertaken by NASA, the National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), the Department of Transportation, and other civil and scientific governmental organizations constitute civil space for the purposes of this paper.

The traditional role of civil space is to advance scientific knowledge through manned and unmanned space exploration of earth, near-earth bodies, the sun, planetary neighbors within the solar system, and deep space. The James Webb Space Telescope, which is scheduled to launch in 2018, is NASA's current flagship civil space project. The Webb Telescope will peer deeper into the origins of the universe than any preceding space science mission. NASA and NOAA are collaborating on unmanned missions to conduct earth science and meteorology experiments. In additional, both agencies cooperate closely to deliver important public services, e.g., weather forecasting and precision measurements of the Earth's environment. In spite of NASA's active slate of projects, government and commercial space professionals often expressed concern to us that NASA lacks a coherent strategic vision for the future.

NASA continues to provide astronauts, supplies, and a steady stream of experiments to the International Space Station. NASA's dependence on the Russian government to provide launch services for American astronauts' access to the ISS (at a cost of approximately $70 million per seat) is cause for major concern. NASA is attempting to restore the United States' capability to conduct manned space flights, which the nation lost with the retirement of the Space Shuttle in 2011. Boeing, Sierra Nevada Corporation, and SpaceX are all contenders for NASA's

Commercial Crew Development contract to provide transportation for American astronauts to and from the ISS. The spacecraft designs of all competing bidders have passed crucial milestones and the winner is expected to launch in 2017.[4] SpaceX and Orbital Sciences Corporation are regularly launching cargo resupply missions to the ISS. The European Space Agency (ESA) is also flying resupply missions to the ISS via the Agency's Automated Transfer Vehicle (ATV); ESA will complete its final ISS resupply mission later this year.[5]

Other significant NASA projects include science, technology, engineering, and math (STEM) programs that will hopefully inspire the next generation of scientists and engineers. The Obama Administration's consolidation of multiple STEM programs, however, has resulted in funding cutbacks and a reduced number of programs that reach fewer students. NASA is continuing work on the Space Launch System (SLS), a rocket system with sufficient thrust to reach the moon and Mars. Advanced propulsion techniques, technology spin-offs, the next Mars rover, and other science and technology investments designed to keep the United States at the forefront of civil space are also on NASA's list of projects.

The FAA's space-related workload is steadily increasing. In 2013, the FAA issued seven orbital launch licenses, one re-entry license, and eight sub-orbital licenses. FAA issuances of orbital launch licenses are expected to double in 2014 due to more frequent launches by Orbital Sciences Corporation and SpaceX. In additional, the FAA has licensed eight spaceports in six states: Alaska, California (two sites), Florida (two sites), New Mexico, Oklahoma, and Virginia. The U.S. government (USG) may be expected to exercise greater oversight over these spaceports as they increase in number and use.

In November 2013, the Obama Administration issued a new space transportation policy with ramifications across all space sectors, including civil space. One of the policy's key provisions calls for utilizing commercial providers to "fulfill government needs."[6] The policy emphasizes the economic benefits of relying on the commercial sector to develop new technologies, maintain the industrial base, spur innovation, increase competition, and provide high-paying technical jobs. Despite flat out-year budget projections, the civil sector appears to be establishing favorable conditions for future expansion in space.[7]

Commercial Space

The overall state of commercial space is healthy, though revenue growth is uneven among the various market sectors. Assessments of the key segments of commercial space (satellite manufacturing, launch, and services) are set forth below.

Commercial Satellite Manufacturing

Satellites have become essential to America's defense, economy, and society -- and to continued U.S. global leadership. A robust U.S. satellite manufacturing industry has built many, if not most, of the more than 1,100 working satellites that currently orbit the Earth.[8] Maintaining the health of the U.S. satellite manufacturing base and its capacity to continue delivering the space-based products and services upon which we have come to rely will be crucial for sustaining U.S. leadership.

The satellite manufacturing industry is highly differentiated and segmented. The products -- satellite buses and payloads that are integrated and assembled into whole satellites for launch into orbit -- are complex, highly technical, and usually made to order for particular mission sets.

Current satellite purchasing patterns reflect the differentiation and segmentation of the market: government purchases for national security; government purchases for civil/scientific

purposes (remote sensing, meteorology, space observation); and commercial purchases for telecommunications (satellite TV, radio, voice, and broadband internet), remote sensing/imaging, and other applications. The operational breakdown of the approximately 1,100 currently functioning satellites, which demonstrates the diversity of the industry, is: commercial communications 38%; government communications 16%; remote sensing 10%; research and development 9%; space science 9%; military surveillance 8%; Position, Navigation, and Timing (PNT) 7%; and meteorology 3%.[9]

The most significant satellite purchasers are: governments (e.g., Department of Defense, NASA, foreign governments); satellite fleet operators/service providers (e.g., Intelsat, Eutelsat, SES, Telesat); consumer broadcasting companies (e.g., DirecTV, SiriusXM radio); other private or national telecommunications companies (e.g., Iridium, Britain's Inmarsat, Norway's Telenor); and remote sensing and imaging companies (e.g., DigitalGlobe, Skybox).

Recent financial data suggest that the state of the U.S. satellite manufacturing industry is sound. According to the Satellite Industry Association, U.S. firms captured nearly 60% ($8.2 billion) of global satellite manufacturing revenues ($14.6 billion) in 2012 (latest data available).[10] Measured by the number of satellites launched, U.S. manufacturers led the way with nearly a one-third (32%) market share, followed by China (23%), Europe (22%), Russia (16%), Japan (2%), and others (4%).[11] U.S. manufacturers won 12 of 18 commercial orders for large GEO satellites in 2012, their best performance in over a decade.[12] Data for 2013 indicate that U.S. manufacturers won 15 of 23 commercial GEO communications satellites orders.[13] U.S. satellite manufacturing firms' revenues increased by 31% in 2012, reflecting higher demand for American-made satellites in a strong year for launches.[14] Healthy demand for satellites was also reflected in global satellite manufacturing industry revenues, which increased by 23% in 2012.[15] Although satellite manufacturing is experiencing higher demand, the dependence of the American industry on U.S. government contracts persists, with such contracts accounting for 61% of U.S. satellite manufacturers' revenues in 2012.[16] Given the industry's dependence on government contracts, satellite firm representatives expressed concern to us about possible decreases in USG spending on satellite systems.

Commercial Launch

Commercial launch service has become one of the most exciting segments of the space industry. Private firms, most notably the new market entrant SpaceX, are investing significant capital in initiatives to reduce the cost of launch. If successful, these initiatives would dramatically change the economics of space use and exploration.

Best estimates based on existing data indicate that delivering a pound of payload to an approximately equatorial circular low earth orbit (LEO) costs between $6,000 and $20,000.[17] [18] Foreign (heavily subsidized) providers are generally on the lower end of the scale and U.S. providers tend to be on the higher end. SpaceX is seeking to lower this cost drastically in a variety of ways, e.g., by streamlining rocket assembly techniques, relying on proven technology, and reusing first stage rockets that return to their launch site and land vertically. While a marketable solution for reusable launch is still under development, SpaceX demonstrated the viability of this concept on April 18, 2014, when a Falcon 9 rocket's first stage landed vertically in the ocean. Through reuse and other measures, SpaceX is forecasting costs of $1,000/lb. to LEO.[19] Proponents of truly reusable launch vehicles believe the costs can be lowered further by "two orders of magnitude," which equates to $100-$300/lb. in today's dollars.[20]

Commercial Satellite Services

The services that space satellites provide are integrated into the basic infrastructure of global society and the fabric of our daily lives. From television and radio broadcasts to telecommunications to global positioning to banking transactions, civil society depends increasingly on satellites to support the infrastructure and services that enable modern life.[21] Commercial satellite service providers use the ubiquity of space to connect users to networks or media, with an unsurpassed advantage in bridging "the last mile" from communication nodes to remote, rural, or emergency operators. Of special note for the national security enterprise, commercial U.S. satellite owner/operators and integrators provide 80% of Department of Defense communications.[22] We recommend that the USG consider concluding long-term capacity utilization arrangements with commercial providers in order to become a more efficient buyer of satellite communications.

Commercial satellite services (CSS) utilize space-based assets and terrestrial hardware to provide access to broadcast, information, communication, and remote sensing networks. This sector is vibrant -- innovative and highly competitive companies are vying for consumers in established markets and expanding space-based applications into new markets. One example of this market creation is business analytics, which small-satellite start-up Skybox Imaging touts to customers as one of its most valuable products. According to Skybox, "technology is a means to an end. We don't design and build our own (satellite) systems for fun . . .we do it because it gives us the flexibility to address your needs in the way that works best for you and your organization."[23] This kind of customer-centric mentality is a driving force for innovation in the CSS sector.

OUTLOOK

From 2014 to 2019

In the short term, the die has been cast for national security space and U.S. civil space. The budgets for defense spending and NASA are essentially flat or declining, thus constraining growth and flexibility in space acquisition. European governments' budgets are equally likely to remain constrained due in part to the effects of the Eurozone crisis and a slow recovery from the Great Recession. The counterbalance to stagnant government budgets is cash-rich commercial service providers, which are leveraging space to deliver profitable content and communications services. Constrained government budgets have provided commercial buyers significant purchasing power in their dealings with satellite builders and launch providers. Commercial imaging, communications to remote geographic areas, and 4K (ultra-high definition) television services will drive the future commercial service market. Space tourism may also emerge as a new commercial market.

From 2019 to 2024

Civil and national security space programs entail long acquisition timelines. Therefore, decisions already made or to be made over the next two years will affect the longer-term outlook for the civil and national security space sectors. Absent a reordering of future federal budget and spending priorities, efficiency at the expense of effectiveness will shape national security and civil space.

DoD has already made the major decisions that will set the basic course of its space programs. Most of DoD's space acquisitions are based on relatively mature technologies. The

stability of USG satellite programs has enabled DoD to capitalize on cost-saving opportunities by contracting with United Launch Alliance (ULA) for the delivery of 36 rocket cores over the next three years. SpaceX, however, has mounted a legal challenge to the contract, claiming it is non-competitive. DoD will open fourteen additional launches to competitive bidding to encourage ULA's competitors to enter the national security space launch business and drive down costs.

Consolidation of ground control systems to integrate and streamline satellite operations is another avenue the DoD should explore to reduce the costs of space operations. DoD should finalize ongoing studies on resiliency and disaggregation of satellite systems to determine whether smaller satellites, hosted payloads, or other proposed solutions make the most sense. The conclusions of such studies will inform key decisions on such issues as ground control systems, user terminals, and launch costs.

The Obama Administration and Congress have largely reprioritized NASA's mission objectives, postponing manned space exploration beyond the current decade. NASA is making significant investments in building the necessary space lift and crew capacity to meet planned timelines. The Obama Administration's decision to extend the ISS to 2024 will support commercial launch to meet NASA's LEO requirement for resupply. Under NASA's Commercial Crew Program, commercial firms will provide manned transport to the ISS.

Commercial space activities remain the best hope for stronger growth in the space industry. Current trends suggest that the future commercial satellite market may be divided between smaller satellites, or constellations of small satellites, and ever-larger and more powerful satellites. The timeline for making cheaper, reusable launch to LEO available will be a key factor in determining how fast the small satellite segment of the market will grow. While satellite manufacturers are touting their small product lines, however, smaller satellites tend to be launched as secondary payloads in conjunction with large satellites. The large, primary satellite payload drives the launch parameters, often resulting in less optimum orbits for smaller satellites. Moreover, small satellites are not likely to penetrate all market sectors. Commercial broadcast (satellite television and radio) and telecommunications service providers, for example, will continue to rely on larger, more powerful satellites to meet their needs. This may encourage the industry to innovate and focus on improved electric propulsion, high-throughput, solar cell, battery, antenna, and other technologies to better meet service provider requirements.

An increase in space "congestion" will be common to both the five-year and ten-year outlooks. Expected trends towards launching increasing numbers of satellites into orbit will place more and more assets into space. While government regulation of space operations and requirements for debris mitigation plans will help ensure the safety and appropriate use of space, more assets in orbit translates into higher risks of kinetic incidents, unintentional or otherwise.

CHALLENGES

National Leadership

Reasserting American leadership in space will not be accomplished through another study. The U.S. government must make a visible, deliberate effort to restore our leadership by influencing, motivating and inspiring another generation. As in the 1950s, the United States must renew and reinvigorate the nation's strategic culture in the halls of government and in America's schools and homes.

National space activities involve many leaders in disparate government agencies, but the U.S. government does not appear to have a unifying vision that aligns each agency's actions with common goals. In the absence of a coherent, strategic vision of governance for the space sector, government leaders are forced to react to events, market forces, and shifting budgets instead of making the difficult, strategic decisions that will enhance the nation's preeminence in space. In an era of limited resources, the lack of a unifying vision and a champion for U.S. space activities may tend to relegate space agencies to ever-shrinking portions of a constrained federal budget.

More broadly, foremost among the challenges facing the country is the swelling federal government debt. The Congressional Budget Office projects that cumulative U.S. government deficits over the next ten year will increase the national debt by nearly $7 trillion.[24] If that projection proves accurate, the United States will have fewer and fewer resources to fund discretionary spending, putting pressure on funding for national security and civil space missions.[25] According to the prominent economist Douglas Holtz-Eakin, "Debt reduction produces jobs and better jobs and better economic growth. Doing nothing, or worse, increasing spending is a profoundly anti-growth strategy."[26] If the United States fails to address its structural fiscal problems, then sustaining technological innovation, international collaboration, and American global space leadership will become a more daunting challenge.

In addition, the United States is falling behind key competitors in science, technology, engineering, and mathematics (STEM) education. The current American education system is not aligned with the demands of U.S. national security, which depends upon a steady stream of qualified STEM graduates. Restoring excellence in education is a national imperative. While the United States excels at STEM education at the university level, it is barely adequate at the secondary school level, and frighteningly lacking at the primary school level. The U.S. education system as a whole must dramatically reinvigorate STEM education at the 5th and 6th grade levels. The first National Defense Education Act of 1958, enacted in response to Sputnik, produced three decades of superlative mathematicians, scientists and engineers. We face a similarly critical moment today -- the right government policies today could have a significant favorable impact on U.S. competitiveness a generation from now.

Emerging International Competition

The United States, once the undisputed leader in space, is quickly losing its lead to a number of nations that are increasingly exploiting space to advance their national security, commercial, and civil interests. Three chief power centers -- Russia, China, and the European Union -- are the primary challengers to U.S. preeminence in space.

Russia

The Soviet Union achieved many of humanity's firsts in space. The Soviet legacy of space achievement lives on today and serves as the inspiration for the Russian Federal Space Agency, commonly referred to as Roscosmos.[27] Russia is a fully capable space-faring nation and exceeds the U.S. capability for manned space flight. The United States is reliant on the Russian program for ISS manned missions and, significantly, for technology that supports U.S. national security launches.

The Russians currently operate two main rocket families, the Proton and the Soyuz. The Proton-M is capable of putting a 20.7 metric ton payload into LEO or a six metric ton payload into Geostationary Transfer Orbit with the addition of another booster stage (termed the "Breeze M" variant by International Launch Services (ILS), the commercial marketing firm for Proton.)[28]

According to ILS, the Proton system has a 95% success rate over 380 launches for the Proton M since 2001. They have a wide and varied customer base of both commercial firms (SES, Intelsat, TURKSAT, EchoStar, Eutelsat, and SiriusXM, to name a few) and Russian scientific and military launches (including the GLONASS constellation.) Roscosmos' second main rocket system is Soyuz. The Soyuz-2,[29] which comes in two- or three-stage configurations and is currently the only launcher capable of transporting astronauts to the ISS, is the latest version. Originally developed in 1966, the Soyuz family has flown over 1,700 times, making it the most highly utilized space launcher in history. Depending on the cosmodrome and launch inclination, the payload capacity of the Soyuz-2 varies between 5,500 and 8,250 kg. It is capable of reaching all standard earth orbits. Arianespace and Airbus Defence and Space are also launching the Soyuz-2 at the CNES Guiana Space Center in Kourou, French Guiana. It has proven to be a cost-effective and reliable system.

Soyuz is also the name of the man-rated (three person capacity) spacecraft launched on top of the rocket (which actually has a different designation but is now generally known as Soyuz due to the association). The first manned Soyuz flight occurred on April 23, 1967. The craft has been updated many times since the initial flight but it is still one of only two spacecraft capable of transporting humans to and from space. A Soyuz craft is constantly docked at the ISS for emergency crew escape in the event of an emergency. The Russians have also developed an unmanned variant called Progress to execute the resupply mission to ISS. Russia has used Progress for many years, first to provide supplies to the now-defunct Soviet Mir Space Station before its current mission of resupplying the ISS.

China

The Chinese space program is healthy, ambitious, and well funded. The Chinese consider space essential to their national power and as necessary for achieving regional hegemony in the face of American resistance. China is only the third nation capable of launching and returning humans from space. The Chinese government aspires to put men on the moon and Mars and to construct a permanent space station. With the world's second largest economy, China has the financial means to achieve its strategic ends. The unanswered question is whether the country possesses the technical capability to execute these complex missions.

The Chinese National Space Agency (CNSA) manages China's space program. However, the People's Liberation Army (PLA) is, and has always been, deeply involved in the activities of the space program. This is consistent with the Chinese view of space power as one facet of "comprehensive national power" that must be used and exploited to further national security ends.[30] The Chinese rocket system, Long March, is based (like its Russian precursors) on Inter-Continental Ballistic Missile development programs. It has a maximum payload to LEO of 12,000 kg. and to GTO of 5,500 kg. The system has been very reliable.

The Chinese have one operational spacecraft, the Shenzhou, for human flight. CNSA designed the craft for long endurance on-orbit; one ship of the class (Shenzhou IV) remained in orbit for nine months before returning to earth. During the ten successful flights of the craft to date, the Chinese have flown a complete series of maneuvers to learn basic spacecraft operations. Two-and three-person crews have flown on the Shenzhou, conducting spacewalks and docking maneuvers with the Tiangong space station. These operations have provided the Chinese an advanced set of skills that will further their goal of establishing a permanent space station by 2023.[31]

Launched on September 29, 2011, Tiangong-1 is a space-lab test bed platform that the Chinese have used to validate various operations and capabilities.[32] One unmanned and two manned missions have docked with Tiangong-1, thus validating its design and operational capability. It has sleeping and exercise equipment for two personnel on board (the third man on the two missions that docked with the lab slept on the Shenzhou craft). The lab is not intended to be a permanent craft; rather, it is a stepping-stone to the larger, permanent facility mentioned above.

The Chinese are interested in providing commercial lift, similar to Russian launch services provided to various commercial entities. China's share of commercial ventures, however, has been very limited due to restrictions placed on the launch of any American technology on a Chinese rocket, a consequence of the 1990s Hughes/Loral incident that led to imposition of harsh export controls under ITAR. The Chinese are in the process of populating an indigenous PNT system (Beidou). The system currently operates regionally, but Beidou will be global and under Chinese control when completed (scheduled for 2020).

The European Union

No single European country has the ability to match Russia, China, or the United States in space. However, as a combined entity the European Union (EU) is a near-peer space power. The European Space Agency (ESA), the EU's space arm, is set up to take advantage of the wealth and talent of the entire EU (and several non-EU countries). According to ESA's website, "Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world."[33]

Ariane 5 is the workhorse of the ESA space launch fleet. Built by Airbus Defence and Space under authority of the French Centre National d'Etudes Spatiales (CNES), Ariane 5 is marketed and operated by Arianespace. It is capable of launching 21,000 kg. to LEO or 10,500 kg. to GTO, depending on configuration. Ariane is currently developing two alternative successors to the Ariane 5, the Ariane 5M and Ariane 6. Later this year, ESA's governing committee will select one -- or perhaps both -- of those launchers for its future requirements.

ESA also launches Soyuz rockets from its facility in French Guiana. ESA decided to start launching Soyuz rockets to augment the capability of the European launch portfolio. The decision was also political, as the EU is a direct neighbor of Russia. The current geopolitical situation in Ukraine and Eastern Europe may change the dynamic of EU-Russia relations.

Although ESA does not have any indigenous manned spacecraft, it does have a cadre of astronauts who travel to the ISS on Soyuz rockets launched from Baikonur. ESA developed the ATV, a pressurized service module, to transport cargo to the ISS. ESA has conducted four resupply missions to the ISS since 2008. NASA has selected the ATV to be adapted for use as the service module for its Orion spacecraft project.

ESA has a high degree of technical competence and a broad array of resources at its disposal. ESA's main spacecraft focus has been communication and scientific satellites and unmanned probes. ESA has partnered in these efforts with NASA and other space agencies around the world. Like Russia and China, the Europeans are working on an indigenous PNT system, Galileo, scheduled to come online by 2020.[34] Being a diverse organization comprising many countries, ESA's decision-making process can be difficult and long.

International Traffic in Arms Regulation

For the last decade, space industry representatives have advocated the easing of U.S. government restrictions on the export of U.S. satellite and launch products and technology. These restrictions, which are codified in the U.S. International Traffic in Arms Regulations administered by the State Department, vastly complicated overseas sales of American space products and rendered the U.S. commercial space industry less competitive in foreign markets. After nearly four years of consultation with industry, the Obama Administration decided to refocus ITAR restrictions on products and technologies truly critical to U.S. defensive capabilities, while placing other, non-critical products under more liberal export regulations administered by the Department of Commerce. The U.S. government issued new, less restrictive export control regulations on May 14, 2014.[35]

Space Launch Vehicle Acquisition

Cost-Plus contracts are currently the primary contract vehicle for government launch services. These often-costly contracts are more suited for acquisitions where requirements and technology maturation are still evolving, rather than for established technologies like space launch. More affordable launch services could be attained if the USG transitioned from its current contract-type use paradigm and procurement methodologies and relaxed certain Federal Acquisition Regulation (FAR) constraints.

The USG contracting structure for launch acquisition would benefit from greater reliance on and more effective utilization of firm-fixed-price (FFP) contracts, which are generally the lowest-cost contracting option for the government. By effectively utilizing FFP contracts, the USG would not pay to reduce the identified risks; rather, the contractor would have to agree to reduce them to a level acceptable for a "go for launch" decision, else use the launch vehicle for a non-USG mission and let the USG mission shift to the first-available "go for launch"-caliber launch vehicle. The contractor's intrinsic business motivation to provide reliable vehicles and minimize negative publicity associated with a USG "no-go" decision should provide the impetus for the contractor to address significant technical risks while providing launch services to the government for far less than under cost-plus contracting arrangements.

Launch Services Cost

Many factors drive the high cost that the U.S. government pays to access space. A dominant driver -- the requirement of "assured access" to space -- is mandated by law. Title 10 U.S. Code 2273 specifically requires "to the maximum extent practicable, that the United States has the capabilities necessary to launch and insert national security payloads into space whenever needed…and at minimum…at least two space launch vehicles (or family of vehicles)…and a robust space launch infrastructure and industrial base."[36] The requirement to access space in an industry characterized by a monopolistic/monopsony relationship between the leading launch provider, ULA, and the USG virtually ensures that the price of launch will be as high as the government is willing to pay.

The second set of cost drivers resembles the traditional economic metrics found in standard industries, especially transportation (e.g., economies of scale, unit cost, competition, market elasticity, entry barriers, best practices, customer and supplier equities, etc.). Applied to launch, both DoD and NASA share the requirement to access space via low cost, reliable, available, and safe means.[37] When designing space systems, current models use the following factors to cost out space access systems: propulsion, aerodynamics, geometry and volume, mass

properties and weight, trajectory and propellant, acquisition costs, operations and support costs. Reducing the cost of space access would involve seeking efficiency and innovation within all of these areas.

Significantly reducing the cost to access space would facilitate long-term space strategies that can sustain the United States' role as the world leader of orbital commerce. One potential area of development to lower the cost of launch is in reusable launch vehicles (RLV). Single-use transportation is not found in any other sector besides space. To reduce launch costs, the USG should actively pursue a reliable RLV solution. As matter of economics, however, the argument in favor of RLV is less than clear, with high developmental costs, technology gaps, and government fiscal priorities serving as obstacles to RLV development.

Space Debris

Today, some 60 nations have boldly ventured into space (utilizing the rockets of eleven countries with launch capabilities). Operational satellites number over 1,100[38] and are increasing as cheaper access to space and innovative applications spur space activity. However, this presence comes at a price. The detritus of human activity in space includes approximately 522,000 objects, consisting not only of spent rocket bodies and defunct satellites but also of objects the size of a softball -- and even paint chips -- that pose daily hazards to operational satellites and endanger astronauts. Understandably, the 2011 National Security Space Strategy characterizes orbital space as "congested."[39]

NASA described the debris field from China's January 11, 2007 successful anti-satellite (ASAT) system test on an old Chinese weather satellite as "the single worst contamination of low Earth orbit (LEO) during the past 50 years." Some of the debris will orbit for decades and likely longer. One year later, Fengyun-1C accounted for 42% of all tracked orbital debris while the United States accounted for 27.5% and Russia for 25.5%.[40] Two years later, on February 10, 2009, an out-of-service Russian communications satellite collided with a smaller, operational Iridium communications satellite. This was the first collision between two spacecraft and the fourth known "hypervelocity collision between two catalogued objects." The resultant orbital debris fields also will pose hazards for decades.[41]

A possible collision between operational space assets and orbital debris threatens economic security. The European Space Agency reports executing at least one collision avoidance maneuver each month. One estimate puts the loss in dollars from such maneuvers at $193 million per year, increasing to $290 million per year within a decade.[42] [43] RAND recommended undertaking demonstration projects to identify promising technologies likely to jumpstart a solution in the event of another Fengyun-1C or a satellite-satellite collision whose effect on the global economy could be far more devastating. Moreover, the study concluded that no single remedy is likely to address the problem.

GOVERNMENT GOALS AND ROLE

The U.S. government unquestionably must play the central role in achieving what we believe should be our ultimate goal as a nation -- sustaining effective U.S. leadership in space. The most crucial government roles for the space industry include: promoting the health of the U.S. industrial base while protecting critical technologies; creating mechanisms that can respond to rapidly developing technologies; protecting intellectual property rights; creating and enforcing a cyber security framework for space; and sustaining innovation and support the growth of U.S.

space industries. Although the 2010 *National Security Strategy* (NSS) recognizes space as "a catalyst for innovation and a hallmark of U.S. technological leadership,"[44] it does not sufficiently define the goals, strategies for achieving them, or measures for determining whether we are making progress toward attaining them. Pending publication of the *2014 NSS*, we note with satisfaction that the 2014 *Quadrennial Defense Review (QDR)* declares that "sustaining U.S. leadership,"[45] is a vital national interest. Achieving this in space requires the United States to establish an integrated whole of government (WoG) space strategy. The existing *National Security Space Strategy* (NSSS)[46] is limited to the DoD and Intelligence Communities, notably excluding a broader WoG focus that could include civil space agencies.

Ensuring the health of the industrial base is critically important given U.S. industry's vital role in undergirding our economy and national security. The USG must strike a sensible balance between support for commercial sales of space products and technologies abroad and rigorous measures that prevent the export of sensitive technologies to adversarial countries. As noted on page 10 above, the USG has recently liberalized export regulations on space products and technologies, a welcome first step towards strengthening the competitiveness of U.S. space firms in overseas markets.

ESSAYS ON MAJOR ISSUES

ESSAY 1: Property Rights

Property rights in space are currently governed by the Treaty on Principles Governing the Activities of Status in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (OST).[47] In addition, international space law consists of various principles adopted by the United Nations (UN) as well as custom and practice.[48] A second treaty, the so-called Moon Treaty, is not considered to be part of space law due to the fact that it has only 15 signatories and has been largely rejected by the international community on the grounds that it makes space resources the "common heritage of mankind."[49]

The OST, which has been ratified by over 102 countries and signed by another 26, sets out general principles that act as the basis for all space law.[50] Articles I, II, VI and VIII of the treaty deal with property rights. Article I states that the "exploration and use" of outer space must be "for the benefit and in the interests of all countries" and "shall be the province of all mankind".[51] Article II prohibits "national appropriation by claim of sovereignty, by means of use or occupation".[52] It is widely held that the article bans nations from the ownership of any part of space and does not allow them to give citizens or companies exclusive use of any territory in space.[53] Article VI requires the "appropriate State Party" to the OST to authorize and supervise the activities of all non-government entities in outer space, including the Moon and other celestial bodies.[54] Finally, Article VIII gives States "jurisdiction and control" over objects and personnel launched into space, including objects landed or constructed on a celestial body.[55] Article VIII has been read to give "de facto property rights to the portion of a celestial body upon which an object has been placed".[56]

Based on past practices, there appear to be a number of areas where custom and usage have established property rights or property-like rights in space. For example, the allocation of rights to use spectrum by the International Telecommunications Union and national governments grants "use of a limited resource in space for business purposes for the lifetime of [a] particular satellite".[57] In addition, although the OST does not address intellectual property rights for things

invented or made in space, the international community accepted the Inter-Governmental Agreement on the Space Station that contained detailed provisions on intellectual property rights.[58] Finally, no country has challenged the United States' or Russia's rights to appropriate lunar material, "an indication that the international community recognizes as customary international law the right to own extraterrestrial resources harvested from celestial bodies".[59]

There is widespread agreement that the current legal framework for space activities has significant limitations that will need to be addressed in order to fully benefit from the commercialization of space. As one commentator noted, "The Outer Space Treaty is riddled with ambiguities. It is silent, outside of affirming freedom of "exploration and use" as to what *sort* of rights parties can claim in celestial bodies. It is silent as to the *circumstances* under which these unspecified property rights might vest, that is, what a person must do to gain whatever property rights are available."[60] The level of ambiguity is particularly high for the use of resources in space.[61] Among the questions that need to be answered is whether resource taking is a "use" of space and whether the prohibition against national appropriation extends to corporations and individuals.[62] Even more troubling is the fact that legal experts are still arguing over the meaning of the "province of all mankind" in Article I of the OST.[63] One group reads the phrase as being nothing more than general guidelines while another reads the phrase in light of the Moon Treaty's language on space being the "common heritage of mankind" (CHM) and argues that all profits from space activities must be spread among all nations regardless of their involvement.[64] The United States has long maintained that the principles of "province of all mankind" and CHM are "general guidelines rather than imperatives to action".[65]

Experts are sharply divided over the timing of reform efforts as well as the form that they should take. One school argues that reforms should be delayed due to the fact that private commercial development of space is still at a very basic stage and that it is impossible to anticipate what issues and technologies will arise.[66] Proponents of this view argue that it does not make sense to worry about a legal framework until three criteria have been achieved: the cost of access to space has dropped significantly, the value of resources on the Moon and NEAs provides an adequate profit margin for their mining and processing, and technologies and safety protocols have been developed that allow for the efficient and safe mining, use, and transport of space resources.[67] According to this school of thought, the reduction in the cost of accessing space due to innovations will eventually produce "a clear opposition of interests" that will force nations to negotiate a new framework.[68] As one expert glibly opined when asked what would produce such a conflict, "It will take the first car wreck, off-planet."[69]

Proponents of revising the legal framework sooner rather than later argue that governments and commercial entities will only be willing to make the massive investments needed for space commerce if there is a system that clearly establishes their legal rights and obligations.[70] In addition, they argue that capital markets, rather than wealthy entrepreneurs alone, are necessary to fund the required investments and that these require legal certainty.[71] The argument in short is that "companies cannot afford to invest the capital necessary for space ventures if ambiguous laws force them into costly and time-consuming litigation in an attempt to protect their investment."[72] Although the proponents make a number of valid points regarding launch costs, the need to develop technology, and the creation of a legal framework that acts as a straitjacket on development, they fail to address a key point. Although it may be true that wealthy individuals will fund development until there is a conflict that needs to be resolved, the so-called "car wreck", they fail to address the consequences of a wreck. In other words, what happens when there is a wreck? Assuming that the conflict is about a key issue, then nations will

have to negotiate a solution, which could take years. While the private sector may be willing to bet on space given the current level of uncertainty, the risks of investment will be substantially higher when there is a major controversy that could result in a solution that threatens their investments. As a result, the private sector could slow down or stop needed investments in research and development or new technology for a period of years while it waits to see how the conflict is resolved. Even proponents of waiting for a future maturation of technology before creating a new legal framework admit that "unless and until a way of assuring private enterprises that their investments in research and development, equipment, and operations in space can be recovered, the insecurity and risks of not having an operating mechanism for establishing these rights will impede the fast growth of commercial space."[73]

Should an international framework fail to materialize, the United States should engage in multilateral negotiations with like-minded countries. A binding international treaty among all or most of the major space-faring nations creating a legal regime for the private commercialization of space would "undoubtedly shape international law, and significantly so, especially if it is the first effort of its kind."[74] The treaty would create great pressure on other countries to either sign onto the treaty or propose an international framework in order to avoid being left behind.

Author: Mr. Shawn Flatt, U. S. Department of State

ESSAY 2: Counterspace Weapons and the Need to Move Beyond Congested, Contested, and Competitive

Without the ability to ensure access to space and deny adversaries the same freedom, the United States risks losing the single most critical capability it possesses. The United States can no longer accept the current space environment -- congested, contested, and competitive. Instead, the United States must adopt a national strategy to move beyond these categories to the next level -- controlled. The way to control space is to weaponize space -- defined here as the development, acquisition, and operational employment of counterspace weapons (including both ground- and space-based). This strategy is the only sensible path to ensure U.S. military and economic security.

The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (informally, the Outer Space Treaty) has long been the international community's guiding premise on the weaponization of outer space. However, the treaty only prohibits the stationing of nuclear weapons and weapons of mass destruction in Earth orbit, outer space, on the moon, or on another celestial body; it says nothing about the placement of other weapons in space.

Acknowledging the limitations in the Outer Space Treaty, various nations and the United Nations have made efforts to formalize prohibitions against weapons in space. The UN Conference on Disarmament has made the Prevention of an Arms Race in Outer Space (PAROS) a priority for the past several decades. Each year since 1983, its First Committee, led by Russia and China, has passed a resolution affirming efforts to achieve PAROS. In addition to leading the PAROS movement, Russia and China jointly proposed a 2008 treaty limiting space weapons. Titled, "Treaty on the Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT)." But even PAROS and PPWT ban only *space-based* weapons; there is no mention of prohibitions on ground-based counterspace capabilities, which are being actively developed by several nations.

Both PAROS and PPWT have found widespread support among a vast majority of the world's nations. Even many inside the United States argue for adoption of these treaties and a ban space weapons. There have been many voices raised in support of banning the weaponization of space. Arguments for this course are that banning weapons would spur peace or that weaponizing space would increase the danger to U.S. space systems by inciting other nations to build their own space weapons. Critics even argue that by weaponizing space, the United States would ignite another arms race, sending the country down a path of uncontrolled spending and creating an environment of uncertainty, distrust, and perhaps even aggression in the realm of outer space.

Space is the new high ground. It is, quite literally, the ground from which the United States can control "the battlefield." Battlefield, in this context, may be a literal battlefield, using space to give U.S. forces an asymmetric advantage in combat as has been demonstrated many, many times since the first Gulf War; or, space may be a figurative battlefield, providing the United States with the strategic advantage to succeed in business, finance, science, innovation, etc. Strategists, both military and business alike, will tell you that ceding the high ground is the quickest way to losing a contest, any contest. Whether it is Lieutenant General Ewell's decision not to occupy the high grounds south of Gettysburg on the first day of the battle (extending the battle two more days and costing more than 50,000 dead and wounded [75]); or, Kodak's decision not to develop the digital camera (a technology the company invented), leading to the company's implosion,[76] history is replete with examples where loss of the high ground resulted in defeat.

Current U.S. military efforts lean heavily to designing satellites to resist attack (resiliency) and moving away from single, large, exquisite systems to smaller, less capable systems but procured in large quantities (disaggregation)[77] in order to offset the threat from counterspace capabilities being rapidly developed and fielded by U.S. adversaries. This effort is only for military and national security satellites, not commercial satellites, which constitute the majority of the U.S. advantage in space. Even if the limited efforts to protect U.S. satellites were expanded to include all U.S. assets, civilian and military, it would not be enough. Protection alone will not stop adversaries from attempting to destroy the asymmetric advantage space offers the United States. The United States must take actions to convince its adversaries that the cost of even attempting to attack U.S. space systems is too high. The only way to do this is if the United States can threaten the space capabilities of those nations that have counterspace capabilities of their own.

The United States is committed to defeating aggression against its assets in space and is developing technologies to "fight" in space if necessary. The United States also states that it reserves the right to defend itself if threatened in space but this statement and other efforts fall short. They lack daring and mettle; they lack the spirit and conviction that signals to adversaries that the United States has zero tolerance for any threat to its space assets. Instead, the United States makes weak comments about the right to self-defense and secretly develops counterspace capabilities while attempting to diplomatically manage the counterspace initiatives of other nations. These mixed signals embolden adversarial efforts to develop ways to attack the U.S. space advantage. It is time to move fully adopt a robust strategy for ensuring U.S. safety and security in space. Potential adversaries must know, without a doubt, that the United States can and will employ both offensive and defensive force in space if and when threatened. The United States must commit, openly and without hesitation, to weaponizing space. This path will not be easy but it is vital to the continued security of the nation.

Author: CDR William "Murry" Carter, USN

ESSAY 3: STEM Education for Leadership in Space: Build Common Core

During the course of this industry study over the past three months, numerous officials have expressed concern about the "graying" space industry workforce. The concern is relatively consistent across government agencies and civilian industry. As a point of reference, Under Secretary of Defense Frank Kendall noted that the space industry is concerned about the "continued sustainability of its workforce and the loss of critical design skills."[78] The report that Kendall sent to Congress goes on to define the problem: nearly three-fourths of the space industry workforce is between the ages of 40-60. In the overall workforce, less than 45% falls in that age group.[79] Clearly, there will be an acute need to quickly develop a new cadre of young engineers in the space industry. The challenge is more severe in this particular industry as opposed to many other science and engineering fields in that many engineering positions in the space industry require U.S. citizenship. It will be difficult to use favorable immigration policies to relieve the pressure on this particular industry.

STEM education is faltering in the United States but there are some good initiatives. One example is DoD STARBASE. The founder of DoD STARBASE explains: "STARBASE takes 5th grade students on a 25-hour odyssey into the exciting world of Science, Technology, Engineering, and Math with hands-on, minds-on academics." [80] STARBASE leverages technically challenging, but exciting STEM education with partnerships with military bases throughout the country to produce the kind of technically savvy leaders DoD will need in the future. The STARBASE Mission Statement explains: "By exposing youth to the technological environments and positive role models found on military bases and installations, the DoD STARBASE program will provide 25 hours of inquiry based instruction, using a common core curriculum that meets the National Standards."[81] I chose DoD STARBASE as a case study for the Space Industry for two reasons: first, it has demonstrated statistically significant results, and second, of its 13 core components developed in 1996, at least seven translate directly to the space industry (Bernoulli's Principle, four forces of flight, space exploration, Newton's Laws of Motion, technology development, flight simulation, and model rocketry).[82]

DoD STARBASE currently operates in 56 locations in 30 states and it has graduated more than 850,000 students since its inception in 1993.[83] STARBASE is primarily funded through the DoD budget, with monies disbursed through the Assistant Secretary of Defense, Reserve Affairs office (OSD/RA).[84] Until 2013, STARBASE was included in the Future Years Defense Program (FYDP).[85] Some STARBASE sites also organize as 501(c)(3) organizations for additional funding, but federal appropriations are key.

Comprehensive studies have shown the program hits the target audience of underprivileged youth in a big way. Eighty-one percent of participants qualified for free or reduced price lunches, 46% were "English language learners," and 84% were racial or ethnic minorities. The study was a long-term study that looked at participants of STARBASE that were subsequently in 10th-12th grades in the 2008-'09 school year.[86] Anecdotal results were consistent: "Results from Wilder Research's long-term follow-up study indicate STARBASE Minnesota is a meaningful and memorable experience for students, even several years after they participated in the program."[87] Statistical comparisons between STARBASE students and a control group with matching demographic backgrounds found previous STARBASE students in high school: had higher junior high science grades, had higher attendance rates, had higher rates of completing

Algebra II (indicating rigorous math study), and had higher college attendance rates after graduation. This study resurveyed these STARBASE alumni in college. Ninety-nine percent of respondents thought the program was valuable, 79% said it increased their interest in STEM, and 26% responded that it impacted their career choices (with an additional 33% responding that it might affect their career choices).[88]

In a fiscally austere environment, if the choice is ships, soldiers, or 5th graders, the 5th graders will lose every time. Yet it is vital to national security for DoD to have enough qualified recruits in 5-10 years. The same could be said for NASA education programs and any number of other well intentioned, high performing STEM programs. Indeed, both DoD and NASA have statutory responsibility to provide STEM education.[89] Therefore, the national security community, in lockstep with the education community, needs to devise ways to institutionalize these vital programs.

STEM programs should target elementary schools through stabilized funding. The Industrial College of the Armed Forces (ICAF, now Eisenhower School) Space Industry Study Report in 2011 identified exactly this need. "In the long term, the space industry will face challenges as a result of systemic STEM education failure beginning in K-5."[90] Secondary and undergraduate STEM education is largely self-selecting, and if children are not excited about such careers by the end of sixth grade, or if they feel they will be to "boring" or "hard," then they will not pursue them in later education. The Committee on STEM Education Reform outlined the strengths of federal STEM education spending: "Most of the CoSTEM agencies [including DoD] support STEM education to meet their specific missions and workforce needs. Some also leverage their facilities, assets, technical workforce, and expertise to support fundamental STEM education."[91] This is precisely what the STARBASE program does. Instead of cutting numerous programs that work and have the support of their agencies (of which STARBASE is only one), why not allow each agency with a vital need for future engineers to develop its own programs? A high diversity of programs both in numbers and content has a higher likelihood of reaching more students and exciting their interest in STEM careers.

It is clear that the U.S. space industry faces unprecedented challenges. One of the greatest challenges is an aging workforce. NASA manned missions in the 1960s and 1970s inspired a generation of young people to want to work in the space industry. Somehow, the U.S. space industry has lost some of that inspirational focus. This lack of inspiration is a clear threat to U.S. leadership in the industry. The keys to exciting students in STEM education are to make it accessible, make it hands-on, and take it out of the classroom. Make it accessible: take it to underprivileged schools, focus on minorities and girls. Make it hands-on: build things, do experiments, have competitions. Take it out of the classroom: take elementary kids to a high school, a nearby military base, or a lab. Unlike some other high-tech fields, the space industry cannot grow its way out of this problem by recruiting the best and brightest from abroad and encouraging friendly immigration policies. The United States will never regain leadership in space unless all levels of government, local, state, and federal, begin a concerted effort to institutionalize exciting and inspiring STEM programs in the nation's elementary schools.

Author: Lt Col Michael "Slick" Casey, USAF

CONCLUSION and RECOMMENDATIONS

The United States is more dependent on space than any other nation. From a national security perspective, "from command and control to communications and intelligence gathering

to weapons targeting, space systems today are a key element of U.S. national security."[92] From an economic perspective, "many space technologies have reached such a level of maturity that some of their applications, such as telecommunications, automated teller machines, meteorology, navigation, stock market data, and transport control, are now an integral part of the daily lives of millions of U.S. residents."[93] U.S. activities in space must be appropriately robust and focused to ensure the nation's leaders have the continued ability to act and dominate in this critical domain.

It is widely perceived that the United States is no longer actively asserting a leadership role in space. Other nations are identifying their interests and are acting accordingly, with little concern for significant U.S. counteraction. U.S. leadership and engagement remain the best means -- and hope -- to bring nations together so that all mankind may share the benefits of space. Continued inattentiveness to the rapidly changing state of play in space may bring the era of U.S. leadership and predominant influence to a close.

Space is and will long remain a strategically important domain that requires a sustained, deliberate effort on the part of the U.S. government to preserve our freedom of action and protect our national interests. We therefore present the following recommendations as a prescription to ensure continued U.S. leadership in space:

Establish Executive-level Space Leadership Council

American leadership in space requires strategic coherence and advocacy by the President of the United States as well as a stable regulatory and policy environment focused on national security outcomes. The United States must take a whole of government approach in establishing space priorities, missions, metrics of success, and accountability. This seminar proposes the creation of a Space Leadership Council within the National Science and Technology Council (NSTC). Established by Executive Order in 1993, the executive-level NSTC is responsible for coordinating the nation's science and technology policy across research and development structures. The President of the United States and the Director of the Office of Science and Technology Policy are its co-chairs. Currently, this council consists of five committees dedicated to: the Environment, Natural Resources and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Math (STEM) Education; and Science and Technology.[94] The addition of a Space Council as a sixth committee focused on the national priorities in civil and national security space will ensure that pressing concerns will receive Presidential attention. In addition, it will produce synergies within the other five committees, the charters of which are anchored in strengthening the foundations of U.S. national security.

The Space Leadership Council should be co-chaired by the Secretary of Defense and the NASA Administrator. The Director of National Intelligence, Department of Energy, Department of the Treasury, Department of State, Department of Transportation, and the Department of Commerce would be designated as members by statute. Principals would establish long-term goals and objectives, properly aligning space efforts to support national space goals as defined in strategic guidance, collecting metrics to achieve priorities during Strategic Processes phases over time, analyzing trends for future strategy development and refinement, and identifying, supporting, and addressing U.S. industrial base and infrastructure deficiencies. Also, at a minimum, the sub-committee structure should include the Office of Management and Budget, the National Reconnaissance Office, the Office of the Secretary of Defense for Policy, and the Executive Agent for Space. "Others" would be added or consulted as necessary. The Council should engage Congress in the early stages of establishing the nation's space priorities and advocate for the required funding.

Support and Leverage Commercial Space

The national security space sector can benefit from a healthier, more dynamic, and more collaborative relationship with the commercial space sector. The U.S. government should support space-centric commercial activities by reforming the strict export control regime on satellite products and technology. While the recent easing of some ITAR export controls is an excellent start, the USG should establish a continuous review mechanism (such as a "next on or off" list) that drives sensible updates of the United States Munitions List. Increasing market access for U.S. companies will improve the economics of space activities for all users, including those in national security organizations. Also, the government should enable commercial operations by monetizing USG space support infrastructure through either the privatization or the commercialization of certain assets.

Increase Collaborative Industry-Government Dialogue

Reformed export controls can be seen as a collaboration success story between industry and government. However, the United States risks further eroding its comparative advantages in space if the USG's ability to identify and correct industrial base constraints is not improved. Unfortunately, according to multiple sources we spoke with during this study, effective collaboration between the USG and industry appears to be trending in the wrong direction. The USG should maintain an open dialogue with industry to improve U.S. competitiveness and foster innovation. Improved government-industry communication will be instrumental in invigorating the launch vehicle and satellite manufacturing industrial base. Closer collaboration between government and industry can reduce costs, increase capabilities, and provide vital support for sustaining U.S. preeminence in the space domain.

Assured Access Through More Affordable Indigenous Launch Capability and Commercial Competition

Reinvigorating the U.S. domestic launch market would end U.S. reliance on Russian manufactured rocket motors and create more commercial opportunities for U.S. companies in both manned and unmanned systems. Future use of orbital and near-earth space will increase, thereby increasing demand for frequent, flexible, and inexpensive launch capabilities.

The USG should encourage the development of an indigenous launch capability that includes reusable launch vehicles by promoting commercial competition. Recent NASA incentive programs, such as Commercial Orbital Transportation Services and Commercial Crew Development, prove that collaborative ventures with commercial partners can be both cost and operationally effective. Further incentives based on the "X-Prize" model can also speed development and delivery of launch solutions, enabling continued U.S. dominance in the current Expendable Launch Vehicle and RLV markets. Once RLVs range LEO, reusable orbital transfer vehicles can ferry payloads to other orbital regimes, again lowering launch costs.

Institute Launch Vehicle Acquisition Reform

The U.S. government should develop and implement an acquisition strategy that capitalizes on the advantages of commercial-style, capabilities-based contracts for launch. These should be firm fixed price contracts that include provisions guaranteeing the USG the right to observe and collect data at the contractor's factory. The acquisition process and contracts should articulate government-held risks and provide the contractor insight into USG reliability concerns.

Contractors would fund risk reduction, and the USG would carry the risk on constellation sustainment schedules, exercising its right to refuse overly risky launch vehicle configurations. Launch contractors should be naturally motivated to cure mission-risk level problems in order to win additional USG business and minimize current and future customer concerns. The USG should consider funding select activities of new market entrants to accelerate their ability to meet launch "reliability" requirements.

Institute International Legal Framework

The current lack of legal clarity in space threatens to impede commercial development efforts and hamper exploration activities in space. The current legal framework has multiple ambiguities, particularly in the area of property rights. A new legal framework for property rights that clearly outlines roles and responsibilities is needed. This framework could be incorporated to existing treaties through an amendment process. Such amendments should contain specific provisions applicable to mining claims, intellectual property rights, liability, and dispute resolution mechanisms that ensure accountability.

Revitalize STEM Education

The U.S. government should reinvest in education based on outcomes. It is a national imperative to regain excellence in education once again. Science, technology, engineering, and math (STEM) programs must target elementary school-aged children, ideally in the fifth and sixth grades, in order to inspire them about the challenging fields connected to space, grants and scholarships promoting STEM education later in a student's career should be designed to promote working in career fields related to national security for the first six years after graduation. Stronger government support for STEM education in elementary school would ensure a more robust flow of engineering talent into the space industrial base.

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