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Industry Study**

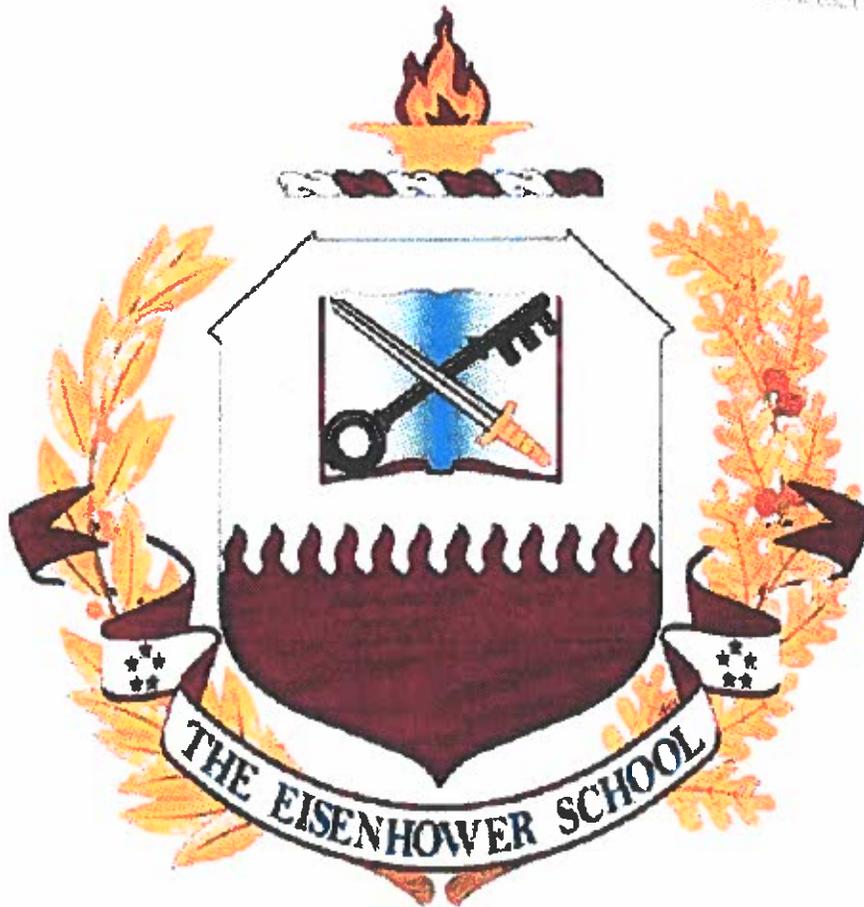
**Industry Report
*Space***

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Abstract: U.S. space leadership is critical to national security, and must be gained, maintained, or reinforced by addressing challenges pertaining to technology, resourcing, and governance. This report analyzes the implications to the U.S. space enterprise from those three dimensions. Data gleaned from site visits, interviews, and firm analyses is used to ascertain milestones and trends. Recommendations are not limited to government policy reforms, but include those for industry and civil society. The report concludes with a call to action to the U.S. Interagency members, and proposes research that would inform a renewed agenda for space.

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The New Space Race: Implications and Recommendations for American Space Leadership in the 21st century from an industry analytics perspective

I. Introduction

The United Nations Outer Space Treaty was signed fifty years ago this year; in retrospect, the world in 1967 seemed a simpler, almost quaint place in comparison to today. By that year, the idea of manned spaceflight had been led by the United States and Soviet Union from the realm of science fiction to science fact. The superpowers had created an impression that their fledgling efforts in space would eventually become routine and bring universal benefits. Signatories to the treaty were “reaffirming the importance of international cooperation in the field of activities in the peaceful exploration and use of outer space.”¹ The impact of new technologies and scientific knowledge brought by the Space Race, while valuable, cloaked the geopolitical and military competition for supremacy between the world’s first space-faring nations. The U.S. would eventually win the race to the Moon in 1969 - a mere eight years after Alan Shephard’s sub-orbital mission. Consequently, America’s technological, economic, and political leadership were affirmed in stark terms with the planting on the Stars and Stripes on the Moon’s barren surface at the *Sea of Tranquility*, even though we came as Neil Armstrong said, “for all mankind.”

America’s leadership in space has now reached another critical inflection point. Military and economic challenges posed by rivals in space are mounting in scope and frequency. On January 11, 2007, exactly forty years and sixteen days after the Outer Space Treaty was signed, China successfully demonstrated the ability to destroy an orbiting satellite using a ground-launched missile.² Since the submission of the last Eisenhower School’s space industry report in May 2016 the following has occurred: Chinese engineers started work on a 440-pound payload space rocket that could be launched from a Y-20 strategic transport plane in flight (March 2017)³; China continued improvements on counterspace capability using its Dong Neng-3 anti-satellite missile (December 2016)⁴; and, Russia tested its PL-19 Nudol anti-satellite missile (December 2016).⁵

Although shrouded in secrecy, it is estimated that China’s space defense budget will reach \$3 billion in 2017.⁶ This budget is part of their five-year plan that culminates with a Chinese space station by 2025, and to the longer-term objectives for manned missions to the Moon and Mars by 2035. The Chinese government, emulating aspects of the U.S. space industry, is providing financial incentives to Chinese start-up companies such as Onespace, a firm many analysts describe as the ‘Chinese SpaceX.’⁷ Chinese authorities consider success in space as a contributor to its international prestige, a motivator to inspire its students to pursue careers in science and technology, and an essential component for national security.⁸

In civilian use of space, foreign capabilities have also improved. In November 2013, forty-two years after the \$137 million *Mariner 9* became the first spacecraft to orbit Mars, India’s *Mangalyaan* orbiter arrived at Mars and became the least expensive interplanetary mission conducted by any nation - a rock bottom cost of \$73 million.⁹ Iran manufactured and launched its *Omid* satellite in 2009 making it the second country in the Middle East (after Israel

in 1980) to accomplish this feat.¹⁰ Some countries (notably China and India) that fifty years ago struggled to feed their populations, now have space capabilities that once exclusively belonged to the U.S. and Russia.

Space is no longer just a proving ground or a showcase for new technologies; rather, it is an indispensable medium that affords America with unique military, economic, and informational powers. Russia's *Sputnik 1*, in 1957, caused a fervor with the American public and U.S. Congress as it represented an affront to national pride, and a potential threat to the nation's security. *Sputnik 1* was a technological achievement, and a validation of the Soviet Union's capability of launching a nuclear attack against the U.S. homeland. Currently, although public outcry is muted if not absent, threats to American space leadership are subtler than during the heyday of the Space Race, and far more complex and unpredictable. Therefore, *U.S. space leadership is critical to national security, and must be gained, maintained, or reinforced by addressing challenges pertaining to technology, resourcing, and governance.* The 2011 U.S. National Security Space Strategy, supports this report's thesis by affirming priorities, such as: safety, stability, and security in space; to maintain and enhance the strategic national security advantages; and to energize the space industrial base. The strategy, corroborating an essential point of this report, recognizes that "a resilient, flexible, and healthy space industrial base must underpin all of our space activities."¹¹

This report analyzes the challenges, opportunities, and implications of American space leadership from three dimensions: technology, resourcing, and governance. Data gleaned from site visits, interviews, and firm analyses is used to ascertain milestones and trends. Recommendations are not limited to government policy reforms, but include those for the industrial base and civil society. There are numerous federal institutions (e.g. Department of Commerce, Department of Defense, and Department of State) that have overlapping (and sometimes, conflicting) influence on the space industry; therefore, improved coordination through the *interagency process* is an imperative. The report concludes with a call to action to the U.S. Interagency members, and proposes research that would inform a renewed agenda for space.

II. Overview of U.S. Space Leadership: The Criticality of Technology, Resourcing, and Governance

The *Apollo* program, the U.S. manned mission to the Moon, and the preceding *Gemini* and *Mercury* programs, are exemplars of the marvels that can be achieved when there is coherence in purpose. This report's conceptual model is based on the U.S. space program of the 1960s when there was a higher level of harmonization between national policy (i.e. **governance**), **resourcing** (i.e. budget, acquisition, human capital), and the industrial base (i.e. a source for requisite **technology**). When these three dimensions are coordinated, U.S. leadership in space advances; conversely, lack of synchronization results in the nation functioning below its full potential, and presents opportunities for foreign competitors to exploit the gaps. For example, government regulations adversely affected the U.S. global market share for satellites. The U.S. Arms Export Control Act's International Traffic in Arms Regulation (ITAR) was introduced in 1998 to safeguard national security by "denying advanced military technology and potential

competitors.”¹² However, prior to ITAR, U.S. spacecraft manufacturers held 63 percent of the global market; by 2002, U.S. share of the global market dipped to 42 percent.

The following sections of the report highlight challenges relative to the dimensions of technology, resourcing, and governance. After this overview, the report provides a series of analyses on these challenges based upon data taken from military leadership, academia, domestic, and foreign industries.

Technology

Maintaining technological superiority. Since World War II, U.S. national security has depended on maintaining a technological advantage over adversaries. In space, as in the other domains, the Department of Defense (DoD) seeks to employ advanced weapon systems that outperform the enemy across all mission sets. In 2015, the U.S. Government spent 61% more on space than all other foreign governments combined.¹³ The FY2017 budget requests include \$8.9 billion for the U.S. Air Force Space activities, \$19 billion for the National Aeronautics and Space Administration, and a classified amount for the National Reconnaissance Office (NRO).¹⁴ The availability of launch services to provide the U.S. with prompt, unimpeded access to space, and a cybersecurity systems to ensure sensitive information is not comprised are key enablers to maintain superiority.

Technology diffusion. America’s achievements in space technology are second to none. The sophistication of deep space observatories like the *Hubble* and *James Webb* telescopes, robotic missions to Mars like *Pathfinder*, and to the outer planets such as *Cassini* continues to distinguish American technological leadership in exploration. Additionally, exquisite spacecraft such as the Air Force’s *Advanced Extremely High Frequency* satellite and the NRO’s intelligence constellations are years, possibly even decades, ahead of U.S. competitors’ capabilities. However, maturation and diffusion of U.S.-inspired technologies enables allies and rivals to “fast follow” without making equivalent investments in basic science and applied research and development. Technology diffusion is an enduring issue that presents a vulnerability to national security. According to an international think tank, “controlling or denying technology to potential technology developers or even recipients will be more difficult in the light of the commercial value such technologies, and because of the greater role of market forces and the declining influence of government controls on technology transfer interactions.”¹⁵

The rise of ‘New Space.’ The most important driver of American space technology during the past ten years is the emergence of space entrepreneurs who constitute ‘New Space.’ Old Space is comprised of prime military contractors (such as Lockheed-Martin, Boeing, Raytheon, and Northrop Grumman) that have operated since the early stages of the Aviation and/or the Space Age. New Space is characterized by aspiring but shrewd entrepreneurs (e.g. Elon Musk of SpaceX, Jeff Bezos of Blue Origin, and Richard Branson of Virgin Orbital) that seek to accomplish the improbable, such as colonizing Mars, not necessarily for national security but for intellectual and emotional satisfaction, and (ultimately) profit.

Some Old Space executives deem the New Space entrepreneurial upstarts as unreliable; New Space staff relish their role as disruptors because change, from their perspective, is long

overdue. This clash of organizational cultures should not be a surprise. Elon Musk had not been born when man landed on the Moon; Jeff Bezos, in 1969, was five years old. Unencumbered by traditions inherent in the military-industrial complex, Musk and Bezos have taken new business models and applied them to established technologies. New Space entrepreneurs are creating and exploiting new markets, and are not beholden to the U.S. Government for contracts. A challenge for the U.S. Government is to leverage New Space's innovation and capacity, while maintaining reliability and security provided by the Old Space industrial base.

Resourcing

The U.S. is the proverbial Goliath in the global space economy. In 2014, the space industry was worth \$330 billion. Of that amount, the U.S. Government's space budget accounted for 13 percent (\$42.96 billion), while government spending by foreign nations accounted for another 11 percent (\$36.21 billion).¹⁶ The remaining 76% of the space economy, or \$250.83 billion, represents commercial space activities such as telecommunications and remote sensing. Within commercial space, according to a 2011 report, the U.S. commanded market shares of 45 percent for global satellite services, 52 percent for satellite manufacturing, 39 percent for launch services, and 45 percent for ground equipment.¹⁷

Enduring challenge of acquisition reform. U.S. Government acquisition processes enable accountability, transparency, and fair competition more so than speed and efficiency. The DoD has been cited to have spent at least \$46 billion between 2001 and 2011 on a dozen weapons systems that never even entered production.¹⁸ As a military analyst noted, "The 2017 National Defense Authorization Act makes clear Congress's frustration with an acquisition system characterized by ever-increasing costs and schedule growth. Reform is sorely needed, but Congress' proposed solution -yet another reorganization of a broken system - is unlikely to be effective."¹⁹ The enduring challenge of government acquisition affects U.S. space leadership by complicating the process by which products and services are sourced.

Aging workforce. The Space Foundation cited, "In 2014, the U.S. civil and commercial space workforce remained one of the largest in the world, with 221,585 workers, but continued to contract." However, the U.S. space industry confronts a substantive headwind related to its workforce. It is predicted that "41 percent of skilled tradesmen in the aerospace industry are eligible to retire in 2017."²⁰ The nation's ability to maintain and grow market share, and exert intellectual leadership in civilian space programs is linked to industry's and academia's ability to gain, retain, and nurture a talented workforce.

Governance

No single authority for space confounds strategy for space. The vitality of the U.S. governance of the space enterprise can be, in part, attributed to the multiplicity of stakeholders. The National Aeronautics and Space Administration (NASA) is arguably the agency that garners the greatest public awareness; however, here are but a few additional actors: the Department of State (DOS), the Federal Aviation Authority (FAA), the Department of Energy (DOE), the Department of Commerce (DOC), the National Oceanic and Atmospheric Association (NOAA), the, the Director of National Intelligence (DNI), the National Security Agency (NSA), the National Geospatial-Intelligence Agency (NGA); and, of course Congress and the President.

The plethora of directives and special interests challenges the formulation and implementation of a strategic plan.

The Executive branch drafts the national space policy and provides a framework around which departments and agencies develop their detailed plans. However, matching resources, markets, and technology with policy has been so vexing that the Trump administration plans to revive the interagency National Space Council to achieve coherence in the space effort.²¹

While the ‘Iron Triangle’ continues its inefficient *pas de trois* of competing interests between the U.S. Congress, industry, and special interest lobbies, China has taken a centralized-planning, comprehensive approach that intimately merges their space agenda with political, military, and economic interests. Dennis Shea, testifying before the House of Representatives’ Space and Technology Committee said, “China’s more deliberate and comprehensive approach will open up opportunities for Beijing to derive important economic, political, and diplomatic benefits from its space program in the near term.”²² China, since 2011, has signed 43 space cooperation agreements or memoranda of understanding with 29 countries, space agencies, and international organizations. These Sino-alliances are designed to strengthen the country’s global influence without coercive military action. The People’s Liberation Army’s book entitled *Unrestricted Warfare* outlined China’s strategy to counter the U.S. by avoiding direct kinetic conflict by use of smart power.²³ This doctrine is reflected in China’s space strategy.

International cooperation and deterrence. The ubiquitous nature of the World Wide Web and flyovers by satellites challenge the Westphalian notion of sovereignty as defined by national borders. America’s security in the 21st century is not constrained by acquiring and defending land, but also depends on expanding spheres of economic, cultural, and political influence. The Outer Space Treaty established a foundation for cooperation, but as more nations have assets (and space debris) in space, the legal ramifications of authority, conflict resolution, and norms of behavior will become a greater issue. Conversely, what strategies and infrastructure should be adopted to prevent the U.S. from being threatened or overwhelmed by hostile forces in the event cooperation and diplomacy fail?

Feedback from Industry

The following sections of the report provide illustrative examples, taken from consultations with industry and academic representatives, on the challenges and trends using the dimensions of technology, resourcing, and governance.

Dimension 1-Technology

“There is no such thing as a war in space, there is just war, it’s with an adversary and if it extends into space we have to figure out how to fight it.”²⁴

- General John Hyten, Commander, U.S. Strategic Command (USSTRATCOM)

The U.S. Government's ability to maintain unimpeded access to space depends upon advanced technology and innovative applications. This section of the report posits five aspects of vital importance (with associated challenges): small satellites, launch services, cybersecurity, dual-use technology, and technology innovation.

1. Small Satellites for Space Domain Mission Assurance

The Space Enterprise Vision (SEV) represents the Commander of Air Force Space Command's concept for aligning U.S. space operations with an environment increasingly threatened by adversary counter-space capabilities. A critical SEV theme is that the U.S. is at an inflection point requiring evolutionary transformation of space command and control, acquisition, and enterprise resiliency. As the DoD advances to implement the SEV in support of space domain mission assurance, it must overcome potential headwinds posed by the immaturity of the small satellite manufacturing industry, and the U.S. Government's lack of clarity in its demand signal.

Two key elements of space domain mission assurance are disaggregation and rapid reconstitution of space capabilities. These elements represent an evolution in traditional defense space operations from a reliance on large, exquisite satellites with long development timelines to the inclusion of smaller satellites to support rapid and responsive launch. As General Hyten stated in Congressional testimony, "we must also explore options to the current paradigm within the DoD of only developing large, complex satellite systems...we must also be able to deliver smaller systems within much shorter timelines."²⁵ Though small satellites are not the only method to achieve reconstitution and or disaggregation, their increasing significance to the National Security Space Enterprise deserves special attention.

Small satellites are spacecraft with a mass of less than 180 kilograms (kg) and include several subclasses of satellites, such as minisatellites (100-180 kg), microsatellites (10-100 kg), nanosatellites (1-10 kg), and picosatellites (0.01-1 kg). The allure of small satellites is due to their ability to be quickly assembled and the low-cost relative to larger spacecraft. Those qualities allow for rapid replacement of spacecraft and use of the latest technology.

A critical challenge to the growth of the small satellite industry is the limited availability of small satellite-dedicated launch. In 2015, there were only 86 worldwide orbital launches, 20 of which were American.²⁶ Within these 20 launches, eight were commercial launches.²⁷ A year later, worldwide orbital launches remained steady at 85 of which 22 of which were U.S., with 11 of those being commercial.²⁸ The preponderance of launch for both years was in support of medium and large satellites. The FAA predict an increase to 41 launches per year through 2026 which it attributes to several medium and large satellite constellations entering a refresh cycle.²⁹ This further underscores the point that medium and large satellites still dominate launch availability.

Small satellites may take advantage of ride-sharing and hosted payloads, but it is unlikely these options can accommodate the estimated 2,400 small satellites projected to launch by 2023.³⁰ Launch schedules are typically tied to the long development cycles of large satellites and their potential delays. A cursory study of the 51 remaining global launches scheduled for 2017

reveals five launch delays and only a few launches dedicated to small satellite missions.³¹ Delays and or multi-year waits for launch negate the advantage of rapid development and frequent technology upgrades that small satellites have over larger and more exquisite systems.

Space Works Enterprises, Inc, which specializes in small satellite industry analysis, projects a 20% decrease from previous projections in the number of small satellites seeking launch through 2023.³² Describing the impact of launch delay, lead author of the report, Bill Doncaster, stated, “concentration on relatively few launch vehicles increases uncertainty in the launch schedule for small satellite operators and limits near-term growth.”³³ Firms including Stratolaunch, Virgin Orbit, XCOR, and Rocket Lab, among others, intend to cater to the small satellite market. These launch vehicles are unproven, and in most cases, are in the design or construction phases. Their potential, until realized, will have little impact on increasing confidence in the growth of the small satellite market. Even if a nascent small launch market emerged in the next few years, estimates indicate that launch costs would remain more expensive compared to larger launch vehicles.³⁴

The U.S. Government can influence industry in favor of expanded small satellite manufacturing and launch capability. U.S. military and civil space consumed over 50 percent of U.S. launches for the last two years and provided as much as 73 percent of U.S. satellite manufacturing revenue.³⁵ The greatest fiscal influence among the space defense stakeholders is wielded by the Air Force, which executes about 90 percent of the military space funding, and the NRO, which controls the classified Intelligence Community (IC)space budget. The preference among these institutions for large satellites, along with the delay in profitable small satellite constellations has muted heavy investment among key satellite manufacturers in small satellite manufacturing or launch.

To prompt industry’s response to a SEV-induced evolution in space operations, the U.S. Government must send a coherent signal to the space defense industry that small satellites are needed. Unfortunately, evidence suggests that efforts to do so are off to a slow start. Discussions with some space industry firms indicate a lack of awareness about the SEV.³⁶ Some firms are not clear what it means in terms of requirements for the U.S. Government. Referring to lingering SEV opacity, a Senior Vice President from INMARSAT stated, “It’s not clear how you go from a vision to an integrated decision...I can’t make investment decisions based on this.”³⁷ A representative of Harris Corporation echoed this sentiment, suggesting there was more the Air Force could do to specify how industry could support the SEV. Another aerospace senior executive echoed the sentiment that the DoD has struggled to define SEV requirements adequately to incentivize investment. The executive suggested a lack of consensus at the top levels of government about the role of small satellites in support of disaggregation.³⁸

It is unlikely that the NRO will be the source of a definitive signal to industry that spurs small satellite investment. NRO’s mission, its culture, and the physics of space encourage reliance on large satellites housing the most advanced technology and requiring significant power. Disaggregation has limited application and it is infeasible to quickly reconstitute advanced NRO capabilities with a small space vehicle. This institution in the national security space enterprise will continue to send a strong demand signal for large satellites requiring heavy-lift launch vehicles.

The Air Force is also demanding medium to large satellites. The Air Force Space and Missile Systems Center (SMC) are working closely with industry partners to improve resilience of systems by making modifications to spacecraft design. Several premiere defense contractors confirmed a preference for investing in modifications rather than constellations of small satellites. Addressing resilience of these medium and large systems has merit given the substantial investment, but this approach competes with the demand signal for disaggregation or resilience enabled by small satellites.

The complexity and fragmentation of space acquisition among the Air Force and the IC exacerbates the problem of sending a clear signal to industry on small satellite demand. A July 2016 report from the U.S. Government Accountability Office (GAO) states that contributors to fragmentation include: existence of 60 stakeholder organizations, space acquisition management responsibilities spread over eight separate organizations, involvement of six separate organizations in setting space requirements, and lack of centralized oversight over the space enterprise.³⁹

The negative impact of these factors on encouraging investment and competition in the small satellite market and corresponding launch market cannot be understated. Firms want to minimize risk and a way to do it in the space industry is to invest in areas with guaranteed government support. Firms have low confidence that the U.S. Government's demand for small satellites will substantially grow. Consequently, firms that are ill-positioned to take advantage of the small satellite market, or are averse to the financial risk associated with this market, continue to focus manufacturing on large, exquisite satellites. Given these firms wield significant influence with the U.S. Congress, their expressed reluctance could serve to undermine the Air Force's budgetary support for small satellites.

2. Launch Services

The space launch market "consists of businesses involved in the manufacture of guided missiles and space vehicles, including the development of prototypes and the manufacture and development of parts, propulsion units, and support equipment used in guided missiles and space vehicles."⁴⁰ Space vehicles and missile manufacturing contains 90 businesses that collectively amassed \$27.7 billion in revenue and \$3 billion in profits in 2016.⁴¹ Market concentration is high with the top six companies in the industry having 83.8% of the revenue.⁴² The top six companies and their market share are Lockheed Martin (31.4%), Raytheon (25.7%), Boeing (10.1%), Orbital ATK (7.1%), Aerojet Rocketdyne (6.1%) and SpaceX (3.4%).⁴³ This market is extremely capital-intensive to enter, thus the barrier to entry is extremely high. When drilling down into the \$27.7 billion in revenues earned by the industry, roughly 35% of the market goes directly into the space vehicle manufacturing business.⁴⁴ An industry snapshot shows an annual growth of 1.6% from 2011 through 2016 with projections of 2.1% growth through the year 2021.⁴⁵

New entrants into the launch market have challenged traditional firms for market share, which - along with decreased government spending - has prompted other companies within the industry to restructure, undergo mergers, and/or lay off employees. SpaceX, as an example, is

driving major changes in the launch market. The market for many years has been dominated by the firms that had little incentive to provide differentiation in products provided. However, SpaceX has reshaped spacecraft manufacturing process and introduced a competitive price structuring system for launch services. SpaceX fabricates nearly all its spacecraft parts. Vertical integration is the key to the firm's competitive advantage because this approach helps control costs and avoid delays caused by inefficient parts suppliers. SpaceX aspires to launch every two weeks and, thanks to its useable rocket technology, it intends to shorten that time to every two days.

New Space entrepreneurs are challenging the rules of the game against the industry establishment like United Launch Alliance by providing innovative and affordable solutions. These 'New Space' launch solutions are still in development, but are likely to fully mature in the next five years.

Telecommunication and data services, and the abiding lure of space exploration, will continue to drive demand for launch services. Space tourism, and mining the Moon and asteroids have the potential of expanding demand for launch providers. Today, many U.S. launch companies have a full schedule with a two-year or greater wait on their manifests. Future growth in commercial space tourism may increase entrants in the launch market in the next decade depending on the spacecraft's design.

The trend toward smaller satellites is also driving demand for launch vehicles.⁴⁶ While this may entice new entrants into the market, it may simply drive more demand on existing launch providers to launch a higher volume of smaller cargo. Any new entrants into the space launch market would be required to overcome the same barriers to entry as it can take 10 to 15 years to develop a viable and reliable launch system.

3. Cybersecurity for Space Domain Mission Assurance

The United States' satellite constellation is an enormous cyber network in outer space, consisting of satellites with links and nodes on the Earth and in various orbital regimes. Unfortunately, space is becoming a contested, competitive, and congested environment. Space systems create an enormous network vulnerable to attack through multiple vectors. Therefore, cybersecurity is essential to ensure mission assurance for space.

"Cybersecurity has emerged as one of the most critical preparedness challenges over the past five years."⁴⁷ Understanding the cybersecurity requirements to protect spacecraft, ground systems, and the links between them can be difficult, especially in the multi-decade lifecycle of a space system. The acquisition and development can take 10 years or longer and, once fielded, the system will typically operate for 15 to 20 years. This lengthy timeline allows an adversary time to "plan, develop, coordinate, and execute an attack."⁴⁸ Also, the potential future technologies that can be used to carry out a cyber-attack against the space system are often unknown at the time of development. Therefore, "mission protection must be addressed at each stage of the acquisition process: requirements development, systems engineering, testing, and sustainment. In each of these stages, system engineers must focus on insulating critical system

components to provide eventual operators with the tools needed to continue mission-critical operations.”⁴⁹

Cyber threats can be both physical and virtual and are assessed based on capability and intent of the actor. Space systems are vulnerable to cyber threats because of their dependency on the cyber domain, especially the ground systems. State actors as well as non-state actors such as hackers, hacktivists, and terrorists are also operating in and through cyberspace. These groups conduct disruptive activities such as hacktivism, information warfare, espionage, and cyber warfare. Adversaries target national critical infrastructure as well as private and public sector systems and networks. Intrusions include theft of sensitive corporate data and trade secrets as well as innovative research and development from U.S. universities. Such activity is national security concern because, as the Federal Bureau of Investigations proclaimed, “cyber intrusions are becoming more commonplace, more dangerous, and more sophisticated.”⁵⁰ The dependency on cyberspace makes space systems vulnerable to cyber-threats. Therefore, cybersecurity must be integrated into each space system, ground system, and the links that connect them.

Federal agencies reported a 1,200% increase in cyber incidents from 2006 through 2014.⁵¹ Additionally, reports indicated that approximately 24% of the attack techniques were unknown, indicating that cybersecurity capabilities were likely unable to detect or stop the intrusion.⁵² The low cost of tools, ease of access, low skill-level required, anonymity and lack of attribution makes operating in cyberspace very attractive for these groups.⁵³ The continued advances in technology and capabilities make the future cyber threat even more complex and alarming.

The rapid growth and use of technology pervades numerous industries. Cyber threats to corporate data are driving an evolution in cybersecurity capabilities and tools. The “Cybersecurity 500 list” of the top 500 firms in the market suggests that there is an abundance of firms that provide cybersecurity capabilities, services, applications, and solutions.⁵⁴ Gartner analysis estimates that worldwide spending on information security exceeded \$75 billion in 2015, a growth of 4.7% from the previous year and will continue to “grow at a compound annual growth rate of 9.8% from 2015 through 2020.”⁵⁵

SMC is soliciting help from industry to develop Enterprise Ground Services (EGS). SMC presented an overview of EGS requirements to the *Protected Anti-Jam Tactical SATCOM Industry Day* in December 2016 to introduce industry to EGS as a means to elicit feedback and assistance from industry. To facilitate public-commercial sector interaction, SMC established an industry collaboration Wiki for EGS, which now has over 62 companies and 280 individual accounts. SMC also identified three near-term key roles for industry: get connected to EGS, participate in government or industry standards working group, and plan for integration of future ground systems onto EGS. SMC recognized that the plan to establish an EGS is challenging and will require input, guidance, and assistance from industry. This is a model for collaborating with industry that can possibly be applied to other systems. Including industry early in the acquisition process can help identify EGS cyber vulnerabilities and leverage industry best practices to mitigate them.

4. Dual-Use Technology for Space Control

With both Russia and China developing capabilities to deny the U.S. the use of spacecraft critical to national defense, the U.S. must prepare to defend these assets when war extends into space.⁵⁶ This preparation includes space control, which supports friendly forces' freedom of action, defeats adversaries' attempts to attack friendly satellites, and nullifies hostile space-based assets.⁵⁷ Space control using space-based capabilities can take advantage of existing technology in a dual-use role because, as Michael Listner, founder of the consulting group Space Law and Policy Solutions, argues, "almost everything we put in space is dual-use—you can use it for a good or malignant purpose."⁵⁸

In this case, dual-use technology is systems or subsystems that can be used for both military and civilian applications.⁵⁹ The primary strength of dual-use technology is to decrease the cost and time to field on-orbit assets. It enables new capabilities without adding proportional stress to the design, manufacturing, and supply chain segments of the space industry. Incorporating dual-use subsystems into a mature satellite design likely only increases cost and time by ten to twenty percent.⁶⁰ Similarly, repurposing a satellite for the space control mission significantly reduces the standard ten-year, \$1 billion spacecraft acquisition.⁶¹ Finally, a satellite that is already operational and can be used in multiple roles has no new design costs or timeline.

For defensive space control, which is passive or active operations that protect on-orbit capabilities from attack, existing technology intended to safeguard spacecraft structure, electronics, and sensors from the harsh environment could become dual-use.⁶² For example, hardening and shielding that protects against environmental radiation could be enhanced to offer some defense against nuclear, laser, or microwave weapons.

Enhanced space situational awareness that enables defensive space control is another opportunity for dual-use technology. An existing commercial electro-optical sensor that is used on a small satellite, such as Terra Bella's constellation of imagers, could be bolted onto a critical on-orbit asset to sense the presence of a threat, triggering autonomous defensive postures.⁶³ The sensor could also provide threat awareness for nearby, friendly satellites.

Another defensive space control method is maneuvering to escape a threat, which requires a level of thrust that can only be generated by chemical propulsion. To ensure adequate thrust for defensive maneuvers, a satellite either needs larger propellant tanks, refueling service, or propulsion service. Space Systems Loral has a contract to build refueling spacecraft and Orbital ATK produces a spacecraft that docks with another satellite to provide thrust, both of which are intended for life-extension purposes but could take on dual-use roles if leveraged to enable evasive actions.⁶⁴

As a complement to defensive space control, offensive space control negates an adversary's use of on-orbit capabilities to interfere with friendly systems.⁶⁵ One space-based method of offensive space control is orbital jamming. If an aggressor satellite is in contact with a ground station or another satellite, jamming can interrupt the downlink or the uplink to disrupt its operations. The U.S. frequently jams its own satellites when one transmission inadvertently

interferes with another, so purposefully using transmissions to jam an aggressor could be a dual-use role for spacecraft communication systems.⁶⁶

Another offensive space control option is to use “defender satellite” rendezvous and proximity operations to interfere with the aggressor. For example, the Orbital ATK spacecraft that docks with another satellite to provide thrust capability could push an aggressor away from its target. Similarly, the Space Systems Loral spacecraft that will be able to refuel and repair on-orbit assets could use its robotics to damage critical aggressor spacecraft components. Additionally, a robotic arm like that used on the space shuttle and International Space Station could adopt the dual-use role of repelling an aggressor.

Overall, there is considerable potential for dual-use technology to help fill the U.S.’ space control gap. It is a time- and cost-effective option to complement U.S. investment in exquisite space control capabilities and enhanced resilience techniques.

5. Innovation for Space Technology Advancement

For the U.S. to maintain the asymmetric advantage it has enjoyed since the Cold War, the defense industrial base must achieve innovative developments in the space technology. Since 2009, prime military contractors have invested less in research and development due to a lack of competition, higher launch services costs that are lowering profit margins and a declining number of U.S. Government contracts.⁶⁷ According to a Center for Strategic and International Studies report, “research and development contracts have borne a disproportionate share of cuts within the DoD contracting portfolio during the current budget drawdown.”⁶⁸ Since the demise of the Apollo program and the Cold War, “many bold ideas for utilization of space were advanced but uniformly deferred or rejected. A persistent reluctance to take great steps, push frontiers, and assume risks with untested but high-leverage techniques has essentially prevented many space applications from becoming what they could or should be.”⁶⁹

Conversely, entrepreneurial New Space start-up companies have gained market share by investing billions in high-risk and high-reward technologies that are commercially-focused. SpaceX has introduced price competition in launch services with the promise of reducing the cost to orbit from \$10,000 per pound to approximately \$2,000 per pound.⁷⁰

The U.S. Government funds the Defense Advanced Research Project Agency and the University Affiliated Research Centers to spur innovation; however, the variability in the size and number of federal grants to these institutions can have a disruptive impact on their work. When federal funding is disrupted, emerging technologies languish in university laboratories that protect their intellectual property, or what has been called technology latency.

Disruptive technologies that can transform the defense and commercial space sectors can take years to study and develop prototypes. However, variance in federal budget appropriations can curtail funding for science research and development due other priorities, and or the long gestation period before tangible results are achieved. This enduring trend reinforces the need to support a long-term strategic plan for the NASA, and other research and development institutions that would match federal budgets to meet desired outcomes.

Dimension 2-Resourcing: Matching actions with resources

“If we look at the demographics of our workforce across Boeing and much of the aerospace industry, about 50 percent of our top engineers and mechanics will be eligible to retire over roughly the next five years.”⁷¹

- Dennis Muilenberg, President, Boeing, 2014

“There will be more acquisition reform this year, and we still have some organizational issues to deal with.”⁷²

- Rep. Mac Thornberry (R-Texas), House Armed Service Committee, February 2017

Resourcing institutions and processes provides materials, funding, and personnel required for an effective space enterprise. The U.S. must focus on resourcing to enhance the strategic national security advantages afforded by space capabilities. Resourcing effectively is an enabler for U.S. space leadership. The greatest resourcing-related challenges are internal rather than external in origin; such as: improving staff knowledge and streamlining acquisition processes; promoting Science, Technology, Engineering, and Mathematics (STEM) education; maintaining a highly skilled workforce; and inspiring the next generation of industry leaders.

1. Changing the Way We Acquire

Space acquisition faces many challenges that can contribute to cost growth, schedule delays, and technical issues if they are not well-managed. Problems include low-quantity buys, the limited industrial base, very stringent standards for components (e.g., space-qualified), high technological complexity, and the inability to cost-effectively repair spacecraft while in orbit. The DoD’s need for large and complex mission-specific systems will remain; however, leveraging the fast-moving capabilities provided, for example, by small satellites should be taken into consideration to meet future mission needs.

The Space and Missile Defense Command (SMDC) leadership stated that it was beginning to authorize Other Transaction Authority (OTA) for prototype projects in an effort to speed up the acquisition process and transition emerging technology into future space acquisitions.⁷³ The authority for OTA (Title 10 U.S.C. 2371), allows the DoD to enter a transaction to fund prototype projects. This capability will allow the space enterprise to capitalize on emerging space technology more quickly in advance of an approved program of record and inform the requirements definition process. These OTAs have the potential to foster new supply chain relationships. Advanced demonstration projects that are not tied to an acquisition program, may be funded through OTAs.

The OTA authority has been presented as linking to the legacy Advanced Concept Technology Develop (ACTD) program that was managed at the Office of the Secretary of Defense (OSD) level for requests, approvals, and funding of projects from the ACTD funding

pool for these prototypes. The DoD Research and Engineering Strategic Guidance appears to only identify prototypes associated with acquisition. There appears to be a gap in guidance for requirements approval and funding for other than program tied advanced demonstration. There is also a gap in requirements and funding approval for other than program of record advanced prototyping. To use OTA authority most effectively to benefit of the space programs requires clear guidance on advanced demonstration project requirements approval, and Planning, Programming, Budgeting, and Execution requirements. OTA is a procurement instrument and not an authority for approving use of requirements and funding.

2. Challenge in Space Sector Workforce

A challenge for U.S. space leadership is how to inspire the younger generation toward interest in the space industry. The aging workforce started working or grew up in the era of NASA's *Apollo* or Space Shuttle programs. These programs generated great enthusiasm among the Baby Boomers and Generation X cohorts to seek employment in high technology industries. With the retirement of the Space Shuttle program and the workforce close to retiring from this era, what will inspire the Millennial and generation Z (post-millennial) generations? For the U.S. to keep a competitive edge in the space industrial base, which is vital to national security, ensuring continued and increased focus in STEM education is the foundation.

It is apparent that New Space companies such as Terra Bella, SpaceX, and Blue Origin are more appealing to high-performing and ambitious scientists and engineers. The millennials are drawn towards these ambitious entrepreneurs with radical visions. In contrast, Old Space companies have acknowledged the difficulties in recruiting younger workers because of a lack of innovative processes and, quite possibly, lack of an aspirational vision for the future. It appears that New Space companies experience relative ease in recruitment. Retention of the New Space workforce is a topic that will need to be revisited in a few years.

The Department of Commerce's U.S. Space Industry Deep Dive surveyed the space industry to identify the skills in demand.⁷⁴ Based on the responses, the list included analytical, design, engineering, management or development, production or manufacturing, quality control, testing, scientific, and others. Collectively, engineering had the most widespread results.

In many cases, in-house training is required to achieve the appropriate skillset beyond education provided by universities. This task requires industry and government to invest in custom training programs, and defer expectations of high employee productivity until the requisite skillsets are achieved. This brings into question whether "academic programs are providing enough hands-on experience."⁷⁵

Another challenge is the perceived stigma of manufacturing jobs. An industry human resource manager commented, "I think there's an overall stigma about manufacturing in general. Manufacturing isn't what it was 20 years ago, and there's this idea that it's a dirty and dark profession."⁷⁶ An aerospace report noted, "Research by the U.S. Bureau of Labor Statistics shows that aerospace manufacturing employment has been on the steady decline since 2012. Over the past three years, in fact, total employment has dropped from 498,600 to 479,900. The

decrease has hit factory personnel particularly hard; the number of production workers has dropped 6.6 percent over this period versus 3.8 percent for all manufacturing employees.”⁷⁷

The unpredictability of government spending can adversely impact research and development, which has a secondary impact on the workforce pipeline and the further advancement of a younger workforce as aging workforces near retirement. This hinders the ability to fully train new employees. A more stable budget would allow the space industry to better plan and have a more stable workforce.

3. Community of Interests

Community of Interests (COIs) are an information gathering group for technology needs sponsored by the OSD. These communities receive intelligence support and up-to-date intelligence information about current and future threats. They also receive emerging technologies information to better align both their research and acquisition priorities. The COI provides a forum for the Combatant Commands to both articulate and prioritize their missions and operational capability needs. These teams work closely with the international cooperation teams to assess if technology gaps can be globally addressed. The COIs help identify the key research needs and articulate them to industry in their specific COI roadmaps. Industry can use these COI roadmaps to identify technical challenges. The COI roadmaps are published on the Defense Innovation Marketplace website, which is used to communicate science and technology needs between government and industry. COIs are a key enabler to help DoD to understand how the adversary will innovate through intelligence and collaborate within the respective community to adapt for technology superiority.

The Space Science and Technology (S&T) COI is a forum for sharing new ideas, technical directions, and technology opportunities joint planning programs, measuring technical progress, and exchanging advances in space S&T. The government should support efforts to make industry more aware of COIs, and how industry could be involved in shaping technology. There is a two-fold benefit with this approach. First, the government would not waste time and money on technology emerging in the commercial market; secondly, industry would have a road map of where research and development investments will further shape space acquisition. An enabling factor to support the space COI's success would be to integrate the operational space programs and space acquisition community into the communication loop. This would give some assurance that the S&T and acquisition community are on the same page in defining the future space technology needs. Their portfolio focus is S&T investments in space-unique technologies that are essential to maintain an U.S. leadership.

Dimension 3-Governance: Challenges and Opportunities

“I’m substantially concerned about the policy direction of the space agency. We have a situation in the U.S. where the White House and Congress are at odds over what the future direction should be.”⁷⁸

-Neil Armstrong, May 24, 2012

There is an ever-increasing reliance on space for strategic and tactical military operations in the United States. Concurrently, there is an emerging threat for potential commercial and military dual-use spacecraft and technology in the New Space future. These factors change the dynamics of military, civil, and commercial space operations, and can negate peaceful expectations formed by The Outer Space Treaty in 1967.

New methods of space utilization, combined with increasingly-crowded orbits caused by miniaturization of technology and lower launch costs, could create an environment that requires improved space traffic control and governance. Strategies are needed for the use of space for military and civilian purposes. These new strategies must help mitigate future risks in the increasingly congested and complex space commons, while preserving the capability for unconstrained space-enabled military operations, to explore and exploit space for the benefit of humanity. A few of the new strategies could involve the following.

1. Organizational Reform Challenges

As our adversaries in the space domain focus on evolving their space capabilities to challenge the U.S. national security, the DoD is forced to better understand the evolution of threat response within the space domain. In the current strategic environment, asymmetric warfare of many varieties continues to challenge the institutional norms of traditional DoD hierarchy especially as non-state actors are becoming increasingly interconnected, sophisticated, and ultimately more lethal. This disproportionality requires a new approach to space organizational design at the Combatant Command level that increases information sharing and decreases the preconceived notions about the space domain that often prevent the proper delegation of authorities.

From an organizational perspective, the military depends on legacy command and control structures led by accomplished commanders who are comfortable in the physical domain and do not understand space-based capabilities, authorities, or the highly technical nature of the domain. As a result, the Combatant Commander fails to articulate clear space requirements and consequently loses the ability to react effectively at the speed required to outpace adversaries capitalizing on asymmetry to level the battlefield. However, operational space resources are consolidated under the Joint Space Operations Center (JSPOC) at Vandenberg Air Force Base (AFB), and the National Space Defense Center (NSDC) formerly named the Joint Interagency Combined Space Operations Center (JICSPOC) at Buckley AFB. DoD Secretary James Mattis addressed this point in an interview with Breaking Defense, noting that “the need for speed in deciding how to react to anti-satellite missiles, cyber-attacks, jamming or dazzling will drive some programmatic choices as well as ‘how you’re going to operate’ as

the NSDC [JICSPOC] continues to hammer out what happens, how it happens and why in space war.”⁷⁹

Considering the current threat profile, the need for organizational reform, coupled with the demand for increased fiscal responsibility, should be an appropriate amount of motivation for senior leadership to begin the evolution from legacy hierarchical organizations into more adaptive, effective models. Senior leaders must be willing to invoke innovative organizational design constructs to address the current and emerging threat environment.

Given the speed of operations and the limits of cognitive processing, it is imperative that commanders embrace an organizational design that can harness the capability of the larger hierarchical bureaucracy while simultaneously decreasing the decision distance between those with the ability to act and those with authority to act.⁸⁰ “The relationship between information dominance and space dominance is seen as especially intimate, for without reliable access to information on a timely basis, one cannot ensure that space weapons and information systems can safely operate or be controlled and used effectively in combat.”⁸¹ Consequently, the organizational framework must be agile both in structure and methods to interpret the space domain. This domain is complex and often presents ill-defined problems, that must be translated into a non-technical means that can be easily understood across organizational hierarchies.⁸² This transition is key to utilizing space as a new environment for which the commander can attain national and theater security objectives.

In the short term, USSTRATCOM should focus on documenting the mission, command and control, responsibilities, and authorities of the JSPOC and NSDC in joint doctrine. A methodical clarification of roles and responsibilities of space assets will ensure Combatant Commands fully understand, implement, and synergize the capabilities this domain brings to bear on U.S. adversaries. One possible division of roles and responsibilities is to align the JSPOC to the more traditional maintenance requirements associated with space as a medium and the NSDC with the responsibilities of offense and defense related to space as a platform. This is similar to how the cyberspace domain delineates network operations in JP 6-0 and offense and defensive operations using the cyber domain as a platform under JP 3-12. Despite this recommendation, it is still unclear if the consolidation of space expertise into two stovepipes with little to no formal or authoritative interaction at the CCMDs is the best use of the DoD’s space capabilities and expertise. Despite this recommendation, it is unclear if the consolidation of space expertise into two stovepipes with little to no formal or authoritative interaction at the CCMDs is the best use of the DoD’s space capabilities and expertise.

Recently, the Director of the National Security Agency and Commander of U.S. Cyber Command warned against putting cyber on a pedestal. He stated that, “Cyber is an operational domain in which the military does a variety of missions and functions, many of which are traditional.”⁸³ The same could be said about the space domain. The admiral told conference attendees, “Don’t make this thing so specialized, so unique, so different that it just gets pushed to the side. That will sub-optimize our ability to execute cyber operations, and quite frankly it will minimize or at least negatively impact, in my view, the operational outcomes, which is the whole reason we’re doing this in the first place.”⁸⁴ Given the technical intricacies and specialization of the space domain, one could draw a parallel to the space domain and question whether the

JSPOC/NSDC is the best organization structure to support the joint warfighter. The current space organizational structure does not mirror that of the natural domains (air, land, sea) and therefore is by right different. Additionally, current doctrine does not match reality, thus making the mechanisms of space utilization in the joint environment and difficult proposition for those not well versed in space operations.

Looking again to the cyber domain, many senior leaders believe the Special Operations Command (SOCOM) command and control model provides the best organizational structure for a High Demand, Low Density asset. The SOCOM model positions a commander, who is singularly responsible to the Combatant Commander within the Combatant Command area of responsibility. Thus, providing the requisite level of advocacy for utilization or non-utilization of special operations assets and capabilities within the joint fight. If this model were applied to the space domain, each regional Combatant Commander would have a Joint Force Space Component Commander and corresponding staff that would be responsible for ensuring space as an enabling medium was always available and for providing synergistic planning with the other domains to ensure we effectively used space as a warfighting platform.

In conclusion, it is unclear if the DoD is willing to invest the resources to transform the current organizational structure to align with the other domains, however it is clear that the future threat environment will provide little time or opportunity to surge forces, which drives the need for clear continuity of operations, established lines of communication and flexible organizational structures that can handle ambiguity effectively.

2. International Norms of Behavior

There are established domestic and international space organizations providing leadership in the space commons. Some of these domestic and international capabilities are overlapping, and many of the international arrangements established by the organizations are informal and non-binding. Currently, there is no universal organization authorizing and controlling all space operations. As space becomes more congested and contested, discerning peaceful or aggressive operations will be more problematic. Also, establishing a unified authority for space traffic control and regulatory enforcement for space operations will challenge all spacefaring nations. The most enduring structures interacting with space traffic and governance are the DoD and the United Nations. Increasingly, there is interest from the private sector as space becomes more accessible, and science and technology matures. Space law and international norms of behavior are nascent, and emerging threats challenge the domain and create new challenges for establishing international norms.

Adversarial spacefaring nations have threatened the space domain with demonstrated destructive capabilities and blatant non-compliance with principles of The Outer Space Treaty of 1967. A recent example of nations acting contradictory to the principles of the Treaty is the demonstration of the anti-satellite missile by China. In addition to introducing a new threat in space, the destruction of the Chinese satellite created a large "debris cloud" with as many as 300,000 pieces of orbital debris being created. Following the Chinese anti-satellite test in 2007, the U.S. space community writ large has done little to shift the status quo of this domain from benign to contested by more than simply space debris. In response to the new threats, the U.S.

and the international space community are taking steps to prioritize space policy and international norms.

The 2010 Space Posture Review was a legislatively mandated review of U.S. national security space policy and objectives, conducted jointly by the Secretary of Defense and the Director of National Intelligence. This report talks about the need to deter, defend, and if necessary, defeat efforts to interfere with or attack U.S. or allied space systems. However, the overarching theme of the document is to ensure the use of space for peaceful purposes leaving the task of securing this domain from weaponization open-ended. Internationally, the United Nations has been the primary institution for space with The Committee on the Peaceful Uses of Outer Space (COPUOS) set up by the General Assembly in 1959 to govern the exploration and use of space for peace, security and development for humanity.⁸⁵ The COPUOS was tasked with reviewing international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the United Nations, encouraging space research programs, and studying legal problems arising from the exploration of outer space. International space law established through the United Nations solidified space sovereignty definitions, sanctioning freedom to use the space commons, but as previously discussed these agreements do not guarantee norms of behaviors and compliance.

If the U.S. is to prevent further erosion of its unimpeded access to space, it will require improvements to current space doctrine that reshape outdated, linear, non-synergistic models for operating in space. Mission assurance gained through improved space control and governance structures will reduce the risk to human spaceflight, and it will also reduce the risk of potential spacecraft destruction. Additional governance must balance with the need for the preservation of strategic and tactical military space capabilities. It must also consider the potential for threatened capabilities in a contested, degraded and operationally limited environment.

3. Classical Deterrence and Its Applicability

Defense leaders recognize the similarities between Cold War nuclear strategy, and space strategy. “Space is just another domain for classic deterrence.”⁸⁶ If the adversary believes the United States can neutralize their counter space capabilities and maintain our capabilities, it provides the basis of deterrence. This idea parallels the conventional theory of mutually assured destruction, but it is more robust than that because the failure of deterrence as it relates to the space domain will have an “immediate impact on the course and result of the war” and the American way of life.

Many of the “future aspects of space competition, conflict, and warfare remain uncertain,” therefore finding ways to “mitigate the advantages of a first strike in space and maintaining the ability to respond” must be codified in DoD doctrine. Douglas Loverro, the Deputy Assistant Secretary of Defense for Space Policy, said, “We think that going down the approach of assurance and denying [an adversary] the benefit from his attack and making it politically difficult for him to attack...that’s a better way to deter attacks in space than depend all upon retaliatory strikes,”⁸⁷ If addressed properly, these tenets will form the foundation of a comprehensive national plan that imposes a powerful strategic pressure on our adversaries and will begin to define the levels of attrition the U.S. is willing to accept regarding space assets.

4. Using the Totality of Statecraft

U.S. leadership in space, as on Earth, is not solely dependent on armaments, but also upon the projection of its diplomatic, economic, and informational sway that constitutes ‘soft power’. Long-term security could be weakened because of inconsistent investment, and incoherent strategies for the other instruments of national power. China, in comparison, is discreetly and skillfully using space to exert influence in developing countries where it also has burgeoning commercial and political interests. An ‘offset’ strategy that relies on a technological advantage over rivals is potentially vulnerable to strategies that integrate and deploy the full dimensions of statecraft.

Joseph Nye, former Assistant Secretary for Defense under the Clinton Administration, coined the term ‘soft power’ to mean the ability to attract and co-opt rather than by coercion (hard power).⁸⁸ Smart power, as defined by the Center for Strategic and International Studies, is “an approach that underscores the necessity of a strong military, but also invests heavily in alliances, partnerships, and institutions of all levels to expand American influence and establish legitimacy of American action.”⁸⁹ Soft power is not a nebulous construct, rather there are tangible outcomes from their application such as: “strengthens international cooperation; secures greater access to foreign markets for [U.S.] goods and services; shapes the international agenda and rules regulating the use of space in ways that would be favorable to the [U.S]; and, attracts foreign expertise and financing which helps [America’s high] technology industries.”⁹⁰

Soft power could be employed to offset destabilizing events so that the need for military intervention (e.g. peacekeeping, humanitarian assistance) would be reduced. For example, the political and economic impacts attributed to the U.S. by the following NASA missions justifies continuation and expansion:

Famine Mitigation. The Famine Early Warning System Network (FEWS-NET), operated by the U.S. Geological Survey (USGS), collaborates with international, regional, and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues.

Pandemic monitoring. Mosquitoes are estimated to transmit disease to more than 700 million people annually, resulting in over a million deaths each year. This project maps the breeding sites for the major vector species, and identifies potential sites for larvicide and insecticide applications.⁹¹

NASA, in many ways, is the public face of the U.S. space enterprise. Visits to NASA facilities, such as Goddard in Greenbelt, Maryland, were display of its ability to conduct peerless science and inspire new generations of American and foreign scientists and entrepreneurs. However, investment in civilian space is not consistently included in military planning. America’s security and space leadership depends on expanding spheres of economic, cultural, and political influence in ways that makes the country indispensable.

5. European Perspective on Cooperation

When comparing the U.S. space community to European counterparts, it is challenging to find similarities. The European Space Agency (ESA) holds a unique position among European Union partners because of a key responsibility to achieve unity of effort. ESA provides multi-national leadership by building consensus among its members. Each of the 22 ESA members contributes to the annual budget with an understanding that whatever space program is funded, a country will receive a portion of program's contract commensurate to its contribution to ESA.

The advantage that ESA has over NASA is that it has predictable funding that allows for more deliberate long-term planning and implementation. However, ESA's significantly smaller annual budget (\$3 billion per year compared to NASA \$19 billion per year), there is less funding for large-scale programs like the James Webb telescope. Additionally, there is not a New Space sector emerging in Europe that is spurring competition Airbus and Thales-Alenia.

Cooperation between ESA and NASA should be enhanced because this partnership will result in mutual benefits. ESA has learned to do more with less; consequently, the U.S. can leverage European expertise in support of small, but cost-effective exploration space missions. When the U.S. is inattentive in its relationship with allies, rivals have an opportunity to fill the vacuum. For examples, NASA's 2013 budget cut forced it to abandon a robotic mission to Mars with the European Space Agency (ESA). A Princeton University Science Policy Fellow noted, "There are long-term disadvantages to continuing to disappoint our ESA colleagues. Our former partners are already looking elsewhere for more stable partnerships on which to build their scientific, technical, and diplomatic futures."⁹² ESA eventually paired with Russia in the wake of NASA's withdrawal.⁹³

III. Recommendations

"Differing organizational structures, legal authorities, duties, responsibilities, and resource levels, all play a role in how agencies interact with each other. When roles, authorities, and resources are clearly defined and in alignment, there are fewer impediments to cooperation."⁹⁴

- Ted Strickler, Executive Director, Arthur D. Simmons Center for the Study of Interagency Cooperation

Space has been characterized as congested, competitive, and contested, and the same could apply the U.S. interagency process. Competing interests and technical specialization, in addition to the factors cited by Strickler, complicate projects that require whole of government coordination. Nonetheless, the urgency and importance of U.S. space leadership requires a systematic engagement of government and non-governmental stakeholders. Consequently, the following recommendations are provided.

Resourcing

Consolidate Acquisition Authorities. The U.S. Government could increase national security space coherency by consolidating DoD and IC space acquisition under a central authority. Centralizing authority would ensure accountability over the comprehensive picture of national security space acquisition with the power to enforce adjustments where necessary. As important, it would increase the likelihood that industry was operating with a clear picture of coherent national security space requirements. As pointed out in a 2016 GAO report, the drawbacks to such a solution is that it would require legislation and changes to both the IC and DoD organizational structures. It would also require a careful balance to ensure that positively evaluated acquisition practices (such as those of the NRO) were maintained as best practices. While this recommendation represents an immense undertaking, the importance of pairing responsibility with authority is evident in criticism that the Principal DoD Space Advisor position to coordinate space activities across DoD and the IC is hamstrung by a lack of authority to direct outside of the Air Force.

Expand Acquisition Course for Space. The space community bundles all space-specific training in the Space 100 through 300 course. These courses are offered outside of the Defense Acquisition University (DAU). Since these skills are critical to the overall success and efficacy of a space program, the acquisition portion of this training, or a specific space acquisition course, should be developed and managed like other government acquisition training certifications. Experience in critical areas of space systems acquisition, including establishing space system cost estimating and testing core capabilities, should be established as a competency and managed accordingly.

Increase Human Capital Investment. Many space industry firms are providing summer internship programs with a commitment that students performing satisfactorily as interns will be offered permanent positions upon graduation. A few further programs discussed by a large defense industry company were the Emerging Leadership program and Mid-Level Leadership program.

Many space industry companies are also gaining better appreciation of what influences and stimulates the millennial generation workforce. Some ideas being implemented include more flexible hours, layout of workspace, more autonomy in work, flatter organizations, and fostering understanding and alignment with the larger goal or strategy.

Restore the Export-Import Bank. Strengthen U.S. economic influence by reinvigorating the Export-Import Bank, and establishing a lending window specifically to support U.S. space products and services. The bank does not compete with private sector lenders, but rather provides financing for transactions that would otherwise not occur because commercial lenders are either unable or unwilling to accept the political or commercial risks inherent in the deal. This arrangement would be especially helpful to expand U.S. commercial space services and products throughout the international market.

Boost Support for STEM and vocational education for aerospace manufacturing. Focus on educational funding for STEM to counter the effects of the aging space workforce and

gaps in future workforce requirements. Increased focus on communication of STEM scholarships, internships, and research opportunities to the public.

Mission Assurance

Provide Clear Guidance on New Strategies to the Industrial Base. The Air Force could reduce uncertainty among key actors in the space industrial base by increasing SEV awareness and specificity. Student engagements with multiple commercial space providers and space industry defense firms indicated that many firms are not aware of the SEV, which diminishes the chances they will invest in supporting its objectives. Those firms familiar with the SEV are unsure which specific capabilities are targets for disaggregation. To encourage investment in alignment with its goals, the Air Force, in cooperation with the NRO, should identify and define those functions suited for disaggregation and those that could be quickly reconstituted at a lesser, yet acceptable, capability level during exigent circumstances.

Incentivize Small Satellite Market. Taking critical action to clarify the specific roles for small satellites in the SEV will facilitate the Air Force incentivizing growth within small satellite manufacturing and launch much the way it did for the heavy launch market and high-end satellite manufacturing: by writing requirements and contracting for it. The refresh rate associated with small satellite constellations, and the long-term nature of defense commitments, could diminish the risk assessed by key manufacturing and launch firms considering small satellite investments. Addressing launch capacity constraints through range infrastructure improvement or mission assurance efficiencies would further enhance these efforts and support market growth.

Leverage Expertise in Private Sector for Space Cybersecurity. Open cooperation with industry early in the acquisition process will help to address the key cybersecurity elements: identification of vulnerabilities; an understanding the threat; and application of policies and standards to define requirements and implement solutions. The government should also look to other industries, such as the financial industry for best practices and methods to address complex, system-of-systems cybersecurity requirements.

Additionally, space system program managers must ensure that requirements to implement Risk Management Framework (RMF) are defined early in the acquisition process for a government space system and are reviewed throughout the process and through sustainment. The new “Risk Management Framework provides a process that integrates security and risk management activities into the system development life cycle.”⁹⁵ This will require government system owners to work closely with industry to assess mission requirements, dependencies, and risk. Additionally, because space systems are a system of systems with security controls managed for each system, government authorities need to review RMF implementation for each system and ensure that risk accepted for one does not compound and impose unacceptable risk to the greater system. In the end, the objective is to manage risk to space systems and safeguard mission assurance. Furthermore, cybersecurity isn’t defined by a one-time requirement, but is an iterative process that requires constant assessment of each factor along with mission requirements and risk.

Capitalize on Dual-Use Technology. The U.S. Air Force should certainly invest in exquisite space control systems that will advance the state of technology, but it should also travel a parallel path of fielding systems that are less costly because they maximize dual-use technology. To reap the full benefits of dual-use technology for space control purposes, the DoD acquisition community must commit to a dual-use strategy at an enterprise level and exchange information with industry on existing and emerging technology as well as space control requirements. Additionally, the U.S. Government should consider putting a framework in place to enable “leasing” commercial refueling, propulsion, and possibly even telecommunications satellites during conflict to serve in a military role as defender satellites.

Deterrence in Space. American military doctrine must evolve to fighting in the space domain, rather than focusing simply on retaining residual capabilities, when current space assets are degraded or destroyed. Moreover, the U.S. Air Force should activate a wing under Air Force Space Command dedicated to offensive space combat operations and power projection in the celestial domain. This will help reverse a historic focus on developing and building capacity and throughput, versus resilience, regarding U.S. space assets. This wing must also be infused with the appropriate number of Intelligence, Surveillance, and Reconnaissance (ISR) professionals dedicated to offensive space missions, and will offset a preponderance of ISR professionals dedicated instead to Air Combat Command-centric missions.

Leverage New Space

Update Space Strategy. Publish a revised National Space Strategy to provide a way ahead for U.S. space based on the new Administration’s vision. The strategy should involve a clear plan to engage and promote the expanding role of the private sector as characterized by ‘New Space.’

Convene an Interagency Working Group on Space Control and Smart Power to facilitate the formulation of a comprehensive defense strategy. This working group will serve to refine plans on the integration of smart power within DoD strategic and tactical plans. Representatives from the space industry should be Ad Hoc members of this working group.

Make Greater Use of Academia. University Affiliated Research Centers and Federally Funded Research and Development Centers such as The Space Dynamics Laboratory at Utah State, the National Center for Atmospheric Studies at the University of Colorado, and the SLAC National Accelerator Laboratory at Stanford University are essential elements that feed the space industry.

Get Space Leadership Issues in the Media. Use social media to present the challenges and opportunities surrounding U.S. space leadership. The public involvement can help drive increased attention (i.e. budget) for the industry. New Space entrepreneurs could be very effective advocates in raising awareness about the importance of space.

IV. Conclusion

America, by size of government expenditure, scope and sophistication of technology, and market penetration, is the Goliath in the global space economy. However, lack of physical strength did not slay Goliath; over-confidence was the source of his downfall. He had dismissed and misinterpreted the threat signal; even a pebble, used skillfully, can be a deadly projectile. This analogy holds true for America's space leadership in the 21st century. Do military leaders, government policy-makers, and captains of industry sense the subtle changes in the space environment that threaten the U.S. ability to remain at peace with prosperity? While our focus is to achieve victory on the battlefields against our adversaries by technological superiority, are we under-valuing (and under-investing) economic competition with our allies in boardrooms by encumbering industry with bureaucratic processes? Is our industrial base sufficiently nimble to adjust to produce what is needed for the sake of national security, even if this means an erosion of corporate profits? Competitors and adversaries see little value in direct confrontation with the U.S.; therefore, greater thought and investment is needed by our strategic leadership on how to counter asymmetric challenges that arise in diplomatic, informational, military, and economic arenas.

U.S. space leadership cannot be exclusively based on domination, but requires an abiding erudition in the application of the appropriate tool for the situation. In some cases, leadership may take the form of creating a broad alliance of international partners to maintain norms of behavior that also addresses national interests (e.g. Outer Space Treaty); it may require serving as a 'junior' partner in a much larger effort (e.g. Mars Express mission with the European Space Authority); or, being the pioneer that opens a new realm of enterprise that ultimately is adopted for the benefit of all (e.g. Internet). This report suggests that America's greatest challenges to space leadership are domestic in nature, such as: the lack of coordination between and within government and non-governmental stakeholders; lack of strategic direction or clarity; bureaucratic processes that inhibit commerce and innovation; and, mercurial demand signals from government that frustrate industry's ability to provide timely service.

The global space economy of \$330 billion⁹⁶, is a rounding error in comparison to the global Gross Domestic Product of \$107 trillion (2014)⁹⁷; however, the industry has a disproportionate influence on the American economy and our ability to project power. An argument could be made that there is a sizeable economic multiplier for every dollar spent related to the space industry.

The precision and robustness of instrumentation, the environment and political consideration associated with launching rockets, and complexity of supply chains and markets needed for profitability to bring these pieces together must, by nature, involve collaboration between government, the private sector, and civil society (e.g. academia). Consequently, America's space leadership depends on this trio more than any other space-faring nation. Impediments or miscommunication between these three entities will only result in jeopardizing our status. As with most partnerships, there is a tendency for one voice to dominate; this cannot be the case with mapping out a new case for space. The budget allocation, for example,

supporting a \$100 million satellite that helps identify underground water sources could help stabilize a fragile state, rather than spending \$500 million to pacify extremists by military means in that same country. The U.S. Interagency members, operating under a greater sense of urgency, must use space leadership to support all dimensions of statecraft.

Finally, this report covers only a fraction of the elements associated with industrial relations in the space industry. The Eisenhower School affords an opportunity to step outside the 'government echo chamber' and analyze policies and trends from the perspective of the commercial and civil sectors. Future classes might consider the following research topics that could add to our understanding of the space industry:

Too big to fail? The military-space industrial complex continues to consolidate into fewer companies. Will the Big Four or Five military firms consolidate into two or three? If so, what are the implications to national security? At what stage should the U.S. Government (being the impetus behind this monosomy) intervene?

New space: a flash or enduring star? Military veterans will exclaim winning a battle does not mean you've won the war. New Space brings excitement, and great possibilities, but is it ready and able for the long haul to support national economic and security interests? What are the objective metrics that will help inform policymakers to appropriately engage New Space ventures, and avoid falling into the trap of "irrational exuberance" (to coin a phrase from Alan Greenspan)?

Next big thing. Commercial industry dominates the space economy. The telecommunication market is a major revenue generator; however, what could be the next big thing? Some argue that autonomous vehicles will be the next big driver of the space industry; however, are current regulations conducive for this technology to blossom? The governance-technology -resourcing paradigm could be used to identify the technologies (and bottlenecks) on the horizon, and the actions needed to assure U.S. leadership.

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