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Space

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ABSTRACT: The United States remains a global leader in space. America's edge is driven by both its pursuit of national security space capabilities for navigation, communication and imagery, as well as technical innovations in the commercial sector by established companies and emerging entrants. This global advantage extends beyond military and commercial satellites to innovation in civil science missions, including remote earth sensing and scientific missions.

The 2015 Eisenhower School Space Industry Study report explores the current state of the U.S. space industry and identifies key emerging trends. The analytic framework for assessing the state of the space industry focuses on progress in the accomplishment of the six goals identified in the 2010 United States National Space Policy (NSP). The Space Industry Seminar analyzed a wide range of governmental and private domestic entities in the Space industry, as well as a sampling of key players of the international industry. The seminar looked at the public organizations that establish requirements and set policy, as well as the commercial firms that research, design, manufacture, operate, and ultimately sell civil, commercial, and military satellites and launch systems. After taking an independent look at all elements of the Space Industry, this document makes specific recommendations to advance progress in meeting the goals of the NSP. In short, the report concludes that the U.S. space industry is competitive, innovative, and is leading the world in space solutions. It further concludes that while the U.S. space enterprise is making significant strides in accomplishing the NSP goals, there remains room for continued improvement. Specifically, this report concludes the U.S. should: (1) take the lead in promoting international standards of conduct in space, (2) enhance resilience, (3) cultivate international cooperation, and (4) generate public enthusiasm about the space domain and the endless possibilities it represents.

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INTRODUCTION

"We choose to go to the moon in this decade and do the other things,
not because they are easy but, because they are hard,
because that goal will serve to organize and measure the best of
our energies and skills, because that challenge is one we are willing to accept,
one we are unwilling to postpone and one which we intend to win.

--John F. Kennedy, *May 25, 1961*

Almost fifty years ago, on June 3rd, 1965, astronaut Ed White completed the first United States' spacewalk as part of the Gemini Four mission. This mission served as one of the precursors to fulfilling President Kennedy's vision of reaching the Moon, accomplished just four years later on July 20, 1969 when astronauts Neil Armstrong and Buzz Aldrin successfully landed the *Eagle* lunar module on the Sea of Tranquility.[1] This milestone marked the culmination of a national effort to achieve a leading position in the exploration and use of the space domain.

Today, space is intertwined in the fabric of America's economic, military, and scientific activities. Every day, American citizens, without thought, rely on space for the Global Positioning System's (GPS) precise position, navigation, and timing (PNT), as well as access to direct to home satellite television and music entertainment. Businesses monitor their global supply chain and conduct communications and transactions across global satellite links. NASA and the scientific community employ Earth observation satellites to monitor the weather, precipitation levels, and climate change while using the International Space Station (ISS) to experiment in microgravity. The United States military-empowered space architecture, can establish global information dominance. However, space has become an increasingly congested, competitive, and contested domain posing a formidable challenge to American supremacy.[2] Today's policy decisions and financial investments will dictate whether the U.S. remains a leader in space and whether we continue to be able to spearhead innovation in this critical domain.

The national security of the United States remains inextricably linked to the employment and preservation of the space domain. This report summarizes the independent observations, conclusions and recommendations of fifteen national security professionals from across the Departments of Defense, State, and Homeland Security assigned to the Eisenhower School Space Industry Study. The analytic framework for assessing the state of the U.S. space industry compares current conditions and trends against the six goals enumerated in the 2010 U.S. National Space Policy (NSP). These goals provided an excellent framework to shape U.S. space policy, research and development priorities, as well as resourcing strategy over the last five years. However, much has transpired since the Obama administration published the NSP, especially trends toward space as a warfighting domain and transformations in commercial space. As a result, the 2015 Eisenhower School Space Industry's Study report re-orders the six goals in the NSP to reflect the proposition that the U.S. should prioritize leading the international community to develop an international framework for standards of conduct and responsible behavior in space, as a necessary component to a space deterrence strategy.

China's employment of a direct ascent anti-satellite (ASAT) weapon to destroy a disabled satellite in 2007, creating over 8,000 pieces of space debris, is one of the most notable demonstrations of irresponsible behavior in the space domain. Since that event, China has reportedly conducted several further ASAT tests under the guise of ballistic missile defense (BMD) tests. Moreover, China has and is continuing to research the development of other, non-kinetic counterspace capabilities as part of a strategy to achieve information dominance and deny space capabilities to a technologically advanced opponent. Unfortunately, offensive space capabilities are not confined to large, space faring states. During the 2012 Arab Spring demonstrations, several states demonstrated the capability to disrupt or deny signals from space. These developments, along with the growing problem of space debris, highlight the need for establishing international standards and cooperation in space.

From the beginning of the space age, international cooperation has been a core component of space exploration and technological development. Despite its vastness, space is a fragile and vulnerable domain. Unlike other warfighting domains, space is unique because it cannot be accessed easily and, with today's capabilities, it is virtually impossible to sanitize once it has been polluted. The U.S. should lead the establishment of global space policy and standards of conduct, by reinvigorating international cooperation aimed at preserving space as a global common for the good of mankind. While in a position of enduring dominance in this domain, the U.S. should use this opportunity to guide the international community to develop and agree upon standards of conduct for space, not only for our national interests but, for the interests of all mankind.

The United States has committed to the development of non-binding transparency and confidence building measures for space on multiple times, yet that commitment has not resulted in the adoption of a code of conduct for space. Most recently and most publicly, within the 2015 National Security Strategy (NSS), the U.S. reaffirmed its commitment to an international code of conduct. Using an international code of conduct as the starting point, this report asserts that the U.S. should lead the international community in developing standards related to space debris mitigation, destructive collisions in space, saturation of the radio frequency spectrum, and a definition of sovereignty for space. By adopting internationally agreed upon standards of behavior, the world will have a legitimate framework that establishes the preconditions for adopting a comprehensive deterrence strategy in space.

Most literature on deterrence discusses the concept in terms of preventing an unwanted behavior through two functions: (1) creating doubt about the adversary's ability to accomplish a goal and/or (2) creating certainty in the unacceptable costs imposed if an action is attempted. The United States' current emphasis on resiliency in its space architecture through disaggregation, hardening, redundancy, and the commercialization of space is about creating doubt in an adversary's risk calculus. Additionally, the U.S. must demonstrate the capability and intent to defeat any entity that attacks a U.S. space capability in any domain. In today's geo-political environment, deterrence is most effective when predicated on legitimacy, as defined by international standards. Internationally codifying sovereignty in space, responsible behavior, and accepted enforcement actions, establishes a standard for legitimacy not only in the international community, but also with the U.S. population.

Finally, this report acknowledges the complexity of furthering goals that at some level appear, in part, to be in conflict. Specifically, there is a natural tension between adopting measures that enhance resilience in space while simultaneously removing barriers to build international cooperation. There is also a strong tension between addressing short term national security goals while simultaneously adopting measures that promote long term global objectives. The same standards of conduct or treaty obligations that on the one hand enhance global preservation of the space domain, on the other hand may provide short term constraints that reduce some degree of U.S. flexibility in space. Those constraints will apply equally to all, whether China, the EU, India, Russia or the U.S.

Responsible behavior in space is linked to virtually every goal of the NSP. Space stability, resilience, international cooperation, inspiring the world to innovate, as well as improving space global monitoring are all furthered by the responsible conduct of space-faring nations. This assertion reinforces the justification for our prioritized recommendations.

Following approximately seven months of discussions, research and first-hand observations with policy makers, government officials, and space industry leaders from the United States, France and Germany, the 2015 Eisenhower Space Industry Report re-orders the six goals in the 2010 NSP to reflect an explicit precedence over other goals. Paraphrasing the wording of the goals, this report prioritizes the six 2010 NSP goals as follows: (1) Strengthen stability in space by establishing international standards of conduct; (2) Increase assurance and resilience of mission-essential functions; (3) Energize competitive domestic industries; (4) Expand international cooperation; (5) Pursue human and robotic initiatives; and (6) Improve space-based Earth and solar observation. The following report examines each of the six U.S. NSP goals in priority order. The rationale for the new, explicit priority order is set forth. In addition, based on an analysis of the space industry, the report presents recommendations and conclusions. Two appendices provide a summary of recommendations, in bullet format in Appendix A, and in table format in Appendix B.

Goal #1: International Standards of Conduct *Strengthen stability in space through: domestic and international measures to promote safe and responsible operations in space; improved information collection and sharing for space object collision avoidance; protection of critical space systems and supporting infrastructures, with special attention to the critical interdependence of space and information systems; and strengthening measures to mitigate orbital debris.*[3]

<u>Introduction</u>

Nearly six decades ago, mankind launched its first satellite into space and with that achievement a vast new domain with infinite opportunities for human innovation and exploration emerged. As human activity in space began, the need for an enduring international law framework aimed at ensuring stability in space became evident. Space has changed significantly since 1957 and there are many new challenges. The 2010 United States National Space Policy (NSP) best summarizes the present challenge to continued stability in space:

> When the space age began, the opportunities to use space were limited to only a few nations, and there were limited consequences for irresponsible or unintentional behavior. Now, we find ourselves in a world where the benefits of space permeate almost every facet of our lives. The growth and evolution of the global economy has ushered in an ever increasing number of nations into space. The interconnected nature of space capabilities and the world's growing dependence on them mean that irresponsible acts in space can have damaging consequences for all of us.[4]

Notwithstanding the fundamental transformation in the number of space-faring nations, as well as the scope of human activity in outer space, the international community has to date been unable to advance standards of conduct or a legal regime that clearly defines today's expectations and consequences of behavior in space. Treaties governing space were ratified soon after the commencement of the space age, between 1967 and 1984. While space capabilities have changed significantly since that timeframe, to include space becoming a war enabler and warfare domain, today's laws do not address the reality of space activity in 2015, creating significant risk.

Analysis

Framing the Issue. U.S. space systems play a critical role in our national defense, and the long term stability of those systems is threatened by three factors which may create instability in space. The first factor is orbital debris, which is a growing risk. The second factor is space weather which can disable or disrupt our systems. The final factor is the intentional or negligent destruction or disruption of space systems by an adversary. An agreed upon international standard of conduct could go far in mitigating the threat of debris, as well intentional or neglectful conduct in space. As outlined in the 2010 National Space Policy, the U.S. "will pursue bilateral and multilateral transparency and confidence-building measures to encourage responsible actions in, and the peaceful use of, space."[5] To that end, one must consider the need for standing and binding international policy, rules, and norms to govern peaceful operation in space.

Although developing, launching, and operating sophisticated space systems remains one of the most complex of human activities; geo-political rivalry precludes the international cooperation that should characterize innovation and security in space. The nations that have composed the international space-faring community have failed to develop and agree on standards of conduct in space for various reasons. Assured access and freedom of maneuver in space, while assumed today, can no longer be seen as guaranteed for tomorrow. Space is a competitive and physically hostile environment, with a proliferation of space-faring nations and over 1,200 satellites in various orbits[6] around the globe. History has proven that in the absence of an adequate rule of law framework, where individuals or entities can resolve their differences rationally, that chaos or conflict ensues. A just rule of law system not only provides the rules but, the consequences for violating those rules. As a matter of international law, those consequences may come in the form of diplomatic reproach and claims of illegitimacy, to in-kind reciprocal treatment by other nations in similar situations. The consequences could also entail financial liability or restitution for intentional or negligent conduct that results in the harm of another's spacecraft, with binding decisions made by an appropriate and agreed upon body.

Despite the international community's commitment to employ space for peaceful purposes, as evidenced by the Outer Space Treaty (OST), it is clear that space technologies are being used to enhance war capabilities at sea, land, air and cyber-space and soon could mean actual combat in outer space. Even the National Space Policy, without support in international law, asserts that peaceful purposes include use for national security purposes. It specifically states:

> All nations have the right to explore and use space for peaceful purposes, and for the benefit of all humanity, in accordance with international law. Consistent with this principle, "peaceful purposes" allows for space to be used for national and homeland security activities.[7]

Code of Conduct. The European Union has proposed a code of conduct to the United Nations, designed as a transparency and confidence building measure.[8] The EU Code of Conduct is focused on space debris, destructive collisions due to the crowding of satellites and the saturation of the radio frequency spectrums in space.[9] This code of conduct is a strong first step towards modernizing the legal framework that supports space activity. In the 2015 NSS, the U.S. has, for the first time, codified in writing, its willingness to endorse such a written, multilateral code of conduct formalizing—and potentially limiting—how nations will conduct activities in the domain of space. This policy may stem from the recognition that the current paradigm is insufficient to secure U.S. interests in space, both for national security and altruistic purposes. Standards of conduct governing the principal space-faring nations are a necessary leap forward to assure space access, to mitigate the consequences of space debris and to build confidence that both new and old participants in space activity will do so responsibly.

In addition to the terms captured in the EU code of conduct, the U.S. should propose additional terms that advance two key points: First, the code must establish a positive definition of title or sovereignty in space—something that currently does not exist—that includes the concepts of orbital position sovereignty based on physical occupation of a place in orbit around the Earth or other celestial body, a reasonable physical safety zone around that space asset, and the right of way for sovereign space assets which prohibits other nations from physically, electronically, or otherwise interfering with its operation. Second, it is also imperative that the code include the establishment, upkeep, and regular publication of a verifiable record of sovereign claims made in the space domain, as well as an empowered entity that can authoritatively arbitrate between nations' competing sovereign claims and remedy intentional or unintentional violations of national sovereignty in space. These stipulations, although politically charged and challenging to reach consensus on, will go far in bringing order to space activity.

Modernized Outer Space Treaty. While a code of conduct is a critical first step, the ultimate goal must be a comprehensive and binding international agreement, to be ratified by all nations, that stipulates the expectations of conduct, consequences and costs of space activity. Looking to the OST, the Convention on Liability, the Moon Agreement and other space related treaties as a governance model, the international community must develop laws that recognize space as a warfare domain, and also acknowledge the changes in commercial use of space. To this end, China and Russia have proposed a legally binding paradigm to curb weapons developments in space.[10] The latest version of the Treaty on Prevention of the Placement of Weapons in Outer Space and the Threat or Use of Force against Outer Space Objects (PPWT), is one of the first attempts to contend with the issue of space as a warfare domain yet, it presents several problems from a U.S. perspective.[11]

Among the most significant gaps in the PPWT is its silence on "direct ascent[12] anti-satellite (ASAT) systems and its failure to address soft-kill weapons such as lasers that could be employed to temporarily disable a satellite."[13] Despite the gaps in the proposed treaty, the PPWT has merits in that it attempts to tackle the hard problems of space as a warfare domain. With the present threat of debris, the proliferation of satellites, and the growing dependence of nations on satellites as terrestrial war enablers, the likelihood of either collisions in space or intentional targeting of national security satellites will only grow.

Conclusion

While several nations individually and secretly are working on sophisticated ASAT technology and capabilities[14], as well as defensive measures to protect their satellites, the same effort is lacking in the establishment of standards of conduct. As a matter of national policy, in order to preserve space for our own security, as well as assured access for centuries to come, the U.S. and the E.U. should engage in strategic cooperation discussions with Russia and China specifically, aimed at finding common ground to move forward on a long standing treaty that is acceptable. In describing the need for this treaty, Russia and China have stated: "We consider a legally binding ban on placement of weapons in outer space as one of the most important instruments of strengthening global stability and equal and indivisible security for all".[15]

The U.S. must exercise global leadership as it engages China and Russia on this important endeavor. The short term concerns that have kept the U.S. from proactively pursuing standards of conduct will ultimately be outweighed by the prospect of a long term rule of law model that the international community can accept and addresses the most important concerns of the 21st century. The vision for space governance must be global and must transcend the short term interests of the few, for the long term benefits of the many for generations to come.

Goal #2: Increase Mission Assurance and Resilience of Mission-Essential functions

Increase assurance and resilience of mission-essential functions enabled by commercial, civil, scientific, and national security spacecraft and supporting infrastructure against disruption, degradation, and destruction, whether from environmental, mechanical, electronic, or hostile causes.[16]

Introduction

The U.S. space industry demonstrated considerable progress toward improving assurance and resilience of mission-essential functions by fielding the Wideband Global System (WGS), MUOS (Mobile User Objective System), and Advanced Extremely High Frequency (AEHF) satellites. Conversely, the space industry's science, technology, engineering, and mathematics (STEM) workforce, which is a core requirement to continue this progress, is at risk. Overall, freedom of U.S. action in space remains inadequately protected.

Senior policy-makers must establish a vision and provide direction in the government's desired strategy to implement satellite cyber defense, the government's use of commercial communication satellites to relay military command and control data and imagery, and the government's investment in high-throughput communication satellites technology to invigorate the space industry and achieve this goal. The U.S. government must also reinvigorate the public's perception of the space industry in order to attract new STEM graduates and secure the future health of the workforce.

Analysis

Cyber Defense. In February 2013, Mandiant, a U.S. cyber-security firm, released a report detailing its seven-year research on China's cyber-espionage unit, Unit 61398, and the known compromise of eleven satellite and telecommunications firms over a five year period from 2008-2012.[17] These compromises represent one avenue for adversaries to interfere with or override U.S. space networks. While techniques for penetrating networks constantly evolve, the field of information assurance (IA) has thoroughly defined universal defensive principles (Confidentiality, Integrity, Availability, Non-repudiation, and Authentication) which should form the foundation of any cyber "defense in depth" approach in the space domain. Creating a space "defense in depth" cyber strategy by analyzing IA principles and its associated risks minimizes overall risk holistically at the lowest possible cost.

Challenges abound with implementing cyber defense on satellites. Availability, specifically the timeliness of information, is reduced by implementing means associated with the other four IA principles, i.e. encryption addresses confidentiality but reduces availability. Storage of data on the payload can enhance integrity, yet penalizes size and power requirements of the satellites. Additionally, implementation of any IA principle will increase cost, not only in technology development but also in overhead associated with specific handling of health monitoring or post-mission data. Most importantly, application of IA principles requires a complete mapping of all stakeholders to their dependent space mission functions to ensure implementation of an IA principle does not affect the stakeholder's access or availability to the information.

DoD's Mix of Military and Commercial Satellites. Radical in approach, rebalancing the mix of command and control (C2) capabilities across commercial and military satellites supports prevention and resiliency, with the added benefit of reducing cost by leveraging the growing commercial communication satellite market. Commercial demand is the "driving power for the global satellite backhaul market which is expected to triple in value – jumping from the 2012 annual revenue of about $800 million to $2.3 billion by 2021."[18] DoD FY2010 satellite communications cost $1.6B with projected growth over the next 15 years to $3B-$5B.[19] Early entry during these growth years will allow DOD the best opportunity to frame standards development toward resiliency and maximize cost savings. By capitalizing on current commercial development now, a switch of some DOD traffic to communication satellite services, i.e. adopting a service versus product paradigm, may reduce the number of required DoD-maintained satellites.

Analyzing the reasons to combine military and commercial satellites onto one system and the process to determine the appropriate mix, highlights key challenges and benefits to DOD senior leaders. Use of commercial satellites to transport C2 information decreases predictability and distributes resiliency implementation cost. To further decentralize and reduce predictability, the DoD needs to create space data transport independence, similar to the already established cargo transport independence between the military airlift fleet and the civil reserve fleet. Data, like cargo, needs to be protectively packaged to an established standard at the origin facility and dynamically transported by whichever military or commercial means is available. True space data transport independence also requires satellite-to-satellite communications, rather than typical satellite-to-ground communication, which currently exists on some national security space constellations; the DoD must drive this demand signal for all communication satellites with commercial vendors.

Use of commercial space communication services could reduce resiliency and have cost implications through existing protections and competition. Commercial vendors already deliver some level of resiliency to commercial consumers at market prices. With an established frequency of service and bandwidth across a multi-year contract, DoD might persuade commercial communication satellite service providers to amortize, or even absorb, the cost of additional levels of resiliency across the service price.

Balancing the appropriate length of a multi-year contract is pivotal, as companies will need enough service years to recapitalize some cost without facing competition while still allowing the government to save money through competition. Since this business case analysis is highly dependent upon space data traffic economies of scale, the DoD needs to determine the full scope of demanded space-based data and the DoD's acceptable risk level for each capability to appropriately determine the amount of required bandwidth and the "right" mix of commercial and military satellites. Ideally, DoD should repeat this process quadrennially to determine the best mix, as strategy and missions change, to capitalize on technology, assess new levels of acceptable risk, and, ultimately, provide the lowest cost for warfighter demands.

Potential U.S. Heavy Launch Gap. The success of SpaceX and its Falcon class of launch vehicles is having a positive impact on the space industrial base as a whole, driving down costs and engendering innovation. However, it is generating significant uncertainty in the U.S. national security space (NSS) launch market—where the tug-of-war between reliability and affordability is the most critical—unwinding United Launch Alliance's (ULA) effective monopoly on NSS launches. In an attempt to compete, ULA is attempting to strategically reposition itself by revamping its business model, announcing in March 2015 that it is shedding its expensive Delta line in favor of the Atlas. However, the Atlas V, in its current configuration, cannot perform East Coast heavy launches.

Complicating NSS launch further, the recent aggressive actions of the Russian government in the Ukraine has U.S. government leaders strongly opposed to the continued use of rocket engines manufactured in Russia, specifically the RD-180 engine. Additionally, The 2015 National Defense Authorization Act contained a section prohibiting the Secretary of Defense from awarding or renewing "a contract for the procurement of property or services for space launch activities under the evolved expendable launch vehicle program if such contract carries out such space launch activities using rocket engines designed or manufactured in the Russian Federation."[20] While the law allows for exceptions, continued political pressure to phase-out Russian rocket engines by 2019 could impact U.S. launch operations and mission assurance.

Efforts are underway to reduce launch risk. SpaceX plans the first flight of their Falcon 9 Heavy this year, with NSS certification flights scheduled for 2016, but the timeline for the Falcon Heavy to complete the certification process is uncertain. If either rocket encounters problems, the timelines become unknowable. Care must be taken not to incur a heavy launch capability gap. The USG needs to tread carefully to ensure the competitive dynamics between Space X and ULA, combined with political dynamics surrounding the New Entrant Certification process and the U.S. dependence on the RD-180 rocket engine, do not lead to either: another sole-source situation, albeit with a new company, nor an unintended "heavy-launch gap." Both outcomes would undermine the concept of assured access.

STEM Workforce. Much of the discussion concerning increased assurance and resilience in mission essential space functions focuses on hardware, software, and process improvement. A critical element often omitted is the supporting workforce. Allocated resources are useless if a properly educated and trained workforce is not available to the space industry and today, the health of that workforce is in jeopardy.

The most recent data available from the Department of Commerce indicates STEM occupations represent about 5.5% of the total work force and are expected to grow 17% by 2018. Of note, this is double the expected growth rate of the non-STEM workforce in the same time period.[21] With this in mind, many assess the U.S. STEM workforce at large is in crisis. Accordingly, there are multiple U.S. government and civilian programs to promote STEM, create a more diverse and gender neutral workforce, and increase the quality of education.[22] Is there really a STEM crisis though?

The U.S. Census Bureau reports 74% of STEM graduates are not employed in STEM jobs.[23] Further, if there were truly a shortage, one would expect salary increases in STEM occupations to outpace other job markets; however, this has not occurred.[24] Despite this data suggesting an overabundance of graduates, the Department of Commerce "Deep Dive" indicated there are 25,000 vacancies for engineers, scientists, and other technical occupations in the space industry.[25] Whether or not there is a national STEM shortage, the pool available to the space industry appears insufficient.

Reasons vary but some believe individuals are choosing to pursue careers outside of the space industry. First, the termination of the space shuttle program eliminated the most visible facet of U.S. space activities and likely reduced overall notoriety. Second, competition for STEM graduates by cutting edge and start-up firms who offer tremendous opportunities is fierce. Non-STEM firms also compete for STEM graduates as they are considered by some to be more logical, systematic, and analytical thinkers.[26] Finally, uncertainty in the industry resulting from fiscal constraints likely weighs on individual assessments of job security and financial well-being. Given individual choices are the issue affecting the space industry STEM workforce, solutions must focus on increasing the appeal while providing a measure of predictability and stability in resource allocation. This should serve to revitalize interest in space careers while satisfying STEM graduate needs for future opportunity and job security.

Conclusion

With an increasingly contested and congested space domain, the U.S. national security space sector remains focused on increasing resilience and mission assurance. Surprisingly, discussions with companies providing hardware and services in the commercial and civil sectors reveal a lack of concern for increasing resilience on their satellites. To achieve this goal in a rapid and realistic timeframe, a global synchronizer for space needs to strategically coordinate and champion a Defense in Depth analysis and action plan across the Services, the academic and think tank support network, and industry. Like trust, resiliency cannot be surged.

Goal #3: Energize Competitive Domestic Industries *Energize competitive domestic industries to participate in global markets and advance the development of: satellite manufacturing; satellite-based services; space launch; terrestrial applications; and increased entrepreneurship.*[27]

Introduction

The 2010 NSP shapes guidelines for U.S. Government support in the development of a robust U.S. domestic commercial space industry—enshrining forces that have been underway. The NSP urges the U.S. Government to support the competitiveness of U.S. firms by encouraging and pursuing innovative partnerships, e.g., NASA crew and cargo contracts; conducting research on next generation launch systems and rocket engines;[28] reforming export policies to enhance the competitiveness of the U.S. space industrial base while addressing national security needs; and revamping U.S. acquisition policies.[29] In addition, the 2013 National Space Transportation Policy (NSTP) charges the Secretary of Defense and NASA to accommodate a wide variety of users on federal launch ranges and urges the private sector to refurbish old spaceports and develop new ones.[30] While these policies have met with some measure of success, engendering competition, more remains to be done.

Analysis

Competitive Market Dynamics. U.S. government policies over the past decade have focused on shifting space activities from the public sector to the more efficient private sector in the form of firm fixed-price contracts.[31] Government policies have encouraged and supported the rise of new entrants and entrepreneurs into the space launch and broader space transportation market, many bankrolled by wealthy individuals, overcoming the hurdle of high upfront capital investment costs. These new entrants are implementing process and pursuing product innovation in the rocket and non-rocket, orbital and sub-orbital launch markets, challenging both domestic and international incumbents. State and Federal policies also continue to encourage the development of commercial launch ranges, with relative newcomer Space Exploration Technologies (SpaceX) set to open a commercial spaceport in Texas to competitively position itself.

The success of SpaceX and its Falcon class of launch vehicles has upended the normally staid space launch market, challenging launch market leader Arianespace for commercial launch, and increasingly, United Launch Alliance's (ULA) monopoly on USG national security launches. The "SpaceX effect" has unleashed a series of mergers, restructurings, and rocket redesigns. In March, ULA announced it will abandon the Delta, focusing on a redesign of the Atlas. The new Airbus-Safran joint venture, Airbus Safran Launchers, will manage Europe's redesign for the Ariane 6. Orbital's merger with ATK—which has much needed second stage engine technology—should complement its strategy to compete for heavier commercial and USG payloads.[32] Following the SpaceX model, many of the companies also are becoming more vertically integrated. The U.S. CubeSat community also leads the international CubeSat launch market (followed by Russia and Japan),[33] and is working to develop low-cost dedicated launch capabilities that will put CubeSats into orbit on an as-needed basis.[34] Conversely, more established launch providers are betting on multiple-manifest launches to serve this burgeoning market. Notwithstanding the positive impact of policy and NASA's efforts to "privatize" space, the US Air Force (USAF) EELV process creates a barrier for entry to the national security launch market.

The NSTP traced a line around a broader industry segment, "Space Transportation," which fits the simple definition of launching a "payload"—broadly defined to include a satellite, cargo, crew, or tourists—into sub-orbit or orbit, on increasingly divergent spacecraft and space systems.[35] Several launch providers have moved into spacecraft manufacturing, based on the provision of space transportation in commercially developed launch vehicles.[36]

Innovation also is occurring in the engine market. Though many rockets, including those used by ULA and Orbital, still depend on "tried and true" Russian engines, the strong domestic congressional opposition to the continued use of the RD-180 is a forcing function for innovation. Political aversion to Russian engines, combined with a desire by companies to add power, new capabilities, or other features to better compete, has energized the engine market. Both Russia and SpaceX are working on methane-powered second-stage engines.[37] ULA has teamed up with Jeff Bezos' Blue Origin to develop a new liquid natural gas and liquid oxygen BE-4 engine as a replacement for the RD-180 used on ULA's Atlas 5 rocket, and plans full scale testing in 2016 with a first flight in 2019.[38] Aerojet/Rocketdyne also is investing money to develop a competitor engine for the Atlas 5, and estimates their AR-1 liquid-fueled hydrocarbon rocket engine is four years from completion. ATK also is looking to develop a solid rocket motor compatible with the current Atlas V rocket. Congress is considering appropriating funds to support the competition to develop a new Atlas engine.[39]

On the services side, several companies have announced their intention to provide new or commoditized services to support their own new business model or enable new business models such as Iridium, O3B, Skybox, or SpaceX/Google plans for an enormous constellation to provide satellite-based broadband services. In response, satellite manufacturers are developing and broadening their satellite portfolios to include smaller satellite offerings and commoditized buses. All of the major manufacturers also are developing and incorporating electric propulsion—both for station keeping and transfer—as appropriate; two fully electrically propelled Boeing satellites were launched in March 2015.

Export Control Reform. For nearly fifteen years, the U.S. space industry clamored for changes in the export control regime, citing it as one of the prime drivers for the erosion of U.S. market share in the international satellite market due to the high costs of compliance, its deterrent impact, and the consequent loss in revenue. The onerous licensing process is particularly challenging for sub-tier suppliers with limited resources, and the processing times hamper competition with international firms marketing "ITAR-free" products.[40] With President Obama's 2009 Export Control Reform initiative as a catalyst, significant changes to the export control regime were adopted in 2014.

Following the Smith Amendment to the 2013 NDAA, the Departments of Commerce and State enacted changes to the Commerce Controlled List (CCL) and United States Munitions List (USML), shifting certain items from the International Traffic and Arms Regulation (ITAR) USML to the Commerce-regulated CCL. The Federal Register Interim Final Rule, effective November 10, 2014, also allows commercial, scientific, and civil satellites under Commerce's jurisdiction to incorporate parts and components listed on the USML, yet remain under Commerce licensing authority.[41] Additionally, the Executive Branch established a single enforcement structure within the Department of Homeland Security—the Export Enforcement Coordination Center—intended to replace multiple organizations and streamline the process.

While a complete overhaul of the system has yet to be realized, the above changes and recent efforts to improve interagency coordination should improve cycle times and increase U.S. competitiveness. Conversely, effective licensing remains critical to national security, as global supply chains and virtual engineering enable technology diffusion. Perhaps the most important outcome of the recent reforms will be the increased agility of the system to respond to technological change, standards, and product life cycles. These changes represent a positive step forward for commercial providers—ultimately putting U.S. firms on a more level playing field with European competitors. Industry likely will remain skeptical in the near term, as challenges remain. Satellite manufacturers still do not have the benefit of a single regulator/licensing authority; the split jurisdiction between the Departments of Commerce and State still can cause miscommunication and lead to licensing delays. These changes do not guarantee a recapture of lost market share, but the reforms significantly reduce a barrier (real or perceived) that hampered U.S. competition in the international satellite manufacturing industry.

Acquisition Issues. Acquisition issues are high on the agenda of many companies and institutions that comprise the U.S. Space Industrial Base. Concerns revolve around the manner in which the USG acquires and manages space-based capabilities, including the lack of one USG voice, acquisition methods that do not reflect funding realties and requirements, as well as concerns over interoperability as the USG moves to leverage COMSAT and address the vast complexities of space-based operations. In an effort to increase efficiencies, do more with less, and strive for continuous improvement in the acquisition process, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD AT&L) has published the Better Buying Power

(BBP) initiative. While BBP, writ-large, takes a fresh look at the acquisition process, with a view to maximizing cost savings, fostering innovation, and providing a level of predictability and assurance to the industrial base, DOD must strongly implement and institutionalize BBP initiatives as they apply to space requirements.

Currently, there is no single point of entry for managing military and commercial satellite capabilities. While the Defense Information Systems Agency (DISA) and the Space and Missile Systems Center (SMC) routinely cooperate, they have divergent roles.[42] Accordingly, there is no single entity that can seamlessly manage and adjudicate the DOD's requirements across both commercial and military space assets.[43]

Contracting and funding mechanisms should provide stability, facilitate the proper forecasting of requirements, and encourage innovation. However, that is not always the case. For example, DOD buys commercial bandwidth on an incremental basis with Operations and Maintenance (O&M) funding, providing only one year of predictability. Single year O&M funding necessarily limits commercial vendors' willingness to make long-term investments to satisfy DOD requirements and stifles innovation. A waiver, which allows agencies to incrementally fund long term contracts with those one-year appropriations, would open the aperture of contracting mechanisms to satisfy DOD requirements, including the innovative use of multi-year contracting mechanisms; there are numerous DOD examples where the use of multi-year procurements resulted in significant savings compared to traditional methods._DOD should partner with industry to design interoperable satellite architectures focused on resiliency and cost efficiency. Leveraging already proven commercial solutions, the hosted payload concept could improve space protection and lead to significant cost savings for NSS capabilities. Focused dialogue with industry on emerging requirements, interoperability and hosted payload trade-offs will allow the DOD to determine the right mix of commercial and military satellites to carry warfighter payloads.

Conclusion

Overall, the competitive dynamic and new vectors of interest could drive the space industry in interesting ways. While U.S. companies are pursuing different strategies to succeed in the sector, cost cutting and new technologies are core foci.[44] Decreasing launch costs, combined with advances in non-rocket launch, and spacecraft and satellite manufacture, could tip the balance in favor of smaller space companies, driving new applications and services whose businesses may otherwise have been marginal.[45] Potentially world-changing space-based technologies, increased demand for satellite-based services in lesser developed nations, aspirations for human spaceflight and a manned mission to Mars could also be real innovation and demand drivers. Certain features of CubeSats, and electric satellite propulsion could reshape markets as well.[46] Many of the new firms may not survive, or demand for their services may not materialize, but the resultant competition should serve to increase innovation to meet perceived challenges. Regardless of the outcome, the industry should emerge healthier.

The USG should consider special procurement authorities or policy changes that provide efficiencies or assist in creating value for vendors. The government should work with the commercial sector to provide insight into routine and emerging space-based requirements, which will allow industry to plan and allocate resources appropriately. This could also include continually assessing areas disadvantaged for satellite services, which could serve as possible new points of entry for sustaining the industrial base. The goal of these activities—increasing commercial opportunities and ensuring the industrial base is competitive—allows the government to leverage the technology and capabilities derived from new investments and innovation.

Goal #4: Enhance International Cooperation *Expand international cooperation on mutually beneficial space activities to: broaden and extend the benefits of space; further the peaceful use of space; and enhance collection and partnership in sharing of space-derived information.*[47]

Introduction

The United States has made strides in furthering international cooperation among space-faring nations yet, there remain significant untapped opportunities for additional collaboration. The ISS symbolizes the epitome of international cooperation in space. Even as the U.S. and Russia are entangled in a stand-off over the Ukraine, Russian cosmonauts and American astronauts are still working together side by side today[48]. On March 27th, 2015, in the midst of strained relations between Moscow and Washington, two veteran astronauts, one Russian and one American, were launched into Space and will spend the next twelve months together on the ISS.[49] The ISS mission exemplifies the type of international cooperation that embodies the vision and goals of space exploration and discovery.

In key areas of debris monitoring, global navigation satellite systems (GNSS), scientific exploration, environmental monitoring and humanitarian assistance/disaster relief, there are varying degrees of positive international cooperation. In other areas, due primarily to competition, intellectual property rights and national security concerns, there is less cooperation than would be expected, even among traditional allies and coalition partners. Notwithstanding some challenges, recent changes in export control laws within the U.S. may provide an impetus for greater sharing of technology and cooperation.

Analysis

Debris Monitoring. The first piece of orbital debris was catalogued in 1967, when a piece of the rocket which launched Sputnik into space remained in orbit. Over the past 50 years, the number of manmade objects in orbit has dramatically increased.[50] One author commented, "The history of the growth of the planet's orbital debris population and the subsequent need to manage it is a classical tale of man's foray into a new frontier."[51] Among the 6,000 satellites launched into space, almost 4,000 remain in orbit, of which only 1,200 (or 30 percent) are still operational.[52] Moreover, many additional pieces of debris have been created with additional upper rocket stages, multiple vehicle carriers, tools, hardware, crewed vehicle refuse, and most notably fragmentation from other exploded rockets and spacecraft.[53] Since 2007 there has been a dramatic increase in the number of fragmentation debris articles in space due to China's intentional destruction of a weather satellite with an anti-satellite missile and the unintentional conjunction of an Iridium satellite with the inoperable Russian Cosmos 2251. These two events alone introduced over 5,000 pieces of debris.[54]

Currently, the U.S. tracks over 23,000 items, 10cm or larger, in orbit around the earth, but many more endanger our spacecraft.[55] The US Space Surveillance Network, led by the Joint Space Operations Center (JSpOC), is the world's leading space debris tracking system, and can only track objects larger than 10cm in LEO orbit and larger than 1m in GEO.[56] Many debris articles in orbit are too small to track. The Chinese ASAT incident alone created over 150,000 pieces of debris larger than 1cm but smaller than 10cm.[57] Scientists estimate the number of pieces of debris over 1mm exceeds 35 million[58]. Due to the speeds of objects in orbit, and the resulting kinetic energy, even very small objects such as these can cause catastrophic damage to satellites, spacecraft, and the ISS. A collision with an object as small as 3mm can "do more damage than a bowling ball traveling at 60 miles per hour."[59] Collision with debris will at best damage any spacecraft and at worst may destroy the spacecraft and create additional debris. A 2011 NASA study concluded that random collisions between spacecraft and orbital debris will cause an increased growth rate of orbital debris and spacecraft failure due to increased collisions with orbital debris.[60] This has the potential to create a spiraling effect of orbital debris, in which some experts predict catastrophic collisions every five to ten years creating ever more lethal debris and then increasing the rate of collisions geometrically.[61]

The first step in addressing orbital debris is improving our mitigation strategy. JSpOC does an admirable job of tracking orbital debris and notifying owner/operators of potential conjunctions, but their capability is limited. While our partners in space are beginning to invest in Space Situational Awareness (SSA); such as Germany's optical tracking of debris in GEO orbit and France's CNES Graves system, most still rely on the JSpOC's data as their core data source.

Among the possible mitigation steps; first, we must improve our ability to track orbital debris, and we cannot afford to do this alone. We must encourage our partners to invest in systems to track debris, or partner with us in investing in systems which can detect and track orbital smaller debris more accurately.

Second, we must continue to limit the debris in orbit through multilateral cooperation, to include exerting pressure on new space-faring nations which might be inclined to ignore current norms. International agreement on the responsibility to limit orbital debris and culpability for damage caused by orbital debris has developed, but is still limited.[62] Through the multinational agreements and code of conduct previously discussed we must seek to limit additional debris objects introduced into, or created in, orbit and increase the enforcement of agreements on damage caused by debris or inoperable spacecraft.

Finally, America must recognize that mitigation may not be sufficient to protect our systems on orbit; remediation may be required. If the theory of cascading, or spiraling, impacts is correct there is already enough debris in orbit to cause need for remediation and considering the various nations with spacecraft in orbit, this would be a superb apolitical project that could bring the best minds and the various resources of the international community to bear.

The U.S. is doing its part, but cannot do it alone. The U.S. owns the satellite catalog and provides tracking information via the Joint Space Operations Center (JSpOC) website www.space-track.org. Space-Track.org "promotes space flight safety, protection of the space environment and the peaceful use of space worldwide by sharing space situational awareness services and information with U.S. and international satellite owners/operators, academia and other entities."[63] Discussions with European space agency's clearly indicated reliance on the JSpOC for conjunction notifications and continued cataloging efforts. As orbits become increasingly populated and space situational awareness and debris removal come to the forefront, this is an area that pooling of foreign resources could augment U.S. capabilities. The aforementioned codes of conduct or international treaty may be a key enabling factor as SSA expands and more countries become involved with space operations.

<u>Earth Observation, Geospatial Information and Global Positioning Systems (GPS)</u>. One of the most promising avenues for expansion of international cooperation is in environmental monitoring, specifically in global climate change, solar activity/space weather, and humanitarian disaster relief and recovery. With the creation of the International Working Group on Satellite-based Emergency Mapping (IWG-SEM) in 2012, the latter is a manifestation of international cooperation to use space resources for the greater good. The working group, currently chaired by

a representative from the German Aerospace Center (DLR), is a voluntary group of thirty-nine non-profit organizations with the mission to:

> Establish best practices between operational satellite-based emergency mapping programs; stimulate communication and collaboration; support the definition of emergency mapping guidelines; strengthen the sharing of expertise and capacities and review relevant technical standards as well as protocols; work with the appropriate organizations to define professional standards for emergency mapping.[64]

The initial focus is on establishment of standards for rapid exchange of geospatial feeds in the event of an emergency, and to date, the organization has made significant progress. Events like the devastating Haiti earthquake and the tsunami and subsequent nuclear disaster in Japan showcased the potential and benefits of international cooperation for disaster relief and recovery. The events also highlighted the need for international formatting standards to better integrate information from multiple sources.

International cooperation in earth observation is also expanding with the advent of the Copernicus satellite constellation developed through the European Space Agency (ESA). ESA intends to make the data accessible to the public domain, which will create opportunities for global commercial use and advance sharing of information regarding climate change. The U.S. intends to "promote the adoption of policies internationally that facilitate full, open, and timely access to government environmental data," and the Copernicus system could be a means for the U.S. and international community to leverage ESA's investment.[65]

In addition to some of the positive dimensions of international cooperation in debris tracking and earth observation, the U.S. has also taken the lead in sharing GPS signals with the world. On point, the NSP specifically states "the U.S. shall provide continuous worldwide access, for peaceful civil uses, to the Global Positioning System (GPS) and its government-provided augmentations, free of direct user charges."[66] Provision of GPS and debris tracking that the U.S. government does alone are great examples of U.S. leadership in the space domain. There are many other opportunities for the sharing of ideas, resources and technology that the international community is only starting to embrace.

Despite progress in international cooperation there are many areas where there remains room for improvement. For example, despite the U.S., France, Germany and the United Kingdom fighting together in various coalitions, whether in Syria or Afghanistan or in earlier days in Iraq, each nation is fixated on its own national security satellites. Might there not be an opportunity to develop some capability in intelligence satellites for NATO? Furthermore, although NASA and ESA have both worked together well in the past, they are both looking today at the ongoing travel to and exploration of Mars as the next major accomplishment. Despite past problems between the U.S. and ESA concerning Mars exploration, is there a good reason why both agencies cannot couple their efforts again? Also, as we look towards researching better capabilities for space weather forecasts; are the best minds from Europe, the U.S. and Asia working together to solve global problems? Regrettably, the answer is likely 'no'.

<u>Export Controls</u>. Export controls can be a significant barrier to international cooperation. The Departments of Commerce and State regulate and authorize transactions in an effort to balance national security and economic objectives.[67] Proponents of tighter controls are concerned about

national security risks, citing that "access to U.S. technology shortens research and development cycles and reduces risks" for competitors and potential adversaries.[68] However, transparency and information sharing are central tenets to international cooperation in many areas of interests, especially in basic research, science and space exploration. In order to advance science, and provide greater access to the space global commons, the U.S. needs to adopt a more straight-forward approach with a single point of entry for licensing requirements. Reforms will not remove licensing requirements but, simplification of the process will not only benefit the U.S. satellite industry, but also may go a long way to making it easier for the academic communities to participate in space-related fields. Universities have shied away from space science due to challenges (both real and perceived) with ITAR.[69] A senior official from University and Government Relations for the Universities Space Research Association claims that ITAR has "had a chilling effect on research and education in space-related fields."[70] He adds, "Universities have actually dumbed down their classes so as not to violate a ban on 'deemed exports' or the export of knowledge or information not in the public domain."[71] Universities interact with foreign nationals (students/professors), and sharing research information would most likely be subject to export controls.[72] Additionally, "regulations have [hindered] the ability to launch U.S. educational payloads on international launch vehicles because foreign counterparts do not want to deal with ITAR."[73]

A 2012 Commerce report contends that the existing regime impeded "U.S .ability to work with partners and [put] U.S. manufacturers at a disadvantage…providing no noticeable benefit to National Security."[74] In other words, given existing multilateral agreements, tight export controls "undermine International Cooperation in space by failing to adequately distinguish between allies and adversaries in its application."[75] Recent changes, easing licensing requirements for thirty-six countries that are members of NATO or members of all four of the multilateral export control agreements puts export control of the space industry more in line with National Policy. [76] Reforms could open up doors for more universities to participate in space-related research, foster more international collaboration in science fields and establish easier pathways to launch. This reprioritization would enable a more efficient management of export control policy, thereby focusing resources and effort only on the most sensitive exports to the most sensitive countries.

Conclusion

The U.S. and the international community continue to make progress in advancing the goal of international cooperation in the fields of science, space exploration, debris monitoring and environmental monitoring. With shrinking budgets for space science and technology it is perhaps more important now, than ever, for like-minded international space-faring nations to come together as much as possible to work collectively, especially in the areas of scientific discovery and exploration, on matters of global interest. Moving forward, in order to eliminate barriers for further international cooperation, the U.S. needs to continue export control reform, and most importantly, as discussed above, the space-faring community needs to reach agreement on a clear legal framework that addresses the most sensitive and potentially non-peaceful uses of space, while simultaneously building confidence in the transparency and the responsible use of space by the major actors.

Goal #5: *Pursue Human and Robotic Initiatives* *Pursue human and robotic initiatives to develop innovative technologies, foster new industries, strengthen* *international partnerships, inspire our Nation and the world, increase humanity's understanding of the Earth, enhance scientific discovery, and explore our solar system and the universe beyond.*[77]

Introduction

Over the past year, NASA continued to lead American efforts in space exploration, international cooperation, and human and robotic initiatives. In January 2014, the United States announced a four year extension to its participation in the International Space Station to 2024.[78] Also, in March 2015, continuing its joint operations of the ISS, both Russia and the United States launched a two-man crew to spend an entire year on the station.[79] In addition to these commitments, NASA also accomplished several milestones in its Orion/Space Launch System (SLS) program. Notwithstanding these positive developments, NASA and the federal government at large, must continue to explore unique and innovative efforts, and develop a strategy to inspire the nation for further support for the important civil space mission.

Analysis

The Future of NASA's Human and Robotic Space Initiatives. Since the beginning of the space program, the United States has been inconsistent in how it prioritizes NASA space initiatives in terms of the national public agenda and federal funding. This has resulted in cycles of feast and famine as other national priorities have pushed space further into the background of the national consciousness.

The greatest era of national space priority began in the Kennedy administration and ended in the Nixon Administration. During this span, the government resourced three complementary initiatives that began with the Mercury program[80] to make spaceflight safe for humans. This was followed by the Gemini program to refine space flight techniques, spacewalks, and docking procedures.[81] This period concluded with the Apollo program's successful moon landings that began in 1969 and ended in 1972 with the 14th and final moonwalk.

During the same era, NASA also complemented the manned space program with three robotic programs to prepare for the moon landings. The Ranger and Lunar Observer missions successfully provided close imagery and mapping of the moon which allowed NASA to pick the site for the moon landing.[82] The NASA Surveyor missions successfully demonstrated soft landings on the moon and helped define propulsion requirements for the Apollo Lunar Module.[83]

During the 1960s, President Kennedy focused the nation on landing a man on the moon and spending reached its peak in 1966 at over 4.4%[84] of the entire federal budget. Since 1974, spending has only surpassed 1% of the federal budget three times.[85] The last time more than 1% was committed to the space program was under President Clinton over twenty years ago.[86] For the past five years, NASA's budget has hovered around 0.5% of the federal budget, which is the lowest it has been since the Eisenhower administration.

The human exploration of Mars represents the next major leap ahead in scientific achievement and represents an opportunity for humanity to become what NASA Director Charles Bolden calls a, "multi-planet species[87]." In order for NASA to maintain steady progress toward this technological achievement, the United States public needs to share in a vision comparable to what President Kennedy defined in his pursuit of the moon, as the opening statement to this report illuminated. Through dedicating public attention and public resources toward this end, the entire planet stands to benefit from leaps in technology and increased understanding of the universe around us.

NASA is a member of the International Space Exploration Coordination Group (ISECG). Members include the space agencies of Canada, China, Europe, France, Germany, India, Japan, Korea, Russia, Ukraine, and the United Kingdom. The ISECG has published a roadmap to explore Mars which includes: continued support for the ISS; an asteroid landing and re-direction; moon landings and basing; manned Mars orbit; possible Mars moon landing; and human Mars landing. In addition to pursuing the exploration of Mars, continued participation in the ISECG may also provide a template for international cooperation that is even more beneficial than the technical achievement.

The NASA Orion/SLS is one of the major projects currently under development by NASA with industry partners Boeing, Lockheed Martin, and Orbital ATK. The SLS, when completed, "will be the world's most powerful rocket" and will support NASA exploration of Mars and even further into deep space.[88] According to NASA, the $7 billion SLS program is on track for a planned 2018 launch readiness date.[89] The successful tests of the Orion spacecraft in December 2014 atop Delta IV Heavy as well as the completed test firing of the SLS system booster in March 2015 are positive signs of NASA's progress toward achieving the agency's vision.

In the realm of robotic innovation, the NASA Goddard Space Center is researching possibilities to extend a satellite operational life through on-station servicing and refueling. Presently, a major limiting factor in the life of a satellite is fuel capacity to support maneuvering. While electronic propulsion will mitigate this operational constraint in the future, NASA is working develop and demonstrate the capability to use a robotic servicing satellite to transfer fuel or even repair a satellite while in orbit.[90] For national security agencies, one major concern with this technology, though, is the rendezvous and proximity operations (RPO) associated with satellite servicing, which could be perceived to or ultimately used for hostile purposes in space; further highlighting a challenge for enhanced space situational awareness.

This concern aside, NASA's developments in both robotics and the SLS represent positive movements to maintain United States' leadership in space and can serve as a launching point to bring back the mystique and allure of the space industry and re-invigorate the American public's interest in space.

Inspire the Nation. In the absence of a new Sputnik type event that drives the nation to a space race, government, civil, and commercial space entities need to increase efforts to boost the fascination with and attractiveness of the space industry. Current projects such as Osiris-Rex and aspirations to travel to Mars must be the focus of an enduring information campaign to rejuvenate popularity and notoriety of the space industry. The unprecedented entrepreneurial endeavors of companies such as SpaceX, Stratolaunch, and Virgin Galactic are other examples of the new direction and future importance of the space industry. Strategic messaging should demonstrate that the U.S. still maintains a robust program despite the cancellation of the Space Shuttle and Constellation programs. The campaign must target university campuses and academia to build fervor in the programs and entice the nation's next generation of scientists and engineers to join the workforce. Many of these ventures are in their infancy however outside the space enthusiast realm, little is known of them but they must become household words.

Aside from strategic messaging, creating stability in the industry is also key. The economic downturn of the late 2000s followed by budget cuts and sequestration in the 2010s, changed the shape of the defense industry and significantly impacted the volume of federal resources attributed to research and development (R&D). The result was these fields became less attractive to the future workforce. At the same time, entrepreneurs and non-STEM firms in the commercial sector who compete for new entrants to the workforce offered a far more enticing opportunity than government service.

The U.S. must resolve ongoing budget issues in order to provide the space industry at large a better vision of future resource allocation. This will allow associated space entities to better plan for the future. It will also reduce uncertainty and contribute directly to increased stability, thereby reducing the severity of budget to budget fluctuations. With stability, individuals are more likely to perceive future job security and satisfaction by working in the space industry and in turn, will help redirect and retain STEM graduates in the workforce.

Finally, with the shift in technological development toward the commercial side, more emphasis needs to be levied on the government sponsored entities that bridge the gap between commercially developed technology and government. Specifically, the University Affiliated Research Centers (UARC) and Federally Funded Research and Development Centers (FFRDC) should be expanded and continued revenue streams guaranteed. This would serve two purposes. First, it would create additional opportunities for STEM employment and guarantee that as R&D migrates to the commercial side, the U.S. government retains capacity to conduct and apply research and the ability to rapidly react to emerging requirements. Second, the UARC's and FFRDC's close relationship with academia enable them to influence and recruit STEM graduates into the defense workforce. This would help to ensure a future stream of qualified workers in the primary defense R&D organizations. Many of these entities carry little depth of talent and expanding their enterprises would help mitigate the risk of future STEM worker shortages. As the commercial sector assumes an increasing role in R&D, the U.S. government should consider measures that mitigate its decrease in direct influence, to include expanding its research centers.

<u>The Future of "Public Space Travel"</u>. Within the commercial sector, space tourism has developed as a way to place space into the reach of the public. In 2006, a Government Accountability Office (GAO) report indicated that at a price point of $200,000 per passenger, orbital and suborbital flights could draw approximately 15,000 passengers a year and generate over $1 billion in revenue by 2021[91]. Experts have also concluded that the number of space tourists could skyrocket to 10 million passengers annually if ticket prices dropped to $5,000[92]. Today, at least nine global corporations are working feverishly to advance public space transportation and the reliability of reusable launch vehicles (RLV). Companies such as XCOR Aerospace, Armadillo Aerospace, SpaceX and Virgin Galactic (VG) may all ultimately support space tourism.

In October 2014, VG experienced a spectacular crash resulting in one fatality; however, it remains undeterred and is pressing forward on the development of a second spacecraft. Despite several recent mishaps and rocket failures, SpaceX and VG continue pursuit of their ultimate ambition to allow customers to experience weightlessness, see Earth from afar, and eventually take extended excursions into space.

Beyond space tourism, SpaceX and VG efforts can potentially improve traditional transport by leveraging space to significantly reduce travel time using the Earth's orbit. For example, a trip by air between Los Angeles and Cairo that now takes about 16 hours, would take about 2 hours. In line with this, VG seeks to be the "1st Space Line" and "democratize space access."

Efforts by companies like XCOR and VG harken back to the early days of aerospace where passion for experimentation drove innovation and progress. Even while pursuing their own space vision, small private firms like XCOR are developing leading-edge technology which ultimately advances the entire space industry. The United States must continue policies and efforts to shepherd and sustain this segment of the space industry.

Conclusion

Continued leadership in space requires an inspiring vision. The American public must become invested and interested in United States' space exploration and missions. The Orion/ SLS program's goals of an asteroid landing and manned flight to Mars may re-invigorate the nation. However, just as important, the government should maintain a regulatory environment that fosters efforts to democratize space for the masses. Although large firms like Boeing and Lockheed Martin dominate the space market, a small spaceport in California or Texas may serve as the launching point for America's vision in space.

Goal #6: Improve Space-based Earth and Solar Observation *Improve space-based Earth and solar observation capabilities needed to conduct science, forecast terrestrial and near-Earth space weather, monitor climate and global change, manage natural resources, and support disaster response and recovery.*[93]

Introduction

Satellite remote sensor technology affords scientists, government officials and policy makers with the tools to acquire information about the Earth's surface and atmosphere. To date, insufficient attention and resources have been allocated towards advancing this key technology to maximize the transfer of critical climate and natural resource information. It is fascinating to see what scientific information about Earth's climate, resources, weather, population trends, and irrigation can be tracked by satellite. Space-based Earth observation could very well be the future of the climate change battle. Europe has been on the climate change fast-track for more than 20 years, as evidenced this year by the French space agency, CNES, focusing on climate change policy.[94] In the United States, climate change awareness has been slower in implementation fueled, in part, by long standing biases. Fifty percent of Americans either do not believe in global warming or don't believe that it's caused by human activity.[95] As other nations lead the charge on global warming mitigation, the U.S. must take steps to strengthen the remote sensing space sector and its contribution to the global monitoring of climate change and natural resources.

Analysis

Addressing Climate Change in US National Security. The 2015 NSS lists "Confront Climate Change"[96] as a primary security goal. The NSS states, "Climate change is an urgent and growing threat to our national security, contributing to increased national disasters, refugee flows, and conflicts over basic resources like food and water."[97] Notwithstanding that acknowledgement the impetus for the development of a cohesive U.S. strategy aimed toward addressing climate change in the context of national security has been elusive. Insufficient attention is given to research, development and operations of systems that could better address the negative impact of climate change.

Unfortunately, documents that flow from the NSS discuss climate change and national security only from the present and fail to look sufficiently into the future. The National Military Strategy: 2011-Redefining America's Military Leadership makes a single mention of climate change: "Climate change combined with increased population centers in or near coastal environments may challenge the ability of weak or developing states to respond to natural disasters."[98] Arguably, the U.S.'s capability in space technology to monitor weather and population is not a problem of responding to natural disasters *when* they occur but, about planning to mitigate them *before* they occur in an effort to prevent instability and natural disasters.

The 2011 Quadrennial Defense Review has a great deal to say about the potential impacts of climate change as a challenge to defense. This document, too, does not speak of prevention or mitigation, but of reaction: “The pressures caused by climate change will influence resource competition while placing additional burdens on economies, societies, and governance institutions…” and “will aggravate stressors abroad such as poverty, environmental degradation, political instability and social tensions…”[99] Sustaining U.S. Global Leadership, Priorities for 21st Century Defense never mentions global warming or climate change.[100] An interesting question would be how the U.S. intends to sustain global leadership without being a force for change in the dynamics of climate change as it relates to space technology.

The 2013 Space Report defines “national security space assets”[101] as those that provide “tactical and strategic intelligence services, navigation data and precision guidance for munitions, secure communications, and monitoring of foreign weapons testing and missile launches.”[102] National security space assets are decidedly military-focused, as though US national security is tied only to protection today without a view to securing a more peaceful future. Oddly, despite the NSS’ declaration of climate change as a national security problem, the 2011 U.S. National Security Space Strategy does not address global warming or climate change.[103] The use of space technology to advance Earth sciences and mitigate climate change impacts globally lags behind other areas of space policy.

National Security Impacts of Natural Resources. America is in a particularly good position to understand the national security impact of the global demand for resources. Energy demand and oil in particular, have been a significant factor in national security decision making. The Carter Doctrine declared preserving the supply of oil as vital to U.S. interests[104] and in the eyes of many, conflicts have started due to the need to preserve that supply. Many expect that water will replace oil as the more critical natural resource in the coming years. It is not unreasonable to presume that future conflicts could emerge to preserve the supply of clean water. Because satellite technology can allow us to monitor and quantify natural resources globally, thereby aiding in predictive planning and thoughtful mitigation strategies, it is imperative that we employ space technology and current space assets to better monitor natural resources on Earth.

Satellite imagery is critical in helping scientists determine what, and when, steps can be taken to prepare for, curtail or mitigate drought, flooding, and catastrophic weather, giving time to discover solutions before significant changes in climate impact solution options. A lack of popular awareness and education, partisan politics and a low ranking in resourcing priority concerning climate change in the U.S., is curtailing the contribution America can make to the knowledge, understanding and technology of this global problem.

U.S. Progress on Earth Observation Sensors in Support of Climate Change Monitoring. According to the National Research Council (NRC), “the nation’s Earth observing capability from space is beginning to wane”[105] and by 2020, the number of Earth observing instruments in orbit may be as little as 25% of what it is today, the NRC says. This decline will require “investment and careful stewardship of the U.S. Earth observations enterprise.”[106]

The importance of space based Earth and solar observation spreads into multiple arenas necessary for U.S. national security, disaster mitigation and recovery and the protection and preservation of natural resources critical to human life which climate change imperils. These key areas can be binned into three basic sections: security, preservation, and science. The United States’ reliance on security of space based systems for priority intelligence collection and direct support to military planning and operations makes having a robust Earth observations system not only a priority, but a necessity. In the preservation arena, innovation and ingenuity have caused an increased demand for space-based systems that provide details on sustainable agriculture and land use, ecological uses for water systems and wildlife management, and observation systems that monitor and manage energy resources. Lastly, in the science realm, and thanks to the United Nations, increased focus and global cooperation have made launching weather forecasting systems and climate change systems to monitor atmospheric, oceanic, terrestrial, and solar space based monitoring programs a global priority.

Conclusion

To meet the U.S. Space Policy's sixth goal of improving space-based Earth and solar observation, the U.S. must endeavor to preserve program spending, while simultaneously leveraging international cooperation options, in this time of austerity. This must include an expansion of capabilities required for science, forecasting Earth and space weather, as well as tracking vicissitudes on Earth, supporting disaster response and recovery and better managing U.S. natural resources. The U.S. must cooperate internationally to treat climate as a global common, monitoring climate change, water, and food sources.

As the fleet of U.S. earth observation satellites ages and new technology in the forms of advanced sensors become available, the U.S. must make an effort to rejuvenate and perform a 'tech-refresh' on the constellation. In order to improve global Earth monitoring and remote sensing capabilities, the community and corresponding space industry must commit to space exploration as critical to the future of U.S. national security and standard of living.

FINAL THOUGHTS

Inspired by President Kennedy's vision and built on the shoulders of three generations of American space scientists, engineers, and astronauts, the U.S. continues to sustain the world's leading space industry, competitively and innovatively. In order to maintain U.S. leadership in space, America must take steps to lead the promotion of international standards of conduct in space, to enhance resilience, to further cultivate international cooperation, and to generate public enthusiasm about the space domain and the endless possibilities it represents.

Responsible conduct by space-faring nations is paramount to the preservation of the space domain. Despite its vastness, space is a fragile and vulnerable domain. Unlike our land, oceans and airspace, space is a challenging domain to reach and an even more challenging domain to sanitize once it has been polluted. Recent events have unequivocally threatened the space domain's peaceful character, and the U.S. should respond with one voice or risk diffusing U.S. credibility and intent. With other space-faring nations' intending to asymmetrically attack U.S. interests through space, the U.S. government must prepare the military, civil, and commercial space sectors to operate in a warfighting domain.

Almost every goal of the NSP is directly linked to responsible behavior in space. Space stability, resilience, international cooperation, inspiring the world to innovate, as well as improving space global monitoring to understand environmental and energy concerns, are all furthered by the responsible conduct of space-faring nations. The environment within which the U.S. and the broader international space community were built continues to evolve. With the inevitable tide of change, powered by competing interests, U.S. strategic leaders must critically examine and refocus past practices in light of present events to secure our own national security interests. This review of U.S. space policy, the global security space enterprise, and the world's space industry, highlight several conclusions. Our observations and ultimate recommendations cover a gamut of topics: international standards of conduct, investment in space resiliency measures, international unity of effort, contracting and resourcing reform, continued orbital debris tracking, improvement of climate change monitoring, incentivizing innovation in robotics, and inspiring the next generation of Americans to dream of space.

This report acknowledges the complexity of executing many of the recommendations discussed and the tension that exists in pursuing goals that may, in part, appear in conflict. In particular, there is a natural tension between measures that enhance resilience in space and measures aimed at simultaneously removing barriers to international cooperation. Furthermore, this report acknowledges the difficulty in finding balance between short term national security concerns and long term global objectives. The same standards of conduct or treaty obligations that likely enhance global preservation of the space domain, applied to every space-faring nation, may also constrain, however slightly, the flexibility in the way we operate in space. The complexity and difficulty of these ambitions, however, along with the political and financial capital that the U.S. will ultimately spend in their pursuit, will be worthwhile if they enhance our ability to protect our national interests.

Standards of Conduct. An international code of conduct, followed by a long range commitment towards a sensible international law framework, in the form of a treaty, furthers U.S. and global equities in the space domain for generations to come. This difficult step will not be easy to achieve given the different global interests involved, the distrust between key nations and the desire within each country to maintain maximum flexibility of action for the future. Nonetheless, despite short terms concerns to establish clear standards of conduct in space, this effort serves to preserve this critical domain for all of mankind for generations to come. We simply cannot afford to follow others in the irresponsible use of this fragile domain.

Space Resilience. The U.S. must defend against attacks, disruptions, and deceptions of space-based assets and space-acquired information. Creation of space protection plans, relying on layered defense, and use of small satellites to disaggregate and distribute capabilities increases resiliency of the NSS architecture and military-related portions of the commercial system.

Incentivize the industry. The United States must focus and energize industry, with one voice. Expanding export control law reform and allowing the use of multi-year contracts will bolster the U.S. space industry's competitiveness despite dwindling defense budgets. Streamlining NSS certification, within acceptable risk levels, will increase competition and further reduce launch costs. Investment in space exploration, robotics, and space tourism will open new markets.

Innovation and Remote Sensing. Through technological creativity, the U.S. simplifies space's complexity and breadth, packaging the commodity into a running watch, a cell phone, or a weather chart. Continued investment in U.S. military, civil, and commercial endeavors will promote innovation and inspire future generations to unravel the mysteries and benefits of space, while improving our ability to monitor and preserve the planet.

International Cooperation. Globally, the United States must continue to lead and leverage the extensive space enterprise for the public good. Current events refocused the world's attention to the growing concern of orbital debris. As the world's leading space surveillance nation, the U.S. must continue to deliver tracking data and conjunction notifications to the world, as well as remote sensing data to support humanitarian relief efforts and combating climate change. International cooperation ultimately represents mankind's best opportunity to pool our collective resources, intellect and technology to not only explore our solar system and the universe but, to also unravel the next scientific breakthrough that will transform life on Earth. This is a goal we can never abandon.

APPENDIX A: SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Develop U.S. Unified Policy on Space as a Warfare Domain. U.S. space policy leaders within the NSC, DoD, NASA and other federal agencies must reach consensus on the direction of space governance and legal norms that address space as a warfare domain. The U.S. must convey deterrence**,** communicating U.S. intent to meet attacks on U.S. space systems with an immediate and overwhelming response, not necessarily in the same domain as the attack. These principles should form the basis for a future U.S. Space Policy.

Support an International Code of Conduct. A commitment by the U.S. to some formal framework of international space conduct is a natural outcome of the changing worldwide strategic environment from bipolar to multipolar and the proliferation of space-based assets into the hands of many nations. The U.S. should seek to establish a positive definition of title or sovereignty that includes the concepts of orbital position sovereignty based on physical occupation of a place in orbit around the Earth or other celestial body, a reasonable physical safety zone around that space asset, and the right of way for sovereign space assets which prohibits other nations from physically, electronically, or otherwise interfering with its operation.

Champion a Modernized Outer Space Treaty. Armed with a unified policy on space governance, the U.S. must lead discussions and negotiations with the EU, China, Russia and other key players within the space community in order to openly discuss a modification to the Outer Space Treaty which acknowledges current capabilities and clearly prohibits specific activity that is harmful to mankind's assured use of space in the future.

Develop "Defense in Depth" Resiliency Plans. Require each owning Service to conduct an individualized Defense in Depth analysis of each identified mission-critical asset while developing and coordinating Space Protection action plans with each stakeholder. Mapping of key tactical stakeholders dependent on each mission-critical space asset will ease coordinating the plans to ensure resiliency implementation efforts do not reduce warfighter availability. Additionally, the mapping would support a functional/risk analysis to determine the amount of eligible space data traffic from each Service which could transit at an appropriate level of risk across commercial communication satellites.

Assign a Global Synchronizer for Space. The divergent roles of the Defense Information Systems Agency (DISA), National Reconnaissance Office, and the Air Force's SMC diffuse USG strategic voice to the space industry and international governments. In line with Joint Publication 1, Para 3.11.d, designating one of these entities as the global synchronizer for managing space assets maximizes efficiency and provides a single focal point for the space industrial base and international community to engage.

Expand Export Control Reform Initiatives. Establish electronic venue for single point of entry for export licensing with integrated decision trees to clarify the routing (ITAR vs. CCL); pursue in-depth reviews on exception basis (by technology and country); and establish clear reportable metrics for license processing and approval.

Expand Multi-National Partners in Limiting Orbital Debris. With an increasing risk of conjunctions from increased participation in space, space-faring nations must agree on standards to limit orbital debris. The U.S. cooperative agreement with the Australians acts as a starting point to build broader consensus.

Create a Separate Budget Category for Space. Establish space as a Major Force Program in the budget to centralize funding for space efforts.

Assign Space Protection as a Mission Area in JP 3-14. Detailing Space Protection in Joint Publication 3-14 ensures unity of effort across the entire interagency.

Pursue the Utility of Small Satellites. Continue the investment in DARPA and UARCS to investigate the use of small satellites or constellations of satellites in order to create redundancy and resilience in our space architecture.

Partner with Industry to Design Interoperable Satellite Architectures. DoD should partner with industry to design interoperable satellite architectures focused on resiliency and cost efficiency. Leveraging already proven commercial solutions, the hosted payload concept could improve Space Protection and lead to significant cost savings for military space functions. Focused dialogue with industry on emerging requirements, interoperability and hosted payload trade-offs will allow the DoD to determine the right mix of commercial and military satellites to carry warfighter payloads.

Expand Space Surveillance Awareness to Assure Attribution. The U.S.' Space Surveillance Awareness (SSA) capabilities to track and catalog over 22,000 space objects are unrivaled. However, micro-satellite technology may make precise space object cataloguing difficult in the future if nations employ deceptive techniques to mask the deployment of a co-orbital space weapon system. Also, if a space code of conduct or space treaty is established, adjudication of space sovereignty claims will require undisputable accurate evidence of satellite locations. Investment in improved SSA and Earth remote sensing is a necessary requirement for deterrence.

Reform Contracting and Funding Procedures. Coupling a possible O&M waiver with the use of multi-year procurement would create a hospitable environment for the development of innovative procurement mechanisms. These mechanisms would provide financial predictability, allowing industry to make long-term investments in technology and capacity, fostering innovation and, consequently satisfying future DOD space requirements. Additionally, the USAF needs to work with the private sector to increase flexibility in the NSS sector, including simplifying certification to enable significant cost savings and improved capabilities for the government—an important win in the days of tight budgets. Improved access to the NSS sector would bolster the competitive position of U.S. launch firms.

Establish a Single Regulator for Satellite Manufacturers. Split jurisdiction can cause miscommunication and licensing issues. Even though licenses are not typically denied, the process can be confusing and prohibitively cumbersome.

Improve Orbital Debris Tracking. The U.S. Space Surveillance can only track objects larger than 10cm in LEO orbit and larger than 1m in GEO[107]; however the Chinese ASAT incident alone created over 150,000 pieces of debris larger than 1cm but smaller than 10cm.[108] With satellites decreasing in size and increasing in complexity, conjunctions with smaller debris will be more hazardous.

Create Public-Private Partnerships for Space Protection and Space Exploration. Visited companies provided creative solutions to increase Space Protection throughout the USG space architecture. Public-private partnerships (PPP,) will provide resources to study and develop current solutions while inspiring future potential solutions. Likewise, PPPs on deep-space exploration will spread research and development costs across all agencies likely to benefit.

Continue Investment in Space Exploration and Robotics. USG involvement in the growing space robotics industry will ensure results complement existing NSS capabilities within policy guidelines rather than compete against them. USG involvement in Space Exploration will drive development along desired paths rather than retrace old ones.

Create a Commercial Space Administration for Space Tourism. Work through the White House Office of Science and Technology Policy (OSTP), the National Security Council (NSC), and Congress, to consolidate all functions/oversight of public space travel under one organization, thereby eliminating the current fragmented construct. Using the International Civil Aviation Organization to initiate, the Commercial Space Administration should develop and adopt a multinational treaty to define globally accepted regulations.

Expand the Space Tourism Policy. As a growing market sector, the National Space Transportation Policy should clearly articulate U.S. commitment to safe and secure space tourism. With companies nearing launch capability within a couple of years, industry deserves to fully understand accredited safety, environmental and quality assurance standards

Heighten STEM Enthusiasm. Given individual choices affect the space industry STEM workforce; solutions must focus on increasing national appeal while providing companies measures of predictability and stability in resource allocation. This should serve to revitalize interest in space careers while satisfying STEM graduate needs for future opportunity and job security. At the same time, continue federal and civilian programs aimed at promoting STEM education and diversification of the workforce.

Increase Climate Change Remote Sensing. Increasing climate change remote sensing capabilities in capacity and periodicity ensures reliable data collection on key U.N. environmental variables. Maximize international cooperation to fill the gaps and share data on areas pertinent to the global common of life-sustaining resources.

Sustain Funding of University Affiliated Research Centers. University Affiliated Research Centers and Federally Funded Research and Development Centers are critical to the development of Advanced Sensors to maintain the U.S. technological edge in Space Observation and Space Protection. Additionally, expansion of UARCs' and FFRDCs' influence and recruit STEM graduates into the space industry workforce.

Appendix B:
TABLE OF RECOMMENDATIONS

Goal 1: International Standards of Conduct
Goal 2: Increase Mission Assurance and Resilience of Mission-Essential Functions
Goal 3: Energize Competitive Domestic Industries
Goal 4: Enhance International Cooperation
Goal 5: Pursue Human and Robotic Initiatives
Goal 6: Improve Space-based Earth and Solar Observation

Recommendation Short Title	*G1*	*G2*	*G3*	*G4*	*G5*	*G6*
Develop U.S. Unified Policy on Space as a Warfare Domain	X	X	x		x	
Support an International Code of Conduct	X	x		X		
Champion a Modernized Outer Space Treaty	X	x		X	x	
Develop "Defense in Depth" Resiliency Plans		X	x		x	
Assign a Global Synchronizer for Space	x	X	X	x	x	x
Expand Export Control Reform Initiatives			X	X		x
Expand Multi-National Partners in Limiting Orbital Debris	X	x	x	X	x	
Create a Separate Budget Category for Space		x	x		X	X
Assign Space Protection as a Mission Area in JP 3-14	x	X	x		x	
Pursue the Utility of Small Satellites		X	X		x	x
Partner with Industry to Design Interoperable Satellite Architectures		X	X		x	x
Invest in High Throughput Satellite Technology		X	x		x	x
Expand Space Surveillance Awareness to Assure Attribution	X	x	x	x		x
Revise Regulatory Environment for Launch and Space Transportation Services		x	X	x	x	
Reform Contracting and Funding Procedures		x	X	x		x
Establish a Single Regulator for Satellite Manufacturers			X		x	
Improve Orbital Debris Tracking	X	x	x	X	x	
Create Public-Private Partnerships for Space Protection and Space Exploration	x	x	X		X	
Continue Investment in Space Exploration and Robotics			x	x	X	
Create Commercial Space Administration for Space Tourism			x	x	X	
Expand the Space Tourism Policy	x		x	x	X	
Heighten STEM Enthusiasm		X	x		X	x
Increase Climate Change Remote Sensing				x		X
Sustain Funding of University Affiliated Research Centers		x	x		X	x

Note: 'X' denotes primary goal, 'x' denotes secondary goal

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