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ABSTRACT: Each president since Truman has issued various space directives, adding his mark on the space programs and policies that have helped shape modern American society. A new president will be elected in November 2016, who will inherit responsibility to shape a new U.S. space policy. What aspects of the current National Space Policy still hold true? What aspects need to be updated based on evolving technologies and strategic conditions? This paper will endeavor to answer these questions through an examination of the space enterprise, an assessment of current conditions in the space industry, and recommendations for the next President of the United States. These recommendations focus on four key issues: resiliency, assured access to space, international cooperation, and *Space 2.0*.

Mr. Kevin Ayers, National Geospatial-Intelligence Agency
COL Scott Beall, U.S. Army
Lt Col Jonathan Creer, U.S. Air Force
Lt Col Kevin Duffy, U.S. Marine Corps
Mr. Peter Hemsch, Department of State
Mr. William Hensley, Department of Defense
Ms. Suzanne Inzerillo, Department of State
Ms. Margaret MacCallum, Department of State
Lt Col Brian Oneill, U.S. Air Force
Mr. Jay Phipps, Defense Intelligence Agency
Lt Col Thomas Preston, U.S. Air Force
Lt Col Stephen Pritchard, U.S. Marine Corps
COL David Slivka, U.S. Army
CDR Brent Tornga, U.S. Navy
COL Theodore White, U.S. Army
Ms. Laura Williams, Defense Information Systems Agency

Dr. Clark Groves, Faculty Lead
Col Bryan Haderlie, U.S. Air Force, Faculty
Ms. Susan Kinney-Perkins, Faculty

Industry Study Outreach and Field Studies

On Campus Presenters:
Smithsonian National Air and Space Museum
Office of the Director of National Intelligence
National Aeronautics and Space Administration (NASA)
George Washington University, Department of Law/Space Law
Satellite Industry Association
Department of Commerce, Bureau of Industry and Security
United Launch Alliance
National Oceanic and Atmospheric Administration (NOAA)
Department of Commerce, Space Trade Office
Japanese Space Agency
Heritage Foundation, China Space Policy
Arianespace
European Space Agency
German Space Agency

Field Studies - Domestic:
Executive Office of the President, Office for Space Policy, Washington, DC
Department of the Air Force, Office of Space Policy, Pentagon
Office of the Under Secretary of Defense for Space Policy, Pentagon
Orbital ATK, Sterling, Virginia
Intelsat, Tysons Corner, Virginia
Iridium Satellite, Tysons Corner, Virginia
Air Force Space Command, Peterson Air Force Base, Colorado
Space and Missile Defense Command, ARSTRAT, Peterson Air Force Base, Colorado
50th Space Wing, Schriever Air Force Base, Colorado
Joint Interagency Combined Space Operations Center, Schriever Air Force Base, Colorado
Space Aggressor Squadron, Schriever Air Force Base, Colorado
Ball Aerospace, Boulder, Colorado
DigitalGlobe, Longmont, Colorado
NASA Goddard Space Flight Center, Greenbelt, Maryland
Wallops Flight Facility, Wallops Island, Virginia
Northrup Grumman Company, Odenton, Maryland
SIRIUS XM Radio, Washington, DC
ICBM Program Office, Hill Air Force Base, Utah
Orbital ATK Launch Systems, Magna, Utah
Orbital ATK Aerospace Structures, Clearfield, Utah
Space Dynamics Lab, Utah State University, Logan, Utah
L-3 Communications Systems, Salt Lake City, Utah
National Geospatial-Intelligence Agency, Springfield, Virginia
U.S. Naval Observatory, Washington, DC
Aerospace Data Facility-East, National Reconnaissance Office, Ft. Belvoir, Virginia
Space Systems Loral, Palo Alto, California
Terra Bella, Mountain View, California

Lockheed-Martin Space Systems, Sunnyvale, California
30th Space Wing, Vandenberg Air Force Base, California
Missile Defense Agency, Vandenberg Air Force Base, California
SpaceX Launch, Vandenberg Air Force Base, California
ULA Launch, Vandenberg Air Force Base, California
The Spaceship Company, Mojave Spaceport, California
XCOR, Mojave Spaceport, California
Masten, Mojave Spaceport, California
Aerojet Rocketdyne, Canoga Park, California
Boeing Space, El Segundo, California
SpaceX, Hawthorne, California
RAND Corporation, Santa Monica, California

Field Studies - International:
Airbus Defence and Space, Toulouse, France
CNES, Toulouse, France
Cite de l’Espace, Toulouse, France
Elta-Space, Toulouse, France
Surrey Satellite Technology, Ltd., Guildford,
UK Reaction Engines, Oxfordshire, UK
UK Space Agency, Oxfordshire, UK
European Space Agency, Oxfordshire, UK
Airbus Defence and Space, Stevenage, UK
AON International Space Brokers, London, UK

"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and reality of tomorrow."
— Robert Goddard, Introduction to the History of Rocket Technology, 1963

Introduction

In June of 2010, the White House issued an updated National Space Policy. This document articulated the Obama Administration's vision for all aspects of space policy for the United States.[1] Space, which began as a domain for Cold War competition between two superpowers in the 1950s, has evolved into a competitive, congested, and contested environment with over 80 spacefaring nations. The next Administration requires an updated National Space Policy to address rapidly evolving space issues that impact all aspects of civilian and military life in modern America.

Arguably, space has become not just a linchpin for U.S. National Security but also a focal point in our daily lives. This is an exciting time to analyze space policy with strategic implications occurring both in the geopolitical environment and in the space industrial base. *Traditional space* and S*pace 2.0* are colliding, and the results will impact not just the National Security apparatus but also the way of life for every American and potentially, all of mankind.

Each president since Truman has issued various space directives, adding his mark on the space programs and policies that have helped shape modern American society. A new president will be elected in November 2016, and will inherit the responsibility of shaping a new U.S. space policy. What aspects of the current National Space Policy still hold true? What aspects need to be updated based on evolving technologies and strategic conditions? This paper will endeavor to answer these questions through an examination of the space enterprise, an assessment of current conditions in the space industry, and recommendations for the next President of the United States. These recommendations focus on four key issues: resiliency, assured access to space, international cooperation, and *Space 2.0*.

Part I: The Space Enterprise

The space enterprise is a system of systems which includes all aspects of military, civil, and commercial space operations, including the manufacturing and services sectors in the space industry and the associated component markets. A strong correlation exists between space technologies developed and matured in the government realm, where the bulk of the risk is taken, and those which have transitioned to the commercial sector; however, in the past few years a few new wholly commercial business models have also emerged. The entire ecosystem is knitted together with a complex set of laws, regulations, and historical norms. Examining the space enterprise means exploring a multifaceted set of interrelated and overlapping issues.

In traditional economic terms, the space industry is comprised of three markets: launch, satellite manufacturing, and satellite services. The space industry is a robust collection of large, medium, and small companies who collaborate and compete within a growing global industry valued at over $322.7 billion, $203 billion of which is centered in the three categories above.[2] A short assessment of each segment—launch, satellite manufacturing, and satellite services—is offered below.

Launching a rocket in to space has become commonplace, but a closer examination reveals a minor miracle every time the projectile leaves Earth's gravity well and places its payload into orbit. Because the technology is so challenging, the commercial launch market is highly concentrated.

Conversely, satellite manufacturing is more competitive and contains quickly advancing technology. The advent of miniaturization, in the form of small satellites, as well as the ever increasing revenue gained through services, is attracting more entrants to the market.

The commercial satellite services market structure is healthy and competitive across all subcategories—fixed satellite services, mobile satellite services, and Earth observation services. The categories within the satellite services market are competing with terrestrial-based companies, expanding the choices for consumers, while incentivizing firms to innovate and invest in technological improvements to remain competitive.

Examining space through an alternative economic lens tells a different story. The primary source of revenue for the industry lies in the services provided from space, as opposed to the equipment used to provide it. It is no longer a viable business case to simply put a satellite into orbit and bounce a signal off of it; now one has to model how to provide a service that competes terrestrially for a fee. Instead of looking simply at the traditional markets of launch, services, and satellite manufacturing to assess the health of the industry, this report will focus on the service market which falls into three sectors as defined by the 2010 National Space policy: National Security, civil, and commercial. Then it will examine manufacturing, which, for purposes of this paper, includes launch and satellites.

The 2016 Industry Study Seminar looked at seven types of services: telecommunications; position, navigation, and timing (PNT); intelligence, surveillance, and reconnaissance (ISR); Earth observation; weather; science; and exploration. National Security space encompasses the first three service categories; civil space encompasses the final four. Commercial services falls into nearly all categories as the technology matured and migrated from the government to the private sector over time. Based on our observations, the U.S. space market is healthy with new entrants driving innovation and pricing. Satellite manufacturing and launch are emerging from strategic disruptions and trending positively. New ideas in process and manufacturing from Space 2.0 companies, such as Space Exploration Technologies (SpaceX) and Blue Origin, are changing how traditional space companies, such as United Launch Alliance (ULA) and Aerojet Rocketdyne, manage their business models in the market.

National Security Space Sector

As noted above, National Security space includes telecommunications, PNT, and ISR. Each of these originated in the National Security arena and served a particular purpose. As the technology matured, it continued to serve that purpose in new and different ways. The United States still enjoys a considerable lead in space capabilities and exquisite satellite systems; however, other countries are closing the gap. The U.S. government continues to bolster its space enterprise, including a considerable increase in the defense budget devoted to space activities.[3] Much of the budget increase has gone to reinforce and enhance Situational Space Awareness (SSA). The United States is also increasing cooperation among allies for SSA through a series of bilateral agreements with the United Kingdom and others, including among other things, sharing data.[4] Further, there is a trend toward commercialization and privatization of National Security space activities which will be discussed below. Although some activities may be commercialized, there will always remain a core government operation, which deals with National Security space.

National Security agencies such as the National Reconnaissance Office (NRO), National Security Agency (NSA), and National Geospatial-Intelligence Agency (NGA) as well as the U.S. Air Force (USAF) are the primary operators for telecommunications, PNT, and ISR. Further, the government purchases telecommunications and ISR from the commercial sector in order to augment in-house capabilities. The PNT signal is owned by the U.S. government and provided free by law as a public good. However, the National Security establishment purchases ground equipment to downlink the signal and make it usable.

Civil Space Sector

Civil space, for the purpose of this paper, is defined as all governmental space activities not related to defense or intelligence purposes. This includes NASA and NOAA activities as well as DoD activities related to weather and the U.S. Geological Survey. Civil space primarily focuses on Earth observation, weather, science, and exploration.

Earth observation includes a wide variety of location-based analytic services, like agriculture, change detection, and disaster mitigation. As sensor technologies advance, so too does our ability to observe the Earth in new and different ways. Internationally, the United States has joined forces with the European Space Agency (ESA) and the Committee on Earth Observation satellites which, "…coordinates civil spaceborne observations of the Earth…" in order to, "…address critical scientific questions and to harmonize satellite mission planning to address gaps and overlaps."[5]

NASA and NOAA are the primary organizations responsible for fulfilling space sector guidance focused on observation, research, and analysis of our Sun and including space weather phenomena, environmental Earth observation, and weather research and forecasting as directed in the 2010 United States National Space Policy.[6] However, our preparedness posture remains heavily reliant on the low probability of a severe event occurring in space.

Weather-related earth observation and forecasting, as well as space-derived weather prediction and modeling, is of vast importance to society as a whole and to world economies as globalization has interconnected and interwoven the socio-economics of humankind. The United States has pledged to work with partners to make weather forecasting data available to the world over as a public good. These efforts and the importance of continued resourcing are recognized and substantiated by the sheer cost of repairs following catastrophic weather events.

NASA continues to lead the world in science and peaceful exploration of space. NASA's current and future focus is eventually putting a man on Mars as well as high-profile science missions such as the James Webb Space Telescope. NASA has also benefited from the lower cost of launch with the entrance of SpaceX, which lowered the price of resupply missions for the International Space Station (ISS).

Interest in outer space and human spaceflight has grown significantly since the 1950s, when only the USSR and the United States possessed spacefaring capabilities. Today several countries are contributing to the International Space Exploration Coordination Group and are deeply invested in their space agencies. They view lunar missions as essential to future human missions to Mars and deep space.[7] Commercial partnerships are also critical to the future of human space exploration. Many private and public companies in the news today share NASA's vision to achieve human space exploration: SpaceX, ULA, Arianeespace, Blue Origin, et al. It will likely take a global effort, across governments and corporations, to further – and bear the cost of – human space exploration. The United States remains visionary about leveraging human space exploration as a means to colonize the Moon or Mars as an alternative to planet Earth.

As NASA prepares for its mission to Mars, one of the critical steps on the path is the Asteroid Redirect Mission. The science collected during this mid-2020s mission will help inform the agency's experts about the orbits of asteroids, their composition, and the viability of extracting minerals and water. That technology will advance the vision of servicing spacecraft in situ, potentially reducing the cost of transporting fuel and other materials to launch new spacecraft.

Commercial Space Sector

The commercial services market is the largest market in the space industry and is steadily growing each year.[8] In 2014, the services market represented $122.9 billion in revenue worldwide.[9] Specifically, the U.S. commercial space market is healthy with new entrants driving innovation and pricing. The commercial space sector has taken technologies developed and matured in the government sector and turned them into markets of their own. However, the business maturation varies through the seven primary services.

The largest revenue source is in consumer telecommunications, which is primarily dominated by the entertainment industry, specifically satellite TV.[10] There are 230 million satellite TV subscribers worldwide, generating $95 billion in revenue for 2014.[11] DirecTV (now part of AT&T) and DISH Network are the two major players in this market, and are in direct competition with terrestrial cable TV providers.[12] Satellite radio, now a monopoly owned by Sirius XM Holdings, is a U.S./Canada-only business that reported $4.6 billion in revenue for 2015.[13] Satellite broadband is the smallest contributor within this segment, as the number of subscribers worldwide is only in the low millions, likely due to more attractive cable and fiber options; however, the technology is evolving rapidly and industry analysts expect steady growth.[14]

With regard to PNT, the commercial sector does not own any of the space infrastructure; however, the government provides the signal for free. The commercial sector focuses on taking that signal and turning it into a profitable aftermarket business case. At this point in the technology maturation, few of us can imagine driving to a new place without GPS. That is what commercial PNT has brought to the consumer. The Global Navigation Satellite Systems (GNSS) industry is highly concentrated with only two global systems available to civilians as of 2016 (GPS and GLONASS) and three regional services. By 2020 both ESA and China are planning to have global GNSS systems resulting in additional market diversification.

The ISR market is nascent, and the commercial demand is uncertain. Companies such as DigitalGlobe and Airbus Defence and Space dominate but their primary customers are the U.S. government and other foreign entities. Companies that can provide high-resolution multispectral, radar, infrared, or hyperspectral imagery can fill high demand specialty niches for the U.S defense and intelligence community. The opportunity for growth lies in business intelligence and data analytics; nonetheless, it is too early to determine whether this market will sustain itself going forward.

The Earth observation market is in a stable period with dominant companies providing high-resolution images with high-geographic precision appropriate for mapping products. Smaller, emerging companies are striving to compete for market segments requiring daily or hourly revisits with one meter or better imaging capabilities. Small satellite-based companies will continue to work toward higher resolution, but their main emphasis is trending toward higher revisit rates, also known as *high temporal resolution*. Defense and intelligence communities in the United States, United Kingdom, and France will continue to purchase services from the commercial sector requiring very high resolution panchromatic and multispectral imaging data from DigitalGlobe and Airbus Defence in order to create accurate foundational maps. However, if companies like UrtheCast, Terra Bella, Planet Labs, or Surrey Satellite Technology can monetize the value of high-temporal resolution imagery, then the commercial Earth observation market will become more competitive. In many ways, emerging companies view themselves not as traditional imaging companies providing Earth observation data or services, but location-based service providers, regardless of data source.

Weather data is provided aftermarket to the commercial sector as a common good and is repackaged and sold to inform consumers. One only needs to turn on The Weather Channel to see the value add provided by the commercial sector. This is a consistent service in high demand and will continue to bring the information directly to consumers around the world.

Science is the one piece of the government sector where there is currently no commercial counterpart, nor plans for one. Science has always been in the purview of civil authorities and until there is a commercial science application, there is no viable business plan and thus no commercial market.

The final service category is exploration. Unlike civil exploration, exploration in the commercial sector is unique in that it grew from wholly private sector demand and with commercial technologies. Contrasting other services, the technology was not passed from the government to the private sector. Space travel was once only a figment of the imagination, then the reality and domain of NASA; now exploration is almost reachable for so-called commercial astronauts. The space tourism industry's current stage of development is comparable to the commercial aviation sector in the 1920s—the capability exists but regular service is not yet available. [15] Three categories of suborbital flight technologies—parabolic flight in a winged aircraft, high-altitude balloons, and suborbital capsule flights—have been proven with test flights, and current demand for space tourism is limited mostly to the mega-rich. However, in an industry where backlog is a key indicator of business health, Virgin Galactic has already booked 700 paying customers,[16] the equivalent of 116 full manifests (six passengers per flight) on its *SpaceShipTwo*. A 2012 Federal Aviation Administration (FAA)-Tauri Group report projects a potential demand of more than 1000 seats per year, with significantly higher demand if the price point declines.[17]

SpaceX and Elon Musk have much more aggressive plans for traveling to the Red Planet. As early as 2018, SpaceX plans to launch the "Red Dragon" with a Falcon Heavy rocket—a larger and more powerful version of the successful Falcon 9—and land it on Mars. Musk has the vision of colonizing Mars and represents the commercial lead in human space exploration.[18]

Of note, there have also been failures in the commercial services market. Iridium went bankrupt in 1999, saved only by new owners, a new business plan, and new satellites that completed its 66-satellite constellation. On the government end of the spectrum, the Russian GLONASS GNSS system was declared operational in 1995 by Russia with 24 satellites but by 2002 it had fallen to only six functional satellites. It took until 2015 for Russia to once again declare GLONASS fully operational with 24 satellites and deliver the government signal to the commercial market. Both of these failures attest to the challenges in the satellite services market driven by the fluctuating demand and high barriers to entry.

Satellite Manufacturing and Launch Services

The satellite manufacturing market is the second smallest segment of the overall global space industry.[19] According to the Satellite Industry Association, satellite manufacturing generated just $15.9 billion in worldwide revenue for 2015.[20] The United States contributed $10.0 billion in revenue with the remaining $5.9 billion from other global manufacturers launching a total of 208 satellites in 2015.[21] Military surveillance and commercial communication satellites comprised 35% of the revenue for spacecraft launched in 2014.[22] The top five prime manufacturers in this segment are MacDonald, Dettwiler, and Associates Ltd. – including Space Systems Loral (SSL) – Airbus Defence and Space, Boeing, Thales, and Lockheed-Martin.[23]

The top five most profitable satellite manufacturing companies represent almost 40% of the market share over the next 10 years.[24] The average price of a communication satellite, the most ubiquitous in orbit, is estimated to be approximately $100 million.[25] With a design life span of approximately 15 years, and a multi-billion dollar revenue stream provided to the service providers, this equation worked for the limited buyers and manufacturers. However, two factors – emerging markets in underdeveloped regions and increased mandate for small satellites – are creating demand for cheaper platforms operating in low Earth orbit (LEO) capable of competing with the formerly unassailable position of geosynchronous (GEO) satellites. This is especially true in the Earth observation market, which was the preponderance of launches in 2014 (51%).[26] New entrants to the market are innovating methods of production and supply in order to reduce cost and apply these technologies to other segments such as satellite broadband. Since 2005, small satellites accounts for the largest number of platforms launched while conversely representing the lowest cost to manufacture.[27] Several companies have plans to launch multi-thousand satellite constellations, but it remains to be seen if this business case is feasible considering the shrinking positions in LEO.

Turning to launch, declining U.S. government spending in the last ten years caused a consolidation in the market when Boeing Integrated Defense Systems and Lockheed Martin created the joint venture, United Launch Alliance (ULA). This joint venture has reduced the U.S. launch market to just three competitors: ULA, SpaceX, and Orbital ATK. Globally, Arianespace dominates the market as a strong challenger, especially in light of the new Ariane 6 rocket. Launch is expensive, traditionally costing between $6,000 and $12,000 per pound depending on whether the final destination is LEO, medium Earth orbit, GEO, or farther in the solar system.[28] Price point pressures in the launch market brought on by SpaceX are driving the cost of launch down.

Part II: Four Key Issues for the Next President of the United States

The National Space Policy is the comprehensive, touchstone document with respect to the United States' approach to space. A number of principles underpin the document. Space is a shared resource and all nations have the right to explore it. Space is a universally competitive environment but without legal sovereignty. Finally, space is critical to the U.S. National Security and accordingly, we must have unfettered access.[29]

The policy explicitly outlines six specific goals: "energize competitive domestic industries; expand international cooperation; strengthen stability in space; increase assurance and resilience of mission-essential functions; pursue human and robotic initiatives; and improve space-based Earth and solar observation."[30] The enduring goals in space do not change rapidly and as such, the 2016 Space Industry Study assessed all of these as worthwhile, but would alter their prioritization. The most critical goal should be a comprehensive plan for resiliency followed by assured access to space, and international cooperation. We believe it essential for the next President to have an understanding of Space 2.0. What follows are the explanations for the four most important issues the next President needs to consider.

Resiliency

Bottom-Line Up Front: America's dependence on space for commerce, communication, and conduct of war is a vulnerability that an enemy properly resourced and with the right expertise could exploit with devastating results. Space has become a warfighting domain that the United States ignores at its peril and a new way of training, equipping, and operating in space should be developed.

The U.S. government and the commercial space industry enjoyed a relatively benign operating environment for the last 50 years. The two primary space powers during that period, the United States and the former Soviet Union —now Russia —agreed in principle to keep space a peaceful environment. That has changed since some 80-odd countries have joined the two primary powers, and the character of Russian space activity has shifted. Steps are required to increase resilience by reforming the space architecture, doctrine, space situational awareness, and space traffic management.

China caused a paradigm shift when it successfully demonstrated its first direct-ascent ASAT weapon test on January 11, 2007.[31] Until then, space was considered a benign environment governed by the rules codified under the 1967 Outer Space Treaty and the Cold War paradigm that protected space systems through the threat of mutually assured destruction. This single event changed the rules and critical, expensive, and long lead-time national defense assets that were once considered untouchable were suddenly vulnerable.

General Hyten, the Commander of Air Force Space Command recently defined resiliency or resilience capacity as, "…realizing our enterprise vision, to developing and acquiring new weapon systems, to developing new tactics, and overhauling the way we train and employ our Airmen."[32] USAF Space Command has also proposed the definition of space disaggregation as "the dispersion of space-based missions, functions or sensors across multiple systems spanning one or more orbital planes, platforms, hosts or domains."[33] There are multiple disaggregation strategies, each with advantages and disadvantages, but they all achieve a level of dispersion of missions, functions, or sensors. Some of the ways to achieve resiliency include changing how the United States approaches space architecture, acquisition, SSA, and space traffic management (STM). Additionally, leaders of U.S. National Security Space need to examine space norms, doctrine, and how the space enterprise will prepare for a contested and congested space environment.

Space Architecture and Acquisition

The essential purpose and benefits of disaggregation provides options within an architecture to reduce cost, increase resiliency, and distribute capability.[34] Some DoD and intelligence community (IC) requirements will dictate the continued need for large satellites with very complex and integrated capabilities to meet classified national defense missions. However, there are increasing opportunities to leverage commercial capacity to meet many National Security requirements. Deploying capabilities within a commercially established constellation provides multiple advantages ranging from lower program costs to increased sensor numeric advantage, while complicating an adversary's decision calculus regarding attacking a commercial system.

DoD's need for large and complex mission-specific systems will remain. Consideration of disaggregated architectures can act as a counter-balance to reduce costs and enhance resiliency. However, the current space system acquisition system is not structured to maximize the possible benefits. The schedule-driven approach versus a knowledge-based approach, the attempt to satisfy all requirements regardless of the technology readiness levels, and the size of the DoD acquisition portfolio has prevented program managers from reliably achieving cost, schedule, and performance objectives.

The common benefits of disaggregation include more flexibility to keep pace with technology advances, reduction of system integration complexity, and reduced development timelines. The continuous incorporation of newer technologies with shorter timelines also encourages industry to remain on the cutting edge of technology and communicates stable demand to incentivize continued technology advancement. However, there are tough challenges that must be considered. Military requirements for radiation hardening, redundancy, and other protective measures, while not foreign to the commercial sector, can limit their willingness to support a disaggregated architecture due to increased development and integration costs.

Whenever possible, multi-year procurement authority should be the DoD's objective for funding satellite acquisition. While multi-year funding is not a panacea to solving cost containment, it does provide a level of predictability for program managers and the industrial base to reduce cost overruns attributed to cash flow limitations impacting program schedules.

As commercialization and government activities expand, our space architectures are increasingly exposed to accidental conjunction or deliberate attack. If the United States is to maintain its space dominance, the DoD and IC acquisition approach must change to become more agile, reduce the cost of space systems and leverage commercial industry technology and capability advances to increase space system resiliency.

Doctrine and Warfighting

Adversary nations and non-state actors may choose to attack U.S. and allied space-related infrastructure using non-kinetic means outside of a declared conflict. The international laws and behavioral norms that guide maritime behavior or aviation safety simply do not have adequate space analogs in order to effectively curb this behavior. As in cyberspace, adversaries have ample and ambiguous maneuver options for non-kinetic attacks in space that threaten U.S. interests but fall short of "armed attack." By including a strong technological attribution component to deterrence efforts in space, the United States can achieve its National Space Policy goals while limiting the effect of—and incentive for—non-kinetic attacks in space.

Currently, the "rules" for space behavior exist in fairly antiquated frameworks, but the sovereign interests of spacefaring nations diverge too much and make development of modern space rules seem unlikely. The 1967 Outer Space Treaty inadequately addresses modern use of space and creates too much room for adversaries to cheat on the spirit and intent of the law.[35] Article 51 of the UN Charter allows for states and alliances to act in self-defense against "armed attack."[36] The concept of armed attack in an era of energy and other new types of weapons invites treaty interpretation ambiguity. Most non-kinetic space weapons will involve some form of electromagnetic energy which suggests that the International Telecommunications Union rules against "harmful interference" also require updating. International law of armed conflict addresses proportionality and distinction in targeting, but creates resiliency problems when considering dual-use hosted payloads on civilian satellites. The United States simply cannot afford to rely on rule of law to protect its interests in space.

Non-kinetic weapons in space exist primarily in the form of lasers, jammers, microwaves, and malicious cyber maneuvers. As many as two dozen states already have the ability to target satellites in LEO with one of these methods.[37] While a ground-based jammer should be detectable and therefore attributable, a space-based jammer may offer the attacker plausible deniability if not anonymity. Cyber and electromagnetic attacks may have temporary or durable effects, but the physics of electromagnetic waves in space suggest that they will occur at the speed of light and potentially from any direction. Small satellites may maneuver up to a friendly satellite for nefarious purposes such as close-aboard electromagnetic effects, physical tampering, orbital interference, or worse. In distant GEO, such maneuvers could be completely undetectable from the ground. While space is vast, satellite flight typically assumes minimal evasive maneuvering. If U.S. satellites have to routinely deplete maneuvering fuel to avoid risk of observation from unfriendly satellites, the enemy may successfully engage in a blocking or denial of service or capability effort without causing any kinetic or electronically harmful effect.

Modern terrestrial weapons systems like fighter aircraft have laser, jamming, and surveillance detection systems aboard. These technologies belong on satellites in order to assist in attribution. They will add cost and weight, but increase deterrence since enemies will be unable to avoid detection.

To remedy the current situation, the Air Force is taking steps by including private satellite operators in military space operations by integrating them in the Joint Space Operations Center (JSpOC).[38] The goal is to reduce costs, focus effort, and enable the Air Force to concentrate on military-related space activities. Additionally, Deputy Secretary Work directed the creation of the Joint Interagency Combined Space Operations Center (JICSpOC) to coordinate processes and procedures in the U.S. space enterprise. JICSpOC's other mission is to create and validate new doctrine and procedures as well as play a part in training the next generation of DoD space operators.

Space Situational Awareness and Space Traffic Management

In order to maintain its global strategic advantage, the United States must continue to sustain a responsive and flexible global military force supported by a robust space architecture. However, the increasing threat environment in space, combined with a forecasted increase in satellite traffic over the coming years, is challenging access to the space capabilities that enable the American way of life and provide a significant strategic advantage. The Department of Defense should take the opportunity to reevaluate the STM burden, focus on SSA, and reprioritize resources as needed. International collaboration in STM will be increasingly critical to the successful continued use of the outer space environment for all spacefaring nations.

For decades, the United States maintained a significant advantage in space, but the strategic environment has changed and that advantage is no longer guaranteed. The space domain is characterized today by increased congestion and competition for limited resources. Assured access to space and satellite communication bandwidth is challenged by an exponential growth in operations by international and commercial users. On a daily basis, Joint Force Combatant Command Space (JFCC Space), via the JSpOC, routinely tracks tens of thousands of objects in Earth's orbit, but the true magnitude of objects in orbit may be much higher. Every piece of debris poses a potential threat to operational satellites.

There is now growing concern among scientists that we have passed a critical concentration point of orbital human-generated objects with an increased forecast of launch and orbital activity, especially in LEO, which will make STM even more complex. Computer simulations at six different space agencies predict that LEO will see additional catastrophic collisions every five to nine years.[39] Such increased potential for debris damage could increase the costs to operate in this critical orbit.

An even greater current concern is that potential U.S. adversaries already possess and continue to refine a wide set of capabilities that pose a threat to our access to space, in order to increase their relative strategic advantage. Several countries have shown commitment and documented progress in the development of capabilities that could deny American use of space, even as they improve launch and on-orbit competencies. These rising issues of congestion and the potential for adversarial contesting are placing an increased burden on the DoD.

The benefits and consequences of America's choice to assume this responsibility have had an impact. The close approach warnings provided by the JSpOC to all satellite operators have greatly increased the visibility and magnitude of the STM challenge, and caused many satellite operators to become more responsible for their orbital activities. However, the entire global space enterprise, and indeed everyone who enjoys the benefits derived from space assets, has become reliant on the U.S. military's SSA capabilities.

The DoD should no longer continue to be the single federal agency responsible for operational STM for the global community. When the USAF assumed the global STM mission, the motive of National Security motives was forefront, and no other country possessed the same capabilities. While U.S. National Security remains paramount, the burden of DoD retaining the global STM mission is no longer valid, based on the evolution of the orbital space environment and the growth of capabilities worldwide.

Representative Jim Bridenstine (R-OK) recently introduced the Space Renaissance Act, which proposes comprehensive changes in space policy and National Security space organization.[40] The Act proposes bold moves, such as moving space collision reporting to the Federal Aviation Administration (FAA) and directing the DoD to integrate commercial and military communications architectures.[41] It also calls on strengthening the role of the Principal Defense Space Advisor (PDSA), which would grant that position more authority to oversee DoD space.[42] As with National Security space, the Space Renaissance Act would make sweeping changes in civil space that include making NASA appropriations multi-year, moving the JSpOC to the FAA, requiring the Secretary of State to seek bilateral and multilateral agreements to unify STM, and reforming the loan guarantee program to support the domestic space industrial base.[43] If the Space Renaissance Act passes as proposed, it will have far-reaching implications across the full spectrum of the American space industry. However, there is one issue that must be addressed beyond the Space Renaissance Act: debris.

Space debris is an agnostic and asymmetric threat to U.S. National Security and requires an immediate and collaborative effort to explicitly define space debris and to produce an all-inclusive reduction and removal solution. There exists a very real and tangible threat of a catastrophic chain reaction of collisions that could create lethal and unusable LEO and GEO within the next two decades. After nearly 60 years of human space endeavors, space debris has become the proverbial wildcard. Its potentially catastrophic impact on future U.S. government, scientific, and commercial space operations, vehicles, and assets will systematically level the playing field for all nations forcing either unprecedented cooperation or assured destruction.

Prior to 2007, the United States and the former Soviet Union were primarily responsible for the majority of man-made space debris, mainly caused by upper stage launch vehicles, with remnants of unexpended fuel resources that exploded and significantly increased the amount of space debris.[44] Two significant space conjunction events recently occurred that increased the amount of space debris in LEO by approximately 50%.[45] In 2007, the Chinese successfully conducted an anti-satellite (ASAT) test destroying one of their defunct satellites, creating a debris cloud of over 3,000 objects greater than 10cm and as many as 150K particles larger than 1cm.[46]

In 2009, a commercial Iridium satellite and a non-operational Russian military satellite collided creating two debris clouds estimated at over 3,000 pieces.[47] These two incidents underscore the dangerous uncertainty of operating in space as these debris clouds will continue to be a significant threat forever unless there is action.[48] In fact, many experts believe the Kessler Syndrome, also known as collisional cascading,[49] predicted in 1978 by NASA scientist David Kessler, may have already breached the tipping point of extensive micro-debris being created by collisions of the current quantity of debris circling the Earth.[50]

There are basically two concepts for space debris removal: by the space vehicle using on-board fuel reserves or some other on-board device to reduce velocity and increase drag to move itself into a deorbiting position or by an external craft, also known as Active Debris Removal (ADR).[51] The first concept is being developed with new technologies as best practices for future satellites to deorbit themselves after their useful life. One example is an electromagnetic tether to be deployed at the end of a spacecraft's performance. This concept involves the tether building up a charge to increase the drag of the craft, reducing its velocity in order for it to deorbit into the atmosphere.[52] However, this new type of technology does nothing to remove debris currently in orbit with no means to deorbit.

The second concept, ADR, uses another orbiting spacecraft to attach, capture, or otherwise influence the debris into a position for deorbiting or removal. ADR is politically contentious and is inhibited by the current jurisprudence where there is no salvage law and where all space assets belong to the original owner in perpetuity. At its core, debris removal vehicles have the potential for dual military and civilian use simply because they are maneuverable craft that can influence another craft in space.[53] Regardless of this concern, there are several companies developing and proving advanced technology solutions to effectively execute an ADR mission.

Assured Access to Space

Bottom-Line Up Front: The U.S. government must set policies that do not curtail the activities of privately held companies while simultaneously providing the resources for long-standing firms to minimize the risk inherent in private investor decisions made using a return on capital model that does not consider national security implications..

America's assured access to space is a requirement for the sake of our National Security as well as our commercial economy. To safeguard access to space, the National Space Policy outlines three key areas where the United States must focus our efforts: work jointly to acquire space launch services that are reliable, responsive to U.S. government needs, and cost effective; enhance operational efficiency, increase capacity, and reduce launch costs; and develop launch systems necessary to ensure and sustain future reliable and efficient access to space.[54] Additionally, Title 10, Section 2273 of the U.S. Code requires "the availability of at least two space launch vehicles (or families of space launch vehicles) capable of delivering into space any payload designated by the Secretary of Defense or the Director of National Intelligence as a National Security payload."[55]

The U.S. government and the commercial launch providers have maintained the availability of at least two space launch vehicles or families of space launch vehicles to support the full spectrum of payload weights with the Atlas V and Delta IV. However, assured access to space was significantly increased when the USAF certified the SpaceX Falcon 9 rocket to launch military satellites, increasing the count to three launch vehicles. Subsequently, SpaceX won its first award to launch a National Security payload in April 2016 with a winning bid of $82.7 million.[56] These two events represent a noteworthy change in the space launch market.

Recent efforts to acquire reliable, responsive, and cost effective space launch have met with success. NASA's Commercial Resupply Services (CRS) contract for the ISS encouraged industry to develop reliable, cost-effective means of resupplying the ISS.[57] Companies such as Orbital ATK and SpaceX have seized upon this innovative public-private partnership to deliver reliable space launch services at reasonable costs. SpaceX has leveraged the CRS contract to further its targeted goal of reducing launch costs 30% by developing reusable launch vehicle technology, having landed their Falcon 9 first stage successfully three times.[58] The high cost of launch remains a driving factor for commercial industry and government access to space in a fiscally-constrained environment. The costs, however, are trending down, due to the efforts and successes of SpaceX and other innovative public-private partnerships.[59]

While the commercial launch market is expanding, NASA is developing a new launch system, the Space Launch System (SLS). The SLS will be NASA's first exploration-class vehicle since the development of the Saturn V. This ambitious project will be capable of lifting the largest payloads into Lunar or Martian orbits, but will be oversized and cost prohibitive for lifting current heavy-sized payloads to Earth orbits. Routine access to Earth orbit will continue to rely on commercial companies such as SpaceX, ULA, and Orbital ATK to service the medium and heavy lift markets. To that end, it is critical the U.S. government ensure appropriate policies are in place to continue encouraging U.S. companies to innovate and find better and more economical ways to launch payloads into orbit. These policies should not be overly restrictive and instead allow the free market to drive pricing and innovation.

In addition to innovation, the United States must also ensure the uninterrupted operation of domestic launch company supply chains and minimize any foreign supplier exposure. Currently the ULA Atlas system relies on Russian-built RD-180 engines, a well-known weakness in its supply chain. The use and supply of the RD-180 became a political issue when Russia invaded Ukraine and annexed the Crimean Peninsula. Section 1608 of the 2015 National Defense Authorization Act (NDAA) restricted the use of the RD-180 rocket engine but that restriction was lifted by the Omnibus spending bill of 2016. The imposition of this restrictive policy and subsequent reversal exposed the vulnerability of this component of the Atlas rocket family supply chain. The effect was clear when ULA stated they could not compete for a U.S. DoD payload because they did not have RD-180 engines available for the launch vehicle. The same omnibus bill also provides funding to accelerate the development of an American replacement for the RD-180.[60] However, there is currently no domestic supplier of an equivalent engine, and while two replacements engines are under development, they will not be ready until after 2019.

Two U.S. companies, Aerojet Rocketdyne and Blue Origin, are aggressively developing new rocket engines to replace the RD-180. Aerojet Rocketdyne is developing the AR1 closed cycle rocket engine that uses a traditional liquid oxygen/kerosene propellant. Blue Origin, a privately held firm, has been developing the BE-4 engine since 2011 that uses liquefied natural gas and liquid oxygen propellants.[61] Both engines are being developed for use on multiple launch vehicles including the Atlas V and the Advanced Boosters being considered for NASA's SLS. The competition to develop a U.S. replacement for the RD-180 is fierce and both companies are on viable paths. The U.S. Air Force has invested in Aerojet Rocketdyne, the historical industry leader, by awarding it a contract to certify and start delivering flight-ready AR1 engines in 2019.[62] The BE-4 engine is the leading candidate to be used in the first stage of ULA's Vulcan vehicle and is projected to be ready for service in 2017.[63] This aggressive competition benefits the U.S. government and commercial customers, spurs innovation within the industrial base, and sets the stage for development of breakthrough technology that can change the industry.

One technology has the potential to positively impact all three of these focus areas – reusable launch. Reusable launch could be the key to responsive, efficient, and cost effective access to space. The key is that the number of launches per year per launcher must be large enough to provide a return on the investment by commercial entities. A study by the Air Force Institute of Technology in 2006 determined that for a reusable launch vehicle to have an economic benefit over an expendable booster there needed to be more than 10 launches per year.[64] SpaceX's Falcon 9 successfully launched 7 times in 2015 and is closing the gap to reach that economically viable milestone.[65] Commercial customers are lining up to launch payloads on a reusable Falcon 9 with over 40 customers manifested on future SpaceX launches.[66] The anticipated reduction in cost is driving demand for SpaceX's reusable rocket technology and has forced long-time launch providers to pursue this capability.

ULA is including reusable capability in its Vulcan rocket design. While SpaceX has chosen to recover the first stage of the Falcon 9, ULA believes its engine recovery concept makes more sense from a business perspective.[67] The Vulcan design will be eventually updated to include the jettisoning and recovery of its main engines that comprise 66% of the cost of the first stage. Regardless of the method, competition and innovation is reenergizing and transforming the launch industry.

The U.S. government has been slow to embrace the idea of launching a National Security payload on a reused vehicle which is prudent based on the low maturity of the technology. The U.S. government recently signed its first contract with SpaceX to launch the GPS 3 satellite constellation in 2018.[68] As the technology matures and demonstrates a predetermined reliability level, the U.S. government should make use of these reusable launchers for government payloads. It will further the reusable launch market and save resources while encouraging the continued development of lower cost reusable launchers.

Ultimately the United States must retain its access to space. Cheaper yet still reliable launch systems with a capability to be launched on a short notice will ensure access to space, decreasing the development time for payloads, and ensuring that the United States continues to dominate space. The U.S. government must set policies to encourage the activities of privately held companies while supporting long-standing firms. Such policies will assure access to space to meet the National Security requirements.

International Cooperation

Bottom-Line Up Front: The U.S. does not operate alone in space, therefore international cooperation in the form of space traffic management framework, support for a UN agency for Space, smart trade policies, and space arms control are critical for peaceful, co-use of space for generations to come.

As noted above, international cooperation is as essential element of STM. The United States does not operate alone in space, so in order for STM to be effective, it must be agreed-upon by all spacefaring nations. The goals of international cooperation involve capitalizing on mutually beneficial space activities, primarily in the civil space sector, and securing the safety and security of all space operators. In 2018, just one year after the next president takes office, this will come to a head in the form of UNISPACE+50, the UN's next major conference on space. "UNISPACE+50 aims to chart the future role of the Committee on the Peaceful Uses of Outer Space (COPUOS), its subsidiary bodies and the UN Office of Outer Space Affairs (UNOOSA) at a time of an evolving and more complex space agenda, when more actors, both governmental and non-governmental, are increasingly involved in space activities."[69] The first concern is as space becomes more congested, and within the context of STM and UNISPACE+50, should we should support a UN agency for space? Can the United States leverage UNISPACE+50 to codify an international framework for STM? The second concern is economic and that comes in the form of trade policies such as export controls and export credit agencies whose outcomes have strong impacts on our domestic industry. Lastly, the next president must give thoughtful consideration to a way forward on space arms control.

Traditionally civil space has been the role of NASA. More recently, the United States has made great strides in developing international partnerships with ISS countries, whose mission has been extended until 2024.[70] While nations work together to determine what will come after the ISS, there are other issues that impact international cooperation and our interactions with the rest of the world. Should the United States leverage its technological and leadership advantage now to establish an international order in space operations, focused on cooperation, scientific discovery, safety, and economic growth? Or should the United States pursue a military-centric, technological advantage while remaining independently focused leaving the establishment of international norms for safety, oversight, and procedural regulation to other nations? The next president may face this very decision.

One historical example of the U.S. shaping the future of international order is the success of the International Civil Aviation Organization (ICAO). The initial ICAO charter focused on international cooperation to support the growth of worldwide aviation. Its emergence was heavily influenced by U.S. leadership and the established norms were laid on the foundation of the U.S. Federal Aviation Administration. The history of ICAO acts as a successful example of U.S. leadership influencing the establishment of a specialized industry with internationally accepted standards under the UN.[71] The current president of the ICAO council acknowledged the growth in space innovation and activity in a recent ICAO Office of Outer Space Affairs (ICAO-UNOOSA) conference saying: "ICAO recognizes that sub-orbital and outer space flights will foster new tourism and transport markets and that investments in related research and development remain at a very healthy level."[72]

The current atmosphere of excitement in the space enterprise provides the perfect launch window for the United States to propose establishing a specialized agency within the UN with similar cooperative goals and purpose as the original ICAO charter. An International Civil Space Organization (ICSO) would be specifically focused on space in order to influence future growth, regulatory guidance, and safety standards in commercial space operations. It would also provide a forum for better communication and provide authoritative oversight in reaching agreements and treaties for military use or dual-purpose space based capabilities. However, it is unclear how these activities would be enforced by the member states.

Despite the challenges of a complex and paradoxical space environment between the United States and other space powers, the benefits of pursuing cooperative solutions and enabling a method of checks and balance within the international community outweigh the negative elements of establishing an ICSO. There is a need for an agency responsible for gathering consensus and charged with ensuring future space operations progress in "a safe and orderly manner on the basis of equality of opportunity" as the UN ICAO charter originally proposed for international civil aviation growth. The United States should build upon the foundation of past successes and international cooperation in space by pursing the formation of a specialized UN space agency.

Next, the president must look toward international trade. Beginning with one of the most fundamental transactions that takes place between two countries, trade is at the heart of any economy. U.S. industry relies on markets, foreign and domestic, to sell its products. U.S. government intervention can support this process, such as financing assistance through the U.S. Export-Import Bank (EXIM) but it can also hinder trade when export policies are too stringent.

Two entities have guided U.S. exports for over 50 years, EXIM and the Organization for Economic Cooperation and Development (OECD). These two organizations now find themselves faced with increasing political and economic pressures both divergent and yet applicable to how they conduct transactions. In order to ensure a consistently competitive environment for U.S. satellite and space components, the United States must adapt its export policies to meet this changing environment.

The model for export consistency has been manifested in the form of the EXIM Bank. Established by President Franklin Delano Roosevelt during the Great Depression in order to "reengage economically with the rest of the world," EXIM has consistently afforded U.S. manufacturers and their foreign partners the financial means to conduct transactions.[73] Since the 2008 economic crisis, the space industry, and specifically satellite manufacturers, have leveraged the financial aid afforded by EXIM in a marketplace defined by increasing competition for limited orders. With an estimated "$4.8 billion in financing for satellite-related transactions," 60% of all U.S. satellite transactions are now processed with EXIM support.[74] Yet, in 2015, the U.S. Congress shuttered EXIM for a period of six months by refusing to re-authorize its charter. At a time when the rest of the industrialized world is bolstering their export banks in order to encourage national industries, the United States is regressing in this critical arena for high technology transactions. The U.S.'s largest competitors in satellite manufacturing have taken aggressive, sustained steps to lure business away from the U.S., as seen in the 6% decline of U.S. satellite manufacturing from 2013-2014.[75] In order to buffer this key industrial base from the effects of government political and budgetary disruption, Congress should gradually privatize EXIM in the model of France's export credit agency COFACE. COFACE functions like an independent, for-profit, federal store front for exports. COFACE does not perform direct lending; it guarantees loans that banks make to French industries with the full backing of the French government.[76] Privatizing EXIM in a similar manner would remove political influence while consistently ensuring government backing in the marketplace.

In the same tone of consistency, the OECD's Arrangement on Officially Supported Export Credits or more simply, the *Arrangement Model*, has guided U.S. export principles since its inception in the 1960s.[77] Meant to ensure that Export Credit Agencies acted in the best interests of the developing world as defined by the free market, the Arrangement Model guided U.S. export principles even though not legally binding. This model is now under attack, specifically by the rise of Asian nations, most notably China. The *Asian Model* now uses export finance not only to support national industries, but also to influence international politics.[78] With a willingness to offer direct lending to emerging markets, this model has gained increasing influence throughout the globe, and has increasingly forced OECD member countries to stray from the ideals of the Arrangement Model. The United States, as an OECD leader, must address other member nations' concerns by officially modifying the Arrangement Model in order to ensure fair play among participating nations. Recognizing and acknowledging the changing face of export credit will aid in establishing an updated model that allows for expansion of credit financing rules in order to compete in the global environment. By altering how we support export financing while concurrently working toward ensuring a level playing field for exports in general, U.S. satellite and space component manufacturers will not only sustain their lead within the marketplace, but further sustain the Nation's consistent technological advantage for the foreseeable future.

Now that we have seen where thoughtful policies can liberalize U.S. trade, it is important to look at the opposing argument. During the 1990s, multiple American-built satellites were destroyed during Chinese launch failures. The resulting joint investigation between the companies and the Chinese government set off a maelstrom regarding technology transfer and altered the course of the U.S. satellite industry for nearly two decades. A Congressional inquiry into the accidents revealed Chinese government agencies learned about sensitive space technology during the course of the investigations. This caused a backlash in Congress and a subsequent decision to move any satellite-related component to the very restrictive U.S. Munitions List (USML) under the auspices of International Traffic in Arms Regulations (ITAR) restrictions, thus barring it from export.[79]

In 2009, President Barack Obama called for a comprehensive review of the USML and the less-restrictive Commerce Control List (CCL). DoD examined the issue and in 2010, Secretary Robert Gates issued a report. By 2013, many of the restrictions were lifted. This change was welcomed by the domestic industry, foreign buyers, and most sectors in the U.S. government, in particular those that deal with international commerce.[80]

To quantify the outcomes of increased protectionism, the Department of Commerce commissioned a study of the space industry which revealed that not only were companies able to directly attribute lost revenue to the increased restrictions, but over time, they were also less likely to invest in further research and development due to the limited potential markets. "…Some chose not to invest in space-related product lines that had inherently limited access to international markets due to export controls."[81] The amount of lost revenue due to ITAR restrictions between 2009 and 2012 was estimated to be between $988 million and $2 billion dollars.[82] Politically there are those who oppose a narrower USML believing some critical technologies continue to need protection. This argument is not without merit but the competing approach argues that each item placed on the USML needs to be scrutinized before making that critical determination. It was the wholesale designation of a type of export that served to degrade the domestic space industry.

Lastly, the next president will need to decide on whether to support "space arms control" or a "code of conduct" for space. As scholar James Moltz has noted, "Relying mainly on weapons to provide security is costly, risky, and escalatory, as these systems often stimulate rivals to develop systems to counteract them, leading to potential arms competitions and the heightening of tensions."[83] Since February 2008, China and Russia have been promoting a "Treaty on the Prevention of the Placement of Weapons in Outer Space and the Threat or Use of Force against Outer Space Objects" (PPWT). The United States views the PPWT as "fundamentally flawed" because it does not address terrestrially based ASAT capabilities and contains no verification provisions,[84] while others note that the draft accord does not address space debris.[85] Nevertheless, the Sino-Russian initiative has won support from some non-spacefaring nations, since, "many countries are attracted, naturally, to the idea of preventing the weaponization of space."[86]

In December 2008, the European Union (EU) began advocating for a "Code of Conduct for Outer Space Activities," a non-binding international agreement in which countries would voluntarily submit to a set of principles such as non-interference with one another's spacecraft and take actions to minimize chances of collision or debris release.[87] The United States generally supports the EU's draft. China and Russia were initially negative, alleging that the Code was developed without sufficient input from non-European countries, and over time they appeared to view the Code and PPWT as mutually exclusive. At the fourth round of multilateral talks on the

Code, in July 2015, two procedural objections were raised, presumably by countries seeking to scuttle the Code, resulting in the meeting being cut short.[88]

The domestic environment adds complexity as U.S. policymakers pursue space arms control. For example, in February 2011, 37 senators wrote to then-Secretary of State Clinton, stating that they were "deeply concerned" regarding the EU's Code.

The following policies are recommended for the next president:

- *Draft a new treaty together with China and Russia:* The United States, China, and Russia have blocked each other's favored initiatives. We should start from scratch and, importantly, draft a new space arms control treaty jointly instead of presenting pre-formed ideas.
- *Win the diplomatic battle:* While negotiating a treaty, we should be cognizant of the parallel diplomatic/public relations struggle that will take place. For example, we ought to highlight the differences between China's 2007 and our 2008 ASAT tests.[89]
- *Increase U.S. investment in verification technology:* Achieving and enforcing a treaty requires an improvement in our ability to verify and will help win over domestic critics.
- *Intensify engagement with domestic arms control critics and accept a muddled outcome:* Make renewed efforts and, if a two-thirds majority cannot be secured to ratify a treaty, a simple majority would provide the political cover necessary to carry out the spirit of the agreement. A similar situation is effective for the UN Convention on the Law of the Sea.

The first three recommendations are consistent with the broad National Space Policy and should serve as the basis for specific initiatives by the next president. The fourth recommendation does not belong in the Policy, but rather should be pursued by the next administration as an essential tactical element for successfully concluding an arms control agreement.

Space 2.0

Bottom-Line Up Front: Space 2.0 companies are beginning to emerge with new, innovative ideas on providing space-based data and services based on unproven business models that could yield economic benefits in the future.

The emergence of new companies focused on delivering small satellite-based data and services, space tourism, and low-cost launch, known as Space 2.0, have opened new market possibilities for consumers and investors. Space 2.0 promises to provide broadband internet services, high-temporal resolution data services, space tourism, and lower cost launch services. However, the impact of Space 2.0 on the satellite manufacturing, space transportation, or launch market remains to be seen, as these companies mature their business models.

In satellite manufacturing, multinational companies have focused in the past on developing and manufacturing large satellite systems that provide longevity and exquisite capability in small numbers for commercial, civil, and National Security customers. For example, the telecommunication satellite market remains dominated by large companies, such as Boeing; MacDonald, Dettwiler, and Associates Ltd.; and Airbus Defence and Space, all providing high throughput capability from large, powerful satellites in LEO and GEO. These companies are continuing to provide large satellites for most of their customers and have significant order backlogs; MacDonald, Dettwiler, & Associates; Boeing Network & Space Systems; and Lockheed Martin had backlogs of $2.9 billion, $7.3 billion, and $17 billion respectively at the beginning of 2016.[90,91,92]

In contrast, Space 2.0 satellite-based companies are focused on providing high-temporal resolution data streams or broadband internet service with large constellations of small satellites as the foundation of their business models. Some U.S.-based companies, like UrtheCast, have proposed networks of small satellites flying in formation in the same orbital plane to provide different sensor types within seconds or minutes of each other.[93] Google's Terra Bella has designed small imaging satellites that it has turned over to MDA/SSL for an initial production run of at least 13 satellites.[94] This constellation, according to Terra Bella, will provide a new high-temporal resolution data stream of visible imagery for Google's already massive big data repositories. The overall economic value of this data remains unknown.

Other companies are working on large constellations to provide broadband internet to the world. Airbus Defence and Space has recognized the potential demand for smaller satellites in the 150 kg to 500 kg range and is planning to manufacture 900 small satellites for the OneWeb constellation at a new facility near Kennedy Space Center in Florida.[95] SpaceX announced in January 2016 that it would manufacture 4,000 small satellites for a worldwide, broadband internet project. that would be available within five years.[96] Since these broadband capabilities would directly compete with terrestrially-based internet providers, it remains to be seen if these business models are actually viable.

Space 2.0 also extends to the nascent space tourism industry. Companies striving to establish themselves in this market, like the Spaceship Company and Blue Origin, are struggling to mature their technology and navigate flight safety regulations in order to begin flight operations and generate revenue. Currently, the U.S. model of licensing launches and issuing permits for experimental vehicles appears to be more appropriate at this stage of industry development. With a small market and unproven commercial value, the U.S. approach of balancing safety, the freedom to innovate, and industry growth is correct.[97] Eventually the industry will reach a point where more regulation is necessary to ensure spaceflight participant safety. Due to the length of time required for rulemaking, and the potential for explosive growth in demand, regulation could easily fail to maintain the correct balance between safety and economic interests if precursors for a regulatory framework are not developed in advance. It is likely that space tourism will remain a marginal, niche industry.

As mentioned above, the success of SpaceX in lowering the costs of launch services and for innovating in the area of reusable launch vehicles has had a major impact on its competitors, ULA and Arianespace, members of the traditional space community. The entry of SpaceX into the market has put downward pressure on the cost of launch and has forced ULA to reexamine its cost structures to remain competitive. Currently ULA is well positioned to maintain its capability in the upper spectrum of heavy launch for the next five years. However, the development of SpaceX's Falcon 9 Heavy—its next generation heavy rocket—and the Ariane 6 will challenge ULA's position. Development of new rocket engines by Blue Origin and Aerojet Rocketdyne to replace the Russian RD-180 used on the Atlas V and as boosters on the Space Launch System (SLS) will address our National Security Space Launch requirements and return this critical capability to the U.S. industrial base.

Government support appears to be key to the success for Space 2.0 companies. Even though NASA has spurred innovation and engendered international cooperation with its private-public ventures, purely commercial efforts such as broadband from space will be more likely to succeed if government contracts for these Space 2.0 services emerge in the future. SpaceX's ISS resupply and National Security space contracts have created secure funding streams for its riskier ventures. Small satellite-based companies are emerging with some government support through

Cooperative Research and Development Agreements and Defense Advanced Research Projects Agency research contracts. However, there is no consistent policy on how the civil and defense communities will support these Space 2.0 companies though the National Geospatial-Intelligence Agency's Commercial GEOINT strategy is focused on determining how to leverage these new technologies for its intelligence and combat support missions.[98]

Conclusion

For much of the last 50 years, the United States National Security space community worried little about hostile threats. Space was mainly used for the strategic purposes of intelligence gathering, nuclear deterrence, and treaty verification. Now, the United States is reliant on the space infrastructure for the projection of military power to maintain its tactical and strategic advantage. The recent combat operations in Afghanistan, Iraq, and Syria have shown a reliance on space capabilities and signify a shift to the operational and tactical impacts of space. There is a growing and valid concern that future conflicts will include attacks on space based assets.

A strength of the U.S. government is in its collaboration with domestic industry. This nexus between public and private companies provides myriad opportunities for both sides to excel. The ability to capitalize on this collaboration will determine the future health of the domestic space industry. Now is the time for the U.S. government to ensure the future of the industry moving forward, before another country fills the gap entirely. The United States needs to work continuously with industry to advance technology and maintain our cutting edge superiority while finding viable commercial applications and markets to maintain the sustainability of the industry. For most companies, the U.S. government cannot be the sole consumer, so maintaining a healthy commercial market serves all parties. The government needs to provide industry with market signals and predictability while ensuring the regulatory environment is conducive to growth. Industry needs to continue to innovate and compete in order to provide the best service at the lowest cost for the taxpayer.

The next President of the United States will face thousands of issues when he or she takes office. Space must be top-tiered on that list. The United States must be ready to tackle resiliency and maintain assured access to space. But so too must it expand and enhance its international cooperation. Lastly the next president must be familiar with the market disruptors in the form of Space 2.0. Space is a changing landscape, and the United States must not only keep up, but lead the way in the next decade and beyond.

Space is now essential to everyday life and this is an exciting period in history with the emergence of new space. Our reliance will only continue to grow on services from beyond and thus, the United States needs to work with industry to build resiliency into all we do. It is only then that the United States will be well-positioned to "Boldly go."

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