AMERICAN SPACE

ENTERPRISE AND SECURITY

POTOMAC INSTITUTE
FOR POLICY STUDIES

January 2018

Contributors to this report include:

Michael Swetnam
Jerry Krassner, PhD
Kathryn Schiller Wurster
Luke Koslosky
Chloe Hite
Erica Turner
Sara Usher, PhD
Derek Denning, PhD

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POTOMAC INSTITUTE FOR POLICY STUDIES
901 N. Stuart St, Suite 1200
Arlington, VA, 22203
www.potomacinstitute.org
Telephone: 703.525.0770; Fax: 703.525.0299
Email: webmaster@potomacinstitute.org

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EXECUTIVE SUMMARY

Commercial development of space, the moon, and eventually the planets has begun. Every major nation on earth is investing heavily in space, while industry is investing hundreds of billions of dollars every year to develop the next commercial enterprise of the human race.

The United States has traditionally led in the development of space technology but today is rapidly falling behind just as industry and commerce are stepping up to the opportunity.

It is now time for the U.S. government to step up, assert U.S. leadership, invest in the economic future of the human race, and maintain America's position as first in space just as we are first on Earth.

Addressing this challenge appropriately will require a retooling of NASA from a research and exploration agency into the arm of government that supports, facilitates, and underwrites the economic development of space. We will need to empower and resource the Department of Defense (DoD) to protect our commercial and national interests in space; maintaining open and free space commerce. And, we will need to direct our vast Intelligence Community (IC) to focus on this new frontier keeping us informed of the activities, intentions, and misintentions of our competitors as well as our adversaries.

Commercial development of space, the moon, and eventually the planets has begun. Space is the next frontier for economic development.

Space is the Next Frontier for Economic Development

Throughout U.S. history, the government has served as a key investor in the essential science, technology, and infrastructure that provided the foundations for commercial enterprise to thrive. To realize our great potential in space, the national space program of the United States needs to be redesigned, with NASA driving and enabling civil and commercial space.

Recommendations for NASA

- NASA must lead a concerted national effort that marshals the entire civil movement of humans in space.
- NASA's mission should shift to leading a civil, commercial, and industrial venture into space enterprise to create a robust industrial infrastructure in low Earth orbit and cislunar space.
- NASA should encourage, partner with, and underwrite the costs and risks of the commercial space industry in coordination with its existing programs. Science and exploration should be mission-driven to support this goal. NASA should coordinate with the Departments of Commerce, State, Transportation, and others as needed.
- NASA should be resourced appropriately to fulfill this mission.

Maintaining Free and Open Space Activities

The Department of Defense is tasked with protection of the United States and our interests globally. As the United States moves to space, we need to further task the Department of Defense with protection of U.S. assets, citizens, and commercial activities in space, as well. Ensuring the free and open flow of people, technology, and commerce in space is critical to U.S. interests today and will only become more so as this new frontier is realized.

Recommendations for the Department of Defense

- The Department of Defense's mission must include the requirement to protect U.S. interest and commerce in space. The Department of Defense should be tasked with ensuring the freedom of U.S. commercial activities in space.
- Expand Title 10 authorities to enable DoD to develop and deploy capabilities for defense of space-based assets.
- The Department of Defense should be resourced appropriately to fulfill this mission.

Maintaining Awareness and Intelligence

The United States Intelligence Community has served as the beacon of warning that ensures our freedom and deters surprise. Our vast global intelligence capability has played a critical role in sustaining U.S. leadership and will be just as critical as we move into space.

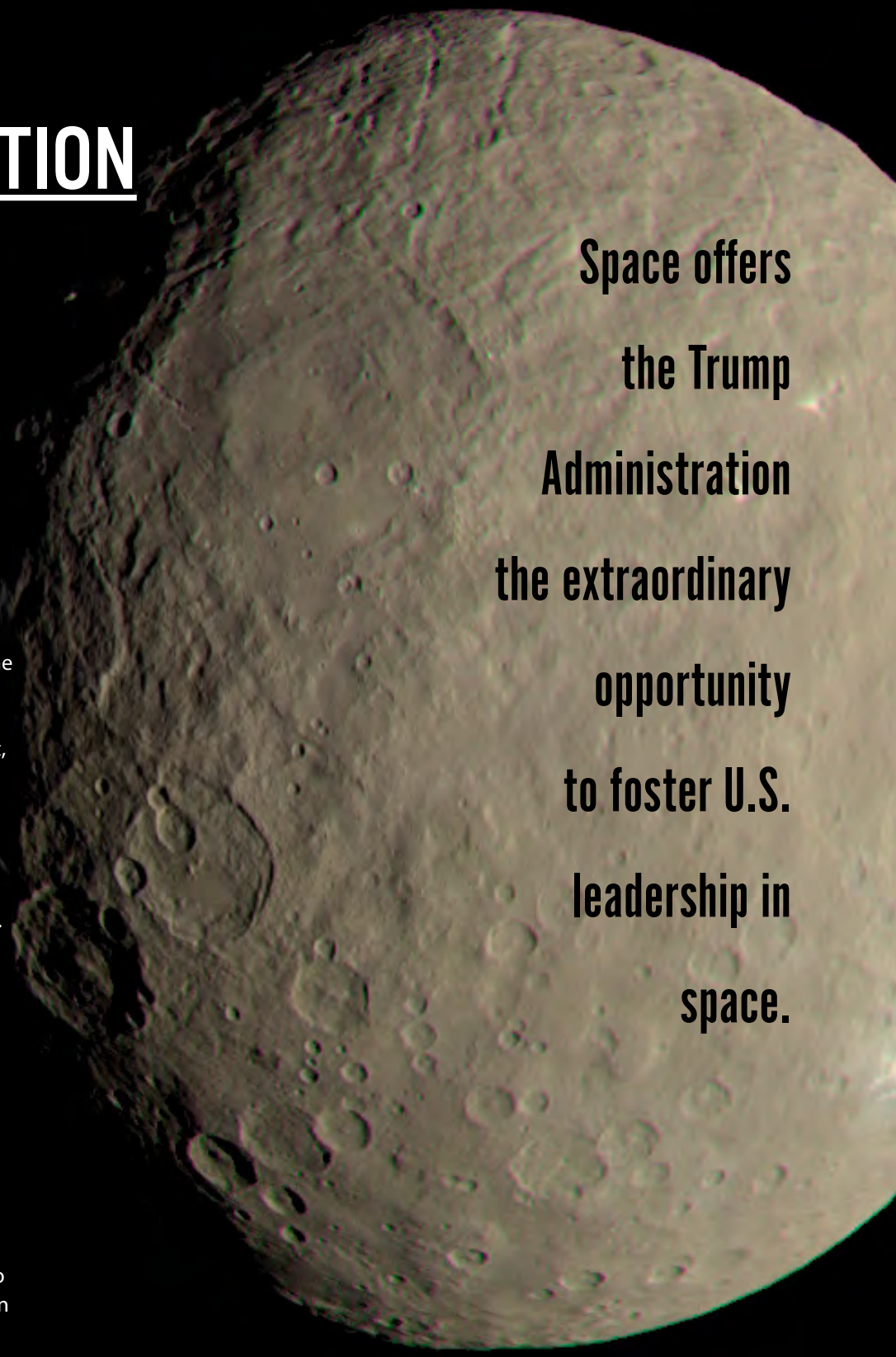
Recommendations for the Intelligence Community

- The Intelligence Community must monitor the space activities and intent of our adversaries.
- The Intelligence Community should continue to develop, procure, and deploy all national security data collection technology under the sole authority of the Director of National Intelligence (DNI) as authorized in USC Title 50, and extend this data gathering to the space domain.
- The Intelligence Community budget should reflect this priority, with appropriate investments.

INTRODUCTION

Space offers the Trump Administration the extraordinary opportunity to follow in the footsteps of past great American leaders by both expanding into a new frontier and creating novel, innovative technologies and industries. The United States is a nation made great by its discoverers and inventors consistently driving innovation and leading exploration, backed always by the strength of its military. Previous seminal investments by the U.S. government such as the Internet, the Human Genome Project, the Interstate Highway System, the semiconductor industry, and countless more highlight the government's ability to catalyze and harness American ingenuity.

In keeping with this tradition, the U.S. has unquestionably been the preeminent power in outer space. This administration has the opportunity to propel U.S. leadership in space to new heights: exploring and creating infrastructure in a new frontier, expanding commercial industry in space with the introduction of new markets, and developing and disseminating technology to allow America to rise further than it ever has before.



Space offers the Trump Administration the extraordinary opportunity to foster U.S. leadership in space.

Photo credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

This opportunity is exciting, but it will not last forever. In sharp contrast to investments of the past, investment in space is not purely an American investment, and is thus not at a time of our choosing. Already, the ascendancy of other competing space-faring nations is threatening the longstanding American space hegemony with possible decline. As demonstrated by the growing capabilities of the People's Republic of China, the U.S. can no longer assuredly guarantee the competitive advantages afforded by its space-based assets. Simultaneously, our economic and defensive reliance on these assets has risen to the point of dependence. As its value continues to rise, space has become a warfighting domain just like air, land, and sea, as was sharply illuminated by Chinese antisatellite (ASAT) test in 2007 that destroyed a malfunctioning weather satellite. Today, "Space is fundamental to every single military operation that occurs on the planet today."[1]

The importance of the space domain to the U.S. economy and its national security will only continue to grow. This environment offers daunting challenges, but also contains vast potential for growth. Space truly is the next frontier for exploration, economic development, and warfare, and this administration can make a concerted national investment to solidify U.S. leadership moving forward.

The historical precedence of past U.S. government investment in promising industries and new frontiers like the railroads, the highway system and the semiconductor industry shows that substantial federal funding is crucial to jumpstart ventures requiring high-cost, high-risk initial investment. This forward-thinking investment is one of the inherent functions of the federal government. No private sector individual, company, or conglomerate will assume responsibility for the economic well-being of its populace or possesses the resources to create new industries. Only government is capable of taking a long-term view of the general health of the economy, and providing the funding for far-reaching investments. Just as the Space Race produced profitable technologies like satellites, this new era of space will create untold new technologies and novel industries. The types of ventures that are currently being envisioned by the commercial sector include asteroid mining, lunar mining, civilian tourism, on-orbit manufacturing, and in-orbit servicing. These are all multi-billion dollar projects that could take companies decades to realize, if at all, due to their new and experimental nature. Such delays could be perilous for the U.S., who might find itself usurped by another country more willing to subsidize its commercial space industry.

NASA is uniquely positioned to function as the mechanism for directing and funding this investment, which would require a fundamental shift in the agency's mission. To do this, NASA's role should be to support, direct, and enable industry, just as the commercial airline industry was fostered under government direction. In-house technology development should be outsourced and contracted to industry, along with a transition from internal science research to funding of research, similar to the practices of the National Science Foundation (NSF). NASA centers should function largely as industry partnership centers rather than full research and development (R&D) procurement, production, and operations centers.

There is successful precedence for this type of restructuring. DoD has a defense industrial base to support its mission, NASA should have a similar space industrial base. The Department of Energy has its own labs, but does not build and operate the whole national grid – that has been commercialized. NASA can become a hybrid of these practices, using best practices from various successful government-commercial ventures while also leveraging its existing institutional knowledge, infrastructure, and expertise in concert with private ventures. Granting NASA an increased budget to further underwrite costs and fund commercial ventures will stimulate a vibrant commercial economy and infrastructure in space.

As the U.S. expands its civilian presence in space through NASA's guidance of the private sector, the Department of Defense (DoD) will have to accompany it to ensure the protection of all na-

tional assets. In the past, the U.S. was able to defend and protect its expanding economic interests through the diligent efforts of the U.S. military. The exploration, expansion and settlement of the U.S. frontier and its commercial interests would not have been possible to defend and maintain without the creation of the frontier forts by the U.S. Army. Similarly, commerce on the high seas was only achievable because of the protection from piracy by the U.S. Navy.

In parallel with historical examples, the competitive trends in space will necessitate a strong military presence for the deterrence of aggression and the protection of critical national interests, over and above the capabilities that exist today including the maintenance of free and open space-lines-of-communication. DoD should build a space defense capability to protect our space assets and keep critical infrastructure open. This will include the ability to defend our space assets in situ, and if necessary, wage war in space. DoD's authorization should be updated to reflect this need. This includes granting the Air Force the authority to acquire, equip, and man all space defense capabilities as necessary, without relying on any Title 50 agencies.

Countries like China have already matured their perspective of space to one of a domain of enterprise by reorganizing its military (e.g., the Strategic Support Force) and heavily investing in various technologies that target vulnerable U.S. space-based operational centers (e.g., A2/AD, kinetic-kill, co-orbital, and directed energy ASAT weapons), with the goal of maintaining lasting infrastructure in space.[2] To maintain leadership in space, we must embrace space as "the next frontier" by protecting our interests and citizens.

The IC's mission should likewise be updated to support the increased DoD mission, and clearly delineate its role. This represents a split in the existing National Reconnaissance Office (NRO) structure; DoD must re-establish acquisition authority for all space assets needed in its expanded mission, while the IC should be authorized to develop, procure, and deploy assets as necessary for all national security data collection technology under the sole authority of the Director of National Intelligence (DNI). As DoD capabilities and potential future conflicts continue to migrate into the space domain, the IC must similarly evolve to collect information and intelligence in outer space, not just from outer space. They should hold responsibility for all space situational awareness, including all collection and dissemination of relevant data, and develop the capabilities to know what adversaries are doing throughout the entire solar system.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ROLE OF GOVERNMENT

BUILDING THE FOUNDATIONS FOR SPACE ENTERPRISE

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The long-term and far-reaching benefits of a large investment in the economic development of space, led by NASA, can be drawn from the history of the United States Government's role in industry and expansion. The United States Government (USG) can incentivize the entire global community to colonize space by jumpstarting the development of domestic civil space. There are numerous historical examples of the USG playing the role of pathfinder for many successful commercial industries, either through investment in infrastructures critical to the development of industry, or through research and development investment of risky but promising new technologies, an inherent government function.

The United States government can drive the future space economy by investing in infrastructure, research and development.

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PAST U.S. GOVERNMENT INVESTMENTS IN INFRASTRUCTURE HAVE LED TO MASSIVE ECONOMIC DEVELOPMENT

The USG has been a trailblazer, spurring the development of healthy and productive private industries that benefit both the government and the private economy alike.

From the roots of westward expansion beginning with Lewis and Clark's expedition, leading to the "Manifest Destiny" movement, the Oregon trail, and the Homestead Act of 1862, the USG has an established history of underwriting industry on new frontiers, resulting in massive returns for the government and a corresponding boost to the American economy and quality of life. From the Homestead Act – an investment of public lands – up to the USG's support of the Human Genome Project – a sustained investment of R&D funding – the USG has been a trailblazer, spurring the development of healthy and productive private industries that benefit both the government and the private economy alike.

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INFRASTRUCTURE INVESTMENT	INITIAL INVESTMENT	OUTCOME	RETURN ON INVESTMENT
Interstate Highway System	Government project over 40 years spending about $113 billion by 1995.	By 1995 the highway had returned $4.1 trillion in total benefits.	Estimated at 36:1 by 1995.
Erie Canal	Federal government invested $107 million to construct the Canal.	By 1882 had collected $3 billion in tolls alone, not including opening transit and new industries.	At least 28:1, with substantially more value in transportation and travel.
S&T INVESTMENT	**INITIAL INVESTMENT**	**OUTCOME**	**RETURN ON INVESTMENT**
Human Genome Project	Federal government invested $9.2 billion.	Massive in biotech industry and related fields valued at $891 billion.	Currently 97:1 and growing.
The Internet	ARPA invested $7 million in ARPANET.	Creation of the Internet, and entire new industry. Businesses directly involved with the Internet generated almost $1 trillion in 2015.	At least1,000,000:1.
Semiconductors	Government contracts totaling $350,000,000 awarded to Western Electric, General Electric, Raytheon, RCA, and Sylvania in 1952-53 and 1956-57 to research transistor technology.	In 2015, the U.S. companies produced 50% of the world's semiconductors, valued at $339 billion.	968:1 and growing, taking into consideration only the investments made by the USG to develop semiconductors for defense industrial base use.

Table 1. Past U.S. Government Investments with Significant Return on Investments. All costs adjusted for inflation to 2017 dollars.

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THE ERIE AND C&O CANALS

In response to a need for expanded transportation routes, with the goal of stimulating an already growing economy and expanding its reach, in 1810 the Legislature formed the Canal Committee, much to the chagrin of the ruling majority.[3] But with time, many came to see the need to think ahead of a rapidly growing economy to promote its continued well-being, and in 1817, Congress passed an Act that allowed for initial construction of the Erie Canal to begin.

The Erie Canal is one of the first examples of a government investment that led to the creation of many new sectors, prompting massive returns on investment for both government and private industry. At its completion in 1825, the Erie Canal was 363 miles long, connecting New York and the upper Midwest.[4] To fund its construction, the New York State government invested approximately $7 million, and in order to put in perspective the enormous economic boon the Canal provided not only to the state of New York but to the nation as a whole, consider this: toll revenue alone from those using the Erie Canal paid off the state bonds taken out to fund it in only nine short years.[5]

Many believe the return on investment (ROI) of the Erie Canal to be incalculable, given its impact on innovation and commercial expansion east-to-west, though the calculated ROI in 1882 from toll revenue alone was $121 million in 1882 dollars.[6] The construction of the Erie Canal seeded the industrialization of New York City into the city the world knows today, dramatically increasing its population. Furthermore, while the economic impact the Erie Canal is difficult to quantify, consider another starling figure: the Erie Canal cut the cost of shipping from $100 per ton of cargo to just $8 per ton of cargo.[7]

Likewise, construction of the Chesapeake and Ohio Canal began in 1828 with mixed public-private investment. The Canal was completed in 1850 with a final price tag of $11 million.[8] The "C&O Canal," as it came to be known, allowed for the shipment of flour, grain, building materials, and later coal to bustling Georgetown, Washington D.C.[9] New jobs sprung up along the C&O Canal, then new towns, and finally the development of a new Canal-localized economy that grew to benefit local and state governments, as well as those working on the Canal. Even though it no longer serves industrial purposes, the C&O Canal still generates revenue and contributes to the economy as a site for recreation and tourism. In this way, though the C&O Canal had an immediate impact on the local economy of the Midwest and mid-Atlantic states, and prompted immediate returns on investment both during its construction and after its completion. Furthermore, the Canal continues to make an economic impact into its old age. In parallel with the potential impacts of NASA seeding the civil development of space, imagine how an initial investment in space infrastructure could enable private industry to dramatically decrease the cost per pound in orbit.

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THE HOMESTEAD ACT OF 1862: GIVING LAND, SEEDING OUR NATION'S WESTWARD EXPANSION

One of the most significant investments in westward expansion was the Homestead Act of 1862, which prompted the industrial development of the West. By offering settlers 160 acres of land in exchange for a 5-year commitment to develop that land, it provided men and women the opportunity to pioneer the western frontier, and simultaneously

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develop and cultivate untouched land. In fact, 10 % of the United States was settled as a result of this Act. The distribution of public land to private citizens revolutionized westward expansion, the effects of which can still be detected today.[10]

THE TRANSCONTINENTAL RAILWAY

The construction of the first transcontinental railway, from Omaha, NE to Sacramento, CA allowed for the opening of general access to the West. No longer did those wishing to manifest their destiny in the Western territories have to slog on foot, in covered wagons through unknown terrain. The USG's investment in the railroad was a shot in the dark, and was an investment too large for private industry to make for the sake of business development. The railroad dramatically reduced the cost and travel time for those who wished to move West, from a six-month-long journey costing $1000, to a week-long trip costing $150.[11] This drove up interest in moving westward, and stimulated the permanent settlement of California and what would become the western United States. The first transcontinental railway system also proved to generate a large profit for private industry, invigorating the economy while providing and easy avenue for westward expansion and thus the creation of new markets.

Similar to the way in which the transcontinental railway brought about a new economy, the first ten years of the Union Pacific Railway saw $50 million worth of cargo shipped every year.[12] Though the construction of the Union Pacific Railway was at heart a private endeavor, the USG passed legislation allocating funds to aide its construction through the Pacific Railroad Acts of 1862 and 1864.[13] Today, the very same railroads in which the USG initially invested are still heavily used for freight, and account for 39.5% of all shipping in the United States.[14]

In a broader sense, the proliferation of railroads, and the USG's investment, led to a boom in innovation, spawning new economic centers and local industries.

The USG's decision to subsidize the construction of the Transcontinental Railway continued the progress set in motion by the construction of the Erie Canal, expanding the United States' economic leadership westward. As history has demonstrated, USG investments in critical infrastructure are not only positive, but play a necessary role in U.S. economic growth and competitiveness. A similar underwriting of private industry's endeavors in developing civil space by NASA would continue the United States' heritage of promoting innovation and driving leadership on the next frontier.

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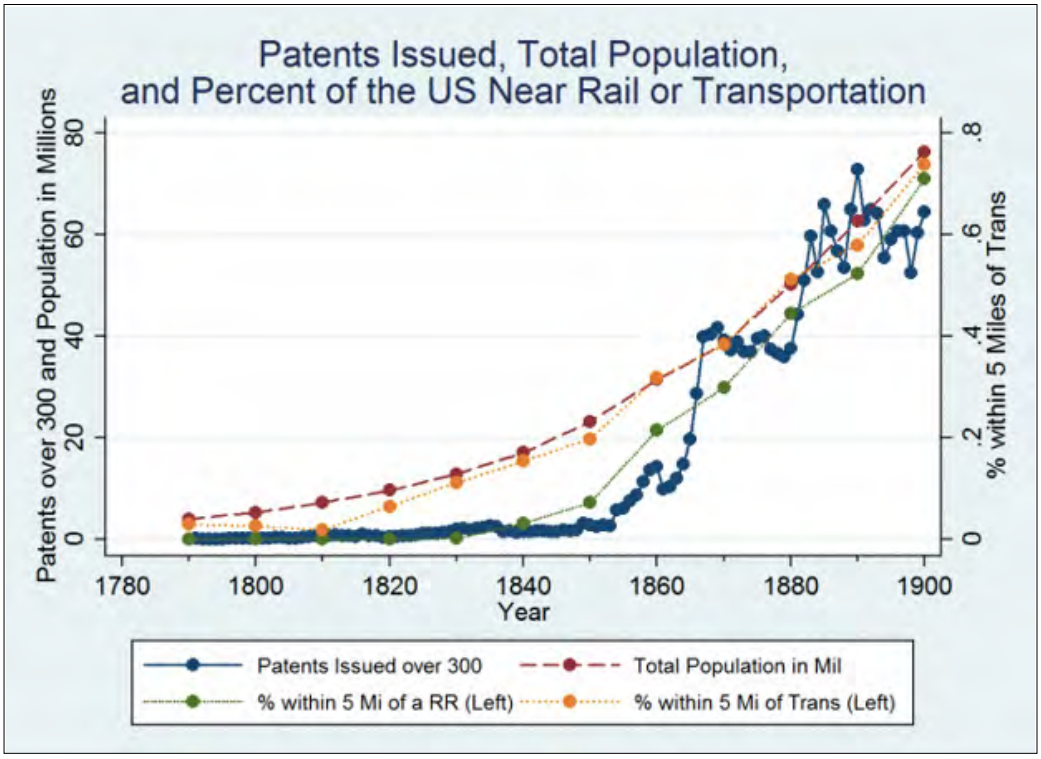

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THE INTERSTATE HIGHWAY SYSTEM

The next great investment made by the government that prompted private industry leadership in a new sector was Dwight D. Eisenhower's Interstate Highway System. In 1956, the Federal-Aid Highway Act (F-AHA) allocated $26 billion to build a 41,000-mile-long network of highways in the United States, estimating that by project's end, costs would total $41 billion. In 1995, ongoing construction, operations, and maintenance had totaled $329 billion dollars (this translates to $58.5 billion in 1956 dollars). Though the Interstate Highway System cost 37% more than the initial estimate made by the Federal-Aid Highway Act, it has directly returned $6 for every $1 spent. Even more, the U.S. as a whole has benefited by a margin of $2.1-2.5 trillion over the 40-year period from 1956 to 1996. This is 6-7.5 times the initial investment made by the USG in 1956.[15, 16]

The Interstate Highway System also served the economic interests not only of the USG itself, fulfilling its need for hastened defense transportation, but of vehicle, oil, gas, and tire companies, as well as union groups. Upon completion, these highways reduced travel time, increased interstate shipping, and provided a boost to automobile industry sales.[17] The act of investing in new modes of interstate travel set in action a chain of other economic events, facilitated by the new ease of interstate travel.

In addition, the construction of federal highways addressed several concerns. They allowed for quick evacuation from urban areas in the case of an atomic attack, a reduction in local traffic, and increased ease of intercontinental travel.[18] As noted, the interstate not only eased travel but allowed for the development of an extensive shipping infrastructure. To date, the Interstate Highway System is the most extensive public works project ever completed, with one of the largest returns on investment in history.[19]

PAST U.S. GOVERNMENT INVESTMENTS IN RESEARCH AND DEVELOPMENT HAVE RESULTED IN ECONOMIC GROWTH

The United States has not only invested in the raw physical infrastructure needed to build a business, but in research and development of preliminary technologies that have grown into multibillion and trillion-dollar technologies. The development of the semiconductor industry, the Internet, and the Human Genome Project all exemplify the way in which USG investment has revolutionized technology as we know it. The research and eventual development of these industries has resulted in massive tax revenues for the USG, increased U.S. economic output, and advanced the U.S.' enduring leadership in the tech industry. A like investment in the space sector will have the same affect, by lowering the barrier to entry for new companies and investors, opening up new markets, and sparking a renaissance of space R&D, with eventual tax returns and offshoot industries to match.

Investment in Research and Development has resulted in massive tax revenues, increased U.S. economic output, and advanced U.S. technological leadership.

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THE HUMAN GENOME PROJECT

United States government investment has also impacted the field of biology, with an investment to sequence the human genome via the Human Genome Project (HGP) in 1988. The National Institutes of Health and the Department of Energy supported this effort that set out to identify all 3 billion base pairs that make up genes in the human DNA sequence.[30] This sequencing research has been used to make advancements in medicine, though this has not been the only impact of the sequencing of the human genome. Thanks to the HGP, impacts have been made in the sectors of renewable energy development, industrial biotechnology, agricultural biosciences, veterinary sciences, environmental science, forensic science, homeland security, and others.[31]

Between 1988 and 2003, the USG invested $5.6 billion (in 2010 dollars), through the completion of the sequencing of the human genome in 2003. It was estimated that up until 2011, the initial investment had led to a $746 billion ROI, with approximately $141 returned to the U.S. economy for every $1 in government funding invested, with more returns every year.[32] In 2010 alone, federal, state, and local income tax revenues totaled $6 billion, more than the government's entire 13-year investment.[33]

The applications of the HGP are manifold, but include the diagnosis of single gene disorders, assessment of genetic disease, the development of new drugs, and gene therapies, to name a few.[34] Perhaps the best part of government investment in the HGP is the scale of returns that the NIH and DOE are already seeing, in such a short time since the end of the project. Those returns will only continue to grow in terms of tax revenue, job creation, personal income, and U.S. economic output. While the HGP is still a relatively recent example of the USG's investment in scientific R&D, it is one of the better examples of the government supporting research that pushes frontier boundaries, creates new industries, and seeds U.S. leadership.

THE DEVELOPMENT OF THE SEMICONDUCTOR INDUSTRY

Semiconductors are the building blocks of all modern-day technology and while one of the largest global industries today, the semiconductor industry dates back to World War II and USG strategic investment to develop Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs). In the late 1940s, DoD distributed R&D funding to several research organizations to encourage competitive development of semiconductors, and NASA has also invested R&D funding to develop semiconductors for use in space.[20] Even more, from 1952-53 the USG helped fund the development of U.S. semiconductor manufacturing capabilities for commercial production, and maintained demand for semiconductors by awarding industrial preparedness contracts to the first manufacturers (Western Electric, General Electric, Raytheon, RCA, and Sylvania).[21] These contracts provided much of the help that commercial industry needed to get their production efforts up and running, and DoD's investment totaled $40 million.[22]

The value of the U.S. investing in semiconductors is that it created a new defense industry, and a technology, that without which, the modern-day world would cease to function. From 1981 to 2011, the semiconductor industry contributed more than any other industry in terms of growth in value added, growing 264.9%, past petroleum refineries and the pharmaceutical industry.[23] In 2015, United States companies produced 50% of the world's semicon-

Photo credit: www.pixabay.com.

ductors, a market valued at $339 billion globally in 2016.[24] In the U.S. alone, the semiconductor industry is the third largest manufacturing industry, contributing $65 billion to the U.S. economy.[25] More importantly, semiconductors today drive a more than $1.3 trillion dollar global economy of goods and services.[26]

THE DEVELOPMENT OF THE INTERNET

The Internet has caused a level of disruption in our modern world that is unmatched. It is an integral part of modern society, undergirding business, government, education, social interaction, and virtually all other aspects of modern life. The creation of the Internet was made possible by the creation of its precursor, ARPANET, a government-funded defense project initially aimed at linking Pentagon computers. Funded on the order of millions of dollars, ARPANET and its progeny the Internet have resulted in novel, multi-billion dollar industries and have optimized an untold number of existing industries. The sprawling nature of the Internet's influence in every industry imaginable makes calculating the ROI of ARPANET impossible, but it can surely be considered one of the most profitable ventures the USG has invested in.

The Advanced Research Projects Agency Network (ARPANET), was an experimental computer network created under DoD in 1969. ARPANET was an end result of years of research in computer communications, prompted by the very real threat of a surprise nuclear attack by the Soviets. ARPA gave birth not only to computer networks and the Internet, but also computer graphics, parallel processing, computer flight simulation, and many other technological innovations.[27] Attempting to measure the total impact of the Internet on the global economy is difficult, but McKinsey in 2011 put it as $8 trillion dollars,[28] and Boston Consulting Group put it around $4 trillion in 2012.[29]

ARPA's development of computer-linking networks would eventually bring the dawn of today's Information Age. This investment seeded the development of novel and now widely used forms of connecting humans to information, goods, services, and each other. Furthermore, because it played an integral role in the creation of the platform used by most modern technology, the United States is a leader in many of the tech-related sectors made possible by the existence of the Internet. While the history of the U.S. government's involvement in the development of the Internet is lesser know, it is one of the best examples of the USG's crucial and timely investment in R&D for a high-risk, high-reward technology, with truly incalculable returns.

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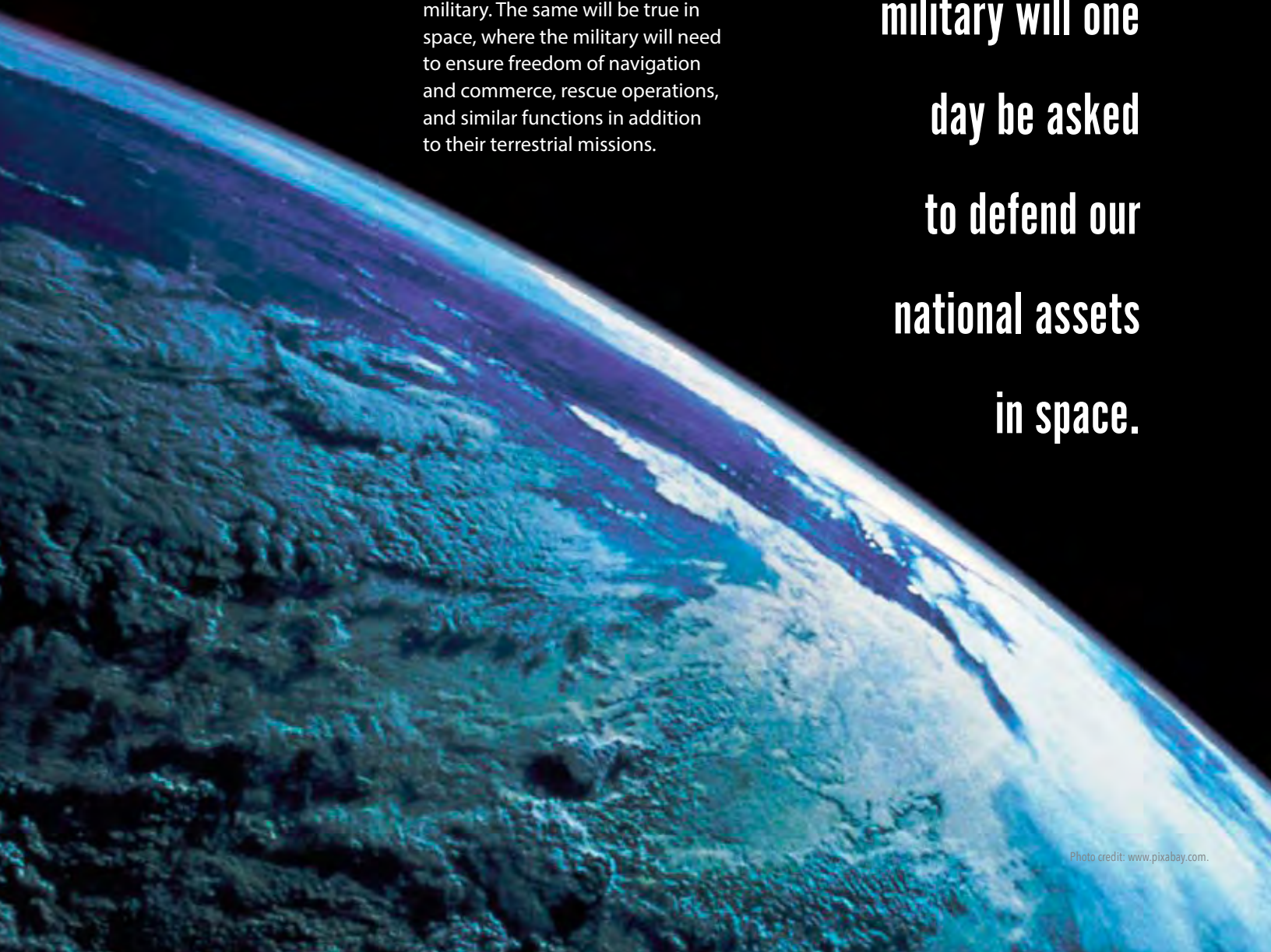
THE ROLE OF DEFENSE IN U.S. ECONOMIC EXPANSION

The role of defense has been crucial in the creation and preservation of U.S. exploration, expansion, and economic advancement that began with the Manifest Destiny and have continued to today.

Exploring and settling the U.S. westward frontier, or enabling a young country to initiate international trade, would not have been possible without the protections afforded by the U.S. military. The same will be true in space, where the military will need to ensure freedom of navigation and commerce, rescue operations, and similar functions in addition to their terrestrial missions.

Just as the Navy defended U.S. merchants against piracy, the U.S. military will one day be asked to defend our national assets in space.



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The formative pressures that led to the U.S. Navy involved protections of similar freedoms, even as the country was in its initial formative period. Interestingly, as early trade contact between the U.S. and China grew substantially, the U.S. built supporting outposts and ports throughout the Pacific. This expansion led to an increase in U.S. diplomatic interaction between the two countries and increasing prominence of U.S. international standing.

However, growing commerce and trade led to the need for military protections. The establishment of the U.S. Navy on 13 October 1775, was a response to piracy that plagued the Atlantic Ocean, Caribbean, and Mediterranean Sea. President George Washington responded by creating the Naval Act of 1794, which authorized the Navy as a defensive force for the protection of merchant ships. Meanwhile, piracy attacks continued well into the 1800s as many former colonies in South America gained independence, creating a niche for pirates to take advantage of unprotected merchant ships.

In response, the U.S. Navy provided escort ships for protection of commercial vessels and small craft ships to search for pirates. As counter-piracy pressures mounted, the USG was driven to invest in science and engineering, which better enabled the Navy to perform its mission. For instance, the first steam-powered ship was a consequence of, and led to the end of, frequent piracy attacks. As piracy attacks decreased in response to defense investment, the U.S. was able to clear the way for American economic interests in South America. By the mid-1800s the Navy was so successful in protecting and preserving U.S. commercial interests that it helped solidify American western expansion all the way to the Pacific Ocean.

So, we see the creation of the Navy was a response to U.S. economic growth that included the development and protection of Freedom of Seas. A growing U.S. economy led to U.S. exploration and expansion across the Pacific, Caribbean and Atlantic, while U.S. interests in commerce and trade increased U.S. diplomatic ties. These ties matured and were preserved by an outward-looking and technologically-advancing U.S. defense structure.

Looking to the westward expansion, in 1790 the U.S. claimed all Indian territory east of the Mississippi River and granted all Indian affairs to the


Image credit: NASA.

War Department (i.e., U.S. Army and U.S. Navy). Westward expansion was incentivized by the U.S. government through legislation that created opportunities for economic mobility (e.g., the Manifest Destiny movement and the Homestead Act of 1862). Subsequently, the government sent troops to maintain law and order and protect commercial assets that developed, so as to assure the continued success of its incentivizing westward expansion.

From 1815 to 1860 the U.S. Army's main function was to protect U.S. settlers from Native Americans. As transportation was a key component of settler protection, the Army was responsible for facilitating easier transportation routes westward. Westward expansion led to an explosion of innovation linked to new infrastructure and transportation routes. Steamboats replaced sails, and the railroad replaced the horse and buggy. These technologies and protections provided by the Army allowed economic growth to surge as settlers were able to move goods and people more freely and safely, which were paramount in solidifying American exploration, expansion, and economic growth.

Fast forward to today, and the critical role of space in society has driven a need for defense in space. The proliferation of counterspace weapons places at risk satellites in all orbital regimes. As in the past, the military is called on to protect freedoms of navigation and operations in the "international waters" of space.

The military must provide such protections in order to ensure the availability of military platforms, whether surveillance, navigational, or otherwise. Today, the focus of space operations is largely in support of terrestrial missions. The resilience of our military space architecture is critical to our warfighting capability. However, in the future, additional military requirements will focus on space-based protections of commercial, as well as military, platforms, and extend beyond the geo belt to the moon, key deep space locations (such as the L1/L2 points), asteroid intercept orbits, and eventually Mars. The military will again be asked to provide services similar to those in the westward expansion, maritime counter-piracy, and similar historical examples, except this time in the global commons of space.

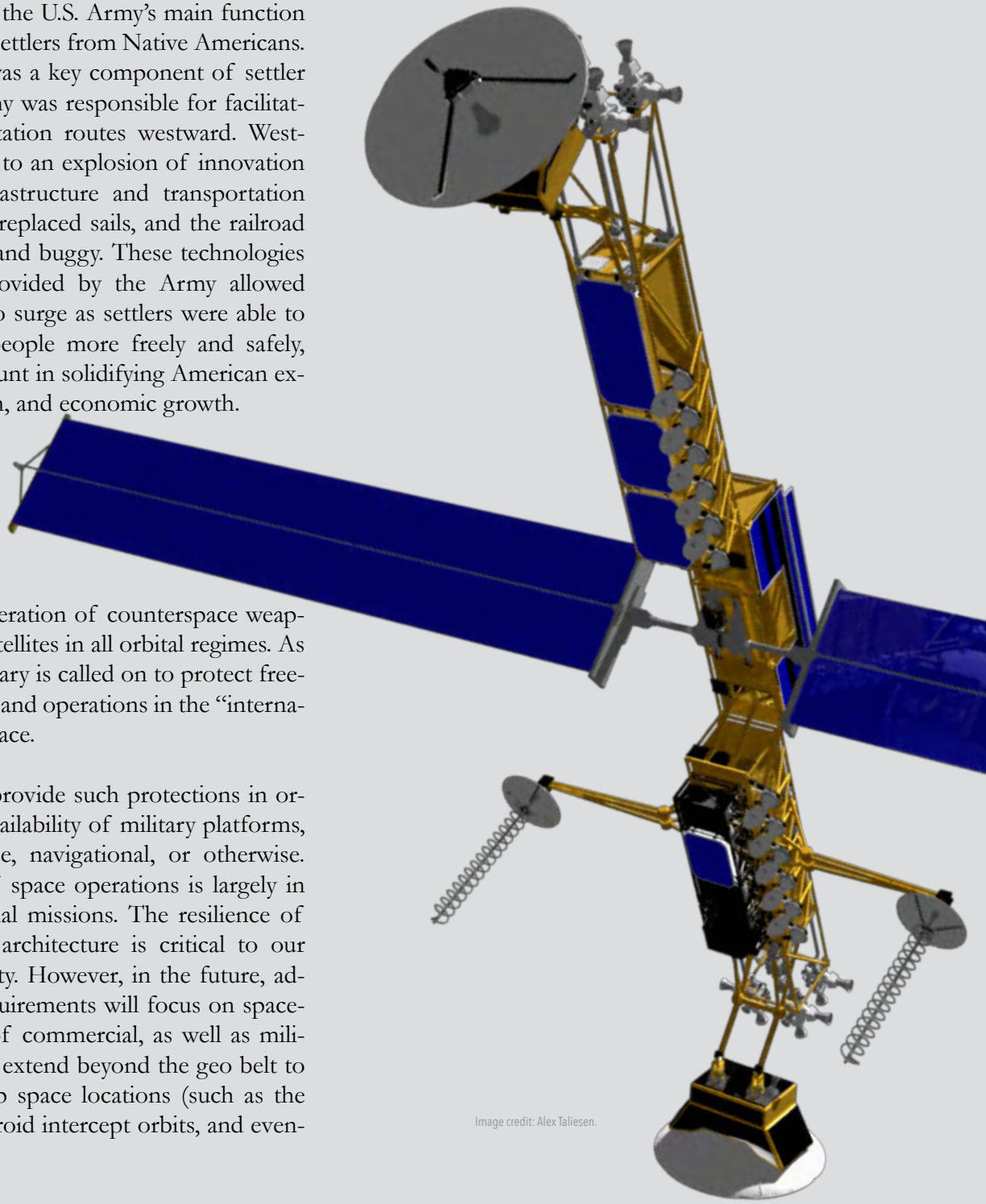


Image credit: Alex Taliesen.

HISTORY OF THE NATIONAL SPACE PROGRAM

The structure of the U.S. space program today – division into civilian, military, intelligence – is a product of the environment of its founding during the early stages of the Cold War. Understanding this division is an important aspect of recognizing the changes that are now necessary in a changed environment.

In 1945, German rocket expert Wernher von Braun published a report for the U.S. Army outlining the possibility of developing a manmade satellite. The military services continued to explore the feasibility of the proposed new technology, and in 1946 Major General Curtis LeMay commissioned a RAND study on the issue.[35] The report concluded that an Earth-orbit satellite was entirely possible and offered a number of non-military benefits, including the gathering of scientific information, weather data collection, and communications, as well as weapons delivery and attack assessment. Most importantly for the coming years, the report noted that "the satellite offers an observation aircraft which cannot be brought down by an enemy who has not mastered similar techniques." While a number of military officials were keen to pursue the findings of these reports and develop capabilities in space, the prospect was met with ambivalence from policymakers and at times outright opposition from OSD.[36] Through the early 1950s, all space-related research and development was kept within the military, and continued at a relatively steady, but slow, pace. The launch of Sputnik on October 5, 1957 changed that, and began the transition to the organizational structure of the modern day.

The structure of the U.S. space program today – division into civilian, military, intelligence – is a product of the environment of its founding during the early stages of the Cold War.

Photo credit: NASA.

The launch of Sputnik created a political and public outcry over the apparent missile-gap. The Soviet Union had beaten America to space, and there was building national pressure to bridge that gap. President Eisenhower was less concerned with the prestige of the Soviet's accomplishment than he was with the confirmation of Soviet intercontinental ballistic missile capabilities. The memory of Pearl Harbor was fresh, and he was increasingly concerned about the potential for a Soviet surprise attack. This fear only furthered the need for a reliable source of intelligence. Purposed and ongoing surveillance options, including balloons and the U-2, were dangerous and had difficulty penetrating the interior of the country, while human intelligence (HUMINT) operations had limited efficacy within the closed society of the USSR. This left reconnaissance satellites as the last remaining viable option. The task facing Eisenhower was to develop the needed technology and conduct the operations covertly, while simultaneously assuaging public anxiety.

The debate over which military service should take lead in this endeavor was fierce. Each branch was pursuing their own space program. The Army was operating the Army Ballistic Missile Agency (ABMA) headed by Wernher von Braun and the Jet Propulsion Labs (JPL), the Office of Naval Research (ONR) was running the Vanguard program, and the Air Force had Western Development Division (WDD) under General Bernard A. Schriever and the WS-117 program with the CIA. The numerous, simultaneous programs created infighting and duplicative research and development, with massive cost and suboptimal results. Furthermore, the optics of military services operating all American space operations risked increased tensions and potential militarization of space. In 1957, Eisenhower tasked James R. Killian, the chair of the newly formed President's Science Advisory Committee (PSAC), to create plan to reorganize the national space program. From the so-called Killian Report provided the seed from which the modern-day organizational structure was formed.

The Killian Report, and by extension the arrangement of the national space program, needed to advance scientific knowledge and provide the research needed to meet military and intelligence needs, while maintaining the secrecy of covert programs, minimizing risk of military escalation in conflict, and assuaging public worries of Soviet space dominance. On this point, Eisenhower said that information from purely scientific exploration should "be made available to all the world. But military research would naturally demand secrecy. The highest priority should go of course to space research with a military application, but because national morale, and to some extent national prestige, could be affected by the results of peaceful space research, this should likewise be pushed, but through a separate agency." To achieve these goals, the report recommended the creation of a separate civilian space agency to advance scientific knowledge and pursue peaceful applications of technology in space, a recommendation that would eventually lead to the creation of NASA through the National Aeronautics and Space Act of 1958.[37]

The emphasis on maintaining peace in space was repeated, and was a driver of NASA's creation instead of restricting research and development to the military services, leading to the unique civilian-military split America maintains to this day. However, military leadership was generally opposed to the plan. Aiming to maximize cooperation between civilian and military space programs, NASA was created from the already existing National Advisory Committee for Aeronautics (NACA) which had a previously established positive working relationship with the military. NASA was also given control of the majority of the Army and Navy's space programs. With that, the Air Force became the leading military service in space, and NASA could promote American interests in space under the auspice of peaceful scientific endeavors.

The need for reconnaissance was still paramount, and military programs in various services still suffered from competing interests, lack of coordination, and duplicative programs. This inter-service rivalry was hurting the ability of any one agency to provide needed technology development to give intelligence capabilities. The Advanced Research Projects Agency (ARPA) was created to rectify this problem in 1958 by bringing all military space


Photo credit: NASA.

R&D under one roof in OSD. Soon after, ARPA began the Discoverer program, which was termed a "satellite technology development effort." In reality, it was a continuation of the Air Force's WS-117 program, and was funded through the CIA to place a reconnaissance satellite in orbit with a classified imaging payload known as Corona.[38] Within a year, the first test was launched, and first successful imaging and recovery from space occurred a year later. The cover provided by NASA as a highly public and peaceful agency was pivotal in obscuring the underlying purpose of highly visible launch tests, and allowed the "freedom of space" and right of overflight established by Sputnik to continue without a race to militarize space. The problem of maintaining peaceful access to and use of space while obtaining vital intelligence through satellites had been solved. By the end of 1959, after the successfully maturing necessary technology for Corona, ARPA transferred most of the Air Force's space programs back to it and moved on.[39]

This left a gap in the management and development of reconnaissance satellites. In 1961, Eisenhower approved the creation the National Reconnaissance Office (NRO) which would be a classified, civilian intelligence agency within DoD responsible for the design, acquisition, and operation of all reconnaissance satellites with minimal bureaucracy. The NRO would house the Air Force, CIA, and Navy programs in a decentralized federation of programs, and in 1962 these were split into the "alphabet programs" which had separate physical locations. The program remained classified and highly effective, despite inter-service rivalry and budgetary battles between the programs, until its declassification in 1992.[40]

With the creation of the NRO, the structure of the national space program was largely cemented. NASA headed up all civil space programs, the Air Force remained the largest military player in DoD space arena (though the other services, especially the Navy, maintained some capabilities), and the NRO headed all classified, intelligence satellite operations for the IC.

Satellites are also increasingly important in military operations. During the Cold War, satellites were primarily used for reconnaissance and as a central component of nuclear architecture. These assets were so strategically important to the U.S. and USSR that they were immune to attack except in the event of a major nuclear exchange. Today, military satellites have been routinely used in conventional warfare since at least the Gulf War in 1991. Called "the first space war" by Air Force General Merrill McPeak, *Operation Desert Storm* is notable for the successful use of GPS-guided precision weapons. Today, military operations are critically dependent on satellite technology for communications, imagery, and navigation.

TRANSITION FROM GOVERNMENT TO COMMERCIAL ENTERPRISE IN SPACE

Space started as a race between two nation states. Today, space is available to everyone.

Early satellites and space launch capabilities were the exclusive domain of governments, with the U.S. and Soviet Union leading the space race. However, the commercial world rapidly entered this domain and vast industries have grown based on this capability, supported by government investment.

The U.S. government heritage of driving economic growth and global economic leadership can translate into the space domain. U.S. government investment in transportation and shipping infrastructure, like the Erie and C&O Canals and the National Highway System, reduced the cost of shipping per ton of cargo and enabled economic development. In the same way, U.S. government investment in developing space launch capability has changed the economics of space, which depends on the cost per pound for launch and orbit. Today, transition to industry is driving a similar decrease in cost of pound per orbit, further democratizing access to space and allowing for the proliferation of U.S. presence and leadership on the next frontier. Enabling this commercial development further will allow the U.S. to seize the economic opportunities offered by future industries.

Photo credit: NASA.

Satellite technology has drastically shaped our contemporary economy and society as they transitioned from government to commercial applications. Satellites have improved business operations in a variety of industries including agriculture, construction, transportation, and banking. In addition to increasing productivity and reducing expenses, satellite technology is now a part of everyday life for the average global citizen, enabling ATM transactions, scientific research, and weather reporting. Commercialization and competition have also allowed for rapid technological progress, with companies attaining capabilities once reserved to the U.S. military including high-resolution satellite imagery, signals intelligence, and space situational awareness.

Space ceased to be an exclusively military domain with the explosion of commercial telecommunications. The first major players in the sector were American Telephone and Telegraph Company's (AT&T's) Bell Laboratories and the Hughes Aircraft Company. In 1962, AT&T paid NASA to launch its first satellite, Telstar 1. The next year, aided by research support from NASA, Hughes Aircraft continued the commercialization trend by developing the first successful geostationary satellite. These events combined to set in motion the development of the global communications satellite industry. In 1962, Congress passed the Communications Satellite Act, which authorized the creation of the Communications Satellite Corporation (Comsat), a private firm that would develop all U.S. commercial satellites. Two years later the international satellite communications consortium Intelsat was formed, function as a public-private consortium that contracted with NASA to launch its satellites. The USSR also pursued satellite technology, putting up a number of satellites and creating, Intersputnik, an organization comprising eight other Communist countries, led by the Soviet Union.

The benefits of GPS in particular have been especially fruitful. Originally developed and launched by DoD in 1973 for military purposes, GPS satellite constellation became fully operational in 1995.[41] It consists of 31 satellites, each containing an atomic clock that synchs regularly with high-precision timing devices at the U.S. Naval Observatory. Phones, ATMs and other devices can register the timing signals from three or four satellites, and use this data to triangulate their relative position on Earth. ATM and point-of-sale transactions rely on GPS time mechanism in order to prevent over-drafting. Likewise, stock market exchanges rely on the precise atomic clocks of GPS in order to systematize the thousands of transactions occurring every minute.

Satellite imaging is also a crucial aspect of today's economy that enables analysis of weather patterns, topography, forest cover, crop yield, pollution, infrastructure quality, and fish abundance.[42] Such imaging empowers better-informed choices for businesses and decision makers. Accurate forecasting about impending storms for example allows for prompt evacuation and fortification of valuable assets. Commercialization and competition in this sector has resulted in rapid technological advancement with far-reaching benefits to society including high spatial resolution, wide geographic coverage, and widespread access to once difficult to access information – now anyone with an Internet connection can analyze satellite imagery using Google Earth.

More recently, the burgeoning commercial launch sector have made great strides. Companies like SpaceX, Blue Origin and Sierra Nevada are proposing unheard of ventures like civilian tourism. The commercial space launch sector in particular is growing rapidly. The United States executed 22 launches in 2016, the most of any country, all of which were conducted by private companies. By improving efficiency with features like reusable lift vehicles, the commercial launch industry is upsetting historic monopolies. The United Launch Alliance for example, a joint venture of Lockheed Martin and Boeing, had a monopoly on military launches for more than a decade until 2016, when the Air Force awarded a contract to SpaceX.

As cost per pound to launch continues to decrease, the number of satellites to be launched over the next decade is projected to increase markedly, with companies like OneWeb planning to launch a constellation of over 700 satellites for the purposes of

providing high-speed broadband.[43] Such crowdedness complicates space traffic management and raises concerns about how to deal with debris moving forward.

In addition to vast satellite constellations and tourism, disruptive activities like asteroid or lunar mining may be a reality in less than a decade. Goldman Sachs published a report in 2017 forecasting the profitability of mining for rare minerals in space. For example, in 2016 Luxembourg legalized asteroid mining[44] and provided millions of euros in funding to American mining companies.[45]

Even military operations and national security applications have become increasingly dependent on commercial satellites. Functions like imagery, communications, and navigation, for example guidance for manned and unmanned military aircraft, rely on both government and commercially owned and operated satellites. In fact, the demand for satellite communications within DoD has so rapidly outpaced DoD's own capabilities that they lease capacity from commercial satellite operations. Commercial satellite imagery is rapidly replacing large, expensive government imaging capabilities, and the demand for imagery and video continues to grow.

Photo credit: Shutterstock.com.

THE FUTURE SPACE ECONOMY

History shows that the U.S. stands to gain economic growth, tax revenue, and new industries and markets by investing in new infrastructure and R&D efforts in space. Government can help propel space enterprise forward by investing in R&D to prove the viability of risky yet promising projects.

Today, the global satellite industry is estimated to be worth about $208 billion,[46] while the global space economy overall is about $330 billion.[47] Estimates of the potential value of the future space industry range from to $1.1 trillion to $2.7 trillion by the 2040s.[48] Several entrepreneurs are making big bets on the space industry with huge investments in new companies and space technologies. Venture capital firms invested $1.8 billion in commercial space startup companies in 2015, which nearly doubled the amount that had been invested in the industry over the previous 15 years combined.[49]

Companies like Stratolaunch Systems and SpaceX are investing millions to decrease the cost of going to space. Others, like Planet Labs and Skybox Imaging are raising millions to explore new enterprises in satellite imagery.[50] These investments are having huge impacts on the cost to go to space, creating a market that is much more accessible than it was some 20 years ago.

Government can help propel space enterprise forward by investing in R&D to prove the viability of risky yet promising projects.

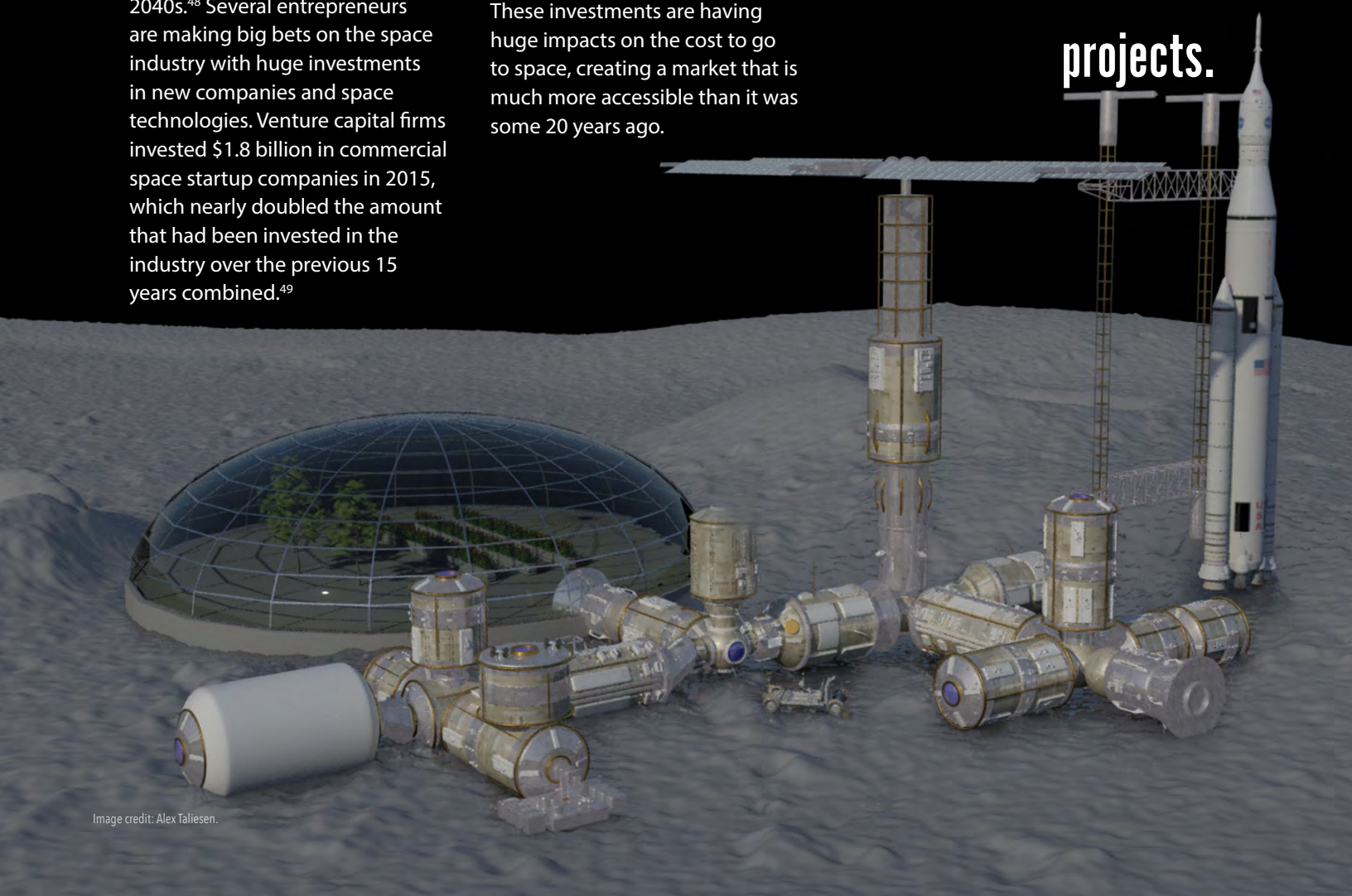


Image credit: Alex Taliesen.

The current cost to launch a satellite has declined to about $60 million, which is projected to fall as low as $5 million in the near future. Satellite mass production could decrease the cost from $500 million to around $500,000 per satellite.[51] As cost per pound to launch continues to decrease, the number of satellites to be launched over the next decade is projected to increase markedly, with companies like OneWeb planning to launch a constellation of over 700 satellites for the purposes of providing high-speed broadband.[52]

However, the space market is much more than just satellite communication and sensor technologies. Enormous amounts of valuable resources exist within our solar system. It is believed that some near-Earth asteroids have resources valued at $5.6 trillion to $27 quintillion.[53] Companies like Planetary Resources and Moon Express are aiming to exploit such objects beyond low Earth orbit. Additionally, there are areas of investor interest in microgravity research, space energy, and space habitats and real estate.[54] Major pharmaceutical companies like Merck and Procter & Gamble have all conducted drug tests on the International Space Station over the past decade. They are utilizing the expanding potential of microgravity research for their pharmaceutical development.[55] Furthermore, in 2016, a Singapore-based company secured $35 million in venture funding to develop "space sweepers," exploiting the space junk commercial sector.[56]

Not only has space become increasingly commercialized, it is also increasingly diverse in terms of nationalities represented. Before the fall of the Berlin wall, the U.S. and the USSR combined launched 93% of all satellites. From 1991 to 2016, 43% of new satellites have been from nations other than the U.S. and Russia – primarily China, Japan, Europe and India. Today, nearly 60 countries operate satellites, numbering approximately 1,738 in total.[57]

Today there is high demand for satellite and space-based services, with new capabilities rapidly being developed. The future of space promises to be even more congested, contested and competitive than it is today, characterized by an abundance of actors, satellites, debris, and uncertain rules of engagement. Countries seeking to augment their wealth look to the stars, where satellite communications and high-speed Internet improve domestic productivity. Similarly, rising world powers looking to garner prestige or make known their technical prowess have ambitious goals in space, from moon landings to colonization of celestial bodies.

The U.S. should be the leader in space now and into the future, but it must continue to invest in the foundations of infrastructure and R&D in order to attain and maintain this dominance. The U.S. needs to seize this opportunity for domestic economic growth, for if it does not, other countries will surely step in to fill the void. Now is the time for the United States to lead investment to stimulate this growth and entry into civil space. The USG should not cede economic leadership in space to foreign adversaries. Our investment in space will continue the United States' economic growth and prosperity in new frontiers.

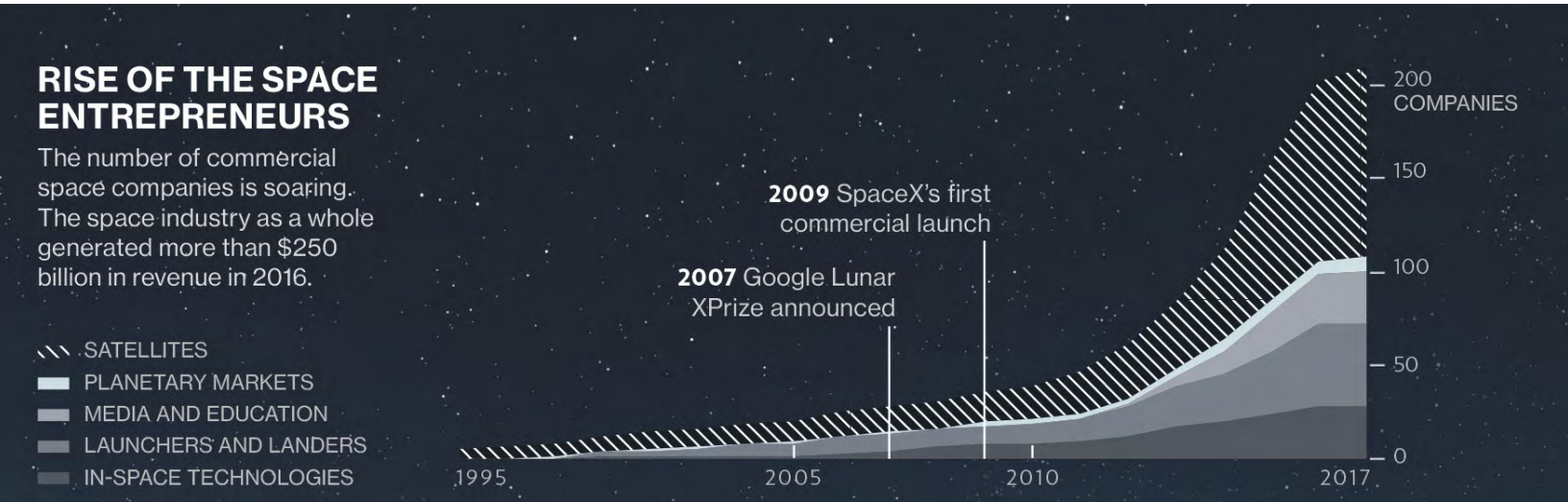
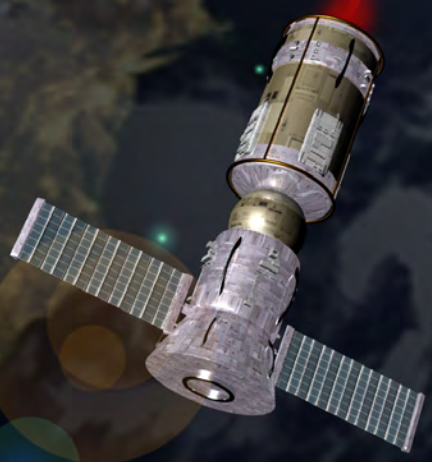


Image credit: Manuel Canales/National Geographic Creative.

SPACE WILL BE A WARFIGHTING DOMAIN

With increasing numbers of nations in space, the threat of war extending there has become all but an eventuality. The provocative actions of China in recent years have stressed this possibility more than at any other time since the Cold War. In 2006, China flashed lasers at U.S. reconnaissance satellites flying over its territory, temporarily dazzling their cameras. In 2007, China tested in earnest its antisatellite (ASAT) capabilities when it destroyed a malfunctioning Chinese weather satellite at an altitude of over 800km, effectively doubling the amount of space debris in low Earth orbit (LEO) and provoking widespread international condemnation. The test was a milestone in the history of space geopolitics, not only because it marked the end of an informal moratorium on ASAT tests since 1985, but also because it put in stark resolution how far were the days of bipolarity in space.[58]



Space is a warfighting domain just like air, land and sea.

– Air Force General John Raymond

Image credit: Alex Taliesen.

"Space is a warfighting domain just like air, land and sea," said Air Force General John Raymond about China's ASAT tests. "In the not-too-distant future, they will be able to use that capability to threaten every spacecraft we have in space. We have to prevent that, and the best way to prevent war is to be prepared for war."[59]

The vulnerability of satellites in particular reveals the inadequacy of current U.S. policy to address potential attack. As of now, there exists no policy document explaining what the response would be to a deliberate attack on U.S. satellites, and accordingly no government body granted authority to carry out such a response. Moreover, even given adequate policy and delegation of responsibility, U.S. technological ability to respond to an attack is lacking. The ability to respond hinges upon the ability to determine the origin of the attack (i.e. attribution), which is not guaranteed. During the Space Race, because there were only two actors capable of mounting attacks on one another, attribution was automatic. Today, not only can many nation states target satellites, but individuals can as well.

Image credit: NASA/Bill Ingalls

"Jammers," devices used to block satellite signals, can be purchased online for a few hundred dollars. During the Iraq War, the U.S. experienced multiple hostile jamming efforts on commercial satellite communication (SATCOM) long after the regime had been toppled. A similar tactic used to interfere with satellites is "spoofing," the manipulation of a satellite signal so that it falsely resembles a legitimate signal. In 2011, Iran claimed that it successfully downed an American drone via GPS spoofing, tricking the drone into landing in Kashmar in northeastern Iran. Though not confirmed by the United States, the minimal damage suffered by the drone in the downing process suggests it was a cyber in nature. North Korea and Russia have likewise been suspected of jamming satellites.[60,61]

Because attribution and constant defense of space assets cannot be guaranteed, the U.S. must make its space assets resilient to retain operational capacity through attacks.[62] In the domain of space, this translates to having the ability to lose some assets without completely succumbing under the pressure of the damage sustained. This is not the case in the present moment; "Our current enterprise is not resilient enough to survive a war that would extend into space," reported Major General Stephen Whiting of the Air Force Space Command, because "most of our current space systems were designed when space was considered a benign environment."[63] In order to reduce the cost of launch, many military space systems have been launched together, meaning that some satellites have communications, surveillance, navigation, and missile-warning capabilities all housed on the same craft. This is a dangerous arrangement that threatens to wipe out vast military capabilities in single point attacks. The ability to repair damaged assets (i.e. reconstitution) is an equally important aspect of securing space systems, but the high cost of launch, combined with little R&D spending in launch optimization, makes reconstitution an unfeasible solution in the event of an attack or a collision with space debris.

These many changes to the space environment since the original national space program was organized throws into sharp relief the need for a modern restructuring.

SPACE STRATEGY

RECOMMENDATIONS FOR ECONOMIC GROWTH AND NATIONAL SECURITY

Image credit: Alex Taliesen

ENABLE AND DRIVE SPACE ENTERPRISE: THE ROLE OF NASA

NASA is uniquely positioned within the federal government to guide the distribution and management of a large-scale investment in the commercial space community. Although NASA has a history of partnership and communication with private industry, the time has come for a fundamental shift in its primary mission away from space research and exploration. The NASA of the future should be chartered to champion and lead the entire civil space effort by incentivizing, partnering with, and underwriting the risk of commercialization of all civil future space capabilities. NASA's role should be to support, direct, and enable industry, just as the commercial airline industry was fostered under government direction. With adequate funds, NASA will use its technical experience and knowledge to find, finance, and accelerate the private projects that will propel the industries of the future, and guarantee human access to and architecture in space.

NASA's forerunner, the National Advisory Committee for Aeronautics (NACA), played a role in stimulating the commercial airline industry; in the same way, NASA can drive the commercial space domain. Through NACA, the federal government conducted largescale R&D efforts and built laboratories to revolutionize military and commercial air flight technology, funding and creating the technology needed to create the modern day commercial airline infrastructure.

The NASA of the future should be chartered to champion and lead the entire civil space effort.

Photo credit: NASA.

NASA has an extended and successful history of working with commercial partners. From its inception, the agency has partnered with private contractors on the development of launch vehicles and spacecraft. However, in early years, program and technology design was guided by NASA dictation and requirements. There has been a steady trend away from this practice – with some setbacks – that include congressional legislation and presidential edicts aimed at increased commercialization. Around the turn of the century, NASA's Alternate Access to Station (AAS) program and Space Launch Initiative (SLI) continued to increase commercial industry establish cost-effective space transportation capabilities and move government away from day-to-day operations, by encouraging development of privately owned and operated second generation reusable launch vehicles (RLVs), but there was still NASA driven requirements in the relationship.[64] The latest and most successful program, resulting in the first commercial spacecraft to reach the International Space Station, is the COTS initiative established in 2005. Over the course of COTS, about $800 million was spent by NASA on the development of two commercial systems. The program represented a significant advance in the affordability of commercial cargo and crew transportation and demonstrated the utility of potential future NASA-funded public-private ventures.[65]

In order to facilitate American leadership in the commercialization and industrialization of space, the federal government must undertake an investment effort in technology R&D and marketization infrastructure similar in scope to past revolutionary government efforts, with NASA leading the effort by partnering with the commercial industry over and above what it has done in the past. This will require new partnership mechanisms, whether it be R&D consortia, innovation clusters, numerous contractual agreements, or other methods, and will require a holistic approach to bring private industry together with the government to support the entire supply chain of a new space infrastructure. This will require partnership and cooperation across each component supplier and system integrator along the supply chain.[66] Furthermore, NASA must leverage its distinctive expertise in component integration and full system design that it has developed over decades of space operations, as well as the design, testing, and construction infrastructure it already has access to at many of its facilities. The investment must help overcome the barriers to largescale private funding as well, namely the prohibitive cost and infrequency of launch, high capital requirements for space infrastructure design, and regulatory roadblocks, and a lack of commercially viable investment options. Overcoming these roadblocks will lead to a self-sustaining market, and is a primary goal of a NASA led federal stimulus.

In-house technology development should be outsourced and contracted to industry, along with a transition from internal science research to funding of research. This will require a shift in NASA's mission from conducting research internally to a funding model more akin to NSF or DARPA, where external performers are funded to meet mission needs. This will also return NASA to its roots in fostering civil aviation as NACA (National Advisory Committee for Aeronautics). NASA centers should function largely as industry partnership centers rather than full R&D, procurement, production, and operations centers.

There are successful precedents for this type of restructuring. DoD has a defense industrial base to support its mission, NASA should have a similar space industrial base. The Department of Energy has its own labs, but does not build and operate the whole national grid – that has been commercialized. NASA can become a hybrid of these practices, using best practices from various successful government-commercial ventures while also leveraging its existing institutional knowledge, infrastructure, and expertise in concert with private ventures. Granting NASA an increased budget to further underwrite costs and fund commercial ventures will stimulate a vibrant commercial economy and infrastructure in space. An investment made by NASA in the civil development of space, similar to seminal investments made in the nation's past, would prompt the certain global leadership of the U.S. in space.

By 2040, revenue generated by the space industry is forecasted to be valued in the trillions of dollars. Every major nation is investing heavily in developing space capabilities. Maintaining and extending leadership in this burgeoning environment will require the government to once again act as a key investor. Today, American industry is leading the way in developing space, but U.S. government investment is still needed to reduce risk and jump-start innovation through research. Waiting for the private sector to commercialize and industrialize space could cede dominance to other competing nations or allow space activities to develop that conflict with U.S. interests. Growth in the space industry will lead to growth of the U.S. economy and therefore an increase in the domestic tax base and U.S. government revenues that are likely to repay these investments many times over.

RECOMMENDATIONS FOR NASA

In order to facilitate American leadership in the commercialization and industrialization of space, the federal government must undertake an investment effort in technology R&D and marketization infrastructure similar in scope to past revolutionary government efforts, with NASA leading the effort by partnering with the commercial industry over and above what it has done in the past. The U.S. needs to seize this opportunity for domestic economic growth, for if it does not, other countries will surely step in to fill the void. Our investment in space will continue the heritage of the United States' ceaseless growth of its economy and prosperity in new frontier, forging a path where others fear to tread.


Photo credit: NASA

Recommendations for NASA

- NASA must lead a concerted national effort that marshals the entire civil movement of humans in space.
- NASA's mission should shift to leading a civil, commercial, and industrial venture into space enterprise to create a robust industrial infrastructure in LEO and cislunar space.
- NASA should encourage, partner with, and underwrite the costs and risks of the commercial space industry in coordination with its existing programs. Science and exploration should be mission-driven to support this goal. NASA should coordinate with the Departments of Commerce, State, Transportation, and others as needed.
- NASA should be resourced appropriately to fulfill this mission.

PROTECT AND DEFEND THE NEW FRONTIER: THE ROLE OF THE DEPARTMENT OF DEFENSE

As NASA propels the commercial space program forward, DoD will be called on to defend our interests and assets in space.

The exploration, expansion and settlement of the U.S. frontier and its commercial interests would not have been possible to defend and maintain without the role of the U.S. military. In parallel with historical examples, such as naval piracy and subsequent creation of the U.S. Navy, or the westward frontier expansion and the U.S. Army's protective role of U.S. settlers, the competitive trends in space will necessitate a strong military presence for deterrence and protection of critical national interests.

"The shifting of space [from] being a benign environment to being a warfighting environment requires different capabilities."

*Air Force Secretary Heather Wilson, in: Garamone, J. DoD News Article. December 2, 2017. "U.S. Must Move Faster or Risk Losing Lead in Space."

Image credit: Alex Taliesen

As NASA propels the commercial space program forward, DoD must mimic its growth. The expansion of United States Code Title 10 to space will be needed to accomplish this, and will require the authorization of new roles and responsibilities within DoD. Title 10 gives DoD the authority to wage war and defend U.S. interests. In keeping with this, the role and responsibilities of all Title 10 agencies must be expanded to include the development and deployment of a full range of capabilities for the defense of all space-based U.S. assets. This includes the authority to equip, arm, and deploy as necessary, in order to ensure economic freedom of U.S. commercial activities in space. DoD must not be beholden to other civilian or intelligence agencies to develop its space-based requirements, and must have the authority to acquire new technology as needed. This expansion is in addition to current protections provided by DoD which includes the support of Earth-based operations. As technology becomes increasingly more sophisticated and complex, the demand for protection and defense of U.S. economic interests in space is imminent.

As shown by the previous brief historical analysis, DoD's role and responsibilities of protecting commercial assets and human outputs is not novel. However, the ability for DoD to evolve to the changing frontier landscape is. The development and subsequent protection of space-based infrastructure will allow DoD to support and enable space exploration by both directly and indirectly improving U.S. quality of life. Moreover, as leaders in space, the U.S. sets the precedence for other countries and non-state actors by providing a safe, secure and innovative climate for space activity; henceforth, U.S. capability in space will not only improve U.S. quality of life, but for all world citizens.

RECOMMENDATIONS FOR THE DEPARTMENT OF DEFENSE

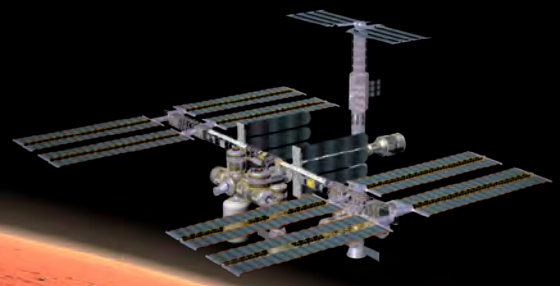
The Department of Defense should build a space defense capability to protect our space assets and keep critical infrastructure open. Countries like China have matured their perspective of space to one of a domain of enterprise by reorganizing its military (e.g., the Strategic Support Force) and heavily investing in various technologies that target vulnerable U.S. space-based operational centers (e.g., A2/AD, kinetic-kill, co-orbital, and directed energy ASAT weapons). To maintain leadership in space, we must embrace space as "the next frontier" by protecting our interests and citizens. To do this DoD must be assigned new roles and responsibilities in an expanded civil space effort. United States Code Title 10 gives DoD the authority to wage war and defend U.S. interests. Title 10 should include the development and deployment of a full range of capabilities for the defense of all space-based U.S. assets.


Photo credit: USAF/Staff Sgt. Shelton Sherrill

Recommendations for the Department of Defense

- The Department of Defense's mission must include the requirement to protect U.S. interest and commerce in space. The Department of Defense should be tasked with ensuring the freedom of U.S. commercial activities in space.
- Expand Title 10 authorities to enable DoD to develop and deploy capabilities for defense of space-based assets.
- The Department of Defense should be resourced appropriately to fulfill this mission.

OUR EYES IN SPACE: THE ROLE OF THE INTELLIGENCE COMMUNITY



The IC must expand and improve its capabilities in tandem with a rapidly evolving space environment.

The Intelligence Community (IC) exists to keep the White House and DoD informed about national security threats wherever they occur. Its major mission areas include counterterrorism, cybersecurity, counter-proliferation, and counterintelligence.[67] These mission areas exist on earth and in space alike, especially as the space domain becomes more crowded. The continued growth of the global space industry means that space-based capabilities and space situational awareness are in the hands of more nation states, non-state actors, and commercial entities. More actors mean more threats, and thus the IC must expand and improve its capabilities in tandem with a rapidly evolving space environment. The IC needs to widen its focus beyond just surveilling Earth from space. It needs to expand its reach to surveil foreign actors' activities in space itself, not just to monitor emerging threats on Earth. Similarly, the IC must expand and improve its capabilities to protect economic assets, especially as space commerce and colonization proliferate.

The U.S. economy is already dependent on space technologies like GPS and imaging satellites, and future financial ventures in space will only amplify this dependence. The IC community, together with the DoD, must increase their presence in space to ensure the stability of space commerce and the security of national security assets. The IC should clarify its mission by explicitly identifying its involvement in the space domain, and the National Reconnaissance Office (NRO) should be disbanded to avoid mission confusion between the IC and DoD. Just as DoD should have the proper authorities to fulfill its expanded mission, the IC should as well.

Photo credit: NASA

Space is a central aspect of the IC's history and identity, starting with the use of spy satellites in the Cold War. The IC's role in space must be stated outright in USC Title 50 moving forward so as to prioritize the IC's surveillance of and information gathering in the increasingly populated and contested space domain, as well as on Earth. The IC's current role in space consists only of operating reconnaissance satellites capable of monitoring potential national security threats on Earth, in support of the National Reconnaissance Office and DoD's mission. This reconnaissance in space is enabled by a variety of satellites with different functions. This includes satellites responsible for capturing high-resolution photography (IMINT), measurement and signatures intelligence (MASINT), and signals intelligence (SIGINT). SIGINT is a broad category of intelligence that includes: communications intelligence (COMINT) – the eavesdropping on voice or messaging communications; foreign instrumentation signals intelligence (FISINT) – the monitoring of non-human communication; and electronic intelligence (ELINT) – the monitoring of non-communications transmissions, like radar.[68] Historically, space intelligence has proved an invaluable resource for the U.S. to avoid conflict. During the Cold War, IMINT and FISINT capabilities allowed both the U.S. and USSR to monitor each other's nuclear arsenals, ultimately paving the way for mutual trust in non-proliferation treaties. Today, such capabilities are enduringly necessary as rogue regimes like North Korea and Iran advance their nuclear ambitions. However, with an increasingly populated space domain, the IC's capabilities in space need to expand to monitor activities in space itself, as threats to national security is no longer earthbound.

A number of adversarial nation states with ambitious space projects present the most immediate national security threats for our space-based assets. In his June 2017 statement to Congress, Director of National Intelligence Dan Coats identified Russia and China as particularly worrisome; "We assess that Russia and China perceive a need to offset any U.S. military advantage derived from military, civil, or commercial space systems and are increasingly considering attacks against satellite systems as part of their future warfare doctrine."[69] Satellite systems are a natural target for adversarial nations because they inform all military operations; satellites handle military communications, enable warfighters to navigate using GPS, can take high-resolution photography of a rival's arsenal, can intercept a rival's communication, and can detect signals from nuclear weapons.

China is also seeking to advance its military capabilities in space, hoping to capitalize on the strategic importance of space in war. As previously discussed, China has already demonstrated a capability to shoot down crucial satellites, rendering real the threat discussed above. The 2007 antisatellite missile (ASAT) test is perhaps the most widely remembered of China's military operations in space, in which a failing Chinese weather satellite was destroyed by a kinetic-kill vehicle, effectively doubling the amount of debris in low Earth orbit and raising questions about whether such an act constituted the militarization of space – strictly prohibited by the Outer Space Treaty of 1967, of which China is a signatory. Furthermore, in multiple reports to Congress, the DoD has described how the Chinese government is investing in defense and intelligence capabilities in space, with particular emphasis on "satellite communication (SATCOM), intelligence, surveillance, and reconnaissance (ISR), [and] satellite navigation (SATNAV)."[70] The report explains that together with its civil space program, the Chinese military is investing in technologies designed to harm or hinder the use of space-based assets by rivals during a conflict, such as directed energy weapons and satellite jammers.[71]

To monitor the activities of adversaries, the IC must prioritize its activities in the space domain. Having robust intelligence capabilities is an important method of deterring aggression from would-be assailants, who would be reluctant to mount attacks easily foreseen by the United States. Such efforts are already underway; In 2014, the Air Force launched two Geosynchronous Space

Situational Awareness Program (GSSAP) satellites for the purposes of collecting intelligence on other satellites in orbit.[72] However, these efforts must be expanded beyond Earth's orbit. As adversarial nations plan missions to distant celestial bodies, intelligence is required to determine if their actions threaten our own space missions. Similarly, with commercial ventures like space tourism and asteroid mining approaching actualization, intelligence will be required to protect from menace these important industries as well as to ensure they are following international regulations. This intelligence will empower DoD to act as a protector in space, ensuring peace and stability that will allow commercial space to flourish.

RECOMMENDATIONS FOR THE INTELLIGENCE COMMUNITY

The role of the IC is to inform the decisions of the White House and DoD and is thus an integral part of the effort to secure U.S. space assets. Should hostile nations set up outposts on nearby celestial bodies, intelligence will be necessary to determine the nature of their activities and the risks they pose. Likewise, should commercial entities build on-orbit operations, intelligence will be necessary to ensure they are following international laws and regulations. The IC must be prepared to move its capabilities beyond Earth's vicinity, to follow the multitude of actors wherever they position themselves, and to inform national security threats wherever they arise. Consequently, we must ensure that the IC has the capability to monitor space activities of our foes.


Photo credit: USMC/Cpl. Benjamin R. Reynolds

Recommendations for the Intelligence Community

- The Intelligence Community must monitor the space activities and intent of our adversaries.
- The Intelligence Community should continue to develop, procure, and deploy all national security data collection technology under the sole authority of the Director of National Intelligence (DNI) as authorized in USC Title 50, and extend this data gathering to the space domain.
- The Intelligence Community budget should reflect this priority, with appropriate investments.

CONCLUSIONS

This document is intended to provide input to the National Space Council and the U.S. government regarding the essential role of government in driving the next phase of space exploration, enterprise, defense, and intelligence.

The Space Race began over six decades ago. Since then, the United States has invested in developing space-faring capabilities, with enormous economic and scientific benefits to the nation. Now, space is the next frontier for economic development and warfare, and the U.S. government should be preparing for this future. Throughout U.S. history, the government has served as a key investor in the essential science, technology, and infrastructure that provided the foundations for commercial enterprise to thrive. There are two fundamental roles of government in space: 1) to drive and enable enterprise, and 2) to protect and defend our interests.

To achieve this vision, the national space program of the United States needs to be redesigned, with NASA driving and enabling the civil and commercial space enterprise; the Department of Defense building a space defense capability to protect our space assets and national interests; and an Intelligence Community capability to monitor the space activities and intent of our adversaries.

To safeguard U.S. leadership in this next frontier, the existing national space program should be reorganized to catalyze a massive financial stimulus that will promote U.S. leadership in every aspect, protected by a robust and resilient defense and intelligence infrastructure.

Photo credit: NASA

NASA Guiding Investment in Space Industry

NASA is uniquely positioned within the federal government to drive and enable exploration and enterprise in space. NASA has a history of productive partnerships with private industry, and has the expertise to drive the research and development that will be needed to conduct space exploration and enterprise successfully. The NASA of the future should be chartered to lead the entire civil space effort by taking on the historic role of the U.S. government in incentivizing, partnering with, and underwriting the risk of commercialization for all future civil space capabilities. It will be the guiding agency to create the infrastructure to open up the new frontier of space. NASA has the technical experience and knowledge to fund, finance, and accelerate the private projects that will propel the industries of the future. For research and development, this will require a shift in NASA's mission from conducting research internally to a funding model more akin to NSF or DARPA, where external performers are funded to meet mission needs. This will also return NASA to its roots in fostering civil aviation as NACA (National Advisory Committee for Aeronautics).

Need for Defense in Space

As the U.S. continues to launch assets into space, the DoD must be able to defend these resources. The exploration, expansion and settlement of new frontiers and their commercial interests would have not been possible to defend and maintain without the role of the U.S. military. We expect the competitive trends in space to necessitate a strong military presence for deterrence and protection of critical national interests. To do this, the DoD must be given new roles and responsibilities in an expanded civil space effort. United States Code Title 10 gives DoD the authority to wage war and defend U.S. interests. Title 10 should include the development and deployment of a full range of capabilities for the defense of all space-based U.S. assets. The expansion of Title 10 to space is the next step in preserving and protecting U.S. commercial interests in space, while affording the U.S. space program to continue its role as a leader in the next frontier. The absolute presence of U.S. defense and protection capabilities from the U.S. military is paramount if the U.S. is to preserve its dominant role in space, and to take advantage of this unprecedented opportunity in the next economic frontier.

Intelligence Capabilities to Accompany Defense

The role of the IC is to inform the decisions of the White House and DoD. As the national space program continues to expand into space, the IC will need to expand its capabilities with it to fulfill this responsibility. Should hostile nations set up outposts on nearby celestial bodies, intelligence will be necessary to determine the nature of their activities and the risks they pose. Likewise, should commercial entities build on-orbit operations, intelligence will be necessary to ensure they are following international laws and regulations. The IC needs to be prepared to move its capabilities beyond Earth's vicinity, to follow the multitude of actors wherever they position themselves, and inform on national security threats wherever they arise.

Following this plan will revitalize the national space program and promote both an economic and a strategic U.S. lead in space, protected by a robust and resilient defense and intelligence infrastructure that will allow this leadership to continue into the future.

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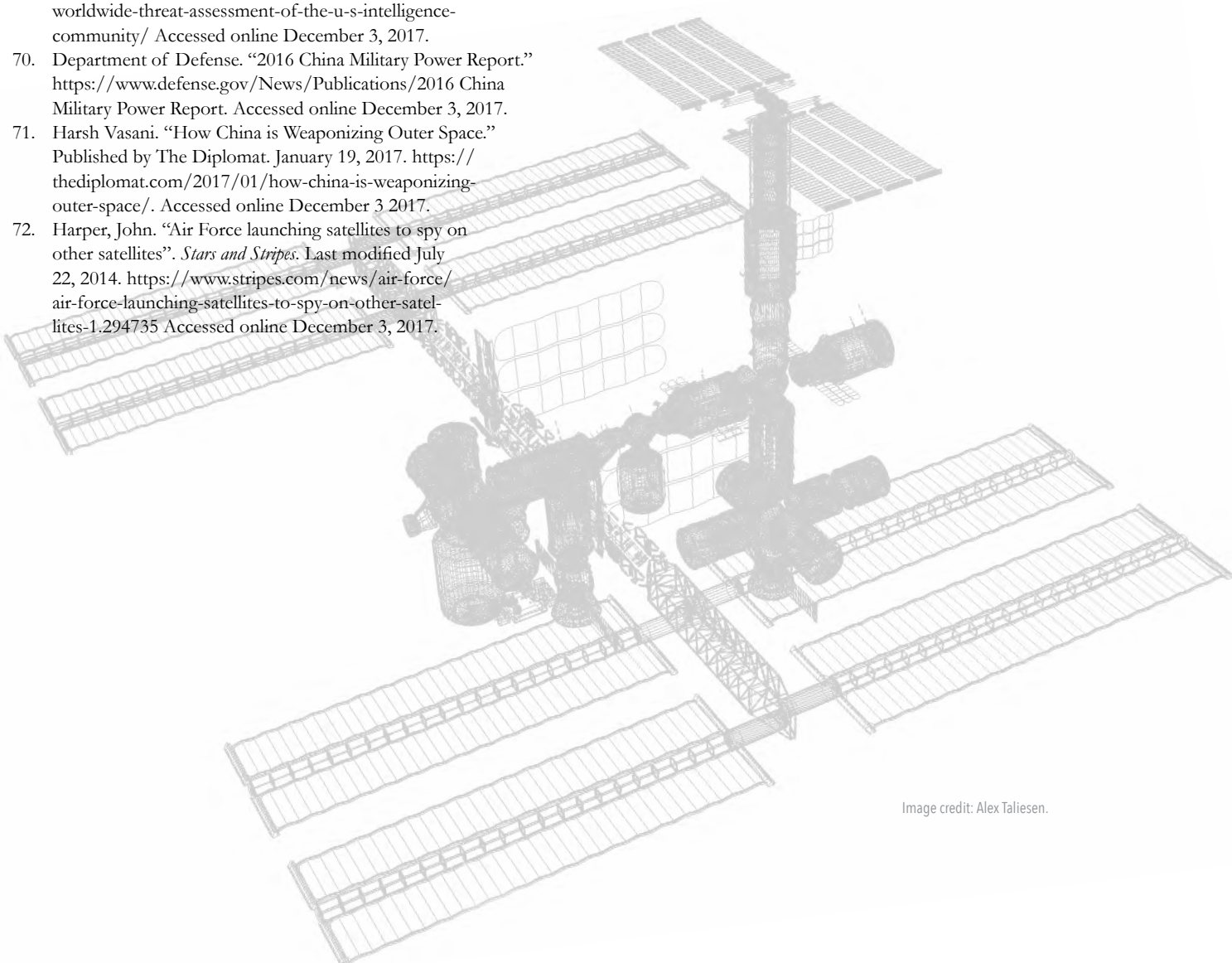

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