

A SPACE POLICY

for the Trump Administration

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About the Authors



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Executive Summary

The administration of Donald Trump finds itself in an exciting and challenging position with regard to space. It is the first administration of the 21st century not to have its strategic focus totally consumed with counter-terrorism wars, the first to be able to lift its vision and see beyond the threats to the here and now. As it looks outward, it will perceive that the United States is in the midst of a transition when it comes to its presence in space. The nation is moving beyond its initial, exploratory steps to establish a more permanent position from which to begin acquiring and processing the resources of space to improve life on Earth as well as establish a self-sustaining cycle of existence in space.

This is not the first time the United States has done this. In the 19th century, having secured independence from European colonial powers, the young nation's focus turned westward toward settling the North American continent. However, before the West could be settled and its resources developed, the region first needed to be explored. The Lewis and Clark Expedition served as the premier example of this government-sponsored effort to establish what resources lay beyond the original thirteen states. Their detailed report allowed the government to establish priorities for further exploration and, ultimately, settlement of the West. The military, in the form of Army forts, moved westward to protect critical transportation junctions and resource concentrations. This initiative helped to bring about the creation of bounded territories, law and order, and eventually more states. Later, once the West had been stabilized to an extent, the government sponsored, in cooperation with industry, the construction of a railroad that spanned the continent, tying East to West. Ultimately other railroads linked with the initial trunk-line on their own initiative, allowing the full exploitation of the resources of the West.

This analogy of government serving in the initial exploring role, providing security, establishing laws, and even serving as the sponsor for initial resource exploitation is useful in considering the United States' current strategic position in space. The government, through its unmanned and manned civil space initiatives, has mapped the solar system, establishing knowledge of key resource concentrations and possible areas for human settlement. It has also established the basic legal premises for future expansion into space. However, we now stand at the cusp of a new era of space activities, an era when space promises to be a profit and resource generation center for nations involved in its exploitation. This era will be marked by increased competition, as key

concentrations are identified and claimed by commercial entities or nation states. Such competitions have historically drawn military forces into play in order to protect national interests.

Given historical precedence and the premise that we face a new era in space, it is appropriate for the Trump administration to promote a policy that is not so much an evolutionary extension of those of previous administrations, but rather a revolutionary leap ahead with regard to the U.S. position in space. Therefore, we propose significant changes in the nation's interpretation and enforcement of international laws that apply to space activities, increased focus in the U.S. civil space program on identifying resource and settlement opportunities, expansion and freeing of the commercial space sector to fully harness the resources and wealth of space, and strengthening national security infrastructure in space both to protect the nation's interests there and to support ongoing military operations on Earth. These initiatives are spelled out in greater detail as follows.

Legal Considerations

The legal frameworks for space policy that the United States has followed since 1967 are no longer sufficient for the future of space exploration. Ambiguity in the 1967 Outer Space Treaty is both a benefit and a curse: although allowing countries to interpret the requirements and restrictions may provide a certain level of freedom, the treaty also contains internal conflicts that provide grounds for possible future conflict with regard to resource development. The Trump administration needs to provide a clear strategy for U.S. space policy efforts and assert a broader interpretation of the 1967 Outer Space Treaty. Because crafting a new international space agreement would be time-consuming and difficult, the best strategy is to provide clarifying guidance with regard to interpreting the current treaty for both domestic and international space actors.

The Necessity of Civil Space Exploration

U.S. civil space efforts should focus on exploration and pioneering endeavors that are necessary but involve no immediate financial incentive sufficient to draw a commercial entity to pursue them. These areas include deep space and first-finder missions—enterprises that offer immense scientific and technical returns but little financial return. They will pave the way for an eager and increasingly capable commercial sector to follow and develop. Additionally, these missions are necessary not only to sustain the United States' global leadership, but also to deepen humankind's understanding of the universe and our place within it.

Where the Government Leads, the Commercial Sector Can Follow

The commercial space sector is growing rapidly in both willingness and capability. The Trump administration should enable the growth of this essential industry by clarifying and streamlining government authorities, reducing overlapping government and commercial efforts, and ensuring that export and import regulations reflect contemporary rationale. The future will require a robust commercial space industry. Failing to properly support the commercial space sector would be a very costly mistake.

National Security in Space

National security requirements are increasingly dependent on technology and resources on-orbit around the Earth. The Trump administration's space policy must acknowledge this critical dependency and invest in efforts to improve resiliency in this domain. Near-peer competitors have spent the past several decades leveraging asymmetric opportunities against the United States; the Trump administration needs to ensure that the country's dependency on space does not turn into another such opportunity.

Introduction

The United States is an instinctive exploring and expanding power with a constant outward urge to discover and develop resources while spreading its basic founding principles. Following the founding of the nation from 13 European colonies on the eastern coast of the North American continent, the United States focused its attention for the next 100 years on constant movement westward until it reached the Pacific and closed the frontier. At that point, it altered the strategic trajectory and began to stretch out across the oceans, following the lead of men such as Senator Henry Cabot Lodge, President Theodore Roosevelt, and Captain Alfred T. Mahan, to establish new markets for U.S. goods and a peaceful sea upon which to trade them. World War II essentially ended the competition on the seas, and soon thereafter, following the inspired vision of President John F. Kennedy, the nation turned its eyes to space.

Due to a confluence of strategic events and initiatives, space is a key domestic and foreign policy area in which the Trump administration can make a substantive, long-lasting contribution to the U.S. global position. However, the government must move quickly, first to establish and then to solidify policy initiatives that will change the direction of U.S. policies concerning space. After decades



Without President Kennedy's change in policy from that of the Eisenhower administration, the United States would not have landed men such as Eugene Cernan (pictured) on the moon. The Trump administration must work quickly to make policy adjustments in order to take full advantage of the strategic opportunities and requirements of space. (NASA)

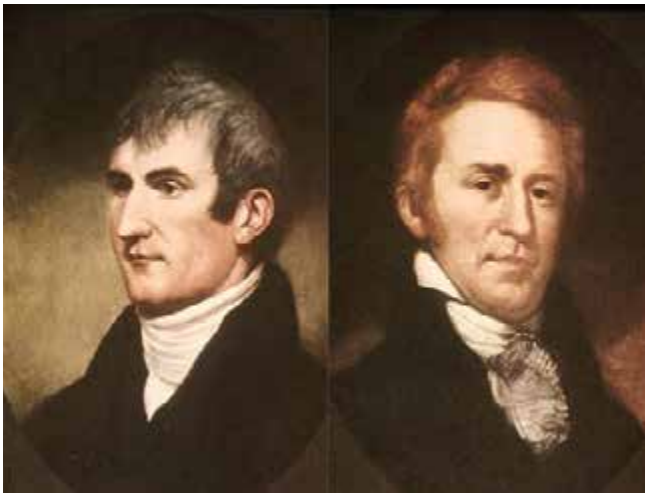
of neglect, the regions beyond Earth are emerging as a key area of international competition. As with many new technologies and areas of competition, it is necessary to convey developing complexities in commonsense terms.

How best can we describe the role of the U.S. government in space in a manner that U.S. citizens will understand and accept? Perhaps a direct comparison to a historic event that most Americans know well—the settling of the West during the 19th century—can serve as an apt analogy for the strategic environment of outer space from legal, civil, commercial, and national security perspectives.

In 1803 Napoleon, facing a prolonged war with Great Britain, sold the Louisiana territory to the United States for 50,000,000 francs, or \$15,000,000 (in 1803 dollars). The purchase effectively doubled U.S. territorial holdings. However, Louisiana and all the land beyond it was largely unexplored and not understood. No one knew what resources lay westward of the Mississippi or how the territory should be managed or distributed. This is somewhat analogous to our understanding today of the solar system and what may lie beyond it. We know, for instance, that the solar system encompasses at least nine planets and various moons and asteroids, but we do not truly understand the composition of these planets and various celestial bodies, even though we learn more every day.

In 1803 the U.S. government, led by the nation's third president, Thomas Jefferson, commissioned an expedition to explore the new territory, find a route to the Pacific, and lay claim to key geographic locations in advance of European powers that would surely be in the hunt for new lands. Led by Army Captain Meriwether Lewis and Second Lieutenant William Clark, the expedition set out in 1804 and returned in 1806, after reaching the Pacific and collecting samples of wildlife and resources along the way. Importantly, at this early point in U.S. development there was no direct and proximate economic incentive to draw commercial entities across the West. This “first movement” of exploration established a territorial “bridgehead” from which to build outward. It was properly seen as a role for government.

When it came time to settle and develop the West, it was not the government but commercial railroads that accomplished the task, although the government did play a role in constructing the railroads. Through a series of Railroad Acts, Congress deeded land, guaranteed long-term bonds, and, with the promise of transporting Army troops, guaranteed that the railroads would have a better-than-even chance of making a profit. However the risk was still largely held by commercial railroad companies.



At the time of Lewis and Clark’s expedition, there was no direct and proximate economic incentive to draw commercial entities across the West, so this “first movement” of exploration and establishing a territorial “bridgehead” was properly seen as a role of government. (Britannica)



The “Golden Spike” (the final railroad spike made of gold) signified the completion of the transcontinental railroad and ushered in the development of the West. (Yale University Libraries)

The Union and Central Pacific Railroads began the effort to lay a transcontinental railroad in 1862 and completed it in 1869, when the “Golden Spike” was driven into the line at Promontory Summit, Utah, unifying the country. Twenty-one years later, Frederick Jackson Turner would author the seminal essay “The Closing of the Frontier,” effectively recognizing that the West had been populated and was in the process of being developed. While government can incentivize populating and commercial development, this should be viewed as a role of the commercial sector, even in space. Once the exploration phase and bridgehead building are complete, it should be Adam Smith’s “hidden hand” and David Ricardo’s free trade that pull commercial interests outward, much as Americans rode the railroads westward in search of wealth during the 19th century. With this in mind, how should we properly view space policy in the 21st century?

While highly prestigious travels into space, such as major manned missions or even high-profile unmanned exploration of other planets, can still grab the front pages of newspapers, Americans today have a broader understanding of the cosmos and its role in terrestrial life. Global positioning services, weather tracking, communications, and entertainment media all flow through space. Highly visible commercial initiatives such as Blue Origin’s announcement of its new rocket engine and SpaceX’s reuse of a first-stage booster signify rapid changes in the economic market associated with space, while NASA’s launch of the Osiris Rex probe to the asteroid Bennu heralds a new venue of exploration. The United States is not alone in its pursuit of the many

opportunities in outer space; other nations are equally motivated by the strategic and economic returns and have stepped forward into the void. As a consequence, Americans have begun to perceive vaguely the implications of a future in which access to space and the services that reside in the newest, and perhaps last, public commons are interrupted.

Much as the Spanish, the Portuguese, and later the Dutch and English competed on the high seas, there is a competition in space between the United States and Russia. This contest can be traced to the Soviet Union’s launch of Sputnik in 1957 and the later entry of the European Union, India, Japan and, perhaps most important, China into space. Much as on the seas, these competitions have long-term economic and security implications for the United States—which has largely upheld the idealism associated with its western liberal perspective, expressed, for instance, by landing on the moon “For All Mankind.” Other space powers, however, have signaled they will not take such a benign approach to future exploration, exploitation, and sovereignty claims in space.¹

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The Trump administration will be the first in the 21st century to have the strategic opportunity to address the nation's future rather than being constrained by ongoing wars. (White House)

Increased opportunities have led to advances in technology, opening new areas of space to routine use. Commercial companies now have the means to routinely access the cosmos at an affordable price. Gone are the days when the government was the main customer in the space-based economy.² This paradigm change has placed today's leaders at a crossroads: to stay the course would require the government to continue shouldering much of the burden; to deviate would encourage greater public-private partnerships. The Trump administration needs to take the lead in establishing the proper role and place of government-led initiatives and clearly delineate the areas that should devolve to the commercial sector. The administration should also acknowledge and explicitly address the reality that earthbound military competitions are inextricably bound to space-based sensors and communications nodes.³ It should both emphasize the importance of ensuring access to space and consider the relative importance of denying others the same access.

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Humankind's future is ever-evolving, but there can be no doubt that it will include Lewis and Clark-like outward exploration as well as Union Pacific Railroad-type efforts to commercially develop, and possibly even efforts to colonize space. The Trump administration will be the first in the 21st century to have the strategic opportunity to address the nation's future rather than being constrained by ongoing wars. Its emphasis on rebuilding the U.S. economy through investment in the manufacturing, industrial, and high-tech economic bases aligns closely with space-centric policies. This report highlights areas of focus, questions to be answered, and options for the future of space, which is already a critical area of national security.

Organizational Structure

This paper is organized around the three chief categories of civil, commercial, and national security approaches to space as seen through the comparative historical lens of the United States' settlement of the West.

Civil space covers the aspects that are government-sponsored and can arguably be understood as exploration roles in which only the government would have an interest or the resources to perform. No financial incentives exist today, nor did they in the days of Lewis and Clark, that would induce private commercial entities to conduct deep exploration of unknown territories. For example, NASA's Juno satellite is currently in a highly elliptical polar orbit around Jupiter; while this is not a venture in which a commercial space firm is likely to

invest, a public investment like Juno might discover something valuable that would entice commercial entities to explore the Jovian system in the future.

The commercial space industry pursues the use of the cosmos for profit, or else because certain visionary leaders understand the importance of space exploration. During the 1968 Apollo 8 spaceflight to the moon, mission control asked astronaut Jim Lovell just who was piloting the craft. He replied, “Isaac Newton,” because gravity did most of the work. Today, if asked what is powering modern spaceflight, the Trump administration should reply, “Adam Smith,” because capitalism seems to be the major engine motivating innovation and growth in this rapidly growing industry. From satellite design and construction to the conception, building, and reuse of ascent engines, the U.S. commercial space sector is on the move, and the Trump administration needs to consider how to best support this growth.

The implications for national security are evolving as well. In the past, space was viewed as a protected sanctuary in which platforms—such as communications satellites, reconnaissance satellites, and global positioning satellites—enabled and augmented military operations on Earth. Today, the cosmos is no longer viewed as such a sanctuary, and nations that would make themselves the enemy of the United States have developed capabilities to degrade or destroy orbiting platforms. A modern space policy must both address the U.S. need to assure access to space and consider the delicate question of whether to deny other nations access to the domain.⁴

This question is part of a larger one that has been raised in the past, but always tangentially: legal considerations in space policy. In the early years of exploration and usage, the domain was largely ungoverned from a legal standpoint. The 1967 Outer Space Treaty (produced as a means of ensuring the peaceful use of space at a time when two superpowers were leveraging activities there as a matter of national power) changed that, providing idealistic legal definitions that set aside a domain where resources were to be shared by all mankind. Other limitations in the treaty, including barring weapons of mass destruction from space, had the advantage of being largely impractical based upon the technology available at the time. Today, resource development and rapid technological advancements in rockets and weapons suggest the need to reconsider the application of law in space. This is why it is appropriate to begin an examination of a proposed space policy for the Trump administration.

The 1967 Outer Space Treaty and the Future of Space Exploration

A critical issue the Trump administration must address is its approach to the 1967 Outer Space Treaty, taking into account current technological and economic developments as well as the actions of other nations with regard to space. During the 19th century, the United States entered into a series of treaties with European powers regarding the interior of the North American continent. These were both aspirational and practical tools to avert or delay conflicts with larger countries until the United States was in a stronger position to protect and promote its interests. In its time, the 1967 Outer Space Treaty served a similar aspirational purpose, providing the basis for the entire current body of international law as it applies to the peaceful use of the space environment.

At the time of the signing, the 1967 agreement provided the United States and the Soviet Union, among other nations, with assurances from which both rival superpowers benefited. The treaty, very simply put, reduced competition in space to that of only prestige, rather than economic or military, and prevented an arms race in space. The 1967 Outer Space Treaty may still offer some benefit today, however, technology and economic opportunities are proving challenging for the treaty. Problematically, Article II states: “Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.” Unfortunately, as one analyst has observed, this prohibition has essentially the same level of wisdom behind it as Pope Alexander VI’s 1496 Papal Bull dividing the outer,



The 1967 Outer Space Treaty was effective during the Cold War; however, questions of its effectiveness arise as capabilities and interests in space evolve and nations pursue their interests. (U.S. National Archives)

unexplored world (from a European viewpoint) between Portugal and Spain.⁵ The bull carried full legal authority until England and the Netherlands decided that it did not, and began acting outside its guidance. This is where the idea of space as a commons is today.

In business and in government, the bottom line matters, and in the case of space, the bottom line is that the Outer Space Treaty has dis-incentivized nations and companies from commercially developing the domain, a troubling consequence. “We Came in Peace for All Mankind” may have been a beautiful sentiment for the Apollo 11 crew as the first humans to step foot on the moon, but no economic entity will fully invest in an enterprise involving the moon (which has many rare mineral resources) or asteroids (some of which are extraordinarily valuable) without having some claim of mineral rights or ownership—which the Outer Space Treaty makes difficult at best.⁶ Since biblical times, the pursuit of profit has been recognized as an important incentive in daily life. Adam Smith dedicated a portion of his *Wealth of Nations* argument to the principle that the pursuit of self-interest

Emirates, who have established new national space laws that allow commercial entities operating within their borders to claim ownership of ores and other resources that are mined or gathered in outer space.⁸ One initiative for the U.S. government to consider is the express authorization and incentivization of the exploitation of resources from space. As long as a commercial entity does not claim the entirety of a celestial body (e.g., the moon or an asteroid), but rather confines itself to simply gathering resources contained within or on that body, then the entity and the government itself are within the confines of the Outer Space Treaty. The key is to pass the minimum number of laws governing authorization and supervision of space operations, in order to encourage the minimally fettered development of space by the commercial sector.

This would not be unlike the legal evolution of the maritime commons over time. At first sailing vessels simply hugged the coast line in order to be assured of their position, but as navigation techniques advanced, ships ventured farther out to sea, bringing about ques-

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in the end advances all of society. While there are justified criticisms of unregulated greed, the pursuit of profit, if enabled by private mineral rights, will create a demand for commercial development of space. Promoting commercial development is only the first reason that the 1967 treaty should be reviewed and profit incentivizing judicial interpretations established. If it is not, the United States will likely fall behind near-peer competitors who are eager to reap the domain’s many economic rewards.

Economic activity in space is covered under the rubric of Article VI of the Outer Space Treaty, which charges signatory nations with authorizing and supervising “non-governmental entities in outer space.” Certainly this clause covers private industry. Legal scholars agree that compliance with this aspect of the treaty is left to each signatory nation to establish. As space-law expert Laura Montgomery stated in her recent testimony before the House Space Subcommittee, “Article VI leaves it to each country to decide which particular activities require regulation, how that regulation will be carried out, and with how much supervision.”⁷ This is certainly the approach being taken by Luxembourg and the United Arab

tions of the sovereignty of the waters they sailed over. This question was largely settled in 1609 when the Dutch philosopher-jurist Hugo Grotius advanced the idea of “Mare Liberum” or, “The Free Sea” as a global commons across which all actors could travel in order to conduct trade with other nations. Grotius’ early work has been codified and updated through the centuries, but his essential argument provided the foundation for the development and expansion of a global economic system that has improved the lives of billions of people worldwide. The concept of the maritime commons has been applied to the air space above the oceans and it is not too far a stretch to see developing space law as a natural extension of current “Law of the Sea” protocols. The high seas are currently part of the global commons where actors are free to harvest resources but prohibited from laying sovereign claim. The same perspective should be adopted for space and the resources within, thereby incentivizing the exploitation of space without encroaching on the idea of a celestial commons. Understandably, the economic exploitation of space may require additional modifications to the 1967 treaty.

The Outer Space Treaty's treatment of military weapons in space should also be reviewed. The agreement prohibits nuclear weapons of mass destruction in space, but by omission it allows for conventional weapon systems. As such, the treaty presents an unrealistic view of space as a peaceful global common set aside for use by all people. This contradicts the reality that the domain represents a position of huge strategic advantage for nations that orbit intelligence, surveillance, and reconnaissance platforms critical to their national security. These nations have also overtly developed weapons (Earth-based at present but with clear space-based potential) to degrade and destroy their competitors' space-based satellites. The United States needs, as a matter of national security, a clear plan to develop systems that both assure its access to the cosmos and, realistically, deny this vital region to opponents.

As U.S. companies develop economic interests in space, the Trump administration should seek to provide a clearer definition of the treaty's Article VI.

As U.S. companies develop economic interests in space, the Trump administration should seek to provide a clearer definition of the treaty's Article VI, which states in part: "The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty." This can be accomplished by building upon existing legal precedents and establishing new ones in space law. In doing so, the United States can seek to legislate and adjudicate future outer space laws that are in line and in keeping with western legal jurisprudence. Of course, the U.S. military will need to be able to defend such legal and economic interests on the "final frontier." The old maritime truism "the flag follows trade" will most assuredly and properly be as accurate in space, as it has been on the high seas or the American plains.

Civil Space

When Thomas Jefferson sent Lewis and Clark's Corps of Discovery Expedition westward in 1804, it was to map the West and make the unknown known. This civil focus has been at the core of U.S. efforts in space since the 1958. When President Kennedy motivated the nation to land a man on the moon and return him safely to Earth, he understood that the knowledge gained by this achievement would benefit all Americans as well as all of humanity. Many of the space policies the new administration will have to consider should continue to seek such practical knowledge while evoking similar aspirations. Initial deep space exploration beyond the Earth-moon system is a mission naturally suited to governmental leadership and sponsorship, benefiting the nation at large through advancements in science and technology, as well as everyone on Earth through its quest for a deeper understanding of humanity's place in the universe. It is necessary to realize up front, however, that the government does not build rockets and rarely builds satellites. It purchases these platforms through a series of public-private partnerships established through directed contract vehicles. It is critical that the Trump administration continue to precisely guide the technological and scientific trajectory of the United States through a robust civil space program.



Curiosity rover on Mars is an example of a pioneering civil space effort. These missions are costly but necessary for the development of capabilities and deeper understandings. (NASA)

U.S. civil space efforts should point toward public goods that are recognizable to the public. In their daily lives, Americans use some of the more crucial advancements generated from civil space, such as television services and communications technologies related to phones and the Internet. Still, lesser-known developments regularly benefit the average American. Satellites provide advanced warning of destructive weather; government-operated sensors allow a deeper view into the cosmos and improve humanity's understanding of the sciences—all of which will one day allow humans to leave this Earth and settle new planets. Regardless of what form the public good may come in, the civil space policies the Trump administration should pursue need to yield benefits that are evident to the public.

Perhaps the core component of a successful civil space policy is a robust unmanned exploration program. As stated previously, “first finder” missions are not the type that the commercial sector is likely to finance and execute. Much in the same way as Lewis and Clark explored the West, it is the proper role of government to establish the “lay of the land” through initial exploratory missions. Current civil projects include the new James Webb Space Telescope, which promises to be the world's premier space telescope for decades to come;⁹ the Mars Curiosity rover, which carries the largest and most advanced suite of instruments ever sent to the Red Planet;¹⁰ and interplanetary probes, which have provided new insights into celestial bodies never before explored, such as Pluto. (See the graphic on page 10 listing these missions.) These unmanned platforms offer Americans the ability to learn about the places to which we cannot yet send humans—places that offer new insights into the creation of our solar system, nearby resources, and the opportunity to test new technologies. It will be key that these programs continue to be integrated into civil space policy, as they provide crucial insights that not only enriches our scientific and technological knowledge, but also paves the way for human exploration of space.

In the pursuit of innovative civil space policies, the United States stands to gain significant economic advantages through manned spaceflight as well. The International Space Station and other low Earth orbit (LEO) manned missions, which in the past were uniquely flown via government-designed Mercury, Gemini, Apollo, and Space Shuttle vehicles, have offered unique environments for experimentation, providing scientific opportunities that cannot be achieved on Earth. It is important to note that today, NASA is

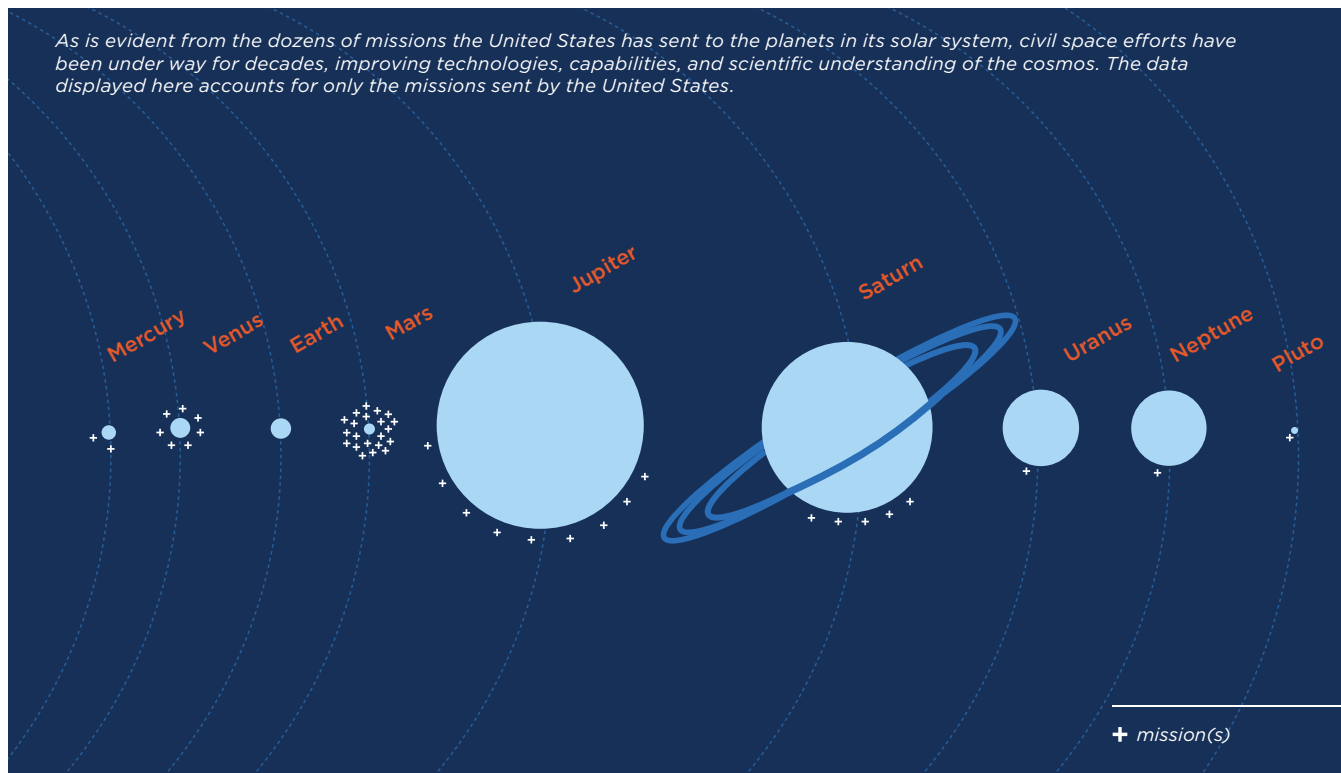
beginning to transition responsibility for manned launch to LEO to commercial entities, Boeing and SpaceX, which are creating and will operate new manned spacecraft. Future leveraging of the unique LEO environments to better understand human biology, robotics, and advanced life support systems—among other research projects—will provide the necessary stepping stones for U.S. movement past LEO to the moon, Mars, and beyond.

Importantly, manned spaceflight remains a cornerstone of the United States' pursuit of economic expansion through science and technology. Past research in LEO has generated leap-ahead technologies related to energy, healthcare, travel, commercial goods, and geology.¹² Future manned exploration beyond LEO has the potential to influence younger generations to pursue similar scientific and exploratory passions. In addition, government-sponsored manned exploration, like Lewis and Clark's Corps of Discovery Expedition, can lead to finding key resources as well as providing the government with the opportunity to establish initial manned settlements that will encourage further development by commercial space entities.



Just as Lewis and Clark's exploration enabled the development of the West, astronauts today will lead pioneering efforts for the development of space. (NOAA)

Organizations willing to close the gap between government pioneering and broad commercial investment, much in the same way as did the Union Pacific Railroad in the late 19th century, are an important component of the civil space effort. At the time, the route from Omaha to Sacramento had been traveled, but no railway connected the two, let alone the continent. The roughly 1,700-mile expanse was untamed wilderness, void of significant settlements.¹³ The Union Pacific Railroad, knowing the risks, embarked on the challenge of closing



MERCURY

1. Mariner 10
2. MESSENGER

VENUS

1. Mariner 2
2. Mariner 5
3. Mariner 10
4. Galileo
5. Pioneer Venus 1
6. Pioneer Venus 2
7. Magellan
8. MESSENGER

MARS

1. Mariner 3
2. Mariner 4
3. Mariner 6
4. Mariner 7
5. Mariner 8
6. Mariner 9
7. Viking 1
8. Viking 2
9. Mars Observer
10. Mars Global Surveyor
11. Mars Pathfinder
12. Mars Climate Orbiter
13. Mars Polar Lander
14. Deep Space 2
15. 2001 Mars Odyssey
16. Spirit
17. Opportunity
18. Mars Reconnaissance Orbiter
19. Phoenix
20. Mars Science Laboratory
21. MAVEN

JUPITER

1. Pioneer 10
2. Pioneer 11
3. Voyager 1
4. Voyager 2
5. Galileo Orbiter
6. Ulysses
7. Galileo Probe
8. Cassini
9. Juno

SATURN

1. Pioneer 11
2. Voyager 1
3. Voyager 2
4. Cassini
5. Huygens

URANUS

1. Voyager 2

NEPTUNE

1. Voyager 2

PLUTO

1. New Horizons

Source:
 Ashley Morrow, "Decades of Discovery: NASA's Exploration of Jupiter," NASA, August 5, 2016, <https://www.nasa.gov/feature/goddard/2016/decades-of-discovery-nasa-s-exploration-of-jupiter/>; "Missions to Mars," The Planetary Society Blog, <http://www.planetary.org/explore/space-topics/space-missions/missions-to-mars.html>; "Missions to Venus and Mercury," The Planetary Society Blog, <http://www.planetary.org/explore/space-topics/space-missions/missions-to-venus-mercury.html>; and "Saturn" NASA, <https://nssdc.gsfc.nasa.gov/planetary/planets/saturnpage.html>.

the railway gap. It leveraged government bonds and land grants to transform previously explored routes into useful commercial railroad lines that advanced the nation's population and economy westward. After the main trunk line was laid, smaller railroads emerged, branching out to the north and south, to service other key areas of the West. The Union Pacific Railroad was the key stimulant of economic development in the region.

Today, the same need for stable economic stimulation exists, but in space. While much of the commercial sector is eager to take part in the space economy, there remains a requirement for the government to partner with commercial entities in the form of grants, bonds, subsidies, and tax incentives to support new investment and forms of technology in space. There are contingencies—both national security and civil space related—that require the nation to maintain a medium or heavy lift rocket in standby mode, ready to launch in 30 days or less with a high degree of confidence in mission success. However, with little financial incentive, no commercial entity would or should absorb such an expensive requirement alone. The government, through its Evolved Expendable Launch Vehicle program, established these requirements and helped usher into existence United Launch Alliance (ULA) to assure the capabilities. ULA's 50-year record (through parent companies Lockheed Martin and Boeing) suffered through a series of initial accidents and setbacks during the first decades, but has established within its modern incarnation a near perfect launch record. Such assurance is critical when dealing with multi-billion dollar cargos or human lives. ULA remains a trusted commercial organization, an analog to the Union Pacific Railroad's relationship with the government for much of the latter half of the 19th century. It is capable, trusted, and in a perfect place to close the gap between government pioneering efforts and greater commercial investment.

Beyond its domestic civil policy, the administration also needs to ensure that its civil space intentions are clearly communicated to allies and scientific partners. Previous administrations have created inefficiencies when civil space policies have been incoherent.¹⁴ To most efficiently expand the United States' scientific and technological understanding, U.S. leaders need to collaborate and work with foreign governments and nongovernmental scientific organizations that also see the inherent value of civil space.



ULA sits today where the Union Pacific Railroad sat in 1860—capable, trusted, and well placed to bridge the gap between government-sponsored exploration and greater commercial investment. (U.S. Air Force)

A successful civil space policy is one in which the government invests in programs whose focus centers on advancements in science and technology. This path requires investment in unmanned exploration that, in a cost-effective and technologically conducive manner, allows humanity to go further, learn more, and risk less. To support both unmanned and manned exploration, an effective civil space policy makes use of all the advantages offered by the commercial space sector, allowing private imagination and investment to develop what the government has pioneered. Finally, a proper civil space policy leverages partners to most efficiently enhance humanity's understanding of the advances on which civilization has come to depend. In the end, a civil space policy should have one overarching goal: development.

Where the Government Leads, the Commercial Sector Can Follow

First comes a definition. There are actually very few purely commercial space efforts, which is to say few space-based platforms built for profit with no research or government interest. Some organizations, for example DirectTV or communications companies such as IntelSat or ImarSat, fall into this narrow definition. Future purely commercial space entities may also include solar power companies that gather cheap energy in vast space-based arrays and then beam it back to receiving stations on earth, but even in this instance the government and military will be significant customers.¹⁵ However, for the purposes of this paper, commercial companies include entities, whether launch services providers or satellite builders, that provide bids to the government and are selected for their competitive prices. It is this contribution—the creation of a growing, thriving market—that is causing the commercial space sector to flourish.

As more affordable access to LEO, medium earth orbits, and geo-stationary orbits becomes a reality and activities related to science, technology, and, most important, the economic incentive outside Earth's atmosphere, humanity can begin to make use of the resources of space. In a logical progression, the lessons learned from operating in LEO can be used to extend humankind's development on the moon, Mars and in and around the asteroid belt region of the solar system. Having tested in LEO spacecraft, habitats, life support systems, and other necessary equipment for sustaining

life outside of Earth, the U.S. government has, more or less, provided the foundation for the private sector to begin colonizing the moon and Mars, and from there to further exploit other regions of space for their economic and scientific value.

The United States' broader space efforts should encourage the development of the commercial space sector by enabling the civil space sector to blaze a pioneering trail. The commercial space sector offers incredible opportunities but often lacks the ability to accomplish the more expensive pioneering projects that the government is better suited to finance. For example, NASA's Curiosity rover cost roughly \$2.5 billion.¹⁶ While the commercial sector may be able to produce that amount of capital, it is looking for a financial return on investment that the government is not. Consequently, in a productive space policy the government would leverage its ability to invest in first-finder projects to incentivize private investment. A commercial sector working from the scientific and technological advances forged by government sponsorship will be key if the United States wishes to remain at the forefront in space.

Going for Gold (and Platinum)

As access to space increases and humanity develops the ability to travel greater distances, the commercial space sector will be well placed to exploit the numerous economic opportunities in places including the moon, Mars, near-Earth objects (NEOs), and the asteroid belt. Asteroids have estimated values in the trillions of dollars and could potentially rid humanity of its dependence on Earth-based resources.¹⁷ Goldman Sachs recently produced a 98-page document for investors detailing the feasibility and lucrativeness of asteroid mining.¹⁸ While the majority of the resource rich asteroids reside in the asteroid belt located between Mars and Jupiter (detailed in the table on page13), fNEOs are plentiful and also likely to hold valuable resources while being a productive stepping stone toward the asteroids which reside in more challenging locations. The point of this venture would be to send raw resources not only back to Earth, but also to outposts on the moon, Mars, or on orbit where they could then be used to manufacture necessary equipment and infrastructure for space-based activities. Mining resources in space would reduce the use of limited resources on Earth while also enabling greater production flexibility, because space-based equipment would no longer be limited to what could be affordably launched from Earth.



SpaceX's innovation in rocket reusability offers the possibility of more affordable access to LEO and beyond. Here, its Falcon 9 rocket lands after launching. (SpaceX)

The moon alone is rich in resources that are valuable here on Earth.²⁰ These are used to make electronic components for everything from hybrid cars to cell phones. Given that 90 percent of the REMs refined on Earth come from China, accessing new sources could greatly benefit the United States.²¹ The Trump administration should press for additional legislative reform

Number of close approaches by near-Earth objects (NEOs), by distance, within the past year (April 2016–April 2017)¹⁹

DISTANCE	NEOS
0.2au (astronomical unit)	1,729
0.1au	1,118
0.05au	702
10LD (lunar distance)	429
5LD	240
1LD	43

NEOs represent potential resources significantly closer to Earth than those found within the asteroid belt. They could be the first step in asteroid mining operations. Astronomical units are a standard unit of measurement that represents the distance from Earth to the sun. Lunar distance represents the distance from Earth to the moon.

by strengthening the 2015 Commercial Space Launch Competitiveness Act with additional firm measures to protect and promote commercial investments in space. Investing in large scale projects related to asteroid mining or colonizing the moon or Mars is a significant enterprise on which key companies in the private sector are eager to embark. The Trump administration should encourage and protect such investments, promoting the idea that companies that invest in space will have a reasonable expectation of profit. Human exploration of the

moon, Mars, and beyond can become another aspect of global competition, and the United States is well positioned to lead the race. Finally, if a new, defined economy is developed in space, the Earth will benefit through trade, just as the U.S. and British economies during the 19th century benefited through large market interactions.

The Advantages of Commercial Innovation and Service

The expansion of the commercial space sector has produced advances in everything from engines and life support systems to complete spacecraft designs.²² These innovations have the potential to lead to affordable access to space, increased efficiency, and greater economic and scientific returns. Leveraging market incentives, commercial companies compete for greater market share; in the process, they innovate and expand the number of scientific and economic opportunities currently available. Commercial companies including ULA, Orbital ATK, SpaceX, Blue Origin, and others are necessary if the United States wants to reduce its dependence

on Russia for access to space and improve operability in space while taking advantage of the economic opportunity created by a more advanced and competitive space sector. A competitive policy must leverage the opportunities provided by the commercial space launch sector.

The commercial space sector is innovating in critical areas, making space-based technologies and access to the cosmos more cost effective. As innovation empowers actors, it also generates new problems requiring further innovation. The company OneWeb plans to launch more than 600 satellites in a constellation by 2027 to provide Internet services to the world.²³ To accomplish this revolutionary task, OneWeb plans to create the first mass-produced assembly line satellite in order to lower production costs while increasing production numbers. SpaceX is also exploring building a mass satellite manufacturing facility.²⁴

While the mass production of satellites is a much-needed capability, it is also a complicating factor. Aging satellites, debris, and other space-based equipment represent an increasing danger, as the growing number of additional objects placed into orbit by nation states and organizations that require on-orbit intelligence perspectives.²⁵ Difficult as it is to conceive, debris



Orbital ATK's work in launch abort engines (pictured) is one among many commercial examples of innovation and improved operability related to space launch. (NASA)

and satellite congestion will increase, as each launch provides not only a payload but also detritus associated with launch vehicles. Economical access to space and an eager commercial sector suggest a remedy for this very costly problem. Space-based servicing vehicles can extend the life of satellites by attaching additional power and maneuvering components. Such vehicles could also potentially remove debris.

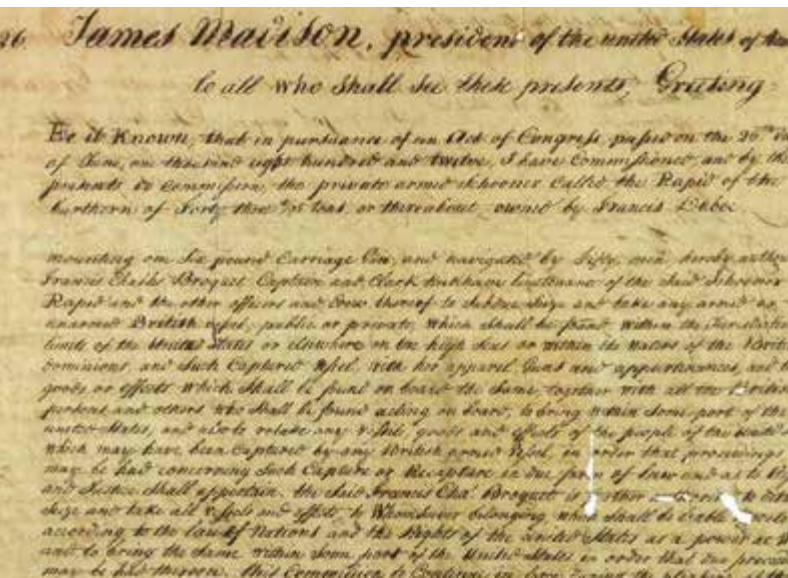
Improvements in innovation and capabilities in the commercial sector require a presidential administration to reexamine NASA’s role. The government should only use NASA for activities to which it is best suited, and not those that are a better fit for the commercial sector. Much in the same way as Congress used letters of marque to allow private maritime vessels to act as military tools of the state—with the promise of payment and profit for their efforts—the government could entice private space ventures to participate in a public mission: cleaning up space debris, acting as situational awareness networks, and servicing nearby satellites, among many other tasks. A successful space policy understands that the government–commercial sector dynamic is an “and” rather than “or” proposition.

ENABLING GROWTH IN THE COMMERCIAL SPACE SECTOR

The commercial space launch sector is growing rapidly. For a very long time this was a rather small sector led by Boeing and Lockheed Martin, but it has grown considerably and now includes new companies such as SpaceX, Blue Origin, Virgin Galactic, and others. This growth has spurred expansion in capabilities as well. The United States executed 22 space launches in 2016, the most of any country, and all were conducted by private companies.²⁶ Of these, ULA is the most experienced and reliable, with 10 years and more than 100 launches with very high reliability.²⁷ Equally important is the innovative work in reusability that SpaceX and Blue Origin are conducting, most notably the March 30, 2017, SpaceX launch of the SES-10 satellite, which for the first time successfully reused the first stage of a previously flown rocket. Other private firms, including Virgin Galactic and Deep Space Industries, have emphasized space tourism and resource mining, thereby providing consumers with access to the cosmos for pleasure and economic opportunity. The growth in commercial space activity is substantial and increased roughly \$100 billion between 2006 and 2015.²⁸ In a typical free market fashion, increased investment is creating upsurges in innovation, efficiency, and economic return.

Growth of the commercial space sector is due to several complementary factors. An increasing market demand for space-based technologies, the pursuit of space-based economic opportunities, and a desire to colonize celestial bodies have been among the main motivators in recent decades.²⁹ Still, while for-profit companies are innovative and arguably represent the future of space exploration, the credit for pioneering their path goes to the government, which remains a primary customer for many of these private organizations and encourages them through beneficial policies. The Trump administration should place emphasis on the commercial sector as the central pillar of future U.S. space activities and thus provide a favorable economic and legislative environment for these organizations to innovate, grow, and offer greater economic and political return for the United States.

Private organizations will also need an improved domestic manufacturing industry that is capable of handling increased demand. The United States has a limited number of both launch facilities and organizations that can produce the necessary rocket technology and equipment. Currently the nation uses Russian RD-180 rocket engines and Soyuz launch vehicles, creating strategic vulnerabilities with regard to assured access to space.³⁰ This is a problem that the United States must alleviate as it pursues greater access to and exploitation of space.



Congress once used letters of marque, authorized in the Constitution, to empower private maritime vessels to act as military assets for the state. The government could use similar legal instruments to entice private space ventures to participate in public missions. (U.S. National Archives)



1870



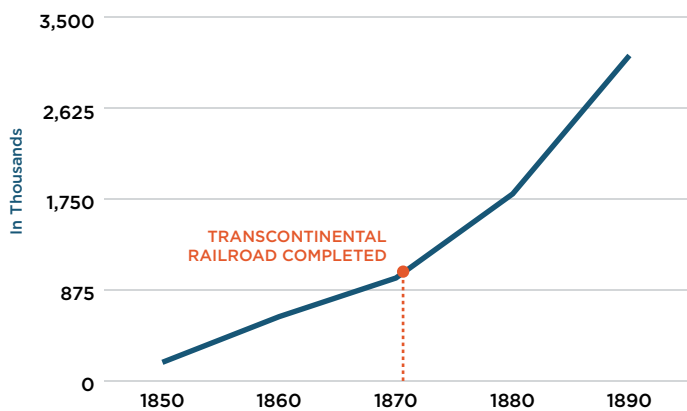
1890

The expansion of the West is reflected in the increase in railway over time. This growth was encouraged by government policy. (Bruce C. Cooper Collection of North American Railroad History)

In order to strengthen the nation’s industrial base and stabilize costs, multi-year service agreements and block-buying launch vehicles of various lift capacities will help to ensure that the commercial sector continues expanding its market reach. The United States must also rethink the bureaucratic bulwarks preventing commercial organizations from both importing and exporting subcomponents from and to overseas suppliers. Limitations associated with disclosing how an imported component will be used in a commercial rocket complicates and slows the innovation process for seller and customer alike. Similarly, preventing the export of services outside the United States discourages a company’s basing of operations on U.S. soil, and it limits organizational growth. These, coupled with a large corporate tax burden, has made the United States a complicated location for a burgeoning industry that is otherwise set to change the way we think about space.

Just as the Lincoln administration encouraged the building of railroads across the U.S. West, the Trump administration should develop strategies that incentivize commercial expansion into space. Where Lincoln used land grants, the Trump administration could leverage tax incentives or time-limited permissions, such as those granted to the British and Dutch East Indies Companies, limited to celestial bodies such as asteroids, or to coordinates such as LaGrange points, to encourage investment and innovation in space. A core component of the commercial space sector is the capacity to take advantage of the many economic opportunities outside Earth’s atmosphere, including mining and tourism. These endeavors are currently untapped markets but have significant investor interest. As depicted in the adjacent graph, the development of the West required government incentive, so too, does the development of space today.

Growth of Western States by Population (in thousands)



There are legislative hurdles, however. Without the capacity to lay claim to space-based resources, the commercial sector will be limited in its economic potential. The 2015 Commercial Space Launch Competitiveness Act provided legal authority for the United States to claim space-based resources,³² but U.S.-based commercial companies will need a broader international consensus regarding ownership or controlling interests. In much the same way as centuries of maritime laws were layered over time to form the legal foundation for the current understanding of the vast oceanic commons, the Trump administration should pursue—through economic, scientific, and technological incentives—international agreements based on existing laws that provide companies with the permissions and legal surety they need.

National Security in Space

When the nation moved westward the Army went with it, establishing forts whose names dot the map of the United States. These fortifications provided protection for local settlers pursuing commercial gains and a base for defensive patrols and operations. In space, the military will fill a similar need. At present the military purpose of space-based systems is to leverage the domain's inherent advantages to ensure the survival of the state by supporting Earth-based operations. However, at this point in their development, these systems have not evolved sufficiently to allow for independent space-based operations. They have neither the capability nor the capacity to plan or conduct space-based campaigns of either an aggressive or a defensive character, or even to fly about the Earth on patrol. By way of comparison, satellites are launched to provide support to and coordination with Earth-based units.³³ This is the type of role that should be carefully considered.

The role of space in the defense of the United States has expanded exponentially since the January 1958 launch of the Explorer 1 satellite. Its primary scientific instrument was a cosmic ray detector, and the Eisenhower administration immediately recognized that space offered an advantage to surveil areas of key interest to U.S. national security. The government began to develop first cameras and then other sensors that could be employed in space, in a series of surveillance satellites grouped under the rubric of project Corona. Near-real-time, and later real-time, surveillance systems provided



Military satellite communication is one of the several space-based technologies on which the U.S. military is critically dependent for operations and planning. (DoD)

the United States intelligence on the Soviet Union's activities and readiness to conduct wartime operations, including nuclear strikes. These capabilities were largely impervious to attack, as no missile was yet capable of bringing down a Corona satellite in the manner that the U-2 spy plane had been in 1960. The Eisenhower administration briefly considered a program that would launch a manned "bomber" spacecraft into low Earth orbit, but later canceled it.³⁴ The development of both theoretical and practical understanding of the full range of activities in space, including the Reagan administration's investments in what was then termed Star Wars—a space-based Strategic Defense Initiative to protect the nation from nuclear ballistic missile attacks—soon led to an expansion of those activities and a commensurate rising stability within the international arena during the waning years of the Cold War.

Space contributed to the military operating environment first with weather forecasting (which has always played a major role in battlefield planning), then surveillance (employing optical, radar, and electronic sensors), communications, and ultimately navigation-timing, which allowed Earth-based weapons to search for, localize, target, and destroy enemy forces from range in a manner never before witnessed. The entire U.S. method of war underwent a significant technological leap with the advent of precision strike. In World War II, B-17 bombers dropped 240 tons of ordnance to destroy a single target, such as a bridge. In Vietnam in 1965, F-4 Phantom II jets dropping "dumb bombs" narrowed that number a bit to 200 tons per target, and, remarkably, that same airplane seven years later would drop only 12.5 tons of precision laser guided ordnance to destroy a target.³⁵ By Operation Desert Storm in 1991, a single aircraft launching with four bombs under its wings could reasonably expect to execute strikes on four targets, with great precision due to space-based assets. This capability has been extended from the land to the maritime environment, where mobility of ships is assumed. As long as the sensor, either air- or space-based, holds the target in its view, a weapon's ability to "acquire" and destroy its target is high.

Today, nations that oppose the United States note this capacity and the political and military advantages afforded by such a high-end capability. In response, competitors have begun to focus on a series of strategies and weapon systems that seek to push U.S. platforms away from their national strategic centers and deny them access to critical nodes. While many of these anti-access/area denial weapons focus on U.S. ships and aircraft, a growing number of systems are also being built to target

space-based capabilities. Anti-satellite weapons that seek to degrade or destroy orbiting U.S. payloads by targeting them with electromagnetic energy, directed energy (lasers), or kinetic mass have been theorized, developed, and tested with great effect by both the Russians and the Chinese. This signals that the United States' overwhelming advantage in space, and its very way of war, are now in question.

This stark realization should indicate to the Trump administration that the early, idealistic age of space exploration and use has come to an end. As a matter of national policy, the United States' Department of Defense, through its military service departments, must continue and strengthen its means to assure access to space under both peaceful and contested conditions. Such a policy should seek the establishment of a deep and resilient inventory of sensor, communications, navigation, and defensive space-based platforms in various orbital configurations to quickly shift or replace active satellites in the event that one or more should be degraded or destroyed. The X-37B program, run by the DoD but shrouded in secrecy, may provide a path to this capacity.³⁶ Next, the United States must establish multiple and redundant launch sites across its territory, on or under the oceans, and seek agreements with allies to gain access to their launch facilities in the event of an attack and disablement of key U.S. ascent locations. Lastly, the United States must work with industry to establish a deep inventory of launch vehicles that can be quickly transported to, and assembled at, various launch sites to create an ability to rapidly repopulate sensors and

other systems. As mentioned previously, naval vessels, including surface ships and submarines, should contain within their onboard weapons magazines solid rockets with communications or sensor small-sats that are already installed and prepared to repopulate capabilities in low Earth orbit. To achieve this high level of resiliency, the Trump administration must first work with the commercial sector to develop the needed space industrial base which affords industry and government entities the capacity to produce necessary capabilities efficiently and at a sustainable price point. Without a robust and efficient space industrial base, the United States' space resiliency will suffer.

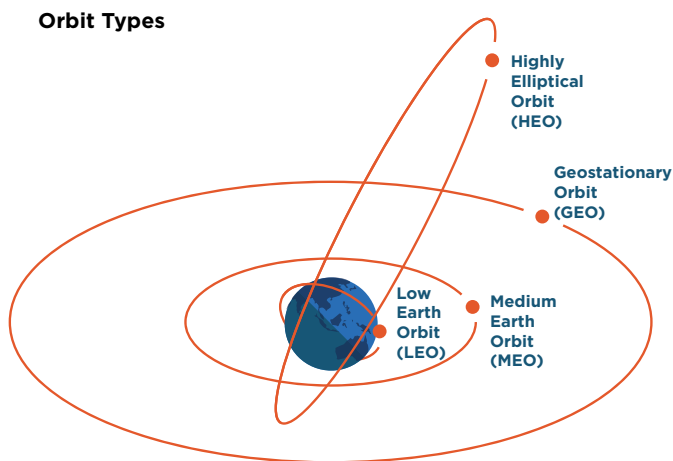
Without a robust and efficient space industrial base, the United States' space resiliency will suffer.

The Trump administration should also consider space-based systems deployed in key orbital locations to serve as on-orbit "forts" capable of employing electromagnetic waves, directed energy beams, and kinetic mass projectiles with the ability to deny space to other powers should they seek to destroy the United States or harm its national interests. Such fortresses could be placed in low Earth orbit, geosynchronous orbit, or just beyond that altitude in the poorly defined "graveyard" orbit. Such a configuration would allow a platform to be lowered into a geosynchronous position at a moment of the United States' choosing. These positions constitute the most immediately available geographic "high-ground" in the strategic competition in space, and nations have already begun to attempt to assign sovereign characteristics to key positions over their homelands.³⁷ Another consideration is one suggested by Elbridge Colby, now Deputy Assistant Secretary of Defense for Strategy and Force Development, in his 2016 report, "From Sanctuary to Battlefield." Colby suggests disaggregating major space-based systems and spreading them out to make them less vulnerable to single-point attacks and more resilient overall.³⁸ Such an approach would ensure U.S. access to space while also detecting and defending against enemy attack on the homeland in the space frontier.

These potential moves speak to a national security requirement to strengthen the U.S. space industrial base by investing across a variety of suppliers and encouraging innovative approaches to aerospace engineering challenges.



The X-37B Orbital Test Vehicle is a new classified space capability being developed by the U.S. Air Force. It was most recently launched on a SpaceX Falcon 9 rocket. (U.S. Air Force)



The Trump administration should consider deploying space-based systems in key orbital locations to serve as “forts.”

Ultimately, it is time to consider a broader strategic concern. Whereas defense policy often has at its base the goal of ensuring the survival of the state, space policy must go further. It is established scientific fact that there have been five mass extinction events on Earth.³⁹ Humans, through space exploration, now have within their grasp the key that will ensure, much as did the biblical Noah in the Book of Genesis, the survival of not only the species, but many other forms of animal and plant life. Reestablishing a U.S. presence on the moon in the form of raw materials mining, and then developing an orbital manufacturing “shipyard” in lunar orbit to produce reusable trans-planetary ships for transport and colonization, should be the first steps for much-needed assurances. There are ample resources on the moon, and the lower gravity of the Earth’s satellite would make it cheaper to lift construction materials into orbit. Also, the age of one-and-done spacecraft is over. Just as launch boosters and ascent/descent modules are being reused today, interplanetary ships will traverse the distances between Earth and Mars many times in their service lives, all for the purpose of expanding the United States’ reach and, ultimately, taking out an insurance policy to preserve the human species. In formulating its policy, the Trump administration should make the necessary investments to facilitate a path to colonization elsewhere in the solar system—in the name of national security.

Conclusion

When Lewis and Clark traveled westward in 1804, they had no idea that a mere 58 years later, railroads would follow them all the way to the Pacific. Today, just shy of the 50th anniversary of Neil Armstrong’s first step on the moon, the demand for access to space is increasing exponentially. The civilization that humanity has produced is intrinsically integrated with the advancement of science and technology. When scientists and engineers make a leap, as did Einstein with his theory of relativity and von Braun with the Saturn V rocket, all of humankind jumps with them. Space-based technology has fueled globalization by enabling communication, military progress, and rapid economic expansion. As states develop, they have no choice but to adopt similar dependencies on space-based assets. This process creates a need for a more expansive and capable space sector, both private and government. For the United States to be successful in the future, the Trump administration needs to promote policies that emphasize this future, rather than an Earthbound past.

A failure to account for the maturation of the space sector will indicate a broader inability to appreciate the value and necessity that the cosmos offers to both private ventures and concerns of national security. New private sector investments in this domain have become critical for U.S. space efforts, signaling a paradigm shift in the value of space from the commercial standpoint. Equally concerning is the growing capabilities of peer competitors who have identified U.S. military dependency on space-based assets as an asymmetric advantage. The United States cannot ignore this changing environment.

Investment in policies that enable greater U.S. exploitation of, and security in, space should start by aggressively advancing commercial claims on ownership of resources obtained in space, and then defending those claims in national and international legal settings. Over time this approach can establish precedents that will guide future interpretations of jurisprudence. The United States should also position itself to defend such claims with military forces, much as it has in the past on the high seas. Russia and China are already creating military capabilities that could target U.S. assets orbiting the Earth, and they are making other investments focused on harvesting the trillions of dollars of space-based resources. The U.S. space industry is uniquely placed to take a leading role, both in matters of national security and the economy. The Trump administration should not take this for granted, and should provide expansive interpretations of current space treaties.



The Trump administration—including Vice President Mike Pence, chair of the National Space Council—needs to create a dynamic new course for the nation that accounts for the urgencies of the strategic environment. (White House)

Growing the U.S. space industrial base and ushering in an era of space-related innovation and dominance is already in motion. To increase the momentum of this movement requires an administration that supports it. The current leadership needs to think critically about where the commercial sector and state interests in space overlap. Unnecessary redundancies between government and private efforts will only increase the cost, while reducing the return. Providing an efficient environment in which the government and the commercial sector work in harmony will be critical.

The roles and responsibilities of the government and private sector in space should be complementary. As with Lewis and Clark and 19th century railroad development, the government should lead pioneering efforts while incentivizing the commercial sector to follow. As the commercial sector grows in capability, the United States will have a space industrial base that can produce innovations critical to national security and the economy. An opportunity presents itself here for a symbiotic relationship between government and commercial efforts in space, and the administration would be wise to encourage it.

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