



Chapter 8

Exploring New Frontiers in Space Policy and Property Rights

The United States has been on the cutting edge of space exploration since the dawn of the space age and has become the world leader in commercial activity in space. In the 20th century, the United States became the first and only nation to send individuals to the Moon. After the end of the Apollo Program, the United States pioneered the Space Shuttle, the world's first reusable spacecraft. Now American engineers have become the first to demonstrate and operationalize the capabilities of commercial spacecraft for orbital cargo delivery, first-stage reusability, and human spaceflight.

In the 21st century, the United States has ushered in a new era of space exploration based on public-private partnerships and the success of private sector investment in space technologies. The Trump Administration recognizes the opportunities and benefits afforded by this new era and has advanced policies that encourage private sector innovation, collaboration with commercial companies, and a regulatory environment more conducive to investment in space. In doing so, this Administration is not only accelerating the development of the today's space industry; it is also laying the foundation for a viable space economy that can continue to develop and expand in the coming decades.

This past year has seen historic advances in spaceflight and space policy, even in the midst of the global COVID-19 pandemic. After the reestablishment of USSPACECOM as a combatant command for the space domain on August 19, 2019, President Trump established the U.S. Space Force (USSF), the sixth branch of the U.S. military, on December 20, 2019. The mission of USSF is to organize, train, and equip space forces to “protect U.S. and allied interests

in space and to provide space capabilities to the joint force” (USSF n.d.). In addition, on May 30, 2020, and November 15, 2020, in major milestones for the partnership between the National Aeronautics and Space Administration (NASA) and the private sector, SpaceX launched a total of six astronauts from Cape Canaveral to the International Space Station (ISS). These missions, which represent the first commercial human spaceflights in history, are an important step for the private sector’s role in the space economy.

In support of these achievements, the Trump Administration has advanced policies that strengthen investor confidence in the space economy to enable the private space sector to flourish. These new policies are creating an environment that spurs investment in innovation and encourages the responsible and sustainable use of space resources. In this spirit, the Administration has released the Artemis Accords, a practical set of principles that will create a safe, peaceful, prosperous, and open future in space. The initial tranche of signatories to these accords was announced on October 13, 2020, and included several other major spacefaring nations and international partners, with more to follow.

With regard to the economic theory of property rights and the large and diverse empirical literature on property rights, the Council of Economic Advisers finds substantial evidence that improving investors’ expectations in a novel economic sector—like space—increases investment in that sector, leading to more innovation and greater benefits. The CEA estimates that private space investment could potentially double in the next eight years, due to President Trump’s executive actions and other enhancements of property rights in space.

Much of the economic growth over the last five hundred years has occurred because economic actors have forgone present consumption to invest in the future. In support of this, a core tenet of the common law tradition is to ensure that future gains from investment accrue to the entities or individuals that make the investment and take on the subsequent risk. A fundamental role of government in this process is to set rules that create expectations about what the future holds for investors. Property rights form a legal and economic basis to support investment and provide a structure for the

allocation and management of resources. Although new norms and systems will evolve with the growth of space exploration, the institution of property rights will be critical to encourage investment for the long-term development of the space economy.

This chapter highlights the Trump Administration's actions to enhance space property rights and maintain the United States' position on the frontier of innovation and economic development in space. A cornerstone of the Administration's policy is to encourage private investment in partnership with the Federal Government. The venture capital firm Space Capital estimated that companies invested \$18 billion in space activities in 2019. The CEA projects that private investment in the space sector will reach \$46 billion a year by 2028 as a result of the policies undertaken to clarify and improve the enforcement of property rights in space.

Property rights can be thought of as a “bundle of sticks,” with each stick providing an aspect of the underlying rights that the owner can expect to receive (Barzel 1997). Sticks, in this case, could refer to the ability to transfer ownership of an asset, the right to earn income from the asset, or the right to restrict others from performing certain acts near the asset. As more sticks are added to the bundle, property rights are further specified, so that the owner can form more precise expectations of the value of a given investment. As activity has developed in space resources, new questions have arisen about property rights in space. The current system of international agreements does not require major changes, but it does need “carefully drafted additions and amendments” for clarification (Hertzfeld and von der Dunk 2005, 82). Recent actions by the Trump Administration seek to provide this clarification.

This chapter illustrates how recent U.S. space policy focuses on ensuring certainty and predictability for private investments in opportunities beyond Earth. The first section discusses current issues in space policy, and the second one addresses recent policy efforts and explains how they provide enhanced security and enforcement of property rights. The subsequent sections explain the economics of property rights theory and review the economic literature on how improving property rights affects investment. The chapter then projects future investment into space activities accounting for the effect of Federal Government policies on investment behavior. The chapter concludes by discussing the benefits of selecting the United States as the flag of choice—that is, the country whose frameworks a business finds most desirable—for space activity and how regulatory reform makes the market more competitive and innovative.

Current Issues in Space Policy and the Space Economy

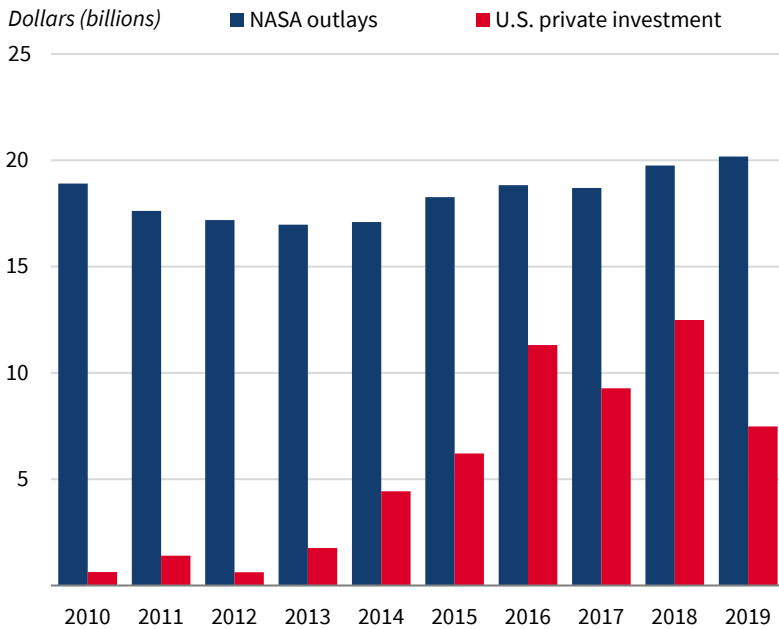
Today, most economic activity in space consists of satellites transmitting telecommunications and remote-sensing data to devices on Earth and the rockets launching these satellites into orbit. This orbital network of satellites has facilitated a variety of civil and economic activity on Earth, including weather forecasting, climate modeling, city planning, emergency response, precision agriculture, satellite television, satellite radio, global broadband Internet, and even app-based ridesharing services.

At this point in time, predicting some future industries in space is possible, but history suggests that anticipating all the emerging industries within the space economy is impossible. However, we can use recent developments in current technologies, such as in the satellite and rocket launch industries, to hypothesize what the future of the space economy could look like. For example, the process of mineral extraction on the Moon and other celestial bodies may become profitable as the costs of extraction fall and innovations in space manufacturing, habitation, and propulsion create a demand for resource availability in space. Space-based solar power is also a possibility, because orbiting solar panels can harness the sun's rays before they dissipate in Earth's atmosphere and can generate more electricity than terrestrially based solar panels. Finally, private companies are hoping to create a market for space tourism through partnerships with the Federal Government and innovations that lower costs, providing an experience quite literally like none other on Earth.

The beginnings of the space economy date to the mid-20th century, when the Soviet Union sent Sputnik 1 into orbit in 1957, spurring a flurry of investment into the space race from national governments. The National Aeronautics and Space Administration (NASA) began operations in 1958, sent the first American into space by 1961, and landed the first human on the Moon in 1969. These accomplishments occurred in parallel with a number of new United Nations treaties as countries around the globe contemplated the prospect of widespread activity in space. Because there were few profitable opportunities for the private sector at the time, the U.S. Government laid the groundwork for a space economy, and the industry developed based on projects funded by taxpayers (Weinzierl 2018).

Most space activity in the 1970s and 1980s involved the launch and operation of satellites for commercial telecommunications, reconnaissance, and surveillance purposes. In 1974, the first satellite of the forthcoming Global Positioning System (GPS) was launched into orbit (Pace et al. 1995). The Department of Defense initially utilized the GPS constellation purely for military purposes. However, in 1983, the United States announced that it would make GPS's standard positioning service available to the general public at no cost. This event initiated private, civilian uses of GPS that have since led to the

Figure 8-1. NASA Outlays and U.S. Private Investment, 2010–19



Sources: Office of Management and Budget; Space Capital; CEA calculations.

Note: NASA = National Aeronautics and Space Administration.

creation of countless new firms, technologies, and applications. O’Connor and others (2019) estimate that GPS has generated about \$1.4 trillion in economic benefits since being made available for civilian and commercial use.

Although governments initially funded all space activities, the private satellite industry grew throughout the second half of the 20th century as companies realized the market opportunity for satellite services, such as telecommunications, broadcasting, and data transmission. More recently, private industry has begun to offer other products and services that had been primarily owned and operated by the Federal Government, such as space launches, crew transportation, and remote sensing. For example, since the Space Shuttle was retired in 2011, private companies such as SpaceX and United Launch Alliance have provided launch services for civil, commercial, and national security space systems. Figure 8-1 shows that nongovernmental equity investment in U.S. space companies is rising in relation to the level of NASA outlays.

This shift from government launch vehicles toward commercial space launch services accelerated in 2005, when NASA began the \$500 million Commercial Orbital Transportation Services (COTS) program. The COTS program operated on fixed-price payments rather than cost-plus procurement, which is intended to incentivize innovation and shift NASA’s role from being

Table 8-1. Composition of Global Space Economy, 2019

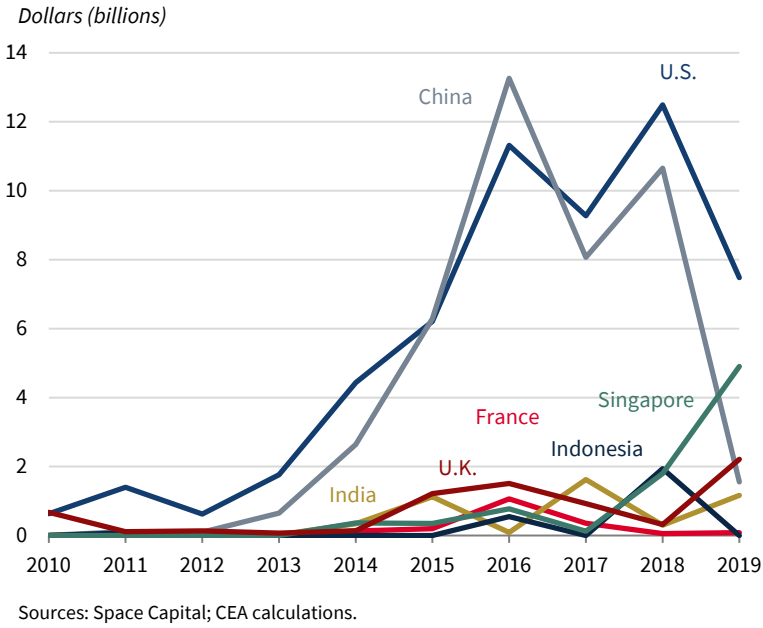
Industry	Good or Service	Spending (billions of dollars)	Percentage of Space Economy
Satellite	Total	270.7	74.0
	Satellite ground equipment	130.3	35.6
	Television	92.0	25.1
	Fixed satellite services	17.7	4.8
	Satellite manufacturing	12.5	3.4
	Satellite radio	6.2	1.7
	Launch services	4.9	1.3
	Broadband	2.8	0.8
	Commercial remote sensing	2.3	0.6
	MSS	2.0	0.5
Nonsatellite	Total	95.3	26.0
	U.S. Government's space budget	57.9	16.0
	European space budget	12.0	3.3
	China's space budget	11.0	3.0
	Russia's space budget	4.1	1.1
	Rest of world's space budget	4.0	1.1
	Japan's space budget	3.1	0.8
	Commercial space flight	1.7	0.5
	India's space budget	1.5	0.4

Sources: Bryce Space and Technology; CEA calculations.

an owner and operator to being a customer for resupply services to the International Space Station. This method of procurement and the use of other contracting mechanisms have been gaining traction elsewhere in the space industry, in an effort to decrease costs and benefit from private innovation (box 8-1). Market competition has since provided stronger incentives for innovation than the existing government monopoly on launches. NASA estimates that the use of commercial services for ISS resupply services alone has saved taxpayers between \$20 billion and \$30 billion since 2011.

Annual estimates of the size of the space economy, incorporating both public and private activities, range from \$360 billion to \$415 billion. The current state of commercial activities still consists primarily of satellites and satellite services with industry revenues of nearly \$270 billion as of 2019, making up 74 percent of the space economy (table 8-1). NASA's activities and procurements still drive a large amount of economic activities across the Nation, however,

Figure 8-2. Nongovernmental Equity Investment in Commercial Space Companies, 2010–19



with NASA’s overall economic impact estimated at over \$64 billion for financial year 2019 based on IMPLAN analysis. Recent technological developments will allow new industries to mature. For example, dramatic reductions in the cost of space launches are increasing the economic viability of private space activities such as tourism and mining. Technologies enabling the Moon, Mars, and asteroid surface operations will mark critical milestones for the next generation of space exploration. The reduced cost of access to space will broaden the set of countries that are able to take advantage of the opportunities in outer space and ensure benefit to people around the globe. Furthermore, in situ resource utilization of space resources derived from celestial bodies themselves for potable water, breathable air, and spacecraft propellant will allow longer-term survival away from Earth’s surface. Once long-term survival in cislunar space is viable, further explorations deeper into space will be possible. And once technologies advance to make long-term survival viable, government policies clarifying property rights will provide the needed framework for a flourishing space economy.

Figure 8-2 shows nongovernmental equity investment in space companies from 2010 through 2019. Most private investment in space companies has occurred in the United States and China, with smaller levels of investment occurring in European and Asian economies. Investment in commercial space companies is only a small percentage of the total space economy, but it reflects

Box 8-1. Public-Private Partnerships for Human Spaceflight

The year 2020 has been historic for NASA, as the SpaceX Crew Dragon Demo-2 mission marked the first commercially developed crewed mission to the International Space Station as part of NASA's Commercial Crew Program. NASA has emphasized the implementation of public-private partnerships to advance space exploration through collaborations with the developing commercial space sector. After NASA's Space Shuttle program ended in 2011, the United States relied on the Russian-designed and operated Soyuz spacecraft to send American astronauts into space. However, the development of domestic commercial alternatives has allowed the U.S. government to regain its domestic human launch capability while supporting U.S. commercial companies.

The Commercial Crew Program, which supported the Crew Dragon mission by providing SpaceX with development funds, also used fixed-price contracts, with NASA working as a partner rather than supervisor. Cost reimbursement or cost-plus contracts had been more commonly used by NASA in the past, because technically complex and novel projects prevented it from receiving accurate advance estimates of risk and cost. However, these types of contracts provide weak incentives for innovation, given that any cost savings innovation undertaken by the firm leads to lower revenues and often incentivizes companies to increase the costs and lengths of their contracts. Fixed-price contracts, conversely, provide strong incentives for innovation and delivery of products or services on time and under budget. Per NASA's 2021 fiscal year budget request, fixed-price contracting is now considered the "first choice whenever possible" due to the incentives produced by placing increased responsibility on contractors.

Public-private partnerships have been shown to lower the costs of space products and services for taxpayers and to speed the growth of the space economy. The Commercial Crew Program's investment in the private sector has driven innovation, efficiency, and effective manufacturing and business techniques, and NASA has projected that it will save between \$20 billion and \$30 billion relative to the cost to develop its own crewed spacecraft. After the Space Shuttle program ended, the cost to fly an American astronaut on a Russian Soyuz rocket rose from \$40 million in 2011 to about \$90 million in 2020, given that the Russians held a monopoly on crewed launch vehicles. A SpaceX launch, by comparison, costs about \$65 million per astronaut. SpaceX is able to reduce costs through new approaches to recover and reuse its spacecraft and launch vehicles.

In 2011, there were zero commercial launches in the United States, because the market was dominated by international competitors that were largely subsidized by their governments. Today, as a direct result of U.S. Government investments in the U.S. commercial space sector, most commercial space launches are conducted in the United States by companies such as SpaceX, which employs over 6,000 people throughout the country.

Looking to the future of public-private partnerships, NASA has been increasingly making the ISS available to commercial research and manufacturing activities, as supported by the ISS National Laboratory. In addition, NASA is allowing visits to the ISS by commercial astronauts aboard SpaceX's Dragon 2 and Boeing's Starliner. Companies are expected to purchase seats on private sector rockets for missions in low-Earth orbit and to the ISS in early 2022. These missions include opportunities for space tourism and commercial enterprise, and represent the next step in the space economy.

In addition, NASA will rely heavily on the private sector for the Artemis program in its mission to accomplish the next chapter in U.S. exploration of deep space: returning humans to the lunar surface by 2024. These include contracts for the Human Landing System to take astronauts to and from the Moon with stays lasting as long as two weeks.

the growing excitement about space companies and optimism for future returns on investment.

Although there has been large growth in economic activity in the space sector as a whole, a significant portion of space industry revenue is still made up of satellite services. As illustrated in table 8-1, over 75 percent of global spending in space is for the satellite industry, and the majority of the remainder is government spending. The only other category that is large enough to break out is the commercial human spaceflight industry.

Space Policy Developments

As investment and innovation grow in the space economy and we surpass new milestones in space exploration, the United States will continue to work to ensure the international and domestic framework for property rights in outer space resources develops in a manner that provides certainty and predictability for industry. Doing so will reinforce the progress the United States has made in the space sector that, based on CEA estimates, could double investment in space and accelerate new space technologies. Here, we first describe the main international treaties and domestic laws that have developed since the 1950s and provide a legal framework that supports the space economy. We then describe the efforts of the Trump Administration to advance and execute these agreements.

The United States is a party to four United Nations treaties on space. The United Nations Outer Space Treaty of 1967 laid the foundation for international space law, establishing outer space as a peaceful territory, designating astronauts as envoys of humankind, and declaring that each State bears responsibility for activities in space, "whether such activities are carried on by governmental agencies or by non-governmental entities." Whereas private

entities are usually responsible for damages they impose, the Outer Space Treaty explicitly states that the country from which the object launches or the country that procures the launch bears responsibility for damages on Earth or in space.

The United States also approved the 1968 Rescue Agreement, which outlined the rescue provisions in the Outer Space Treaty requiring countries to assist personnel when landing within national borders or in places not under any jurisdiction, such as space. The Liability Convention, which entered into force in 1972, clarified the meaning of “launching State” to be the country “which launches or procures the launching of a space object” or “from whose territory or facility a space object is launched.” The convention also defined what “damage” consists of and outlined a diplomatic process for resolving claims for compensation.

Finally, the United States agreed to be a party to the 1976 Registration Convention that instructs nations to register space objects launched into orbit or space. While the United States was a party to these four early United Nations treaties and resolutions establishing international space law, it did not ratify the United Nations Moon Agreement in 1979, which effectively banned private ownership of extraterrestrial property. Many other major spacefaring nations, including Russia and the People’s Republic of China, are not parties to the Moon Agreement.

Domestically, the United States has gradually developed a framework of private property rights in space through legislative and executive action. U.S. space law was first codified in the 1958 National Aeronautics and Space Act, which created NASA, although military space activities were already under way within the Department of Defense. The Commercial Space Launch Act of 1984 created the process for licensing U.S. commercial space launches. The subsequent Commercial Space Launch Amendments of 1988 encouraged commercial space launches by providing Federal Government indemnification for damages exceeding \$500 million to more than \$2 billion.

Moving into the 21st century, three concrete policy achievements helped further codify property rights in space. First, the U.S. Commercial Space Launch Competitiveness Act of 2015 established the statutory framework for the Federal Government to permit domestic private entities to extract and use resources in space:

A United States citizen engaged in commercial recovery of an asteroid resource or a space resource . . . shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.

The U.S. Commercial Space Launch Competitiveness Act designates how the United States licenses and approves attempts to utilize space resources in line with authority granted to national governments in the Outer Space Treaty. Article VI of the Outer Space Treaty states that “activities of non-governmental entities in outer space . . . shall require authorization and continuing supervision by the appropriate State Party to the Treaty.”

In 2020, the Trump Administration further clarified expectations and responsibilities for commercial activities in space by enumerating the U.S. position on property rights and laying out principles for international bilateral agreements. In April 2020, the Trump Administration announced Executive Order 13914, “Encouraging International Support for the Recovery and Use of Space Resources.” This executive order announced the United States’ intention to work with international partners to ensure that commercial exploration and the use of space resources is consistent with applicable laws. It also explicitly rejected the Moon Agreement, which the United States had not signed, because it was perceived to have prevented the application of private property rights to resources in space.

On October 13, 2020, the United States and seven partner spacefaring nations signed the Artemis Accords, a set of principles grounded in the Outer Space Treaty to ensure safety and avoid conflict. The principles of the Artemis Accords are peaceful exploration, transparency, interoperability, emergency assistance, registration of space objects, release of scientific data, preserving heritage, space resources, deconfliction of activities, and orbital debris. The Artemis Accords uphold that resource extraction and utilization must comply with the Outer Space Treaty, while also affirming that “extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty.” The accords provide investors with more certainty when considering other countries’ positions on resource extraction. Eight founding member nations signed the Artemis Accords: Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates, the United Kingdom, and the United States. NASA anticipates that additional countries will join the Artemis Accords in the months and years ahead.

Taken together, these three policy developments built on past treaties and laws to further clarify outer space property rights. The increased security of property rights should lead to increased investment and economic activity, as individuals are able to form expectations and plan for future returns on that investment. As is discussed further below, the ability to make long-term plans has many direct and indirect positive effects.

The Economics of Property Rights

A large body of economic literature demonstrates the positive effects on investment from the initiation of policies that are similar to the space policy

developments discussed above. The examples come from a wide range of geographies, natural resources, and time periods. This section provides an overview of the economic theory of property rights as well as several examples of the theory in practice, including how it applies to the space economy.

North (1991) considers the importance of institutions for shaping and constraining political, economic, and social interactions. Institutions guide economic change toward more growth, decline, or stagnation, depending on the incentive structure they enforce. Tangibly, government institutions determine and enforce property rights as rules governing the economy that shape the competitiveness and efficiency of markets. As rules for property rights are further specified, market participants interact with more certainty about the benefits and costs of potential activities.

The seminal work of Demsetz (1967) outlines the economics behind the evolution of property rights. Property rights bring clarity to people when they are weighing potential decisions. Accordingly, the benefits to setting and further clarifying property rights allow individuals to form more accurate expectations of how the rest of society will interact and respond to their actions. Property rights encourage an individual to undertake investments with the understanding of which benefits will accrue to that individual.

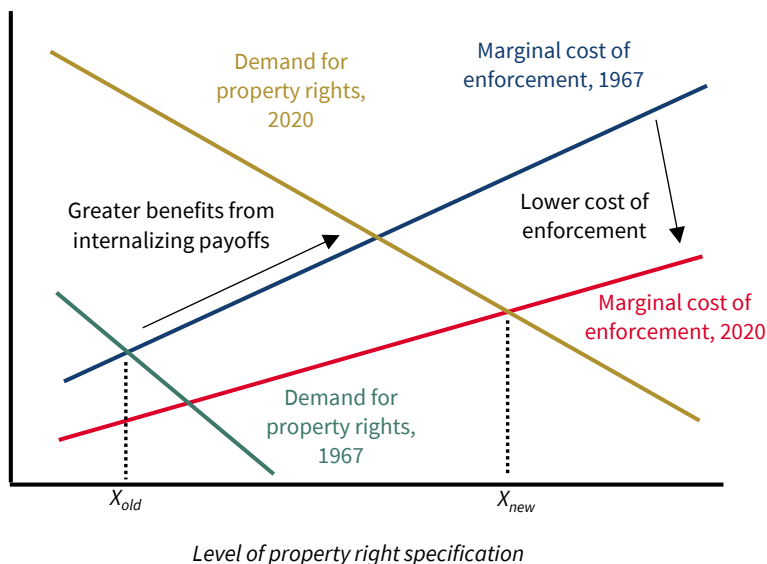
Establishing and enforcing property rights impose costs on society, as resources are devoted to monitoring and ensuring compliance. An individual's expectations are based on the understanding that the rest of society will comply with the rights specified, but if other parties are allowed to violate an individual's property right without recourse, then it will be difficult to set expectations.

As figure 8-3 shows, the optimal specification of property rights changes as the benefits and costs change. The figure depicts the optimal specification of property rights at two different points in time. In 1967, when the Outer Space Treaty was signed, there were only two entities engaged in outer space activity: the United States and Soviet Union. As access to space and other space technologies have increased, the benefits that companies can expect from engaging in economic activity in space have grown. These increase the benefits of property right specification, as ensuring investors have clear expectations about how benefits accrue across society will lead to higher gains from investment.

Advances in technology that improve monitoring and enforcement will lower the cost of further specifying property rights or adding more "sticks" to the bundle. This decrease in the cost of enforcement, along with the increase in the benefits from setting investment expectations, implies that the optimal level of property rights specification should increase (as shown in figure 8-3). The Artemis Accords, for example, are giving investors clearer guidance for how civil space activities will be conducted and the principles that will guide government decisionmaking. Although the Artemis Accords do not apply directly

Figure 8-3. Marginal Cost and Benefit of Property Rights Specification

Cost of enforcement



to the private sector, the United States is responsible, via Article VI of the 1967 Outer Space Treaty, for all individuals subject to its jurisdiction or control. In this regard, the principles of the Artemis Accords provide clarification to companies about the role of governments in space and eliminate uncertainty about public-private interactions.

Historical Examples of Property Rights Evolution

Historical examples of the development of property rights establish that without these extra sticks in the property rights bundle, we should expect to see higher costs and lower benefits from investments in the space economy, potentially hindering future developments in outer space.

The early history of oil drilling provides an example of how resources are likely to be wasted if property rights are not established in a timely manner. Until the early 20th century, oil was not considered property until it was extracted. This led to what Libecap and Smith (2002) call extractive anarchy. Companies drilled wells without concern for maximizing the amount of oil produced from a well, but instead sought to be the first to extract and claim ownership of the oil. Oil flows from a well because of the pressure inside the reservoir; if too many wells are drilled into one reservoir, then the pressure escapes too quickly to push the oil in the reservoir up the well. As a result, less oil is extracted. By 1914, the director of the Federal Bureau of Mines estimated that

a quarter of the value of all petroleum production was being wasted due to the race to extract oil. Further, due to oil and natural gas being found together in a reservoir, the lower-valued natural gas was often vented into the atmosphere to ensure that the oil was extracted and thus ownership was secured. As time went on, the structure of property rights for oil and gas has changed to allow for increased value to be created from investments in resource extraction.

Without clear in situ property rights for subsurface resources, space could see a repeat of this behavior for its natural resources. Many elements that are common in space are frequently used in important technologies. Iron, aluminum, and titanium are elements critical to the production of electrical components. Silicon is a raw material for solar panels and computers. Extracted water can be broken down into hydrogen and oxygen to meet a variety of needs—oxygen is breathable, recombining hydrogen and oxygen generates electrical power, and liquid hydrogen and liquid oxygen can serve as propellants (Butow et al. 2020). Though it may sound futuristic, we can imagine a situation where mining expeditions recklessly extract resources from various celestial bodies, severely depleting the deposit of resources and diminishing the returns on future investment in mining. Therefore, defining property rights now to ensure the responsible use of resources in space could lead to future higher levels of demand and investment in exploration and a more sustainable space economy.

A similar story emerges for mineral rights in Nevada during the 19th century (Libecap 1978). As new deposits of minerals were found, especially those deposits further underground requiring increased investment for extraction, the specification and enforcement of property rights increased. One of the largest deposits in Nevada, the Comstock Lode, was discovered while Nevada was still a Federal territory. Property rights for discoveries on Federal lands were lacking at the time, so citizens created a series of local laws and eventually founded the State of Nevada to ensure these property rights. Libecap (1978) shows that as deposits increased in value, local property rights specification also increased. It may seem difficult to imagine how local property rights would be formed in space as in territorial Nevada, given the lack of settlements in space. However, this history implies that it is important to set these rules as economic actors spend extended time in space in order to maximize the future investment in the space economy.

Investment Responses to Property Right Enhancement

All the space policy developments discussed above have improved the ability of investors to set expectations for the manner in which benefits flow from investments in space. The historical examples given argue that further specifying property rights will bolster investment in the space economy. Increased investments in the space economy will lead to advances in space technology. In this subsection, we discuss the economics literature that addresses the

effects of setting and strengthening property rights on both investment and economic growth. The research presented here aims to convey that the benefits for economic activity from improved setting of expectations that clarifies property rights is universal and not just due to specific circumstances of time and/or place.

Losses from short-term decisionmaking. A growing concern for future space exploration activities arises from a lack of property rights security leading to short-term decisionmaking, which may inhibit long-term human activity. Many empirical studies show that insecure property rights lead to investment decisions with lower values. Many of these studies have come from analyses of water rights in the western United States. In what is known as the Prior Appropriation Doctrine, water rights are handed out based on a “first in time, first in right” principle. Given that the amount of water available changes each year due to precipitation patterns, water rights holders that were, earlier in time, known as senior rights holders are more likely to receive their water allocation each year than those that were later in time, known as junior rights holders.

Leonard and Libecap (2019) argue that the Prior Appropriation Doctrine, with its clear rights for senior rights holders, allowed for investment in irrigation technologies. Given the climate of the western United States, large-scale investment in irrigation is required to maximize the productivity of large swaths of land. Leonard and Libecap estimate that 16 percent of western States’ income in 1930 is attributable to investments made in irrigation that would not have occurred without secure property rights.

Another concern with insecure property rights is that owners of natural resources rush to extract them to ensure that they accrue the benefits of their investments. This rush to extract resources has a detrimental effect on the value obtained from those resources and other negative spillover effects on society. One example is the increase in the rate of deforestation that occurs when property rights for the land are insecure (Bohn and Deacon 2000). Ferreira (2004) finds that those countries with clearly defined property rights experience less deforestation than those with weaker protections. Kemal and Lange (2018) find that a reduced chance of oil well expropriation in Indonesia lowered the rate of extraction by up to 40 percent.

If short-term decisionmaking prevails in the initial incursions into space, the future of the space economy could be seriously harmed. Depleting the resources necessary to sustain life in space would mean having to transport these resources from Earth at a prohibitive cost and complexity. Therefore, protecting and responsibly using the resources available in space is more efficient in the long term. If done prudently, establishing property rights in space could diminish the risk of short-term decisionmaking and strengthen the ability of humans to receive benefits from space.

Enhanced investment and asset value. Frameworks such as the U.S. Commercial Space Launch Competitiveness Act and the Artemis Accords enhance property rights by providing clear expectations of the benefits one can receive from their investment and providing a list of principles that partner nations will follow as a way to encourage economic activity in space. One branch of the economics literature uses legal or legislative decisions that enhance or diminish property rights to determine how investment and asset values respond to a change in property rights specification. We discuss this literature here. Later in the chapter, we apply the conclusions of these studies to estimate the value of enhancing property rights in space.

Alston and Smith (2020) measure the effect of uncertain property rights resulting from the manner in which Northern Pacific Railroad's land grants were structured. The Federal Government provided generous land grants to railroad companies in hopes of ensuring the quick buildout of rail infrastructure. Northern Pacific was granted almost 16 percent of the land area in Montana, a State that requires coordination among its farmers and ranchers to irrigate any tract of land for productive use. Delays in the completion of the rail line in the 1870s led to uncertainty as to whether Northern Pacific owned (and could sell) land in its land grant or whether the land was the property of the Federal Government.

As a result of this uncertainty, completed irrigation projects averaged delays of four years, while investment in irrigation projects decreased by 28 percent. Insecure property rights affected the landowners whose rights were secure, because irrigation projects often require coordination among many parcels due to their high capital costs. The delay in undertaking irrigation investments led to these landowners being more junior water rights holders and, subsequently, holding less secure water rights. In total, Montana's economic activity was 6 percent lower in 1930 as a result of these insecure property rights.

Grainger and Costello (2014) compare the value of more secure property rights for fisheries in the United States, Canada, and New Zealand. New Zealand's regulations on quotas to operate in a given fishery explicitly state that these quotas are a property right, yet similar quota systems in the United States and Canada have regulations that explicitly state that the quotas are not property rights. The fact that the United States' and Canada's fishery quotas are not as secure as New Zealand's quotas leads to a lower perpetuity value of the quotas relative to their current annual value. Because U.S. and Canadian firms have the potential for their quotas to be taken away without recourse, their assets have lower values relative to New Zealand's firms. In an additional analysis, Grainger and Costello (2014) show that the increased security of property rights with the settling of an ownership dispute between native New Zealanders, known as the Maori, and New Zealanders of European descent improved the perpetuity value of fishing quotas by 50 percent. Ensuring that

property rights will be honored is very important for market participants in understanding the value of their asset.

Galiani and Schargodsky (2010) use a court case in Argentina to estimate the effect of secure property rights for one's home on household decisions. Their results show that households that gained secure property rights increased their investments in the home structure. Investment in walls and roofs increased by 40 percent and 47 percent, respectively, as a result of households being granted title to the home. Though not directly related to space assets, the available evidence demonstrates that more secure property rights lead to other spillover benefits that are not directly related to the assets on which a property rights are granted. Galiani and Schargodsky (2010) find that when households had increased property rights security, they increased investment in their children's education. Children in households who obtained the secure property rights on their land achieved an extra 0.7 year of schooling on average. This is an important spillover effect given the large individual and societal benefits of extra years of education (see chapter 7 of this *Report*).

Telecommunications satellites orbiting Earth provide an example of positive spillovers from ensuring secure property rights in space. The International Telecommunication Union (ITU) is an organization that standardizes rules and regulations for a wide range of communications. Through the ITU, the United States was able to operate satellites that used specific frequencies to transmit information to Earth, thereby allowing companies to invest in utilizing those signals for commercial purposes. Communications satellites in geosynchronous orbit rely on the ITU to secure access to specific orbital slots as well as specific frequencies.

Protection against expropriation. A number of nongovernmental organizations produce indices that measure property rights protections or general institutional quality. The indices attempt to quantify the relative level of property rights characteristics, such as the rule of law or protection against expropriation risk, that are consistent across countries and time. A large body of economics literature uses these country-level indices of institutional quality to determine the extent to which improvements in property rights enforcement affect economic outcomes. Policies initiated under the Trump Administration would likely alter these indices in a measurable way if there were a property rights index for space.

Seminal work by Acemoglu, Johnson, and Robinson (2001) shows that improving the enforcement of property rights, in this case property rights that protect against expropriation risk, has large effects on gross domestic product (GDP). In their analysis, the authors show that a one-unit improvement in the protection against expropriation risk would lead to more than doubling GDP per capita 10 years later.

Similar results are found when researchers examine specific industries. For example, Cust and Harding (2020) show that firms drill for oil twice as

often in countries with stronger property rights enforcement relative to their neighbors with weaker property rights. They also show that the effect of the enforcement of rights is most important for private international oil companies relative to national oil companies, highlighting the important role of stronger rights for harnessing private investment. Bohn and Deacon (2000) find a similar pattern for the effect on oil drilling as property rights security improves, with a 30 percent increase in security leading to a 60 percent increase in drilling per year.

Some changes in property rights enforcement come through improvements in technology. Hornbeck (2010) uses the invention and widespread use of barbed wire as a technology advancement that reduced the costs of enforcing property rights in agriculture. Importantly, Hornbeck compares areas that had access to timber for wooden fences with those that did not and finds a 23 percent relative improvement in crop productivity when barbed wire came into use, as barbed wire lowered the relative cost of fencing. Most of the gain came from farmers altering the type of crop that they planted once they were confident that livestock would not destroy the crop. This increased ability to effectively enforce property rights led to investments that increased the total area of farmland that had been improved by 19 percentage points, while also increasing land values. In many ways, this example of marking off territory is similar to the Artemis Accords' "Deconfliction of Activities" Principle. This principle prescribes setting "safety zones" to limit harmful interference and keep the probability of accidental loss to a minimum.

The Effects of Policies on Investment in Space Industries

The previous section detailed the expansive literature showing that more secure property rights increase both investment and economic activity. The examples discussed varied across time and space, leaving little doubt that the results are not driven by random chance; the studies as a whole reveal that the findings hold outside specific examples. Because the examples are numerous and varied, determining an average effect of more secure property rights on investment is difficult. Each study concerns a particular improvement in the security of property rights that is difficult to quantify. However, it is still a goal of this chapter to estimate the effect of the last year's space policy developments on future investment, given the available evidence.

Table 8-2 summarizes the effects of most of the studies discussed in the previous section. All these effects are large in magnitude. Another data point is the increase of investment in the space economy in the United States with the passage of the U.S. Commercial Space Launch Competitiveness Act in 2015 relative to investments in other countries. Using the Space Capital data discussed in the second section, and the historical examples given above, the CEA

Table 8-2. Summary of Effects of Property Rights Improvement

Study	Industry	Cause	Effect	Timing of Impact
Acemoglu, Johnson, and Robinson (2001)	All	Expropriation risk	GDP per capita increased 100%	10 years
Alston and Smith (2020)	Land	Tenure uncertainty	Investment delayed	5–10 years
Bohn and Deacon (2000)	Oil	Expropriation risk	Investment increased 100%	Immediate
Cust and Harding (2020)	Oil	Expropriation risk	Investment increased 200%	Immediate
Galiani and Schargodsky (2010)	Housing	Tenure uncertainty	Investment increased 40%	15 years
Grainger and Costello (2014)	Fisheries	Tenure uncertainty	Asset value increased 50%	Immediate
Hornbeck (2010)	Agriculture	Enforcement	Productivity increased 23%	5–10 years
Leonard and Libecap (2019)	Water	Tenure uncertainty	Income 16% higher	40 years

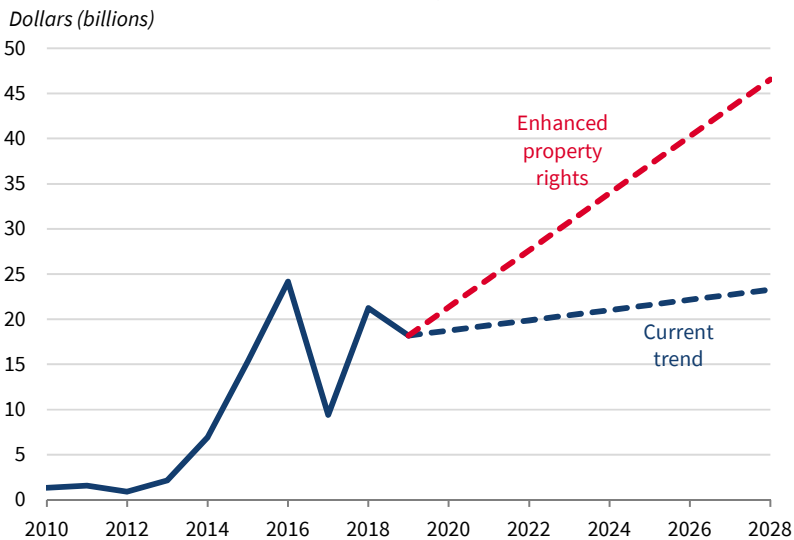
Note: This table summarizes the main findings of the papers discussed in the previous section of the main text. Each study has a different issue with property rights and the impact on the outcomes of interest.

estimates the increase in investment in the United States due to the improved property rights specification in 2015. Controlling for country and time period effects, the data show a statistically significant increase in investment of 92 percent—or roughly double—in the United States since passage of the U.S. Commercial Space Launch Competitiveness Act relative to countries that did not improve property specification. Together, these small improvements in the security of property rights have the potential to lead to large increases in investment. As an approximation, the CEA assumes that these improvements in property rights security will double the amount of investment in space. This number is in line with the evidence that has been discussed here.

To project the effect of the enhancements of property rights security that the Trump Administration’s policies have achieved, the CEA starts with data from Space Capital on total private investment in space activities. Figure 8-4 illustrates the increasing rate of private investment in space activities.

The review of the literature discussed above shows that further property rights specification leads to increased investment and further economic

Figure 8-4. Nongovernmental Equity Investment in Commercial Space Companies in the United States, 2010–28



Sources: Space Capital; CEA calculations.

Note: Data before 2020 reflect actual investment; subsequent years are forecasts.

activity. In figure 8-4, the diverging lines from 2020 to 2028 project the expected path of private investment as a result of policy developments in 2020.

The Space Capital data suggest that a linear projection of private investment in space would reach \$23 billion in 2028, which is illustrated by the blue dashed line in figure 8-4. However, this does not take into account property rights enhancements that occurred in 2020 or will be occurring in the future. Therefore, the CEA projects that private investment in space will reach \$46 billion by 2028. This projection is based on a doubling of investment over the eight-year period, which is in line with empirical estimates in the academic literature discussed above.

Establishing rights to distant resources with the goals of incentivizing economic development and investment has not always produced the desired results. The above-mentioned examples demonstrate how property rights specification and security can lead to increased investment. However, aligning incentives is a necessary but not sufficient condition in the short term. For example, the leading asteroid mining companies that were supporting the space resources language in the Commercial Space Launch Amendments Act of 2004 have both failed, despite the benefit of positive Federal legislation. In addition, the Deep Seabed Hard Mineral Resources Act, which was passed in 1980, established a legal system for extracting resources from the deep seabed with hopes of achieving economic viability before 2000. Forty years after the law's passage, the deep seabed mineral extraction industry still lacks the

technology for economical extraction and does not bolster the argument that enhanced property rights typically unlock commercial value. Certain similarities do exist with the space industry, such as the need for technological innovation, the considerable distance to the resources, and some uncertainty about the types of resources for extraction.

Moreover, the space resource extraction industry currently lacks a customer base other than national governments, and even government demand will not become substantive until robust human and robotic operations on the lunar surface and elsewhere can be established. However, several key differences would support a space resource extraction industry. First, the commercial space industry benefits from public investment in civil space exploration, which might result in a decreased amount of investment necessary for the development of basic technologies. In addition, space exploration and research remain a national priority for many countries, which may drive further development of the industrial base. Moreover, space resource extraction potentially offers more valuable resources than deep sea mining (Barton and Recht 2018).

Looking Ahead

Increased investment, flowing from the enhancement of property rights, expands the possibilities of economic activity in space and transforms abstract issues into real considerations for national economies, companies, and individuals.

Flag of Choice

The origins of spacecraft and the settlement of international disputes beyond Earth's surface remain critical issues for space policy. The flag of choice in commercial space activity will depend on a nation's ability to provide the domestic infrastructure and international support needed to spur investment while mitigating risk. The development of a healthy space economy built on a strong industrial base, sensible regulatory environment, and the enforcement of property rights, along with national support in international disputes, will ensure that the United States becomes and remains the flag of choice for private space ventures.

Space vehicles, similar to naval vessels, are required to operate under the laws, or "flag," of a particular country. The process of flagging occurs when a company incorporates itself in a country or launches from that country. Once flagged, the vessel must abide by the flag state's laws, which include tax liabilities as well as labor and environmental regulations (Taghdiri 2013). The process of selecting a flag leads companies to seek flag countries with a legal, policy, and regulatory environment that is most favorable for their business activities.

The practice of finding a “flag of convenience” is one threat to maintaining a functional system of space travel, because companies could opt for flags of countries with little oversight, as is seen with waterborne vessels (Llinás 2016). Panama, for example, has become the flag of choice for ships, with more than double the number of ships of any other country due to an easy registration process and low-cost labor. In contrast to maritime law, which places the responsibility for redressing damages on private actors, the 1967 UN Outer Space Treaty established that countries assume the full responsibility and risk of spacecraft launching from their territory. This forces countries to weigh the costs and benefits of flagging spacecraft before allowing them to launch from their territories. Inevitably, accidents in space will occur, such as with the 2009 satellite collision between Iridium 33 and Cosmos 2251. The incident occurred when the Cosmos 2251, a derelict satellite from Russia, collided with Iridium 33, a commercial U.S. communications satellite, and both parties placed the blame on the other for not avoiding the collision. The United States and Russia were able to settle the potential dispute outside the Liability Convention, but this event highlighted the need for a predictable system for resolving disputes in space to provide the certainty needed for long-term investment in space ventures. Flying under the flag of the United States will provide companies with the backing of a sovereign state with substantial diplomatic capital that is willing to engage on their behalf, supporting a growing space economy in the United States (box 8-2).

Incentivizing the Private Sector

The Department of Defense continues to foster partnerships with the private sector through design competitions that award contracts to both large and small space technology companies, and through consulting programs that mentor small companies in competing for these contracts. These events and programs include the Space Enterprise Consortium; the Space Pitch Day, which awards grants to accelerate new technology; and the National Security Space Launch, which is helping to create new engines and launch vehicles. These partnerships help break down barriers to entry for smaller firms in this industry, which will drive competition and innovation, while decreasing the cost of operating within the space economy. To ensure that the United States maintains its leadership in space innovation and remains the flag of choice for space commerce, it must maintain a business-friendly regulatory environment that offers streamlined permitting, encourages innovation and risk-taking, and safeguards workers, the public, and property.

The Trump Administration has prioritized regulatory reform over the past four years, and it continues to focus on cutting red tape in the space sector. With regulatory authorities distributed among the Federal Aviation Administration, Federal Communications Commission, and National Oceanic Atmospheric Administration, the Trump Administration has made efforts to

Box 8-2. National Security and Space

Space-based capabilities are crucial for the United States' security. Space has become a primary component of U.S. military operations, including missile warning, geolocation and navigation, target identification, and activities to track adversaries. Remote-sensing satellites have greatly improved military and intelligence collection capabilities, thereby reducing other countries' ability to carry out covert military exercises and operations.

As advancements in the space sector occur, such as technological improvements and lower barriers to entry, foreign governments are developing capabilities that could threaten the United States' freedom to operate in space. In a 2020 report, the Defense Intelligence Agency points out how China and Russia, in particular, are trying to undermine the United States' advantage in space (DIA 2019). For example, Chinese and Russian military doctrines present a view that counterspace capabilities serve as a tool to reduce the effectiveness of U.S. and allied military forces. Both countries have developed extensive space surveillance networks that enable them to monitor, track, and target American and allied forces. Additionally, both China and Russia are working on their cyberspace and jamming capabilities.

The Trump Administration recognizes the importance of establishing and maintaining influence in space and providing space security for U.S. interests and the American people. In March 2018, the White House unveiled a new National Space Strategy that places an emphasis on “peace through strength in the space domain.” Though adversaries are attempting to use space as a weapon, the United States' stance is to protect the space domain from conflict and secure the United States' vital interests in space—namely, the freedom of operation in space to advance security, economic prosperity, and scientific knowledge.

Although peace in the space domain is a top priority, the National Space Strategy affirms that the United States needs to be vigilant about any harmful interference within the space domain that negatively affects America's or its allies' vital interests and must “deter, counter, and defeat” any such threats.

Space systems are vital to the U.S. economy and national security, and they enable key functions such as global communications; positioning, navigation, and timing; scientific observation; exploration; weather monitoring; and multiple vital national defense applications. In September 2020, President Trump issued Space Policy Directive (SPD)–5, “Cybersecurity Principles for Space Systems,” which provides guidance on the protection of space assets and supporting infrastructure from evolving cyber threats.

The National Space Strategy also emphasizes the importance of better leveraging and supporting the commercial sector to ensure that American companies are leaders in space technology. This is discussed more throughout this chapter.

To strengthen the United States' military position in the space domain, President Trump established the United States Space Force (USSF) as the

sixth branch of the U.S. Armed Forces by signing the National Defense Authorization Act for fiscal year 2020. Vice President Pence has stated that the mission of the Space Force is to “develop and implement the unique strategy, doctrine, tactics, techniques and procedures our armed forces need to deter and defeat a new generation of threats in space” (Pence 2019). Its responsibilities include “developing military space professionals, acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to our Combatant Commands” (USSF 2020).

modernize the authorization process for new space missions, as directed in Space Policy Directive-2. In addition, Federal Government procurement regulations are often complex and burdensome for the private sector. In fact, government-procured space systems were historically characterized by high costs, long program schedules, and frequent delays due to these regulations (Butow et al. 2020). This discouraged efficiency, innovation, and the entrance of new actors into the market. In the interest of increasing competition and innovation while reducing costs and bureaucracy, the Administration continues to remove undue regulatory barriers and increase the efficiency of existing processes. Doing so will foster a free and prosperous space economy, enable commercial space companies to operate more efficiently, and allow new firms to participate in the private space industry.

Furthermore, the Administration has recognized the important role the Federal Government plays in promoting an environment that encourages investment in the space economy. This starts with outlining clear and coordinated policy goals and stimulating public and private activity to achieve them. By increasingly shifting the role of the government in the space domain from that of owner and operator of technology to that of customer of private products and services, the United States increases demand for commercial activity and supports the growth of a viable space economy.

For example, NASA can use commercial service contracts within the Artemis Program, including those governing transportation, communications, and power systems to facilitate the return of manned missions to the lunar surface and to encourage their permanent operation there. The Department of Defense also serves a critical role in creating demand within the private sector because this Administration has prioritized the protection of national security in space. Applying the same concepts to space resources, the Federal Government can reduce risk to the private sector for new technologies such as space mining and manufacturing. By acting as an initial, substantial, and dependable customer for early entrants into space resource markets, the Federal Government can encourage private investment by offering to purchase products on forward contracts. With the assured revenue that comes from

these contracts, private firms can use increased economies of scale to further reduce the costs of these new technologies, which opens the market to new customers.

Prioritizing regulatory reform and investment in the space sector builds a strong foundation for a thriving space economy. The Trump Administration has taken action to make this future a reality, and it will continue to foster the environment that spurs investment in the private space sector.

Conclusion

Secure property rights are a fundamental tenet of the U.S. economy. Property rights help individuals and firms set expectations for how the outcome of their investments will be distributed. However, there are costs for setting up and further specifying property rights. The literature on the economics of property rights discusses how to balance the benefits from improved expectation setting for individuals' investment decisions against the costs of enforcement. Although applications like space mining and space solar power satellites might be decades away from being profitable enterprises, it is worth laying the foundation for the emergence of future space industries now.

Economic activity in space will benefit from further property rights enhancement and specification, which is advantageous when net enforcement costs are exceeded by net benefits. To this end, the Trump Administration has initiated policies to enhance property rights and thus to encourage further investment in space. The Executive Order "Encouraging International Support for the Recovery and Use of Space Resources" and the Artemis Accords help to further property rights specification by rejecting an ineffective treaty that suggests communal property and by motivating other economies to follow the United States' lead in developing safe and sustainable best practices in space.

Recent policies to improve the ability of firms to gain certainty regarding their investments lay the foundation for further development of the space economy. The academic literature provides many examples across time, geographic range, and resource application of the large effects on investment and economic activity driven by enhanced property rights security. Based on these previous experiences with improvements in property rights security, the CEA estimates that recent Trump Administration policies will add an additional \$23 billion to private investment in the space sector by 2028. Property rights enhancement, coupled with public-private partnerships, can solidify the long-term health of the commercial space economy.