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# Assessment of the Utility of a Government Strategic Investment Fund for Space

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Government Strategic Investment  
Fund for Space**

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## Executive Summary

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The White House has set an overarching policy goal of maintaining U.S. leadership in space, especially with respect to civil space exploration. In Space Policy Directive-1, the Administration set two specific objectives in support of this overarching goal: “the return of humans to the Moon for long-term exploration and utilization” and “the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship” (White House 2017).

The purpose of this report is to provide an assessment of the utility of a government strategic investment fund to achieve these policy goals. Achieving the first policy goal implies that NASA will need to reduce the costs and accelerate the development and procurement of systems needed for civil space exploration, especially a return to the Moon. Achieving the second goal will entail fostering the growth of private space markets through both improvements to regulations and through the use of economic policy instruments. The report compares the efficacy of a strategic investment fund with other U.S. Government economic policy instruments to achieve these policy goals.

The findings of this study are drawn from a review of reports and academic journal articles on the use of government strategic investment funds and other economic policy instruments for achieving U.S. policy goals for space and other technological sectors; our assessments of the past performance of government strategic investment funds both in the United States and in other countries; the public finance literature; and interviews with almost 70 representatives of investment funds—such as In-Q-Tel, industry, and government agencies, as well as with academics and other observers engaged with the space industry.

### **What Is a Strategic Investment Fund?**

By definition, a government strategic investment fund makes equity investments in companies, often start-ups, engaged in activities of particular interest to the government. The government may use a strategic investment fund to support the development of industries to achieve policy goals such as improving the environment, fostering regional development, or creating new technologies. In addition to the main goal, the government may also use strategic investment funds to: (1) identify and understand emerging and new technologies and companies; (2) move technologies of interest to the government from the

research and development (R&D) stage to a final product more quickly; and (3) induce companies to develop products to address the needs of and contract with the government.

Government strategic investment funds differ from private venture capital (VC) funds in that they focus on achieving a public policy goal—such as tailoring a technology to satisfy government needs—rather than pursuing high rates of return on investments, the goal of private VC funds. They differ from other government economic policy instruments such as R&D grants or contracts in that through the provision of equity finance, they can exert greater influence on a company than would be possible with grants or contracts. Funds require a greater level of due diligence and understanding of companies and industries than is typical for traditional government grant-making and contracting programs.

## **Approach**

To evaluate the potential utility of a strategic investment fund for space, we first identify the types of activities needed to achieve the Administration’s two principal space-related policy goals: (1) reduce the costs and accelerate the development and procurement of systems needed for civil space exploration, and (2) foster the growth of private space markets. We next identify challenges to undertaking these activities or building these systems using traditional funding sources. The usefulness of a strategic investment fund is assessed on how well such a fund could overcome these challenges, and on an in-depth review of how well U.S. and foreign government strategic investment funds have performed in the past.

## **Key Challenges to Achieving U.S. Policy Goals in Space**

We identified from our interviews nine categories of challenges to achieving U.S. policy goals in space that a government strategic investment fund might address (Table ES-1). One key challenge to procuring systems for human exploration in a timely and cost-effective manner is the U.S. Government’s use of requirements-based, cost-plus contracting when companies are willing and able to provide their own solutions at a fixed price. While cost-plus contracting enables companies to take on technologically risky development efforts and allows more direct oversight from NASA, it tends to increase monitoring and contracting costs and may lengthen timelines. It may also encourage government decision-makers to fixate on 100 percent solutions over “good enough” solutions when 100 percent solutions are unnecessary, precluding companies with products designed for sale to businesses and households in private markets from bidding on some NASA contracts.

A key challenge to the growth of private space markets is lack of proven demand for products and services that space companies are attempting to develop. The high cost of

testing and evaluation has also prevented smaller companies from bringing products to market.

## Need for a Strategic Investment Fund

Our research finds that government strategic investment funds either do not address the challenges that our interviewees identified, or that there are other instruments that address them better (Table ES-1).

**Table ES-1. Preferred Economic Policy Instrument by Challenge Compared to Government Strategic Investment Fund (GSIF)**

Goal	Challenge	Role of GSIF	Preferred Economic Policy Instrument
<b>Reduce costs and accelerate development and procurement of systems for civil space exploration</b>	Cost-plus contracting increases costs, lengthens development times, and reduces incentives to innovate on cost	Low	Increase the use of solutions-based, fixed-price contracting
	Requirements for 100% solutions can lead to the exclusion of lower cost “good enough” solutions		
	Many contracting regulations make it difficult for non-traditional entities with innovative solutions to work with NASA		
<b>Foster the growth of private space markets</b>	Insufficient demand for products from specialized suppliers makes products unnecessarily expensive		Increase size of R&D grants and R&D contracts
	Insufficient or unproven demand for products and services (especially those with longer timeframes) inhibits upfront private investment	None	If NASA needs the product, provide R&D funding or use advance purchase agreements to signal interest
	Lack of commonality between government and private market requirements makes products more expensive than needed	Low	Increase the use of solutions-based, fixed-price contracting
	High cost of testing and evaluation prevents companies from bringing products to market, especially start-ups and smaller firms	Medium	Increase the use of in-kind subsidies
	Government funding timelines are not aligned with private approaches, making government funds less useful	Medium	Increase the size and accelerate timelines of R&D grants, contracts, and programs
	Failure of capital markets to provide funding for promising ideas in space	Medium	

While a fund could address some of the challenges related to fostering the growth of private space markets (the last three rows in Table ES-1), a strategic investment fund faces

other challenges that reduce its value as a preferred policy instrument. In particular, due to the research and due diligence required to run a strategic investment fund, the costs of operating such funds are higher than using other policy instruments like R&D grants. Our research showed that similar funds in the United States cost as much as six times more to operate than the costs of implementing other economic policy instruments such as R&D grants. Surveys have found that government strategic investment funds underperform private VC funds; investments by government strategic investment funds resulted in less rapid growth in revenues and employment than investments by private VC funds, and rates of return were lower.

Accordingly, we recommend that the U.S. Government not set up a strategic investment fund for space. Such a fund would not directly address the challenges facing NASA or space companies targeting products to businesses or households. As argued by several venture capitalists who invest in space companies and from several new space companies themselves, investment capital is generally available for commercially viable new space companies with solid management and near-term products. Those companies whose products will take longer to bring to market are better supported through targeted R&D contracts and grants than equity investments by a government investment fund. If the government's goal is to have more funds available for space companies, as has been the case in several other countries that do not have a strong private VC community, it could simply provide the funds through grants without adding the complexity of making equity investments through a strategic investment fund.

To achieve the policy goal of reducing the costs of and accelerating the development and procurement of systems for civil space exploration, NASA should employ fixed-price solutions-based contracting rather than requirements-based, cost-plus contracting whenever possible. NASA could, for example, make solutions-based contracting the norm, requiring justifications for programs or projects to be funded through cost-plus contracting.

To foster the growth of private space markets, NASA should similarly strive to increase the number of solutions-based contracts whenever possible. In addition, it should increase the number, diversity, and size of its R&D contracts and grants, and expand the provision of in-kind subsidies such as launches and testing facilities, both on the ground and in space to enable on-orbit research, development, testing, and evaluation.



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# 1. Introduction

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The White House has set an overarching U.S. policy goal of maintaining U.S. leadership in space, especially with respect to civil space exploration. In Space Policy Directive-1, the Administration set two specific objectives in support of this overarching goal: “the return of humans to the Moon for long-term exploration and utilization” and “the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship” (White House 2017). Congress has articulated similar goals as well: the NASA Transition Authorization Act of 2017 states that the United States must “maintain and enhance its leadership in space exploration and space science, and continue to expand freedom and economic opportunities in space for all Americans” (U.S. Congress 2017). Achieving the first policy goal implies that NASA will need to reduce the costs and accelerate the development and procurement of systems needed for civil space exploration, especially a return to the Moon. Achieving the second goal will entail fostering the growth of private space markets through both improvements to regulations and through the use of economic policy instruments.

If the United States is to return to the Moon within the confines of appropriated budgets, NASA will have to procure the necessary systems more quickly and at lower cost than it has in the past. Based on NASA’s history of cost overruns and delays in major systems (GAO 2017), and given that no major increases are expected in NASA’s funding levels for the foreseeable future, more effective economic policy instruments will be needed to reduce costs and accelerate the deployment of these new systems. The U.S. Government also wishes to foster the growth of private sector commercial activity in space. With the signing of Space Policy Directive-2, the Administration has already begun to streamline regulations related to commercial use of space (White House 2018). However, the U.S. Government is searching for more effective economic policy instruments to achieve this goal as well.

NASA already has a number of policy instruments and programs at its disposal to pursue these goals, some of which have been developed within the last 10 years. To speed the development of new technologies and to reduce government costs of space flight, NASA created the Commercial Orbital Transportation Services (COTS) and Commercial Crew programs. NASA also supports commercial activities in space through organizations such as the Center for the Advancement of Science in Space (CASIS), which provides research grants to researchers and companies to develop new technologies for human space flight, as well as smaller, newer programs such as iTech (a collaboration with the National

Institute of Aerospace), which connects companies developing technologies that might be of interest to NASA with potential investors.

Several analysts view some of these newer NASA policy instruments, most notably COTS, as having been successful in reducing NASA acquisition costs even if they have not been broadly transferable across all of NASA (NASA 2014; Zapata 2017). The U.S. Government has contemplated other policy instruments and programs to improve NASA procurement and foster the growth of private space markets. One such instrument is a government strategic investment fund that would make equity investments in new companies focused on space. In contrast to venture capital (VC) or private equity funds, which make investments in hopes of achieving high rates of return, government strategic investment funds make equity investments in pursuit of public policy goals.

Some government agencies have created and operated strategic investment funds to support the development of products and services they need, and to support and connect with innovative companies. In 1999, the intelligence community (IC) created a not-for-profit firm, In-Q-Tel, to improve IC access to new commercial technological developments in industries of interest and to improve IC acquisition of these technologies. NASA created and briefly operated a fund called Red Planet Capital (RPC) in 2006 to support new companies with technologies of interest to NASA, although it was closed after only a few months of operation and a single investment. The U.S. Government is currently revisiting the idea of creating a strategic investment fund focused on space to help achieve its policy goals.

## **A. Purpose**

The purpose of this project is to provide an assessment of the utility of a strategic investment fund to achieve U.S. policy goals for space. The study addresses three overarching questions:

What would be the utility of a U.S. Government strategic investment fund for accelerating the development and delivery of technologies for human space exploration and for fostering the growth of the commercial space industry?

How would the efficacy of a U.S. Government strategic investment fund compare with that of alternative economic policy instruments for achieving the U.S. Government's goals for space?

Drawing on the answers to the above two questions, should the U.S. Government set up and operate a strategic investment fund for space, and if so, how should it organize such a fund?

## **B. Approach and Organization of Report**

In Chapter 2, we identify the types of activities needed to achieve the U.S. space policy goals of reducing the cost and accelerating the development of systems needed for the U.S. civil space exploration program and to foster the growth of private space markets. We split these activities by two dimensions. The first dimension differentiates by customer, whether governments and philanthropists, or businesses and households. The second dimension distinguishes by the location of the activity, in either near-Earth orbit, which includes space from low Earth orbit (LEO) to geostationary orbit (GEO), or cislunar and deep space, which includes the area around the Moon, the lunar surface, and beyond.

We determine whether each activity addresses a *final demand* such as human exploration or the provision of satellite broadband services to households, or a *derived demand* generated by these final demands such as lunar landers to bring astronauts to the Moon's surface or launch services to bring a satellite to LEO. We next assess the impediments to undertaking these activities or building these systems using traditional funding sources. The usefulness of a strategic investment fund is assessed on how well such a fund could overcome these impediments and on an in-depth review of how well U.S. and foreign government strategic investment funds have performed in the past.

In Chapter 3, we define a strategic government investment fund and describe models of such funds. We identify features that would be most appropriate for a strategic investment fund focused on space by drawing on case studies of past and present funds that have been directed at technologies of interest to the U.S. Government; the operations of private sector VC funds—the closest analogy; and the experiences of other government strategic investment funds.

In Chapter 4, we discuss the primary challenges faced by U.S. Government agencies trying to reduce the costs and accelerate the development of systems needed for civil space exploration, as well as the major challenges facing companies (especially newer companies that plan to sell goods and services not only to the government, but also to businesses and households). In particular, we identify the challenges these companies face in attracting sufficient capital, transforming a technology into a marketable product, finding customers, and ultimately becoming profitable.

In Chapter 5, we compare the goals and features of a government strategic investment fund with the challenges inhibiting progress towards the two U.S. policy goals, noting where other policy options might be more effective to achieve these goals.

Chapter 6 presents conclusions concerning the utility of a government strategic investment fund and potential alternatives that might be useful in addressing the challenges and may warrant further attention.

The report includes five appendices. Appendix A lists the subject matter experts interviewed for the study. Appendix B presents case studies of three government

investment funds (In-Q-Tel, RPC, and OnPoint Technologies). Appendix C includes case studies of two other government organizations designed to foster technological development (Satellite Applications Catapult in the United Kingdom and Defense Innovation Unit (DIU, formerly known as Defense Innovation Unit Experimental or DIUx) within the U.S. Department of Defense). Appendix D describes additional economic policy instruments that the U.S. Government employs or could employ to achieve the stated policy goals. Appendix E summarizes how a fund, if it were to be pursued, would be set up.

Figure 1 shows the distribution by sector and expertise of the almost 70 individuals we interviewed for this study. We also drew on government documents and commercial and academic publications on the space industrial sector, including reports by Davidson et al. on NASA policy instruments to support commercialization of space (Davidson et al. 2010a; Davidson et al. 2010b). The assessments of the efficacy of specific economic policy instruments for achieving U.S. policy goals in space are drawn from reports published by the Inspector General of NASA, the Government Accountability Office (GAO), reports from non-governmental entities, and observations gleaned from the interviews. In addition to interviews, we examined government policy documents, U.S. budget material, empirical studies of the effectiveness of similar policy instruments in other sectors or agencies, and economic analyses to assess the efficacy of government strategic investment funds and other economic policy instruments that could be employed to pursue U.S. policy goals for space. Research for this report was conducted between October 2017 and August 2018.

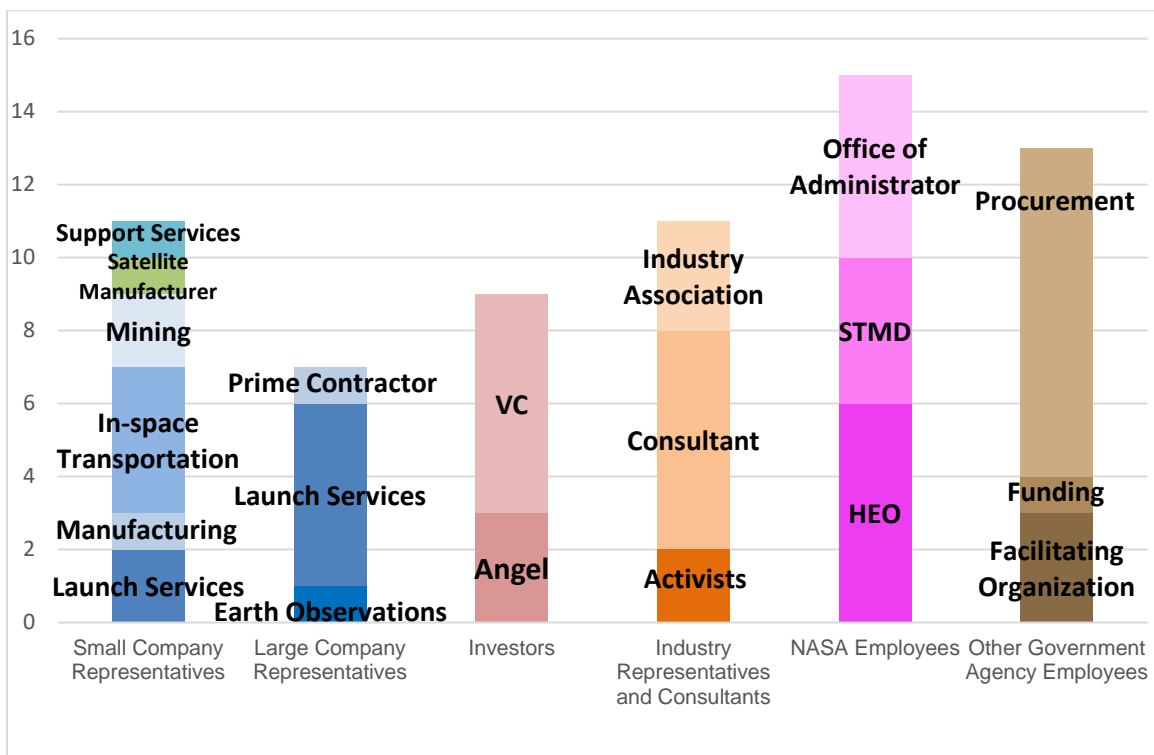


Figure 1. Distribution by Organization of Individuals Interviewed



## 2. Framework for the Assessment

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In this chapter, we assess the potential utility of a government strategic investment fund for achieving two U.S. Government policy goals for space:

1. Reducing the costs and accelerating the development and procurement of systems needed for civil space exploration, and
2. Fostering the growth of private space markets.

Both goals entail the development and production of new technologies and systems for space. To be effective, economic policy instruments—including a government strategic investment fund—need to provide incentives for companies to create and produce new technologies and systems, both for civil space exploration and for sale to households and businesses. In this chapter, we discuss the characteristics of the products and markets that these space companies are targeting and the challenges they face in selling their products. We also develop a framework for systematically examining barriers to economic activities in space.

### A. Demand for Goods and Services Pertaining to Space

Companies either sell products directly to end users or produce and sell intermediate goods and services used to make these end-use products. Purchases of goods and services by end users are considered *final demand*. Demand for intermediate goods and services and factors of production used to produce end-use products are derived from final demand; it is thus referred to as *derived demand*. For example, demand for new satellites from satellite manufacturers derives from the final demand from governments, businesses, and households for the services satellites provide: telecommunications, navigation, weather forecasting, or Earth observations. Without demand for these services, satellite manufacturers would have no market for their wares from satellite operators. Demand for satellite launch services, in turn, derives from satellite operators' need to place satellites in orbit. Sales by companies satisfying derived demand are limited by the sales of the end-use products that generate demand for their products: sales of inputs cannot exceed the value of sales of the final products in which they are used.

The distinction between final and derived demand and the limits final demand places on derived demand are frequently lost in discussions of government support for the space industry. Proponents of potential investments, both governmental and private, in projects such as propellant depots in space, machinery for converting ice to propellant, and

commercial lunar landers and prospectors sometimes focus more on savings in launch mass and less on the revenues that the activities using these services would need to generate to create sufficient demand for these projects to be commercially viable. Rob Coneybeer, managing director at Shasta Ventures, a VC firm focused on space, states: “Have an idea with proven end-user demand and a compelling use case...think of space as a means to an end-user, and not an end in itself” (Bailey 2018). Derived demand for space industry products does not exist without final demand for space services, whether from governments, households, or businesses. When assessing policy measures designed to foster the growth of the space industry, including strategic government investments, policymakers need to be aware of the size and strength of the final demand for products from space that will be needed to support derived demand for products from supplier industries such as satellite manufacturing and launch services.

## **1. Final Demand**

Final demand for goods and services in and from space currently consists of purchases of systems by government agencies (and occasionally, philanthropists) to pursue policy goals for space, such as human space exploration, and purchases of goods and services generated in space by private businesses and households for their own use. The largest source of final demand from households and businesses for goods and services produced in space is for satellite telecommunications and video services. Purchases of navigation services and Earth observations are other components of private final demand from space.

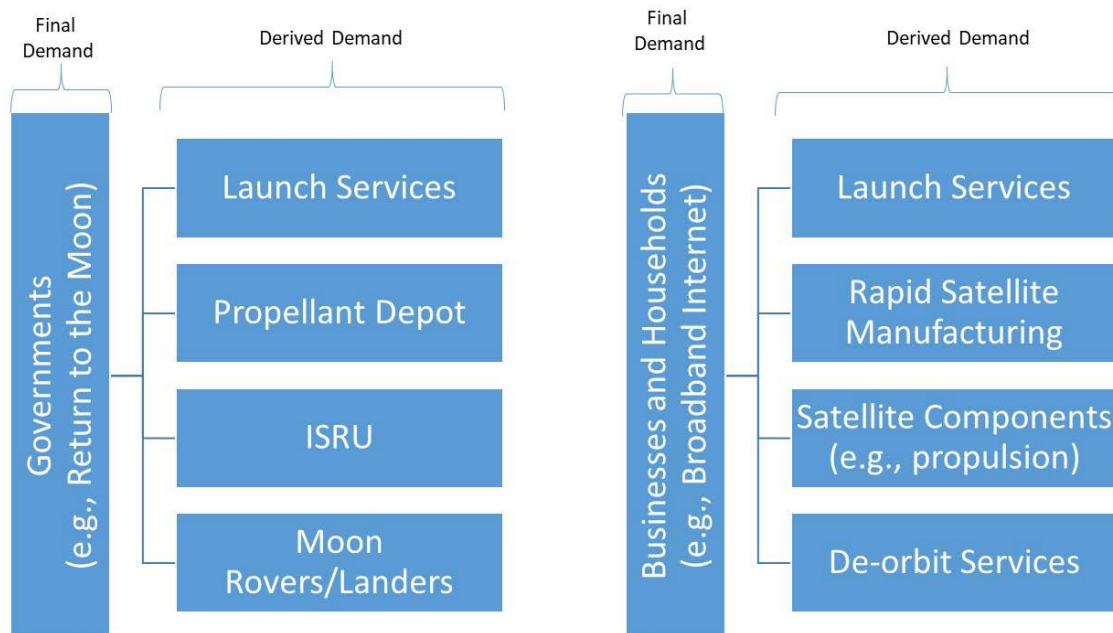
The distinction between final demand from governments and final demand from households and businesses is an important one that is sometimes lost in discussions about the “commercialization” of space. Goods and services purchased by both entities are produced by commercial firms, but government demand is dictated by public policy goals (e.g., human exploration of the Moon) and the budgets allocated to meet those goals. Final private sector demand from households and businesses (e.g., for direct broadcasting services from GEO) is determined by the desire of consumers to acquire these services, the quality and cost of the service (e.g., transmission), and the costs and quality of alternatives (e.g., terrestrial fiber optic cable for TV broadcasts).

## **2. Derived Demand**

Purchases by both the U.S. Government and by businesses and households stimulate derived demand for components, subsystems, and services needed to make end-use products and services. For example, every satellite purchased by the U.S. Government or telecommunications satellite operators generates a derived demand for a launch to put the satellite into orbit. Providers of launch services in turn create a derived demand for rocket engines, propellant, and sub-systems.

When the U.S. Government is the ultimate customer, derived demand stems from government goals and missions. For example, if the U.S. Government aggressively pursues a return to the Moon, and provides the increased budgets needed to support that mission, this policy goal and the associated budgets will generate derived demand for rockets capable of reaching lunar orbit and possibly lunar landers and habitats. Without this final demand from NASA, these products have no market unless philanthropists or foreign governments adopt this goal.

In the case of derived demand from the private sector, demand for launch services depends on increased demand for satellites from companies such as Intelsat, which in turn is driven by demand for satellite telecommunications and video services from households and businesses. For example, without the final demand from households and businesses, SpaceX would have no private sector demand for its rockets. Figure 2 illustrates these concepts.



**Figure 2. Illustration of Final Demand and Derived Demand for Space Services**

## **B. Commercial Activity in Space and Private Space Markets**

During the course of our research, we found inconsistent definitions of several concepts used to discuss economic policy instruments and space more broadly. The first is the definition of the term *commercial space*. In 1991, the Bush Administration described commercial space sector activities as the “provision of products and services such that: private capital is at risk; there are existing, or potential, non-governmental customers for the activity; the commercial market ultimately determines the viability of the activity; and primary responsibility and management initiative for the activity resides with the private

sector” (White House, 1991). More recently, the 2010 National Space Policy noted that the term commercial “refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential non-governmental customers” (White House 2010). In both of these cases, commercial space refers to activity where some customers are or will eventually be non-governmental entities and where some private capital is at risk in the business.

Within the space community as well as the Federal Government, *commercial* is sometimes defined as a transaction in which the seller takes the risk of designing and bringing a product to market and faces competition from other companies for the sale of its products. At times, the definition of *commercial* is constrained to only those transactions where the company sells its products to the private sector, not the government, which excludes contracts awarded on a cost-plus basis, as these types of contracts greatly reduce contractor risk. Such a definition excludes goods and services produced under contracts where NASA has dictated the design and is the sole buyer. Under this definition, companies that are awarded cost-plus contracts, such as prime contractors to NASA, are not considered *commercial* companies.

We find this limited definition of commercial problematic. Both Lockheed Martin and SpaceX are private companies. Their boards of directors and chief executive officers (CEO) determine how the companies are operated and what investments are made. Consequently, for the purposes of this report, we adopt the more general definition of *commercial activity* as the sale of any good or service by a private sector entity regardless of the customer. Under this definition, commercial activity includes purchases of rockets or capsules, such as SLS and Orion, under cost-plus contracts from traditional contractors such as Boeing or Lockheed Martin, as well as purchases of launch services at a fixed price from Orbital ATK or SpaceX.

We define *private space markets* as markets for the sale of space-related goods and services to customers other than the U.S. Government, primarily businesses and households for their own final use. The intermediate goods or factors of production associated with the production of those products are also considered part of private space markets. Under this definition, private space markets exclude sales to governments. For the purposes of this study, we focus on the public policy goal of fostering the growth of these private space markets. We focus on this goal because in the United States (and other countries as well) government budgets for space are likely to stagnate in coming years. Thus, growth in the space industry will depend heavily on growth in demand in private space markets, which will be from households and businesses.

The terms *space market* and *space economy* are frequently used interchangeably to describe a network of buyers and sellers that trade goods or services either produced on the Earth for use in space, or produced in space—whether consumed in space or on the Earth. Space economy implies that there is an economy *in* space. In this report, we use *space market* rather than *space economy*, as there are currently no buyers of products located in space: all purchasers of products used for or produced in space live on Earth, and all transactions take place on Earth. We use the term *space industry* to describe those companies and other entities that produce goods and services in or for space.

### C. Location of Space Activities

The economic policy instruments to be used to pursue the two U.S. Government objectives (reducing NASA costs and accelerating development and procurement of systems needed for civil space exploration; and fostering the growth of private space markets) may be affected by the location in space where the product is to be produced or used. For this report, we separate space into two regions: near Earth space, and cislunar and deep space. Producing goods or services in near Earth space—LEO, medium Earth orbit (MEO), GEO, or highly elliptical orbit (HEO)—is easier and less costly than in cislunar and deep space, which we define for this report as space beyond GEO or HEO, including the surfaces of the Moon or Mars.<sup>1</sup>

All activities in space directed at private markets currently take place in near-Earth space. Cislunar space looms much larger in importance for government policy goals than it does for private space markets because of the U.S. Government’s interest in human space exploration on the Moon.<sup>2</sup> The Administration has set a goal of sending astronauts to the Moon, and eventually to Mars. NASA conducts a number of other activities in deep space, sending scientific probes, landers, and other spacecraft around the solar system. However, many activities intended to achieve U.S. Government civil space exploration policy goals, such as the operation of the International Space Station (ISS), still take place in near-Earth space.

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<sup>1</sup> Cislunar space can be defined as the volume of the sphere formed by rotating the Moon’s orbit around Earth (i.e., any part of space between the Earth and the Moon). Some volumes within that sphere, such as LEO, are distinguished by other names. Practically, cislunar space is a useful label for the volume between GEO and the Moon’s orbit. Earth-Moon Lagrange points L4 and L5, the stable regions of the Moon’s Trojan points along the Moon’s orbit, are also considered cislunar.

<sup>2</sup> This is not to say that no one is planning private economic activities for cislunar space. SpaceX has announced plans (and subsequently delayed them) to take private tourists around the Moon, and there are at least two companies developing lunar landers and attempting to sell payload space on them to private buyers.

## **D. Activities in Space**

A broad range of economic activities could take place in space, from internet services from LEO, to direct broadcast television from satellites in GEO, to lunar tourism and mining. In all, we identified over 30 distinct economic activities that could take place either near Earth or in cislunar or deep space. Some of these activities satisfy final demand and others derived demand.

Revenues for companies that are focused on satisfying final demand are dictated by either government budgets or their ability to attract private customers for their products, usually facing competition from terrestrial alternatives. Policy measures to foster the growth of these companies are likely to focus on either helping these companies more effectively address government needs or expanding customer demand for their products.

Companies that produce goods and services that rely on the derived demand generated from companies satisfying final demand are constrained by the revenues of their key customers. Policy measures to foster the growth of these companies must first address constraints on their sales imposed by limitations on final demand from customers. For example, some of our interviewees proposed U.S. Government policies to support the creation of propellant depots in space. Decisions regarding whether government support for propellant depots is warranted need to be based on a clear understanding of the likely extent of final demand for whatever end goals require propellant. If the number of trips to the Moon planned by NASA or other funders is too small, or direct launches from Earth to the Moon are cheaper than refueling in space, derived demand for propellant is unlikely to materialize; public policy support for this technology would be unwarranted. This example illustrates the importance of understanding the potential revenues from final demand for a product or service, and whether or not these revenues will be sufficient to cover the costs of the intermediate goods and services that suppliers hope to sell to either the government or purveyors of products from space.

By dividing activities according to both the source of final demand and the location of the activity, we are better able to define the challenges that economic policy instruments will need to address. For example, the U.S. Government is focused on reducing costs and accelerating the development of new technologies, while companies focused on private space markets are concerned about getting their products to market or expanding their customer base. Due to these differences in focus, the economic policy instrument best suited to address each will likely differ.

Table 1 lists select ongoing or proposed economic activities in space. The list is divided into four quadrants along two axes: the source of final demand (whether governments and philanthropists or households and businesses) and the location of the activity (whether near Earth or cislunar and deep space). We consider demand from foreign state-owned companies, such as foreign state-owned satellite service providers, as private

sector demand, not government because the end customer primarily consists of households and businesses.

**Table 1. Selected Potential Activities in Space by Location and Source of Final Demand**

		Governments and philanthropists		Households and businesses	
		Final Demand	Derived Demand	Final Demand	Derived Demand
<b>Near-Earth Orbits</b>	<b>Quadrant One</b>	<ul style="list-style-type: none"> <li>• Human space exploration</li> <li>• Science</li> <li>• Defense</li> <li>• Intelligence</li> <li>• Ground communications</li> <li>• Earth weather</li> <li>• Remote sensing</li> <li>• Positioning, navigation, and timing (PNT)</li> <li>• Debris removal</li> </ul>	<ul style="list-style-type: none"> <li>• International Space Station</li> <li>• Launch services</li> <li>• Communications with spacecraft</li> <li>• Technology testing</li> <li>• R&amp;D</li> <li>• Spacecraft servicing, assembly, and manufacturing</li> <li>• Propellant depots</li> </ul>	<b>Quadrant Three</b>	<ul style="list-style-type: none"> <li>• Direct broadcast television</li> <li>• Satellite communications</li> <li>• Satellite broadband internet services</li> <li>• Remote sensing</li> <li>• Space tourism</li> <li>• Advertising in space</li> <li>• Manufacturing in space for Earth</li> </ul>
		<b>Quadrant Two</b>	<ul style="list-style-type: none"> <li>• Science</li> <li>• Exploration of deep space</li> <li>• Human lunar and Mars missions</li> <li>• Space weather</li> <li>• Planetary defense</li> <li>• Education</li> </ul>	<ul style="list-style-type: none"> <li>• Lunar landers</li> <li>• Lunar habitats</li> <li>• Launch services</li> <li>• Communications with spacecraft</li> <li>• Spacecraft power generation and distribution</li> <li>• In situ resource utilization (ISRU)</li> <li>• Mining</li> <li>• Propellant generation</li> <li>• Spacecraft servicing</li> </ul>	<b>Quadrant Four</b>
<b>Cislunar and Deep Space</b>					

- Quadrant One encompasses near-Earth orbits and government demand. It includes final demand by the government for human space exploration, science, and defense and intelligence activities in space. It also includes activities such as weather forecasting, remote sensing, and positioning, navigation, and timing (PNT) services. For many of these sectors, the U.S. Government plays an

outsized role in supporting them. For example, in remote sensing, the government purchases a large fraction of privately generated imagery and provides some satellite imagery for free or below cost as a public good. Derived demand in this quadrant includes the use of the ISS in support of human space flight and scientific experiments, as well as satellites, such as the Hubble Space Telescope, used for scientific purposes.

- Quadrant Two encompasses demand from governments and philanthropists for activities in cislunar and deep space. Final demand in this quadrant is currently dominated by NASA's deep space scientific missions and includes human exploration of the Moon or Mars. This final demand also comes from philanthropists that fund activities in space not directed at making a profit, such as private efforts to send spacecraft to the Moon or to land humans on Mars. Derived demand in this quadrant includes demand for launch vehicles that can reach lunar orbit, lunar landers, lunar habitats, and communications systems between the Moon and Earth. The proposed NASA Gateway in cislunar space and a lunar habitat are other examples of derived demand. If the United States returns to the Moon, the U.S. Government will, at least initially, be the primary customer for these new systems and technologies. Through one means or another, all initial human exploration of the Moon is likely to be funded by governments, including the U.S. Government.
- Quadrant Three encompasses private demand for goods and services produced in near-Earth space. Some private space markets are well established. For example, direct broadcast television is the largest private market for space services in GEO (Bryce Space and Technology 2017). Satellite telecommunications is another well-established private market. Other private markets, such as remote sensing, are growing. Final demand from businesses and households for other goods and services produced in near Earth orbit has not yet been firmly established; these goods and services include space tourism, the manufacturing of products in microgravity such as silicon carbide and exotic optical fibers for sale on Earth, advertising, filming, and other activities in space (Crane, Corbin, Lal, et al. 2017). These industries have yet to be shown to be commercially viable, although private passengers have paid for eight trips to space (Crane, Corbin, Lal, et al. 2017). Final demand in Quadrant Three supports a number of derived demand activities, including launch services, communications, and satellite manufacturing.
- Quadrant Four encompasses private demand for goods and services produced in cislunar and deep space. Attempts to establish private space markets in cislunar space are nascent, although a few companies have outlined plans for final demand activities—such as lunar tourism or mining metals on asteroids for sale



on Earth—that fall into Quadrant Four. Most companies that are developing plans for activities in cislunar space are focused on derived demand for goods or services, such as lunar landers or utilization of in situ resources (e.g., lunar ice to manufacture rocket propellant). The final demand that generates derived demand for these activities is likely to come from governments rather than from households or businesses, at least until costs fall dramatically. Therefore, derived demand for these services is most likely to fall into Quadrant Two.

Table 1 illustrates that most derived demand (e.g., launch services; spacecraft servicing, assembly and manufacturing) is common to final demand from both governments and businesses and households. It also shows that human exploration and science fall under both the near-Earth and cislunar and deep space categories. Many companies operate, or plan to operate, in more than one quadrant. However, markets in each quadrant differ, posing different challenges to these companies. Throughout the report, we use this quadrant framework to categorize activities and challenges according to source of final demand and location of activity.



### **3. Government Strategic Investment Funds**

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#### **A. Definition**

A government strategic investment fund makes equity investments in companies, often start-ups, engaged in activities of particular interest to the government. These activities can include developing products that the government may wish to purchase to achieve public policy goals (e.g., national security). The government may also support the development of industries that would help government policy goals of cleaning up the environment, fostering regional development, or creating new technologies. Government strategic investment funds differ from private VC funds in that they focus on achieving a public policy goal—such as developing technologies that satisfy government needs—rather than pursuing high rates of returns on investments, the primary goal of private equity and VC funds (Webb et al. 2014).

Governments that have invested in strategic investment funds recognize the key role that innovative new companies can play in generating productivity growth, creating higher paying jobs, and introducing new competition into established markets dominated by incumbent firms (Audretsch 1995). Due to asymmetric information and concerns on the part of financiers about the ability of entrepreneurs to honor their financial obligations, innovative new companies may have difficulty raising capital, especially during their early years (Carpenter and Petersen 2002). In some countries, private VC firms have emerged to provide this financing, but due to imperfections in capital markets, private investors may underinvest in new companies. Consequently, some governments have chosen to create government strategic investment funds to provide these firms with additional capital (Cumming et al. 2009). Some of these governments have chosen to focus the government strategic investment funds on investments designed to generate specific social payoffs or positive externalities for society as a whole (Colombo et al. 2014). In general, however, governments have created strategic investment funds to provide additional equity capital to start-ups, often in high technology industries.

Australia, Belgium, the Canadian provinces, China, the European Union, Luxembourg, Israel, and the United Kingdom, and others have set up such government strategic investment funds (Colombo et al. 2014, European Commission 2016). The U.S. Government was one of the first countries to support VC-type investments. In 1958 it set up Small Business Investment Companies (SBICs), a program that uses privately owned and managed investment funds, licensed and regulated by the Small Business

Administration (SBA), to invest in small companies in specific industries (Small Business Administration n.d.). SBICs continue to operate in the United States.

While governments of countries other than the United States have tended to focus their strategic investment funds on fostering growth in specific industries or regions, recent U.S. Government strategic investment funds have been established to improve the procurement of technologies of interest to the U.S. Government. These funds have been set up with four main goals in mind:

- Help the government identify and understand emerging and new technologies and companies;
- Move technologies of interest to the government from the R&D stage to a final product more quickly; and
- Induce companies to develop products to address the needs of and contract with the government.

## **B. Characteristics**

### **1. Operations**

Because of the successes of private VC funds in supporting the growth of high technology start-ups, government strategic investment funds tend to mimic many features of VC funds. Teams that operate strategic investment funds are relatively small compared to the government bureaucracies that they serve. Staff may run from dozens to a few hundred people. Much like in a private VC firm, part of the staff researches the companies before making investment decisions, focusing on the companies' finances, business plans, technologies, and operations. Like VC funds, strategic investment funds target small companies at an early stage of development, where a small amount of money coupled with technical and business advice is particularly impactful.

Government funds have also adopted similar timelines to VC firms, targeting technologies that should become commercially available 4 to 7 years from the time of the initial investment and planning to exit the company within 7 to 10 years (Zider 1998; interviews with representatives of VC firms).

Policymakers in the United States and in other countries have found that if time-to-market and time-to-exit for government strategic investment funds differ significantly from those of private VC firms, the investment is unlikely to be successful (Murray et al. 2012). If a fund is structured for less than 7 years, companies do not have time to grow to a point where large returns are captured through initial public offerings or sale to an established company. Investments that cannot be profitably exited in less than 10 years have failed to generate the growth expected of successful new start-ups (Zider 1998). If the company is

unready to exit through acquisition or an initial public offering within this timeframe, both the technology it is developing and the company itself may not be commercially viable. Technologies of interest to the government that are unlikely to be ready for the market within 7 to 10 years (e.g., fusion reactors) are better financed through other mechanisms such as R&D grants or contracts rather than equity investments; R&D grants or contracts can be better focused on developing the specific technology without concern for immediate commercial viability (Webb et al. 2014).

Recently, governments have often chosen to sponsor rather than operate strategic investment funds (Murray et al. 2012). For example, the government strategic investment fund used by the IC, In-Q-Tel, is a non-profit company independent of the U.S. Government. It is provided funds by several agencies within the national security community to make investments in technologies of interest to the IC. The shift from government-operated to government-backed funds in the United States and abroad stems from previous failures of government-operated funds (Murray et al 2012). Economic studies have found that when civil servants choose firms in which to invest, the results have been poor (Avnimelech and Teubal 2006). When government agencies have been directly involved in investments in new ventures, they have a high probability of disrupting the market by misallocating capital and crowding out private investors (Cumming and MacIntosh 2006). As a consequence, more successful government-backed funds have outsourced their operations to private fund managers, with the government simply providing the financial resources and general direction.

Government strategic investment funds typically target companies that are focused on the commercial market, rather than on government sales. For example, In-Q-Tel strives to ensure that at least two-thirds of a product's sales will eventually be to non-government customers. If the government is the sole customer for a product, a more appropriate means of acquiring the product would be through normal government procurement procedures, which allow the government to better ensure that the product meets its needs.

## **2. Differences between Government Strategic Investment Funds and VC Firms**

Government strategic investment funds differ from traditional VC funds in a number of ways; they are not just VC funds transplanted into the government. Like VC firms, government strategic investment funds pursue positive rates of return, as such returns indicate that the companies in which the funds have been invested are commercially viable. However, the purpose of government strategic investment funds is to satisfy the technological or strategic needs of its government customer, not to pursue high rates of return by investing in promising companies. If an investment does not result in a technology the government customer will use, the investment is considered unsuccessful, even if the return on invested capital is high.

Government strategic investment funds typically hire additional staff to coordinate with the government sponsor; in many cases, the staff work with the sponsoring agency to identify needs for new technologies and search for viable solutions within the start-up community. Government strategic investment funds designed to spur regional development need additional staff to work with local governments and business communities. Government strategic investment funds have access to technical experts in the sponsoring agency, who can monitor and review the technologies of candidate firms. Because of this access, government strategic investment funds tend to have stronger, deeper technological benches than typical private VC firms, according to interviews with both government-supported and private sector VC firms.

Because government strategic investment funds have different objectives than private VC funds, if the government fund has a controlling interest in a company, it may push the company to make decisions that support government objectives, at the expense of the company's commercial viability. Consequently, to ensure that the company pursues commercial as well as government goals, and to reassure private VC funds that the company will be pursuing high rates of return, rather than solely government goals, operators of government strategic investment funds have concluded that private investors should control the company; government strategic investment funds usually prefer to hold minority stakes. Investing with private VC firms willing to take larger ownership shares in the company than the government strategic investment fund validates the government fund's decision to invest, demonstrating that other investors also believe the company and its technologies will become commercially successful. In some instances, a government fund may choose not to exercise its ownership rights to vote its shares so as to refrain from playing an active role overseeing the company's management. Consequently, investments by government strategic investment funds are typically modest in size. For example, In-Q-Tel's average investment is \$1.5 million, and its maximum is \$3 million (interviews).

### **3. U.S. Government Legal Authorities to Establish Strategic Investment Funds**

In the past, U.S. Government funding has been provided to strategic investment funds under laws that permit U.S. Government agencies to engage in transactions outside Federal Acquisition Regulations (FAR), which traditionally govern how government agencies purchase or lease goods and services from commercial providers. Other Transaction Authorities (OTA) or OTA-like mechanisms have been a primary mechanism for making government investments in such funds. These mechanisms are more flexible than contracts under the FAR and offer the U.S. Government an alternative means to engage with commercial entities.

The goals and characteristics of a strategic investment fund for space would be similar to those of other strategic investment funds focused on specific industries. Such a fund would target small, emerging companies that have the greatest need for early capital and

where small equity investments by a government fund would have the greatest impact. It would recruit staff with expertise in both the specific industry as well as capital markets. In the case of space, one option would be to set up a government fund to provide grants, make loans, or make loan guarantees in addition to making equity investments (Davidson 2010). Because offering grants and loans requires different skills than making small equity investments in emerging companies, and because loans usually entail larger outlays than equity investments, we restrict our discussion of strategic investment funds to more traditional organizations that focus on equity investments.

## **C. Examples of U.S. Government Strategic Investment Funds**

### **1. Central Intelligence Agency: In-Q-Tel**

In-Q-Tel was founded in the late 1990s to help the Central Intelligence Agency (CIA) better understand existing products in commercial information technology (IT) and other technology sectors and to support the development of specific technologies designed for the commercial market that could meet the CIA's needs. Its charter emphasized that In-Q-Tel's vision was to help the CIA develop competences in IT that exist in the private sector, but which at the time the CIA lacked. In-Q-Tel was also set up to explore new areas of research to develop capabilities for the country's national security mission (Lofquist 2011).

In-Q-Tel currently invests in companies by partnering with other VC firms after conducting due diligence on a company's business case and technology. In-Q-Tel only makes investments that are likely to provide a benefit for the IC beyond potential financial gain. If In-Q-Tel's conditions are met, it acquires equity warrants in the company, giving the fund a minority stake in the company. Although In-Q-Tel does not have voting rights because it makes its investment in the form of warrants, it does maintain a seat on the company's board of directors. Its investment has the same opportunities for financial gain as those of other investors who make investments at the same time as In-Q-Tel. By acquiring only a minority stake, In-Q-Tel ensures its investments have buy-in from the private market, reinforcing the due diligence work of the fund.

In exchange for its investment, In-Q-Tel is able to influence the development of a product to better meet the needs of the CIA and other IC entities. In-Q-Tel has provided the IC better access to key commercial markets, helping the IC determine what R&D it should conduct in-house and what can be purchased from the commercial market.

In-Q-Tel is viewed as a successful government investment fund (interviews). To date, it has invested in 172 reported start-ups (Page 2018), the products of which are often purchased and used by the customer agencies in the IC. The success of In-Q-Tel led at least five other U.S. agencies to seriously consider starting their own VCs (Lofquist 2011). Two of these funds, the Army's OnPoint Technologies and NASA's Red Planet Capital, offer

insight into other models of government strategic investment funds. They are discussed in more detail alongside In-Q-Tel in Appendix B.

## **2. Army: OnPoint Technologies**

OnPoint Technologies was a VC fund for the U.S. Army. Its inception dates to 2002, when the U.S. Army was given a one-time allocation of \$25 million to establish a VC fund (Osama 2008). The Army created a non-profit organization to run an endowment that would contract with a private VC firm to invest the \$25 million in a portfolio of companies developing technologies of interest to the Army. After a competitive request for proposals, the Army selected MILCOM Technologies/Arsenal Venture Partners to operate a for-profit VC fund and named it OnPoint Technologies (CB Insights 2016). Like In-Q-Tel, OnPoint Technologies would only invest in a company alongside private VC firms. OnPoint's investments were also small, ranging from \$500,000 to \$2 million. After its first allocation of \$25 million, OnPoint Technologies did not receive additional funding. Although we found no official notice that OnPoint has ceased to exist, the Army Venture Capital Initiative's website has not been updated since 2015 (AVCI 2015), and the last investment OnPoint Technologies made was in 2016 (Crunchbase 2018). We were informed by an interviewee that OnPoint no longer operates.

## **3. NASA: Red Planet Capital**

In 2006, NASA created its own strategic investment fund, Red Planet Capital (RPC), with a proposed budget of approximately \$90 million over 5 years (Lofquist 2011). Its creation was motivated by concerns that the U.S. space program was falling behind those of other countries and that NASA was not spending enough money to stay current with developments in some technologies (e.g., advanced materials, electronics, and biomedical needs) (Lofquist 2011). The organization of RPC was unique among government investment funds: rather than providing appropriated funds directly to the VC firm, NASA entered into a funded Space Act agreement with a non-profit corporation, Red Planet Capital, Inc., established to act as an intermediary (Borda n.d.). The non-profit corporation then invested money in Red Planet Capital Partners, a for-profit, independent VC firm meant to operate as a typical VC firm after being given a "shopping list" by NASA (Lofquist 2011). The non-profit organization would then release money to the VC firm for specific investments (Lofquist 2011).

Opposition to RPC, primarily from the White House Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP), resulted in its unexpected closure just months after opening. The same policymakers in the White House that supported In-Q-Tel opposed RPC: they found a government strategic investment fund a relevant mechanism for supporting technologies of interest to the IC, but not necessarily for other proposed areas (e.g., civil space, energy, or the Navy) (Lofquist 2011). While



NASA's leadership supported the creation of RPC, it decided not to resist its closure, choosing instead to focus on other issues. During less than 6 months of operation, RPC only made one investment of \$800,000, which was leveraged by \$12.4 million from private VC (Lofquist 2011).

## **D. Advantages and Disadvantages of Strategic Investment Funds**

### **1. For the Government**

As noted above, the primary reasons for governments to create strategic investment funds are 1) to provide capital to new firms in high technology sectors in hopes of stimulating economic growth, and 2) to back companies that support government policies and can generate social payoffs and positive externalities. Government strategic investment funds also provide governments with a means of obtaining a financial return on government-sponsored research and development. Some U.S. Government agencies have established strategic investments funds for other policy reasons. These funds give the agencies an equity stake in a company with a technology of interest, allowing the agencies to influence the design of a technological solution that can better meet the agencies' missions and needs. These funds also offer agencies earlier opportunities to give feedback on a product or clarify their needs with the company.

Government strategic investment funds have disadvantages. In a survey of over 20 evaluations of the impact of government strategic investment funds, Colombo et al. (2014) found that in some instances, government strategic investment funds added to available capital and drew in additional private sector VC; however, in many others, they displaced or crowded out private VC funds, making less capital available overall. In general, private VC firms more successfully chose firms that grew rapidly, increasing employment and generating substantial rates of return (Colombo et al. 2014). Though government strategic investment funds were found to contribute to innovation, they failed to increase employment (Colombo et al. 2014).

If the government wishes to acquire a new technology, it is often more cost-effective for the government to purchase that technology directly, rather than investing in a company that may or may not successfully develop it (Webb et al. 2014). Additionally, a fund is only useful for small start-ups at a stage where small amounts of equity capital can be used to influence the development of a new technology. However, most U.S. Government procurements of new systems or technologies are made from established companies. In the United States, the ownership and operation of companies is considered an inherently private activity; a government strategic investment fund introduces state-provided capital into the private sector. The economics literature finds that governments have not been as successful as the private sector in fostering entrepreneurship or making investment decisions (Minetti 2008).

Investment funds are expensive to operate: as much as a third of In-Q-Tel’s revenues are spent on staff and other fund operating expenses (estimated from interview data). The Australian Innovation Investment Fund spent more than 17 percent of its total pooled capital on management fees and administrative costs—it invested \$545 million AUS but spent \$130 million AUS for operations (Australian Government 2011).

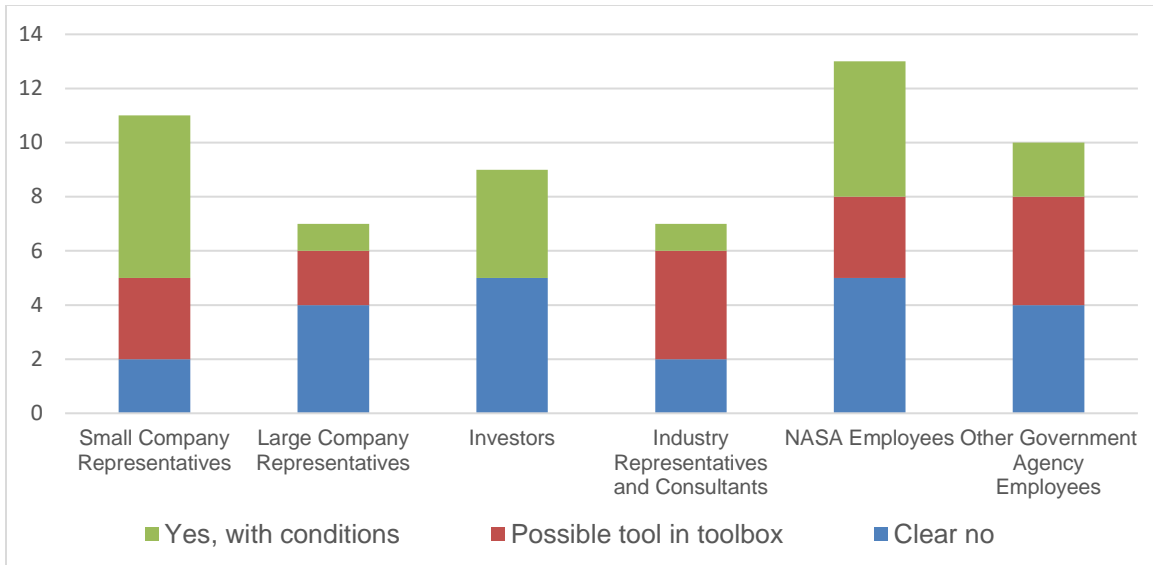
## **2. For the Companies**

A government strategic investment fund can be an attractive partner for a start-up: in addition to providing capital, it connects the company to government customers. The fund’s expertise regarding government client’s technical needs, as well as regular interactions with the client, helps the company efficiently develop products suited to government needs. In a strategic investment fund, lines of communication between the investor and the company are kept open, as expertise and advice are shared. Small companies in particular may value the knowledge and influence that the government investor can offer. Investments from a government fund can provide the company with a “halo effect,” enabling it to leverage that government support into private investments.

However, there are potential downsides for companies that accept investments from a government strategic investment fund. First, the objectives of a government strategic investment fund may differ from those of the company’s management or private investors in the company. The goal of the government strategic investment fund is for the company to develop and successfully sell products that meet the needs of the sponsoring agency, while the goal of private investors is to exit their investment with a high return. Conflicts between these two goals can, in principle, hobble the company’s operations. Second, the government strategic investment fund’s focus on developing suitable products may divert the company’s attention from developing more profitable, commercially viable products for non-government customers. The continued apparent success of In-Q-Tel, however, shows that, at least for that particular fund, the advantages have outweighed the disadvantages for many companies.

## **E. Interviewee Opinions on the Utility of a Strategic Investment Fund**

We asked stakeholders interviewed for this report whether they believe a strategic investment fund would be of value to support the U.S. Government space policy goals described above. Figure 3 breaks down respondent feedback by employer. Among the individuals we interviewed, small firms were the most supportive of such a fund, while large companies, investors, and government agencies (other than NASA) were the least supportive.



Note: Of the experts interviewed, 57 addressed the question directly or indirectly.

**Figure 3. Interviewee Responses on the Utility of a Strategic Investment Fund**

Interviewees disagreed on whether a government strategic investment fund would be a useful policy instrument. Some respondents stated they were not familiar enough with the concept of a strategic investment fund to offer an opinion. Indeed, not all individuals who advocated a strategic investment fund for space fully understood the mechanism or the implications of such a fund. In some discussions, individuals endorsing strategic investment funds were actually referring to a government fund that would provide grants to companies, not one that would take equity stakes. When asked whether they would be comfortable with the government taking an equity stake in their company, some interviewees who had initially responded positively to a strategic investment fund said they would be uncomfortable with the government doing so. Other respondents said that a government stake would be acceptable; they believed that the terms offered by a government strategic investment fund would likely be more favorable than those offered by a private VC firm. Some interviewees from private VC firms were concerned about subsidized competition from the government. They noted that a government strategic investment fund might undermine their business because it would offer better terms than they felt were warranted. Overall, however, investors were split: some supported the idea of a government strategic investment fund for space, but a slight majority said there is no need for such a fund. Investors that supported the idea of a government strategic investment fund generally did so with the proviso that the fund be restricted to a minority stake, among other limitations.

## **F. Key Findings**

Drawing on past experiences of government-sponsored strategic investment funds, we identified the following conditions under which a government strategic investment fund for space would be more likely to be successful:

- The fund should help government agencies with interests in space to identify, understand, and use emerging and new space technologies; identify companies to develop products that address the needs of these agencies; move space technologies of interest from the R&D stage to a final product more quickly; and purchase space products from businesses that otherwise would be unlikely to contract with the government.
- The fund should be set up as an external non-profit organization, not as a government-owned company or as part of a government agency.
- The fund should invest in companies where the technology is expected to come to market in a 7–10 year timeframe to best enable technology development and commercial applicability. If the timeline for bringing the product to market is longer than 10 years, the fund should not be used.
- The fund should have direct access to the offices within the sponsoring agencies so as to be fully aware of government customer needs and promote the fund's uses and capabilities.
- Investments should be kept modest to spread investment risk, and the fund should be restricted to holding a minority stake so that it does not control the company. Any board position taken by the fund should be advisory.
- The fund should be assessed based on how well it achieves its public policy purpose and meets the needs of the sponsoring agencies, in addition to other metrics such as rate of return. However, the products resulting from the investment should have commercial prospects: most sales should be expected to be made to non-government customers.
- The fund should have bipartisan congressional and Executive support, as well as a strong and well-connected board of directors.

## 4. Challenges in the Space Sector

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Achieving the U.S. policy goals for space of reducing the costs and accelerating the development and procurement of systems needed for civil space exploration, and fostering the growth of private space markets will require overcoming several challenges. In this chapter, we present these challenges, based on interviews with experts and supported by documents from government and industry. While this chapter is based primarily on interviews with experts—with minimal interpretation by STPI—all responses are non-attributational. Appendix A lists the names and affiliations of the interviewees.

We found that challenges differed across sources of demand (whether government or households and businesses), but not across location of services (whether near-Earth or cislunar space), primarily because there is currently little demand from households and businesses for goods or services produced in cislunar and deep space. In Section A, we draw on the interviews to categorize the major problems NASA faces in reducing the costs and timelines of developing and producing new systems. In Section B, we make use of the interviews to identify the problems that space companies, especially those that have emerged in recent years, encounter selling to private space markets and building their businesses.

### A. Challenges Related to Reducing Costs and Accelerating the Development and Procurement of Systems for Civil Space Exploration

If the United States is to return to the Moon within the confines of proposed budgets and timelines, NASA will have to procure the necessary systems at lower cost and more quickly than it has in the past. It will also need to reduce operating and procurement costs of existing NASA programs, such as the ISS, to allocate funds for human exploration of deep space. According to the experts interviewed, four major issues pose challenges to these operational changes.

#### 1. Requirements-based Cost-plus Contracting Increases Costs, Lengthens Development Times, and Reduces Incentives to Innovate on Cost

Experts interviewed for the study noted that requirements-based, cost-plus contracting, when unnecessary, can substantially increase program costs because of higher overhead costs and unneeded program requirements. Many of our interviewees, both from government and the private sector, said that requirements-based government contracts

added to their contracting and management costs. They often resulted in less innovative or more expensive products that took more time to develop and procure. Interviewees noted that the greatest downside of cost-plus contracts is that they provide firms with fewer incentives to innovate on cost, since the contractor is reimbursed for all expenses plus provided a profit margin. Official U.S. Government documents and reports also show that requirements-based contracts add to costs (GAO 2016, GAO 2017a, and GAO 2017b). Extensive documentation requirements contribute to increased overhead costs and timelines, both for the government and the contractors. According to interviewees, extensive documentation of costs dissuades some companies, especially smaller businesses, from pursuing government contracts, potentially limiting government acquisition of innovative technologies.

## **2. Requirements for 100 Percent Solutions May Exclude Lower Cost, but “Good Enough” Solutions**

Stipulating that systems must meet 100 percent of acquisition requirements, especially if some of those requirements are unnecessary, increases the cost of the procurement and lengthens the schedule. Such requirements may result in products that have little commercial applicability due to their higher price. For example, the U.S. Government’s requirement for the Space Shuttle to have a large cross-range capability for military purposes forced designers to make decisions that increased the costs of the system, making the Shuttle less attractive for launches of commercial satellites. Interviewees noted that requirements-based contracts, especially those that do not consider commercial applications, forestall sharing development costs with the private sector, as the system is too expensive for many potential private sector purchasers.

Requirements-based, cost-plus contracting may foreclose the purchase of products that would otherwise satisfy the needs of the mission but fail to meet 100 percent of the set requirements. The Department of Defense (DOD) has found that requirements-based contracting can increase costs and lengthen development times. It has set up two offices, the Strategic Capabilities Office (SCO) and DIU, to experiment with other contracting mechanisms so as to reduce costs and accelerate the procurement of new technologies. DIU, in particular, has focused on attempting to identify off-the-shelf technologies available from smaller commercial companies—that are not traditional DOD contractors—that would satisfy the needs of combatant commands. According to interviewees, products developed and purchased using these two organizations and their contracting authorities meet government needs and have appreciably lower costs than those that would meet 100 percent of the requirements.

Like DOD, NASA has also incurred higher costs because of requirements-based contracting. Because of stringent, differing requirements for each mission, NASA frequently builds custom instruments and components for individual missions, rather than

procuring common components from a commercial source. One interviewee provided an illustration: science missions frequently build custom spectrometers to meet mission requirements. NASA could save money and reduce technological risk while still meeting most scientific requirements by procuring one spectrometer design from the private sector and using it for multiple missions.

### **3. Complicated Contracting Requirements Discourage Non-traditional Suppliers from Submitting Bids to NASA**

Many interviewees, especially those from smaller companies, stated that beyond adding to overhead costs, contracting rules under the FAR are burdensome and difficult to understand. Representatives of some companies said their organizations made the decision not to bid on NASA contracts because of these difficulties. Several interviewees also said that NASA's procurement process is too time-consuming, from writing proposals to waiting for the award to executing the contract. These long timelines discourage companies from pursuing NASA contracts, especially in industries where technologies change rapidly and business contracts are generally quickly concluded, such as in IT.

Start-ups that offer new, innovative technological solutions find it difficult to win contracts because they do not have the resources to demonstrate the reliability of their products to NASA's high standards. They also do not have the personnel necessary to navigate complicated contracting processes.

### **4. Insufficient Demand for Products from Specialized Suppliers Makes Components Unnecessarily Expensive**

Some interviewees argued that demand for some critical space components, both from the U.S. Government and the private space market, is insufficient to support a specialized supplier. They argue that because of limited sales volumes, profit margins on these components are too low to provide a sufficient return on investment to attract investors, especially venture capitalists. This is exacerbated by a lack of overlap in the demand for products from government and private purchasers, as discussed in Subsection 4.B.2 below. The continuing high cost of these components may make reducing government costs a challenge.

## **B. Challenges Related to Fostering the Growth of Private Space Markets**

In this section, we summarize five challenges related to the growth of private sector space markets (Table 1 in Chapter 2 provides a partial listing of private space-based activities). Some private sector space markets are well established (e.g., those for direct broadcasting and satellite telecommunications), and households and businesses have supplanted the U.S. Government as the primary customers for these services. The U.S.

Government does, however, continue to play an important role in these markets; in addition to being a major customer, it also provides permits for satellite launches and assigns spectrum to be used for broadcast services.

Private companies are increasingly selling other satellite services—services in which the U.S. Government has been the dominant provider and purchaser—to businesses and households. Some companies are launching their own satellites and providing their own satellite imagery, although the U.S. Government continues to be a major purchaser. Increasingly, however, both imagery and analytical services, such as tailored weather forecasts and business intelligence, are being offered to households and businesses by private companies.

Markets such as on-orbit satellite servicing are emerging, whereas others such as space tourism, on-orbit assembly, or manufacturing in space, remain nascent (Crane et al. 2017). Certain markets, such as asteroid mining, are at a conceptual stage today, but are expected by some stakeholders to have large future revenues (Goldman Sachs 2018; Morgan Stanley 2018). To effectively support the growth of private space markets, economic policy instruments should address the challenges below.

### **1. Insufficient or Unproven Demand for Their Products Makes it Difficult for Small Companies to Raise Capital**

To raise funds, companies looking for VC investments have to validate the potential size of their markets, generally either through advance purchase agreements with solvent customers, or by demonstrating that their products are better and cheaper than competing products sold by existing providers. Interviewees from companies attempting to sell to nascent markets or markets that have not yet materialized, such as space mining companies, stated that one of their biggest challenges has been uncertainty regarding the potential size of markets for their products. Venture capitalists echo this uncertainty, specifically regarding the timeframe in which market demand for these products will materialize. Several interviewees noted their difficulty attracting VC because demand for their product is unknown, insufficient, or not broadly accepted.

The business plans of many companies that intend to operate in cislunar space involve activities such as transportation services and the production or storage of propellant in space. Because this demand is derived from other activities in space, the commercial viability of these activities depends on the demand for activities such as exploration, science, or tourism. Unless sufficient demand for their products emerges from these activities, these companies will not be commercially viable. For companies that plan to sell these derived goods or services for cislunar activities, governments are currently the only customers, as final demand from businesses and households for economic activities in cislunar space has yet to materialize. For companies that hope to sell their goods or service in near Earth orbits, such as propellant from in-space depots for travel to the Moon,



customers need to construct new systems (e.g., transports that would fly between the Earth and the Moon or from LEO to GEO) to enable use of their products. In short, STPI's interviews revealed that many start-up space companies are focusing on activities that depend on derived demand from markets that do not currently exist, and are therefore limited in their abilities to acquire investment.<sup>3</sup>

## **2. Lack of Commonality between Government and Private Market Requirements Makes Products More Expensive**

Some space companies, often suppliers of components, stated that differences in requirements between government and private markets make it difficult to operate profitably. To sell to the government, the companies have to design their products to meet government requirements, raising costs. Because few commercial suppliers can meet government standards, many NASA missions individually develop the same components and instruments—such as spectrometers, batteries, valves, or strobe lights for re-entry—which results in much higher costs than if several missions were to purchase the same product from one supplier. Private customers are often more interested in lower costs, rather than the capabilities or levels of reliability that government contracts demand. Consequently, products designed for the government may be overdesigned for private markets. Private sector buyers are unwilling to pay the higher prices needed to cover the costs of manufacturing to government requirements, but products that can be produced at a price of interest to private buyers fail to meet government requirements. Several interviewees noted that requirements for NASA-purchased systems did not align with their companies' strategic plans or commercialization efforts. These companies often have to choose between designing the product to please the government or private customers. However, interviewees stated that they need sales to both sets of customers to make their businesses viable.

## **3. High Cost of Testing and Evaluation Prevents Smaller Companies from Bringing Products to Market**

To sell products for use in space, prospective sellers need to demonstrate that the products will function in the harsh space environment, which necessitates testing and evaluation, including *in situ* testing. Launching a product and testing it in space is expensive, potentially running in the millions of dollars, even when the product is launched as a secondary payload. While there are many emerging launch providers, the high cost of

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<sup>3</sup> The “chicken-and-egg” problem becomes more acute when the prospective buyer is risk-averse. NASA and other government agencies are unlikely to rely on unproven technologies for expensive missions. These agencies have generally sought to set requirements for all components of the systems needed to achieve their mission. Timing is another issue. If major programs are delayed, demand, such as for propellant stored in space, may not materialize in time to generate the revenues needed for providers to prevent bankruptcy.

testing and evaluation remains a barrier to producing new products for space. One company representative indicated that the cost of testing was so high that the company would be willing to give equity to a launch company in exchange for the chance to fly and test its product. These issues can be exacerbated by the lack of funding for “industrial commons” facilities (e.g., database curation, ground testing facilities such as thermal and vacuum chambers, radiation testing) (Lal et al. 2017).

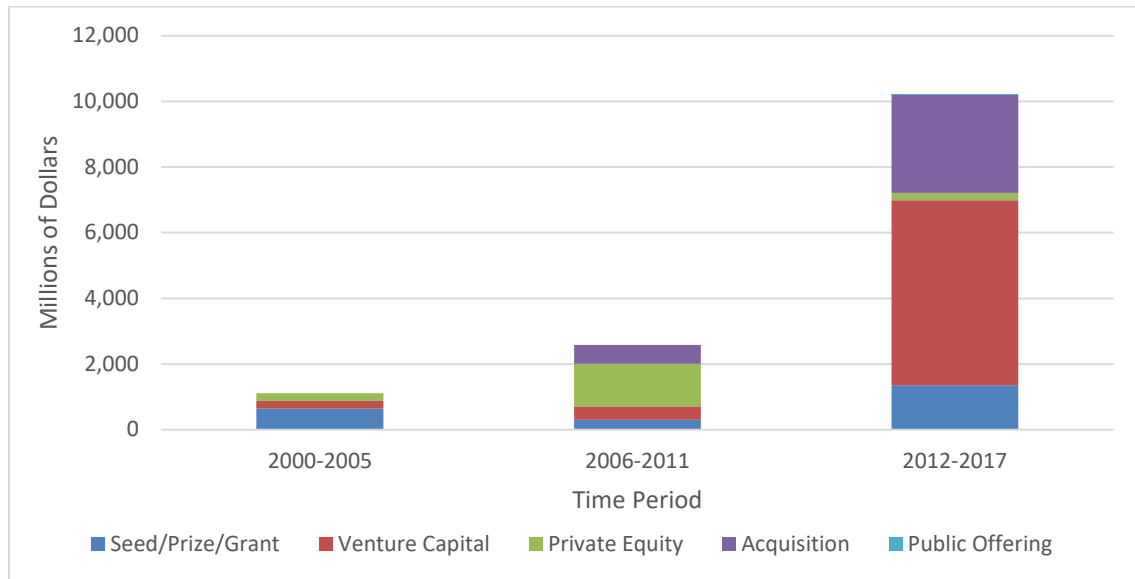
#### **4. Government Funding Timelines Are Not Aligned with Private Sector Timelines, Making Government Funds Less Useful**

Many interviewees stated that the traditional instruments used by the government to support commercialization and development of new technologies are less effective than they could be. Small Business Innovation Research (SBIR) awards, in particular, while generally appreciated, were described as being too small; applications take too much effort, and grant decisions and final awards take too much time. The most common complaint was that the relatively lengthy timeframe required to receive the grant diminishes the usefulness of the funds. Some groups mentioned that SBIR awards do not sufficiently focus on entrepreneurship and the scalability of a small company; rather, SBIR awards tend to be given to firms whose primary activity is R&D and which do not aggressively expect widespread commercialization of their technologies once they have been developed. This focus may not be productive if the SBIR program is used to foster the development of private space markets. Many interviewees said they would like the U.S. Government to increase funding for research in early-stage technologies, for example, in situ resource utilization (ISRU), which can potentially be sold to private buyers. They also recommended expanding technology transfer programs. R&D grants are especially useful for early-stage technologies that may take 10 or more years to mature, which was considered the earliest timeframe for a commercial market for these technologies to emerge.

#### **5. Capital Markets Sometimes Fail to Provide Funding for Promising Ideas of Space Companies**

Opinions amongst our interviewees differed about the availability of capital for private sector firms, especially start-ups. Companies offering products and services that will be ready for sale in the near term (e.g., LEO-based satellite services, satellite servicing in GEO) generally said they do not lack financing. For these products and services, current levels of capital available for space start-ups are plentiful. Respondents in this category argued that any space start-up with a good idea and a solid business plan could attract funding. Figures on VC investment in space companies support respondent views, as VC funding for space companies has been growing rapidly (Figure 4).

However, VC investment has been concentrated in a small number of services and products. According to Space Angels Network, between 2012 and 2016 more than 90 percent of private equity investments in space companies has been in companies manufacturing and operating satellites and launchers (Space Angels Network 2018).



Source: Bryce Space and Technology. "Start-Up Space: Update on Investment in Commercial Space Ventures 2018."

**Figure 4. Investment in Space Companies 2000-2017**

A second group of individuals, those from firms offering products and services that face longer timelines to commercial viability (e.g., activities like ISRU, asteroid mining, and on-orbit assembly and manufacturing), often stated they had difficulty attracting sufficient funding. The upfront investment in these activities is often very high, similar to the costs of drilling an offshore oil well or building a new microchip manufacturing facility. In light of the highly uncertain returns on prospective investments in these unproven space activities, it is not surprising that these individuals have found the VC community reluctant to invest in their companies, especially in early-stage investment rounds.

These interviewees attributed the difficulties in attracting investment to: (1) traditional VC firms require a return on investment in a timeframe shorter than space companies can currently meet; (2) most VC firms do not have sufficient technical knowledge to assess companies selling space technologies and therefore avoid investing in space; (3) venture capitalists are unwilling to accept the levels of technical risk involved in space technologies; and (4) VC firms are dissuaded by the high initial capital needs of space start-ups, given the unpredictable returns on investments.

A third view on the topic came from VC and angel investors who were split on the issue of financing. Some investors stated that funding for space companies is more than

adequate, while others argued that the industry would benefit from more funding. Investors who said private funding is sufficient claimed that funding provided by the government through a strategic investment fund would be detrimental to their activities because the government would provide capital at lower rates and at more favorable terms for companies than those warranted by the market, making private investment dollars less attractive to start-ups. As shown by Colombo et al. (2014), this is a real concern: government-supported VC firms in Canada pushed down returns to the point that private sector VC firms exited the market, thereby reducing the total amount of investment available for start-ups.

In short, interviewees suggest financing is sufficient for companies pursuing near-term space activities where revenues are more certain. However, financing is a challenge for activities with longer timelines and uncertain returns, as well as those that require testing and evaluation in space. Start-ups find these activities too expensive to finance, even if the customer is to be the government.

### **C. Summary**

To determine the suitability of a government strategic investment fund to support the two major policy goals we have defined, STPI interviewed experts and stakeholders in both the space sector and investment firms to determine what these individuals perceive as the major challenges to achieving these goals. To reduce the cost and accelerate the development of technologies for space, interviewees flagged requirements-based, cost-plus contracting as the key challenge. According to interviewees, this mode of contracting tends to increase overhead costs and encourage decision-makers to fixate on 100 percent solutions, ignoring lower cost but “good enough” solutions. It also tends to preclude small companies, especially start-ups, from bidding on NASA contracts and limits incentives for contractors to reduce costs.

A key challenge to fostering the growth of private space markets is insufficient or unproven demand for new space products or services being developed by smaller companies. As a result of lack of demand, companies have fewer financing options—both governmental and non-governmental. Lack of capital also makes it difficult for start-ups to engage in activities such as testing and evaluation of their products and services. Table 2 summarizes the major challenges covered in this chapter by category.

**Table 2. Key Challenges to Achieving U.S. Government Policy Goals for Space**

	<b>Reduce costs and accelerate development and procurement of systems for civil space exploration</b>	<b>Foster the growth of private space markets</b>
<b>Near Earth space</b>	<ul style="list-style-type: none"> <li>• Requirements-based, cost-plus contracting increases costs, lengthens development times, and reduces incentives to innovate on cost</li> <li>• Requirements for 100% solutions may exclude lower cost, but “good enough” solutions</li> <li>• Complicated contracting requirements discourage non-traditional suppliers from submitting bids to NASA</li> </ul>	<ul style="list-style-type: none"> <li>• Insufficient or unproven demand for their products makes it difficult for small companies to raise capital</li> <li>• Lack of commonality between government and private market requirements makes products more expensive</li> <li>• High cost of testing and evaluation prevents smaller companies from bringing products to market</li> </ul>
<b>Cislunar or deep space</b>	<ul style="list-style-type: none"> <li>• Insufficient demand for products from specialized suppliers makes components unnecessarily expensive</li> </ul>	<ul style="list-style-type: none"> <li>• Government funding timelines are not aligned with private sector timelines, making government funds less useful</li> <li>• Capital markets sometimes fail to provide funding for promising ideas of space companies</li> </ul>



## **5. Would a Strategic Investment Fund Address Challenges to Achieving U.S. Goals for Space?**

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In this chapter, we compare the goals and features of a government strategic investment fund—as discussed in Chapter 3—with the challenges identified in Chapter 4 for achieving the U.S. policy goals of (1) reducing the costs and accelerating the development and procurement of systems needed for civil space exploration, and (2) fostering the growth of private space markets. For challenges that are not addressed by a government strategic investment fund, we discuss other policy options that might be more effective. Appendix D describes these economic policy instruments in more detail.

### **A. Reducing Costs and Accelerating Development and Procurement of Systems for Civil Space Exploration**

#### **1. Challenges Related to Contracting**

As discussed in Chapter 4, interviewees said the key challenge to reducing the costs and accelerating the development of civil space systems is over-reliance on requirements-based, cost-plus contracting. Interviewees indicated that this form of contracting increases costs, forces decision-makers to demand 100 percent rather than “good enough” solutions, and discourages smaller companies from bidding on NASA contracts.

A government strategic investment fund would not address these challenges. Such funds are designed to provide additional capital and to a lesser extent technical and business advice to small businesses, especially start-ups, not to address problems related to contracting mechanisms. Other policy instruments would be more effective.

#### **a. Requirements-based, Cost-plus Contracting Increases Costs, Lengthens Development Times, and Reduces Incentives to Innovate on Cost**

There is substantial economic literature concerning the respective advantages and disadvantages of various contracting mechanisms.<sup>4</sup> This literature finds that fixed-price contracts reduce costs relative to cost-plus contracts, but that cost-plus contracts allow for higher quality and a greater degree of flexibility (See, for example, Bajari and Tadelis 2001; Nicosia 2002). In government contracting, Harmon et al. came to similar conclusions

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<sup>4</sup> Oliver E. Williamson’s seminal work on organizational theory is a cornerstone of this literature (Williamson 1983, 1996).

(2013). For Department of Defense acquisitions, firm-fixed-price contracts result in lower costs for items where the system design is mature and stable, as these types of contracts provide the greatest incentives for contractors to invest in cost-reducing innovations (Harmon et al. 2013).

NASA has had some experience with fixed-price contracting, or more broadly, solutions-based contracting: contracts where the provider offers a technical solution at a fixed price rather than building a system to NASA requirements under a cost-plus contract. In the case of NASA, solutions-based contracting has incorporated grant-like contracts with fixed-price, milestone-based payments to cover part of development costs. These development contracts are followed by fixed-price purchase agreements to buy the product or service after it has been demonstrated to meet requirements. For example, NASA has employed fully funded Space Act Agreements as part of its experiments with solutions-based contracting.

NASA used solutions-based contracting in its COTS program to develop spacecraft and capsules to transport cargo to the ISS. It has subsequently employed Cargo Resupply Service (CRS) contracts for each launch of cargo to the ISS. (See Appendix D for a detailed description of these programs.) NASA also used a form of solutions-based contracting for NextSTEP to fund competing designs for the Gateway.

According to two studies, COTS and CRS and their use of solutions-based contracting have been highly successful. One study found that the cost per flight of CRS was a small fraction of the cost of using the Shuttle for resupply missions, that the new rockets were developed at far less cost in aggregate than prior rocket development programs, and that NASA funded less than half of development costs for these rockets (NASA 2014). Zapata (2017) compared life cycle costs per delivery of SpaceX's Falcon rocket and Dragon capsule and Orbital ATK's Antares rocket and Cygnus capsule with similar deliveries using the Space Shuttle. Zapata found that the costs per delivery of the two programs were one-third to one-half the cost per delivery by the Space Shuttle, although the comparison between the Shuttle and the two new vehicles may not be completely analogous, as they are different vehicles built for different applications. Zapata also found that NASA management costs added only an additional five percent to the much lower cost of the COTS program, compared to an additional 13 percent of the much higher cost of the Space Shuttle and other cost-plus programs. The difference in NASA management costs stems from the different role NASA plays in the two types of programs: under cost-plus contracting NASA sets requirements and conducts continuous oversight; under fixed-price contracting NASA focuses only on whether companies have provided the contracted service or product, not on the cost of developing the technology and producing the product.

Several components of NASA's civil space program to return to the Moon should be conducive to the use of solutions-based contracting. Many of the technologies needed for a lunar mission are already in use or have already undergone extensive development. For



example, NASA has operated environmental control and life support systems (ECLSS) on the ISS and other spacecraft for decades. Although these systems would need to be more sophisticated for deep space applications (e.g., higher water recycling rates), they are already undergoing incremental technological improvements that should be sufficient for the Gateway. Solar panels for deep space are another relatively mature technology. Based on the economics literature from other fields and the experience of NASA, DOD, and other agencies, solutions-based contracting should result in lower costs, more innovative technologies, and faster development of many of the technologies and systems needed for the United States to return to the Moon.

For those parts of NASA’s civil space program that entail the development of untested, completely new technologies—such as the design of a spacecraft to transport humans to Mars—requirements-based, cost-plus contracting may be preferable to fixed-price contracts. Cost-plus contracting assures contractors that the costs of exploring various technology avenues, some of which could lead to dead ends, will be covered. The contractors do not need to estimate these unknown costs to incorporate them into a fixed-price bid. If the contractor can devise a solution more quickly and cheaply than expected, the government is protected from paying substantially more than required to produce the product.

**b. Requirements for 100% Solutions May Exclude Lower Cost, but “Good Enough” Solutions**

As discussed in Chapter 4, interviewees stated that NASA requirements sometimes preclude the use of less expensive components or systems because those components or systems do not meet 100 percent of specified requirements, even if some specifications may be more demanding than necessary. In other words, systems that could have been “good-enough” have been rejected. Because detailed requirements are not specified, solutions-based contracting provides more flexibility and opens up opportunities to utilize satisfactory solutions at lower cost.

**c. Complicated Contracting Requirements Discourage Non-Traditional Suppliers from Submitting Bids to NASA**

Solutions-based contracting makes contracting with NASA easier for small suppliers, small start-ups, and other non-traditional suppliers. Fixed-price contracts and programs like COTS obviate the need for contractors to establish separate accounting programs to track hours and costs in contrast to the demands of regulations for cost-plus contracts. Consequently, fixed-price contracting can significantly reduce contracting costs for these companies.

## **2. Challenges Related to Supporting Specialized Suppliers of Components**

Some interviewees argued that NASA could reduce costs by standardizing the purchase of components from specialized suppliers rather than repeatedly ordering specially designed, one-of-a-kind components or instruments. However, to develop and produce such components, specialized suppliers of components need to have sufficient demand to bring innovative, lower cost products to market.

Although a government strategic investment fund for space could be used to provide equity capital to support companies that make specialized components, the economics literature and interviewees indicate that other policy instruments would be more effective. If the strategic investment fund invests in a company whose product fails to satisfy government needs, the strategic investment fund would continue to own part of a company that would no longer be developing a product of interest to the government. Using a strategic investment fund to make equity investments in these companies would appear to tilt procurement towards companies that have attracted the investment, building in a potential procurement bias that could result in procurement competitions no longer being free and fair.

Interviewees stressed that orders, not financing, has been the most important barrier to making the production of special components for NASA a viable business. Several interviewees argued that the best policy instrument to support small suppliers would be advance purchase agreements. Under such agreements, suppliers can develop products incorporating new technologies, knowing they will be able to sell them in large enough quantities to cover their costs once they enter production. NASA and DOD have used variants of advance purchase agreements to support the development of some new space technologies, for example, block buys for launch vehicles, such as the Evolved Expendable Launch Vehicle (EELV) program and CRS. Companies were confident that if orders were guaranteed, they would be able to secure financing.

Advance purchase agreements, however, can be difficult for the government to employ. The U.S. Government faces legal constraints on making contractual commitments for years when funds have not yet been appropriated. If the technology is still being developed, NASA might lack the information necessary to negotiate appropriate prices or purchase volumes, making an advance purchase agreement difficult to write. NASA also faces legal constraints on committing to purchases of products that are still under development.

R&D grants and contracts provide an alternative to advance purchase agreements. The U.S. Government does not face the same legal issues in providing R&D grants as it does for advance purchase agreements, especially for products in early stages of development. R&D grants can be given to companies proffering to make specialized components before the product is ready for sale, providing funding for product

development. Companies have used grants, such as SBIR grants, to show investors that the government may be a future customer, increasing the likelihood that the company can raise capital to cover the costs of bringing the product to market. R&D grants and contracts are more flexible and less expensive than equity investments. If a company receiving such a grant or contract fails to meet a development milestone, NASA can stop providing funding whereas once an equity investment is made, the investor holds an ownership stake even if the company is no longer developing products of interest to the government.

## **B. Fostering the Development of Private Space Markets**

### **1. Challenges Related to Insufficient or Unproven Demand**

Across the board, interviewees stated that the primary challenge facing newer or smaller space companies targeting private space markets has been lack of or unproven demand for their products. Lack of or unproven demand for its products limits a company's ability to obtain investment.

A strategic investment fund would not solve the problem of insufficient demand for these companies. A strategic government investment fund for space is designed to provide equity capital and business and technical advice; it would not serve to generate private demand for products from new space companies.

Other policy instruments can be used to address this challenge more directly. Several interviewees advocated the use of advance purchase agreements by NASA as a means to jump-start demand for products (e.g., propellant to be sold in space) that could also be sold to businesses and households on private space markets. Newer space companies said that with an advance purchase agreement from NASA in hand, they could attract the investment necessary to develop new technologies. Venture capitalists with whom we spoke concurred.

It is not clear, however, whether advance purchase agreements by NASA would be an effective policy tool for supporting the development of products for the private sector. Historically, the U.S. Government has not purchased products it does not need simply to support the development of products designed to be sold to households and businesses. Moreover, advance purchase agreements could end up creating demand for products that may turn out to be uneconomic. If companies create a product that meets the terms of a government purchase agreement, it may be a more complicated and therefore more expensive system than is needed by private customers. If the price of the resulting system is too high for potential private customers, sales to the private sector will fail to materialize, defeating the purpose of the policy intervention.

If despite these drawbacks the U.S. Government chooses to employ advance purchase agreements to stimulate demand for private space markets, it should use reverse auctions

or similar policy instruments to set prices; the government should not arbitrarily set a price. In reverse auctions, potential suppliers compete to provide the product, such as propellant stored in lunar orbit, at the lowest price possible. Reverse auctions reveal the prices at which companies believe they can provide the good or service, thereby preventing the government from overpaying.

R&D grants and contracts could be used to help space companies develop products for the private market, although for legal reasons the U.S. Government would likely need to make sure the product also serves a government purpose. Historically, the U.S. Government has played a role in developing markets for microchips, computers, and telecommunications satellites by financing the R&D to create the products it needs, as well as through its purchases of those products. Companies that initially developed these new technologies and products for sale to the U.S. Government later modified them to meet the needs of households and private businesses. More traditionally, the U.S. Government has fostered the development of new industries by creating an environment in which the private sector has the freedom to develop new products and market them to households and businesses itself, not through government intermediation.

## **2. Challenges Related to Reconciling the Lack of Commonality between Government and Private Sector Requirements**

A strategic government investment fund for space does not appear to have a role in reconciling government and private sector requirements. This problem is caused by government contracting requirements that preclude government purchases of commercial products, not by lack of equity finance. By using solutions-based contracting rather than setting rigid requirements, NASA would better support the development of products and companies that serve private space markets as well as sell to NASA.

More extensive use of solutions-based contracting for NASA procurements would have the additional benefit of making it possible for companies to incorporate products designed for sale on the private space market into their submissions for NASA. DIU, for example, employs only solutions-based contracts to source commercial products for military use. Because DIU searches for solutions that sufficiently meet mission needs rather than prepares system requirements that bids must meet, companies are able to submit commercial products, saving development time and funds for both the company and the military.

## **3. Challenges Related to the High Costs of Testing and Evaluation**

A strategic government investment fund for space could provide equity capital to cover the costs of testing and evaluation of new products, but scaling up the size of programs (such as the NASA Flight Opportunities Program) that provide in-kind subsidies

is more straightforward. Government equity investments would be a more complicated and therefore more costly way of providing these services.

In light of the high cost of taking technologies through mid-technology readiness levels, NASA has subsidized activities that help companies test, evaluate, and demonstrate their technologies. The ISS currently offers programs through CASIS to host experiments and test equipment and products at reduced or no charge to companies. For example, Bigelow, a manufacturer of expandable spacecraft modules, has been permitted to dock an expandable habitation module to the ISS for testing. The ISS is also hosting a test of an apparatus to produce exotic fiber optic cable in microgravity as well as an additive manufacturing printer.

These in-kind subsidies (e.g., integration, launch, use of ground-based facilities such as vacuum chambers and wind tunnels, use of space-based facilities such as the ISS and astronaut time) help companies bring products to market by covering some of the costs of testing concepts and products. Raising funding levels in order to scale up the provision of these in-kind subsidies would be an important source of support for space companies attempting to bring products to market for businesses and households. For example, NASA could expand the Flight Opportunities Program to include launching a broader array of payloads to Earth orbits other than just to the ISS.

#### **4. Challenges Related to Government Funding Timelines Not Being Aligned with Private Sector Timelines**

Several interviewees said NASA R&D grants were often too small, applications take too much effort, and grant decisions and final awards take too much time to address the timelines and financing needs of new start-ups. In particular, SBIR grants were considered less useful than other R&D grants. The most common complaint was that the time required to apply for and be awarded a SBIR grant was much longer than the time before the product's next innovation cycle. Some interviewees also stated that SBIRs do not sufficiently focus on the scalability needed by start-ups focused on private space markets. In some cases, SBIRs support firms that conduct R&D only for NASA and do not aggressively target private sector customers for their products.

Because equity investments require a higher level of due diligence and negotiations between the investor and the firm than R&D grants, a government strategic investment fund would not be a good candidate for accelerating disbursements of R&D funding. The most direct way to address this challenge would be to increase the size of R&D grants, especially SBIR grants; simplify applications; and set shorter review and disbursement deadlines.

Accelerating and simplifying grant-making procedures will be challenging. In public presentations, NASA leadership has stated that it would be infeasible to change timelines

associated with SBIR programs. It might be useful for NASA to consider an organization designed to accelerate the dissemination of grants.

## **5. Challenges Related to Capital Markets Not Providing Adequate Funding for Promising Ideas of Space Companies**

Many interviewees indicated that companies developing new technologies and products for sale on private space markets (e.g., propulsion systems for small satellites) face financial hurdles to bringing their technologies to market. Although financing is needed throughout the development process, interviewees stated that the types of funding needed vary depending upon the product's state of development. There was a general consensus, emphasized by venture capitalists, that technologies need to be within a few years of being ready to be sold before a company is prepared for an injection of equity or other funds.

Several interviewees argued there is a shortage of capital to bring space products to market that are ready for commercial sale. These individuals argued that a government strategic investment fund for space would provide capital necessary for this step. We did not find evidence of a shortage of capital for emerging space companies with products ready for commercial sale (e.g., LEO-based remote sensing) that have prospects of generating revenues in the near-term. However, many interviewees, both those with products almost ready for sale and those that will not have products for sale for a long time, said that more capital would be useful.

Because we did not find strong evidence that space companies with commercially ready products and solid business plans are unable to obtain VC, we do not find the need for a government strategic investment fund to provide additional capital for space companies persuasive. The tangible and intangible costs of setting up and operating such a fund are high (e.g., cost of running the fund and the difficulties of maintaining political support). Despite the high capital costs of some potential space technologies, we also found the use of other government capital subsidies, such as government loans or loan guarantees, for fostering the growth of private space markets inadvisable. The U.S. Government generally insists that a company has sufficient capital to cover a substantial share of the investment when the potential loss from a loan guarantee is large. For this reason, loan guarantees have not been widely available for space start-ups with technologies that require very high upfront investments, as these companies lack the equity capital demanded by the government to reduce the risk of guaranteeing loans.

For companies with products that are not yet ready for market (e.g., asteroid mining, in-space manufacturing), government funding in the form of R&D grants is a more effective policy instrument than equity from a government strategic investment fund. In contrast to capital subsidies, such as government equity investments or government loans, R&D grants leave the firm with no financial obligations. They are also less difficult to

negotiate than equity investments. From the government side, R&D grants can be targeted at specific technical challenges without the government taking an equity stake in a company. From the point of view of the company, application and administrative costs are manageable, although timelines need to be accelerated.

In general, interviewees found R&D grants and contracts provided by NASA's Space Technology Mission Directorate most useful for financing the development of technologies that serve NASA's needs but can also be sold to households and businesses. As noted above, SBIRs were considered less effective. To further support the development of private space markets, these programs could be scaled up and expanded.





## 6. Conclusions

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The purpose of this study is to provide the government with an assessment of the utility of a government strategic investment fund to achieve two U.S. space policy goals: (1) reducing costs and accelerating the development and procurement of systems for civil space exploration, especially a return to the Moon, and 2) fostering the growth of private space markets. In this chapter, we present our responses to the three overarching questions posed for this assessment:

- What would be the utility of a U.S. Government strategic investment fund for accelerating the development and delivery of technologies for human space exploration and for fostering the growth of the commercial space industry?
- How would the efficacy of a U.S. Government strategic investment fund compare with that of alternative economic policy instruments for achieving the U.S. Government's goals for space?
- Should the U.S. Government set up and operate a strategic investment fund for space, and if so, how should it organize such a fund?

Sections A and B, below, answer the first two questions. Because we conclude that a government strategic investment fund for space is not a good idea, we answer the third question in Appendix E.

### **A. Utility of a U.S. Government Strategic Investment Fund for Space**

The primary reasons for governments to create strategic investment funds are to provide capital to new firms in pursuit of policy goals such as stimulating economic growth, supporting companies that generate social payoffs and positive externalities, or influencing a company to design or tailor its products to better serve the government's needs. By holding an equity stake in the company, the government agency is, in principle, able to influence the company to make decisions better aligned with government policy goals, like designing a technological solution better tailored to the needs of a government agency. Holding an equity stake in a company also provides the government with earlier opportunities to give feedback on the product, or clarify demand.

In the case of space, the purpose of a U.S. Government strategic investment fund would be to provide equity capital to promising space start-ups developing products that would serve to reduce the costs and accelerate the development and procurement of systems needed for civil space exploration, and that would foster the growth of private

space markets. As discussed in Chapter 4, the most pressing challenges facing the U.S. Government and the space industry in pursuing these two goals fall into nine categories. **We find a government strategic investment fund for space would not be the best policy instrument to address these challenges.** Government strategic investment funds pursue policy goals through the provision of equity capital to promising start-ups. Based on interviews, the growth in VC available for space start-ups, and sales of space industry products, we concluded that a lack of markets, not a lack of capital is the most pressing need of these companies, whether those targeting NASA or private markets. Government strategic investment funds do not and cannot generate demand for new products for space start-ups.

**The substitution of solutions-based contracting mechanisms for cost-plus contracting would best serve to reduce costs of and accelerate the development of new systems needed for civil space exploration.** Expanding use of R&D grants or contracts could also help achieve this goal. If the government wishes to acquire a new technology, in general it would be more cost-effective for the government to fund the development of that technology directly through R&D contracts or grants, rather than purchase part of a company that may or may not succeed in developing the technology.

**A government strategic investment fund would be an inefficient policy instrument to spur the growth of private space markets.** Investment funds are designed to provide equity capital to companies with products that are almost ready to be sold in commercial markets. Activities such as asteroid mining or on-orbit manufacturing that will not be generating revenues from sales to private markets for a long time are better supported through research grants or other forms of government support. The timelines for these endeavors are too long to make government equity investment a preferred means of support.

**A government equity fund is not needed for NASA to gain insight into the space start-up community.** The U.S. Government set up In-Q-Tel, Red Planet Capital and OnPoint Technologies, the last two of which are no longer active, to gain insight into potential products of interest from start-ups targeted at U.S. commercial markets. DOD and the IC needed an instrument to gain information about emerging companies and their technologies. Organizations such as In-Q-Tel and DIU serve this purpose. NASA does not have these needs: because NASA is such a dominant purchaser of products in the space sector, start-ups are by-and-large cognizant of NASA's needs. Similarly, NASA has many avenues through which to learn about the capabilities of space start-ups—unlike the IC, which is not as well connected to emerging advances in the broader technology sector.

**A government strategic investment fund for space would be costly to set up and operate—as much as six times higher than those of other economic policy instruments such as R&D grants.** Our review of prior U.S. strategic investment funds shows that significant and sustained political support is required to create and sustain these funds.

Without such support, a strategic government investment fund for space would likely fail. As discussed in Chapter 3, a survey of over 20 evaluations of the impact of government strategic investment funds found that government strategic investment funds underperformed private VC funds. Investments by government strategic investment funds resulted in less rapid growth in revenues and employment than investments by private VC funds. Not surprisingly, rates of return were lower as well.

## **B. Alternative Economic Policy Instruments for Addressing Challenges to Achieving U.S. Policy Goals for Space**

In Chapter 5, we discussed the advantages and disadvantages of policy instruments other than a government strategic investment fund for addressing challenges to the achievement of our policy goals for space. Below, we discuss which of these instruments would best address these challenges. Table 3 maps those instruments to the challenges. In Appendix D, we present a more comprehensive list of economic policy instruments for addressing these challenges.

### **1. Economic Policy Instruments to Reduce Costs and Accelerate Development and Procurement of Systems for Civil Space Exploration**

For systems built with relatively mature technologies, solutions-based contracting can reduce costs compared to requirements-based contracting. To minimize costs and speed the deployment of new systems for human space exploration, NASA will need to make greater use of these solutions-based contracting approaches. Even with the investments already made in SLS and Orion, NASA could still benefit from employing these types of contracting arrangements for launch of cargo and humans to the Moon.

When evaluating bids using solutions-based contracting, NASA should use contracting mechanisms that evaluate the bid in its entirety; a substantially less costly solution should be considered even it does not meet 100 percent of requirements, provided it adequately solves the problem. Solutions-based contracting would also reduce some of the difficulties and costs of contracting with NASA. Replacing traditional methods of contracting with more solutions-based contracting would also open up possibilities for companies selling products to private space markets to also sell to NASA.

**Table 3. Preferred Economic Policy Instrument by Challenge Compared to Government Strategic Investment Fund (GSIF)**

<b>Goal</b>	<b>Challenge</b>	<b>Role of GSIF</b>	<b>Preferred Economic Policy Instrument</b>
<b>Reduce costs and accelerate development and procurement of systems for civil space exploration</b>	Cost-plus contracting increases costs, lengthens development times, and reduces incentives to innovate on cost	Low	Increase the use of solutions-based, fixed-price contracting
	Requirements for 100% solutions can lead to the exclusion of lower cost “good enough” solutions		
	Many contracting regulations make it difficult for non-traditional entities with innovative solutions to work with NASA		
<b>Foster the growth of private space markets</b>	Insufficient demand for products from specialized suppliers makes products unnecessarily expensive		Increase size of R&D grants and R&D contracts
	Insufficient or unproven demand for products and services (especially those with longer timeframes) inhibits upfront private investment	None	If NASA needs the product, provide R&D funding or use advance purchase agreements to signal interest
	Lack of commonality between government and private market requirements makes products more expensive than needed	Low	Increase the use of solutions-based, fixed-price contracting
	High cost of testing and evaluation prevents companies from bringing products to market, especially start-ups and smaller firms	Medium	Increase the use of in-kind subsidies
	Government funding timelines are not aligned with private approaches, making government funds less useful	Medium	Increase the size and accelerate timelines of R&D grants, contracts, and programs
	Failure of capital markets to provide funding for promising ideas in space	Medium	

For small new suppliers with technologies not close to being ready for the market, R&D grants, including SBIRs, and R&D contracts are more effective economic policy instruments than capital subsidies, such as government equity investments, loan guarantees, or tax incentives. At earlier stages of technological development, costs and capabilities are too uncertain to write advance purchase agreements, and technological risks and time horizons are too uncertain for equity investors. NASA could increase the number and size of its R&D grants to help companies develop new technologies that may reduce NASA’s costs or lead to growth in private space markets.

Several interviewees indicated that NASA has been reluctant to make substantial investments in novel approaches that could be perceived as overly risky. They argue that

this aversion to taking risks has resulted in the use of technological solutions that reduce mission scope, lower scientific returns, and result in less innovative or more expensive developments. The U.S. Government could examine whether to create an organization—inside NASA or elsewhere—to fund higher-risk projects that promise substantial gains in capabilities or lower costs. The organization—set up to co-fund projects similar to the NASA Tipping Point program—would fund emerging, transformative technologies and ideas for space, especially promising nontraditional architectures that would otherwise not receive substantial support.

To ensure that the fund is used to support riskier projects, it would need to be located outside NASA’s existing human exploration or science directorates, possibly even outside NASA. The organization would differ from programs such as the NASA Innovative Advanced Concepts (NIAC) Program in that it would not be limited to funding early stage research, and would also be able to support activities such as marketing, information exchanges, and providing common infrastructure. In addition to providing research grants, the organization could provide funding for the development of prototypes, similar to DIU, SCO, and other organizations created by DOD to accelerate innovation, technology development, and deployment. If created, it should closely coordinate its activities with the procurement of new systems for the goals of human exploration and science missions.

## **2. Economic Policy Instruments to Foster the Growth of Private Space Markets**

Our research found that the primary problem facing organizations interested in selling to private space markets is lack of demand. If NASA needs a product that will also be sold in private space markets, it may be able to use advance purchase agreements to procure the product, thereby supporting sales of the product.

Launching a product and testing it in space is expensive, running in the millions of dollars even when the product is launched as a secondary payload. Start-ups frequently cannot afford the high costs of testing, but also cannot bring their products to market until they have been tested in space. To support the growth of private space markets, NASA should expand the provision of in-kind subsidies such as subsidized launch, integration, and testing at NASA facilities and on the ISS for small space companies and space start-ups.

At early stages of technological development, technical risks and time horizons are too uncertain for equity investors, including VC funds. At these stages, research grants or contracts tend to be more effective than advance purchase agreements or equity investments for developing technologies to move towards commercialization. Research grants do not impose financial obligations on the company, but help the company overcome specific technological hurdles. NASA should scale up programs that provide research grants or contracts. Measures to shorten the time for proposal review and award for

research grants, especially SBIRs, would also be useful in fostering the growth of private space markets.

### **C. Recommendations**

Based on our findings in this report, we recommend that the U.S. Government not set up a strategic investment fund for space. Such a fund would not address, in a cost-effective way, the primary challenges facing the achievement of U.S. Government policy goals for space, of reducing costs and accelerating development and procurement of systems for civil space exploration, and fostering the growth of private space markets. We believe that these challenges are best addressed by: (1) pressing NASA to use solutions-based contracting, except when cost-plus contracting can be shown to offer substantial advantages; (2) increasing the number, size, and pace of its R&D grants; and (3) expanding the scale of the provision of in-kind subsidies such as launch and testing facilities.

## Appendix A. Interviewees

Organization	Name
Astrobotic	Dan Hendrickson
Astrobotic	Fraser Kitchell
Bryce Space and Technology	Carissa Christensen
Bryce Space and Technology	Raphael Perrino
Caelus Partners	Jose Ocasio-Christian
Chandah Space Technologies	Adil Jafry
Cislunar Space Development Company (CSDC)	Dallas Bienhoff
Coalition for Deep Space Exploration	Mary Lynne Dittmar
Coalition for Deep Space Exploration	Thomas Culligan
Colliers International	Dylan Taylor
DOD DARPA	Scott Ulrey
DOD Strategic Capabilities Office (SCO)	Will Roper
Deep Space Industries	Bill Miller
Digital Globe	Walter Scott
DIU	Josh Hartman
DIU	Steve Butow
Finance Technology Leverage	Glen Surles
GEN Space	Stephan Reckie
In-Q-Tel	Thomas Gillespie
In-Q-Tel	Ryan Lewis
In-Q-Tel	Lisa Porter
In-Q-Tel	Lisbeth Poulos
In-Q-Tel	Todd Stavish
In-Q-Tel	Matt Strottman
Former In-Q-Tel	Michael Griffin
Former In-Q-Tel, RPC; now at Alsop Louie Partners	Gillman Louie
Lockheed Martin	Robie Samanta Roy
Made in Space	Anonymous

<b>Organization</b>	<b>Name</b>
Masten Space Systems	Sean Mahoney
Moon Express	Ben Roberts
Nanoracks	Jeff Manber
NASA	Courtney Bailey
NASA	Patrick Besha
NASA	Kira Blackwell
NASA	Tom Cremins
NASA	Jason Crusan
NASA	Marybeth Edeen
NASA	Jay Falker
NASA	Richard French
NASA	Robert Lightfoot
NASA	Alex MacDonald
NASA	Phil McAlister
NASA	Dan Rasky
NASA	John Scott
NASA	Sam Scimemi
NASA	Jeff Sheehy
NextGen Space LLC	Charles Miller
NIST	Jason Boehm
The Pareto Group	Derek Blazensky
Planet	Robbie Schingler
Planetary Resources	James Orsulak
Planetary Society	Jason Callahan
Satellite Applications Catapult	Stuart Martin
Space Angels	Chad Anderson
Space Frontier Foundation	Rick Tumlinson
Spacefaring Institute	Michael Snead
SpaceX	Joshua Brost
SpaceX	Mat Dunn
Starbridge	Michael Mealling
Ubiquity	Sunil Nagaraj
ULA	Tory Bruno
ULA	David Kornuta
ULA	Bernard Kutter



<b>Organization</b>	<b>Name</b>
University of Arizona	Stephen Fleming
XCOR	Jeff Greason
XFund	Brandon Farwell



## **Appendix B.**

# **Case Studies of Government Strategic Investment Funds**

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### **In-Q-Tel**

#### **Description**

In-Q-Tel is a non-profit strategic investment fund that serves the CIA and other U.S. intelligence agencies; it is not part of the government. The fund was set up in 1999 with support from the Director of Central Intelligence in response to concerns that private industry—not the government—was leading technological developments in IT. By the late 1990s, leaders of intelligence agencies were aware that the private sector was developing and selling IT of interest to the IC that had not yet been acquired by the IC (Business Executive for National Security [BENS] 2001). The Director of Central Intelligence and other leaders of the IC recognized that the CIA could benefit from more closely interacting with the commercial IT sector and from employing staff with backgrounds in the IT industry (BENS 2001).

The purpose of In-Q-Tel is to help the IC take advantage of commercial technologies that could be useful for the IC's missions. In-Q-Tel pursues this goal by offering the IC insight into technologies emerging from Silicon Valley and other technology hubs and facilitating the IC's adaptation of those technologies. Although it is structured as an investment fund, In-Q-Tel's primary purpose is to function as a technology accelerator. Its major strength is its ability to track, understand, and apply developing technologies to customer agencies' problems. This allows the CIA and other agencies to use their resources elsewhere, rather than investing internal R&D money in these problem areas.

In-Q-Tel's relationship with the CIA is formalized through a contract. Its relationship with its 10 other customer agencies—DOD's J39, the National Geospatial-Intelligence Agency, the National Security Agency, the National Reconnaissance Office and other U.S. intelligence agencies—is formalized with memoranda of understanding through the CIA. Before making an investment, In-Q-Tel first asks customer agencies to articulate their problems—without stipulating the specific form or requirements of potential technological solutions. Each year, agencies provide In-Q-Tel with problem statements that include both mission and baseline requirements. In-Q-Tel searches for technologies best suited to the customer's need. In-Q-Tel communicates with the CIA through the CIA's In-Q-Tel Interface Center (QIC). The QIC disseminates information about In-Q-Tel's investments

in technologies of interest to relevant groups within the CIA and helps transfer technological solutions from the companies to the government customer.

The CIA is In-Q-Tel's largest funder, although it provides less than half of In-Q-Tel's total funding. The other intelligence agencies channel funding to In-Q-Tel through the CIA. Customer agencies often co-fund investments, allowing In-Q-Tel to invest in more companies. In-Q-Tel receives about \$120 million annually from the IC. Some portion of these funds, as well as earnings from its investments, may be either used to provide grants, separate from equity investments, to companies to develop their technologies. Grants range from \$250,000 to \$500,000 and are used to develop early relationships with new companies of interest. About 60 percent of the companies that receive an initial seed grant—and the guidance that comes with it—later receive a larger follow-on investment from In-Q-Tel. Proceeds from past investments are used in accordance with an agreement between In-Q-Tel and the CIA. About 30 percent of In-Q-Tel's total funding is used to cover its operating costs.

In-Q-Tel makes about 50 new investments per year, of which the average is \$1.5 million and the maximum is \$3 million, for a total of about \$75 million of investments annually. Its remaining revenues are used to cover operating costs, to provide grants, and other expenditures. Investment commitments are disbursed over several years. In-Q-Tel always co-invests with private VC funds and remains a minority investor in every investment. As of the beginning of 2018, it had invested in 400 companies alongside 2,400 different funds.

In-Q-Tel employs 144 people, many of whom have technical expertise. Its board of directors consists of 11 individuals with backgrounds from academia, business, and the government (although current government employees hold no seats). The fund makes its equity investments in the form of warrants, a guarantee to be able to buy stock at a fixed price at a later date. Because In-Q-Tel's investment is in the form of warrants, it does not have voting rights for companies in which it invests, as its ownership stakes are only realized if the warrants are exercised, which only occurs when In-Q-Tel exits the investment.

Both In-Q-Tel and the IC believe that if the government is the primary market for a given technology, traditional government procurement mechanisms are superior ways to develop and procure that technology. For this reason, In-Q-Tel tries to ensure that the government is at most one-third of a company's expected customer base; the other two thirds of the sales are supposed to be to the private sector. In-Q-Tel works with both the companies and government customers to ensure the product is developing at a pace and manner that will meet the IC's needs—a focus not shared by private VC funds, which concentrate on generating high returns on investments. In-Q-Tel often invests in companies at a stage when it is easier to make changes in technologies—where a technology can be evaluated, but is not yet on the market, so the company is still amenable to In-Q-Tel's

efforts to shape the technology to suit the IC's needs. However, in doing so, In-Q-Tel does not dictate the specific technical requirements of a product; rather, it offers information to assist the company in making sure the product meets the IC's needs.

In-Q-Tel takes about 6 months to source and execute an investment. It conducts extensive technical and business due diligence when considering an investment, primarily focusing on mitigating technical risks and relying on its private investment partners to mitigate other business risks. This in-depth vetting process produces a "halo effect," generating greater investor interest in companies that have passed In-Q-Tel's investigations. In-Q-Tel's participation validates the product for other potential investors as well as the eventual customer agency. Over the course of the investment, funding is provided to the company in tranches over a set time period during which the company must meet milestones. The timeframe from investment to product varies significantly between software to hardware. On the low end, a unique data or software product can take 12 to 18 months to move from investment to market. Hardware moves more slowly, as prototyping may take longer.

In its role as a technology accelerator, In-Q-Tel differs from traditional VC funds in a few key ways. It is most analogous to a corporate strategic investment fund: its purpose is to discover and invest in innovative technologies that meet the needs of the IC, and to convey information about emerging commercial technologies that should be of interest to the IC. In-Q-Tel's investments may serve as "smart money," an indicator that the company is developing an interesting technology that is likely to have a market, which will thus encourage additional VC firms and others to invest.

In addition to its investment, In-Q-Tel may provide funding to help a company meet the requirements of the government customer through non-recurring engineering support. For example, if In-Q-Tel invests in a database company for the CIA, and the CIA has classification or security encryption requirements, In-Q-Tel may pay the company for the work necessary to address the CIA's needs. Through this non-recurring engineering support, project managers and system engineers at In-Q-Tel help bridge a start-up's need to move rapidly with the government's need for systems that meet the IC's needs. At a strategic level, In-Q-Tel leverages corporate dollars and development to develop products for government use.

In-Q-Tel assesses its performance based on whether its IC customers ultimately purchase the technologies developed by the companies in which it invests, not on the return on its investments. If the product is a commercial success, but not adopted by the IC, the investment is considered unsuccessful; the investment is also considered unsuccessful if the company fails.

To fulfill its mission to keep customer agencies up-to-date on emerging technologies, In-Q-Tel goes beyond surveying the market: it engages and builds relationships with start-

ups and VC firms and tracks technology development in commercial markets for the IC. Its mandate gives its staff the flexibility to investigate whether a technology is likely to be useful to the IC.

In-Q-Tel's ability to perform strict technical due diligence has recently increased with the creation of four laboratories inside the company, each of which focuses on a specific set of technologies—Lab41 (Advanced Analytics), B.Next (Biotechnology), CosmiQ Works (Commercial Space), and Cyber Reboot (Cybersecurity). Although the laboratories function much the same as the rest of In-Q-Tel, they focus on topics of interest within their technology area, especially emerging technologies. For example, CosmiQ Works brings together representatives from In-Q-Tel, government, industry, and academia to address space-related challenges that have high potential for mission impact. The laboratories also provide support to In-Q-Tel's investment team as the investment team pursues relationships with space-related start-up companies, focusing on broadening investments to include technologies that could be applicable to space—even if they are not necessarily being developed by space companies.

Initially, the business community worried that In-Q-Tel would compete with private VC funds. To minimize overlap and avoid picking winners, crowding out investors, or complicating other investment dynamics in later stage activities, In-Q-Tel focuses on Series A and B funding, rather than later stages. In-Q-Tel avoids competing with other funds by maintaining only observer (non-voting) status on boards by investing through equity warrants. It does not set valuations and does not knowingly compete with others for an investment opportunity. Through these efforts, as well as by openly sharing information regarding business plans with other investors, In-Q-Tel has built a positive reputation among investors.

Some of In-Q-Tel's investments are made publicly available; some remain undisclosed. Decisions about disclosure were historically based on requests from government customers; recently, some companies have requested that In-Q-Tel's investments not be disclosed publicly. Companies that choose to disclose this investment, however, can benefit from the halo effect generated by an investment by In-Q-Tel.

## **Lessons**

**The fund must be accessible to the commercial companies of interest.** Technology start-ups have often been averse to working with the government, citing lengthy and difficult procurement processes (e.g., the negative experience of DOD trying to contract with small companies through the FAR) and rigid technology requirements. By offering a model with which technology start-ups feel comfortable working, In-Q-Tel has enhanced its appeal to potential partners. The media attention received by Gilman Louie, a video game entrepreneur, when he became In-Q-Tel's CEO helped: articles in the media referred to In-Q-Tel as a VC fund, generating greater attention and interest from the private sector.

**Both In-Q-Tel and the IC believe that if the government is the primary market for a given technology, traditional government procurement mechanisms are superior ways to develop and procure that technology.** In-Q-Tel only invests alongside private investors, and only selects companies where less than a third of their sales are expected to be to government customers.

**Communicating and integrating with customer agencies are highly important.** In-Q-Tel's ability to advance the development of products used by the IC and other national security customers depends on its ability to communicate with its customer agencies and the companies in which it invests. The importance of a clear process for moving the technology from the company receiving the investment to the customer agency cannot be overstated. Despite initial hesitation, the CIA established an office, called the QIC, to work closely with In-Q-Tel to offer information regarding needs and problem statements and to integrate technologies in which In-Q-Tel has invested into programs. The QIC, staffed by individuals who could make prototyping and acquisition decisions, facilitated this process. The CIA's willingness to accept In-Q-Tel's investment decisions—and thus the firm's ability to function independently—has also been an important aspect of In-Q-Tel's success.

**A government strategic investment fund must be politically connected.** Political support from the sponsoring agency, the Executive Office of the President, and Congress is necessary to create an innovative organization or process. In-Q-Tel initially faced pushback from parts of the CIA, given the CIA's cultural hesitancy to accept technologies developed outside the IC. However, a politically connected board of directors advocated for the fund and worked to build the necessary support throughout the government. Without political support from across the government, businesses might have been hesitant to accept investment from In-Q-Tel. The board helped In-Q-Tel overcome skepticism and concern from members of Congress regarding its business model (BENS 2001). In-Q-Tel's branding as a technology accelerator rather than a VC fund also helped deflect political opposition as many State and local governments have supported efforts to accelerate the development and adoption of new technologies; VC is perceived as less of an activity for government.

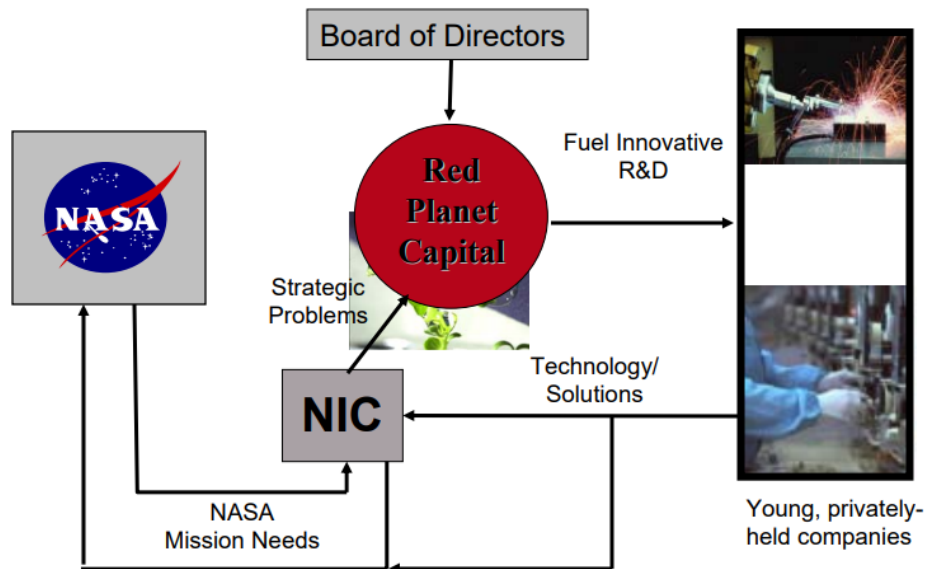
## **Red Planet Capital**

### **Description**

Red Planet Capital (RPC) was a VC fund associated with NASA that operated between September 2006 and early 2007. In 2004, prior to founding RPC, NASA began a program called Enterprise Engine, an organization designed to work with the VC community and private industry to facilitate NASA's acquisition of commercial technology. Enterprise Engine was to operate in a manner similar to In-Q-Tel. NASA was interested in using Enterprise Engine and RPC to develop advanced materials, electronics,

and biomedical technologies for space. NASA was concerned that it was unable to effectively integrate and work with smaller companies pursuing innovative technology development in the same way it was able to leverage technologies developed by larger space companies. NASA had concluded that small, newly established companies were the sources of much innovation, but these companies were not interacting with NASA or the government more broadly, and, often were not interested in doing so. NASA leaders believed that a VC firm might allow NASA to better reach out to these companies. The fund was to “be managed according to commercial investment principles” (NASA 2004, 158). NASA leadership decided to explore options to set up a non-profit organization that would be NASA’s agent for investments, with the goal of establishing a non-profit organization to manage such a fund by the start of 2005 (NASA 2004, 158).

The Enterprise Engine, however, was cancelled in FY 2005 (NASA 2005). In February 2006, NASA released a request for information on how to structure an investment fund, stating that the fund’s first year budget would be \$11 million, followed by \$20 million annually in later years. Fifty-seven groups submitted responses. After evaluating proposals and conducting a series of interviews, in May 2006, NASA selected the winning proposal, submitted by three venture capitalists from SBV Venture Partners (Lofquist 2011).



Source: Lockyer 2005.

**Figure B.1: Organization of Red Planet Capital**

The organization of RPC was unique among government investment funds: rather than providing appropriated funds directly to the VC firm, NASA entered into a funded Space Act agreement with a non-profit corporation, Red Planet Capital, Inc., established to act as an intermediary (Borda n.d.). The non-profit corporation then invested money in Red Planet Capital Partners, a for-profit, independent VC firm meant to operate as a typical



VC firm after being given a “shopping list” by NASA (Lofquist 2011). The non-profit organization would release money to the VC firm when needed (Lofquist 2011).

To help guide technology investments, every quarter a steering committee at NASA was to compile a list of problems that might be solved using commercial technologies from start-up companies; this list of problems was to be sent to RPC. Rather than creating requirements documents for specific systems, NASA would leave the solutions to the companies identified by RPC. If RPC encountered a technology NASA might want, RPC was to write a “technology note,” a description of the technology and its possible application to NASA, and send it to an interface center at NASA’s center located in Ames, California, which in turn was to send it to subject matter experts employed across NASA for evaluation. The interface center was to work directly with RPC to identify opportunities for technology transfer and to work with field centers to identify problems that new technologies could solve. To improve communication and utilization of the fund, individuals involved with RPC visited NASA field centers to share information about the fund’s capabilities with scientists and to learn about the needs of the centers.

RPC began operation in September 2006. The investment fund had three general partners, and the non-profit was run by two trustees (Lofquist 2011). RPC was to invest between \$200,000 and \$1 million in early-stage funding rounds and between \$5 million and \$10 million in later-stage rounds (Osama 2008). Unlike In-Q-Tel or OnPoint (see below), which eventually had their own sources of funding derived from profits on previous investments or from a dedicated endowment, respectively, due to its recent establishment RPC’s sole source of funding was congressional allocations in the NASA budget (Osama, 2008).

RPC was shut down in early 2007 due to opposition from OSTP and the Office of Management and Budget (OMB). An increased interest in government VC funds from a number of agencies, especially the Department of Energy (DOE), led to policy concerns about the nature of these organizations. Due to the increased interest in government VC funds by various agencies, concerns about the cost of these funds, as well as pressures on discretionary spending and questions of whether these investment funds were needed, OMB decided not to request funds for FY 2008 for any government VC fund, with the exception of In-Q-Tel, thus ending RPC and other government VC fund initiatives (Lofquist 2011; Osama 2008). Several employees of OSTP and OMB argued that in principle the government should not take equity stakes in private companies (Lofquist 2011). Some government officials that had been key early supporters of In-Q-Tel were involved in the decision to stop other agencies from establishing their own VC funds. RPC was later transformed into a fully private VC fund with no public support called Astrolabe Ventures, which closed several years later.

During its short lifetime, RPC made one investment—in a company called AlterG, which made a treadmill used for physical therapy based on technology transferred from

NASA (Lofquist 2011). Lisa Lockyer, the Acting Deputy Director of Innovative Partnerships who ran the interface center at NASA Ames, reported that for every dollar RPC invested in AlterG, the private sector invested over \$15 (Lofquist 2011). Because RPC operated for less than a year and invested in only one company, evaluating its structure and potential for success is difficult. Its one investment, \$800,000 in AlterG, helped that company leverage \$12.4 million in private VC. AlterG's products are being sold both commercially and to NASA. Whether NASA needed to make an equity investment in the company in order to procure the product is unclear.

## **Lessons**

**The primary lesson to be learned from RPC is the need for political support and interagency consensus regarding a government strategic investment fund.** Although RPC was largely presented as an organization following the In-Q-Tel model, deliberations regarding whether NASA had the same needs as the CIA contributed to doubts regarding NASA's need for a government-funded VC fund.

Neither OSTP nor OMB was completely in agreement with NASA that RPC was necessary or whether it was a policy instrument the Federal Government should employ. OSTP and OMB questioned whether spending government money on VC firms was an inherently government function and a good use of taxpayer funds. The strong support for In-Q-Tel from its board of directors and CIA leadership, and its track record of success, helped it overcome OMB's concerns. A number of interviewees familiar with RPC, In-Q-Tel, or both emphasized the importance of strong political support, especially at high levels. The closure of RPC was largely the result of this lack of support. If that support is lacking for future government strategic investment funds, they are unlikely to survive philosophical or budgetary challenges.

## **OnPoint Technologies/Army Venture Capital Fund**

### **Description**

OnPoint Technologies is considered the first government-sponsored VC group to follow the In-Q-Tel model, serving as a VC fund for the U.S. Army. Its inception dates to 2002, when the U.S. Army was given a one-time allocation of \$25 million by Congress (in the DOD Appropriations Act for Fiscal Year 2002) to set up a VC fund (Osama 2008). The goal, similar to that of In-Q-Tel, was to help the Army work with small innovative companies that would not typically contract with the Department of Defense.

Because future allocations were not guaranteed, the Army created a non-profit organization to run an endowment that would contract with a private VC firm to invest the \$25 million in a portfolio of companies with technologies of interest to the Army. Specific interests included improved energy and power sources, such as lighter batteries. After a

competitive request for proposals, the Army selected MILCOM Technologies/Arsenal Venture Partners to operate a for-profit VC fund, OnPoint Technologies (CB Insights 2016).

Like In-Q-Tel, OnPoint Technologies would only invest in a company alongside private VC firms. OnPoint Technologies investments ranged from \$500,000 to \$2 million, similar in size to those of In-Q-Tel. OnPoint initially focused on mobile power generation (Osama 2008). Although there is no official notice that OnPoint no longer exists, the Army Venture Capital Initiative's website has not been updated since 2015 (AVCI 2015); the last investment OnPoint Technologies made was in 2016 (Crunchbase 2018). We were informed by an interviewee that OnPoint has ceased to function.

## **Lessons**

**Strong government support is needed for a government strategic investment fund to survive.** The government's support for OnPoint Technologies did not last long enough for the fund to be evaluated from either a process or an outcome perspective. Although OnPoint Technologies seems to have survived for 14 years, it does not appear to have been given additional funds beyond the initial \$25 million. Little information regarding its investments is available. OnPoint Technologies seemed to lack proponents within the Army or the U.S. Government more broadly to provide the necessary political support.



## **Appendix C.**

# **Case Studies of Organizations to Foster the Commercial Space Sector or Improve Government Procurement**

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### **Satellite Applications Catapult**

#### **Description**

In 2013, the government of the United Kingdom concluded that technologies at mid-technological readiness (TRL) levels were not receiving sufficient attention from organizations engaged in R&D in the United Kingdom. Universities, research centers, and other institutes were developing technologies to low TRLs, while the business community was primarily interested in developing these technologies for markets once they reached TRL 6 or 7, leaving a gap in the development pipeline. To address this issue, the United Kingdom established the Catapult Centers, private technology acceleration institutes that received a portion of their funding from the government. The primary purpose of the Catapult Centers is to help the research community transition products to the commercial sector with the end goal of developing industries in emerging technologies in the United Kingdom. They specialize in a particular technology area (e.g., biomedical engineering, factory operation and automation, or laser technology) and conduct client-oriented, applied research supported by contracts from government and industry.

The Catapult Centers are modeled after Germany's Fraunhofer Institutes. To bridge the gap between basic research and commercial activity, the Fraunhofer Institutes leverage connections with universities and industry to transition basic research at universities to applied research at Fraunhofer Institutes to product development by industry. Each Fraunhofer Institute operates as an accountable R&D organization that may serve German and international clients, including small, medium, and large corporations and other organizations. Each institute receives one-third of its budget annually as "base" funding from the Fraunhofer Society, which in turn receives its institutional funding directly from the German federal and regional governments. This base funding provides an assured source of annual revenue from the German and regional governments that an Institute can use at its discretion. Typical uses of this base funding are basic research, assistance to small companies, marketing, and other activities to maintain or improve the core capabilities of the Institute. This base funding enables the Fraunhofer Institutes to be forward looking and

“work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now” (Fraunhofer Institute 2010). The Fraunhofer Society’s goals are for its Institutes to leverage this base funding to generate another third of their operating budgets by competing for public research funds at the national, regional, or European Union level. The remaining funding is acquired through R&D contracts with industry.

Catapults use their funds to help companies raise financing, demonstrate their technologies, gain access to government support, enable early demonstrations of technologies at TRL 3–5, and identify potential customers. In the beginning stages of each project, the Catapults finance significant aspects of the product or relationship, although over time the customer’s share of funding is expected to increase until the Catapult is no longer involved. The Catapults have addressed the issue of competition with industry sensitively, bidding only on work that they could uniquely do and avoiding displacing commercial activities that would have occurred without their involvement.

The Satellite Applications Catapult is one of the Catapult Centers. It works to develop the United Kingdom’s private space industry and supports private sector users of space technologies. This center focuses on the challenges businesses face when using or developing products that rely on satellite technologies by addressing demand-side barriers to adopting those technologies. Of Satellite Application Catapult’s 140 employees, about a third are space technology specialists. The remainder work in business development and marketing or have experience in targeted sectors (e.g., agriculture, health, and defense). To build awareness of the benefits of satellite information and services within a specific sector, the Center usually hires a senior leader in that sector as a consultant to inform others in the field about satellite technologies. The Catapult also coordinates the Technology Transfer Network on behalf of the European Space Agency and serves as the point of contact for network-related issues (Satellite Applications Catapult 2013).

One of Satellite Application Catapult’s primary functions is to understand and mitigate the problems non-space industries have in adopting satellite services, such as a lack of awareness regarding satellite capabilities, reluctance to rely on a new technology, and factors that discourage a company from abandoning outdated technologies, such as prohibitively high prices, bureaucracy, or heritage technologies. The Catapult does not procure goods for the government or accelerate prototypes for government use; rather, it uses government funds to develop the satellite services industry by expanding uses to other sectors, thus supporting the United Kingdom’s commercial space industry as a whole.

A specific program of note is Satellite Applications Catapult’s On-Orbit Demonstrator. Understanding the importance of flight demonstrations to commercial entities seeking investments, and aware of the often prohibitively high costs of such in-flight tests and demonstrations, the Catapult offers a reliable schedule of testing opportunities, launching a CubeSat roughly every 6 months. Companies use a

straightforward system to apply to test their technologies in space aboard the CubeSat. Having space-qualified products enables the company to then raise investment. The Catapult purchases these flights using competitive bidding; as of spring 2018, it has used Nanoracks to arrange launches and tests.

Satellite Applications Catapult's financing model was designed to evolve over time. Ever since it was established in 2013, the group has received £10 million a year from the British government. Catapult receives additional funding through collaborative partner programs and for conducting R&D for mid-level research, prototyping, and early designs (TRL 5–7), as well as from commercial activities in which the Catapult generates intellectual property or unique capabilities that are then sold to third party customers (TRL 6–8). Catapult initially intended to reach funding levels of £20 million annually from non-government partners within 8 years of its establishment in 2013. In 2017, it received £17 million; it expects to achieve the target of £20 million 2 years early—by 2019. The core element of this funding enables activities at lower TRLs (3–4) and funds the balance of the costs of developing new technologies; recent levels of core funding are expected to continue, if not increase, to allow sustained support for developing technologies at mid-level TRLs.

The £10 million annually received from the British government is used to help diverse companies in several economic sectors develop the commercial potential of an idea or product connected to space. Although the government may later serve as a customer of the commercial groups that have worked with Satellite Applications Catapult, it does so through separate procurements independent of Satellite Applications Catapult's relationship with the company.

The center's success is measured by a number of metrics, including the number of new products coming into service, the number of direct sales the team has mediated, the value of the investments the team has helped broker, the exports the team has supported, and the value of those exports. The center measures the contributions of its sectors to GDP growth and job creation. The downstream results of an initial investment are taken into consideration as well—the center conducts a value analysis of investments to track its contributions to testing and prototyping to create a new product or service that will in turn generate revenues for that business. In a review of the center's activities in 2017, the organization was found to have played a significant role in developing the commercial environment around several space technologies (EY 2017). The Satellite Applications Catapult has reported that a key to its success was conducting early case studies to demonstrate the organization's abilities.

## **Lessons**

Although not enough time has elapsed since the creation of the Satellite Applications Catapult to fully evaluate whether it has helped the U.K. commercial sector to grow, the

Catapult may serve as a model for how the U.S. Government can support the commercial development of emerging technology sectors.

**Satellite Applications Catapult demonstrates the importance of forming connections with the technology community—reaching across a number of sectors of potential application.** This activity mirrors the Fraunhofer model, the success of which is largely based on its integration into Germany’s system of innovation. These connections have facilitated the ability of the center to leverage technology sectors through its consultants and other outreach efforts.

**Satellite Applications Catapult shows the importance of clearly communicating project descriptions and having a strong awareness of activities in sectors beyond space industries to enable its staff to expand the use of satellite services and data and integrate these services into non-space businesses.** Its staff remains technically adept and works to ensure its efforts are publicly accessible and easily understood by the target audience, which includes current and aspiring spacefaring companies as well as organizations that hope to use and benefit from space capabilities and information.

## **Defense Innovation Unit (DIU)**

### **Description**

DIU (formerly Defense Innovation Unit Experimental or DIUx) is an organization within DOD designed to facilitate the adoption of innovative commercial technologies that are either on the market or soon to enter it to solve near-term problems for the services or combatant commands. The group operates by connecting components of the services—DOD “customers”—to private businesses that have a prototype commercial technology that may solve the customer’s problem. The organization was created in 2015 under Secretary of Defense Ashton Carter to test a new method of procurement for the Pentagon: DOD’s Other Transaction Authority (OTA) for Prototype Projects (10 USC § 2371b). DIU acquires commercial technologies from businesses not part of the traditional defense industrial base, including those that are new or previously have not shown interest in pursuing Federal contracts. Major areas of interest have included autonomous vehicles, artificial intelligence, cryptography, data analytics, communications, and space systems.

DOD’s OTA for Prototype Projects permits DIU to fund a broad range of activities; it is flexible enough to allow DIU to run pilot programs for technologies that are commercially available, but not already in use by the military. Transactions under this authority require that the company be either a nontraditional defense contractor or a small business, or contribute at least one third of the cost of the prototype project. The costs of pilot projects are generally split three-to-one between the customer and DIU (Carberry 2017), although DIU plans to transition to full funding by its customers (the services and



the combatant commands) as the program grows. Customer funding comes almost exclusively from RDT&E budgets. Prototype contracts have ranged from \$500,000 to \$10 million, depending on the complexity of the technology and the process by which the technology is to be adapted for military use. Contracts are firm-fixed price; funding is distributed upon achieving specified milestones. DIU uses the Army Contracting Command of New Jersey for contracting support.

A typical DIU project cycle begins when a DOD customer approaches DIU with a problem. In lieu of developing a request for proposal that meets specified system requirements, DIU works with the customer to create a “problem statement,” a short description of the customer’s challenge. DIU then issues a competitive solicitation—known as a Commercial Solutions Opening (CSO)—for technology white papers. The CSO is posted concurrently on FedBizOpps.gov, DIU’s website and other government means for posting solicitations. The solicitation is typically open for 7 to 10 business days. During the solicitation, DIU encourages companies it knows may have a potential solution to apply. After the CSO closes, if the customer is interested in working with specific companies that did not apply, DIU will contact those companies to solicit additional proposals.

Over the following 2 weeks, DIU convenes meetings with potential customers throughout DOD to review the white papers submitted by potential bidders. In addition to evaluating the technology’s applicability to potential customers’ problems, DIU and customers pay significant attention to the commercial viability of the technology. The companies invited to pitch their product are selected through a poll among customers. With only a few exceptions, technologies of selected companies are already sold commercially or are nearing commercial sale. VC or private equity firms have often already invested or expressed interest in these companies. Following a round of pitches, the customer awards a contract to the winning bid for a prototype. The total time from the receipt of a company response to the CSO to the award of a pilot project for a prototype is typically 3 to 4 months.

Pilot projects vary in length depending on the maturity of the technology and how difficult it is to adapt to DOD applications, but can be on the order of several months. Throughout the project, most companies communicate frequently with the customer and modify products to meet the customer’s needs. Hardware projects use rapid prototyping to meet user demands.

If the prototype is successful, the pilot project can be transitioned to a procurement contract or transaction. Because the initial contract for the prototype has been competitively bid, the procurement contract does not need to be re-bid. Although products are developed for a specific customer, any component of DOD may purchase any products developed during the project without issuing a separate contract. After moving to a procurement contract, project funds come exclusively from the customer’s procurement budget.

In early 2018, the power of DIU and the military to transition prototypes to procurement under the OTA for Prototype Projects was challenged (GAO 2018). In response to protests concerning the Army's failure to compete a bid for a large software package developed under a DIU contract, GAO found that the Army had insufficiently articulated the possibility of a procurement contract in the original OTA and that the procurement contract was issued before the prototype project was fully complete, violating the OTA statute. The former point may affect other DIU projects, if already-issued prototype OTA agreements do not include a provision for a follow-on procurement award. In the decision, however, GAO also re-affirmed the military's broad interpretation of what constitutes a prototype project and the military's ability to use OTAs.

DIU was reorganized in May 2016 to streamline decision-making and correct problems that arose during the first 8 months of its operation. Because of this and other issues, Congress has curtailed some of DIU's activities, especially early in its operations. As an example of one such program, one of DIU's early prototype projects, a synthetic aperture radar satellite system, ran afoul of the National Reconnaissance Office (NRO), which argued that DIU was procuring a satellite constellation, an activity that had previously been solely the domain of NRO. NRO complained to Congress, which in turn pressured DIU to cancel the project, despite protests from DIU that the prototype project was not a procurement. Due to DIU's rocky start, Congress reduced DIU's authorized operations budget by 25 percent and RDT&E budget by 75 percent in the 2017 National Defense Authorization Act until DOD submitted a plan for long-term activities, organizational and management structure, and de-conflicting programs with the rest of DOD and the IC (U.S. Congress 2017). The 2017 National Defense Authorization Act also moved DIU from reporting directly to the Secretary of Defense to the Under Secretary for Research and Engineering. From these experiences, DIU reported that it learned to approach Congress earlier regarding projects that could be controversial and to share information and solicit feedback from interested parties earlier in projects to reduce conflicts.

Because DIU is still a young organization, many of its metrics of success are still evolving. In general, the customer judges projects on avoided costs stemming from using a commercial solution rather than requesting a tailored solution using typical DOD requirements-based contracting mechanisms and whether the prototype meets or surpasses the performance threshold of existing systems. The degree of specificity of the requirements for a given project can vary. For some projects, meeting the performance capabilities of existing military systems may be sufficient; for others, strict system requirements may be set. For DIU, success is not based solely on cost savings and technical performance, but also on whether customers want to use the product. If a prototype is deemed successful, customers can elect to move it to a procurement contract.

DIU has operated in its current form for less than 2 years. Initial results have been favorable. Between May 2016 and December 2017, DIU supported 61 pilot contracts with \$145 million in funding (Lord 2017); three of these projects have been transitioned to procurement contracts totaling over \$2 billion in value (Cassidy et al. 2018). DIU reports that for every dollar it has spent on a prototype project, the company has been able to raise five times that amount in additional capital. Much of this halo effect comes from VC firms' interest in a company after it has secured DOD as a potential customer. Evaluating DIU will become easier over the next year as more initial prototype projects reach completion. If DIU is able to transition a number of these projects to procurement contracts, it will be considered a success.

Representatives of DIU say that the organization's successes have stemmed from differences in the goals and procedures of DIU compared to DOD offices that use more traditional procurement procedures. DIU moves much more quickly to procurement, engages with a wider set of potential commercial suppliers, and has a different culture than traditional procurement offices. DIU awards contracts for prototypes between 2 to 4 months after the CSO. If the pilot program is successful, the project can move to procurement within approximately a year after the initial prototype pilot program contract has been issued. By focusing on commercial technologies, DIU reduces DOD costs by leveraging commercial demand to share development costs. In contrast, traditional procurement cycles can take 2 or more years. DIU credits its speed to its culture, using the OTA, and encouraging staff to move through the contracting process quickly. The OTA for prototype projects has been of particular importance for speeding procurement, as it enables DOD to move from prototype to procurement without a prolonged bidding process, provided the prototype contract has been completed.

DIU says that its major benefit for DOD is better access to the commercial world. Because of connections with start-ups and VC funds, DIU is aware of technologies that traditional DOD procurement offices are not. Representatives of DIU believe they are changing the procurement culture within DOD. DIU reported initial reluctance within some components of DOD to outsource certain activities to the commercial sector. Because DIU offers a relatively risk-free environment to prototype commercial technologies at low cost for military use, it has won over many components of the military that have previously been hesitant to use commercial technologies. For some of its pilot projects, DIU has measured its success not only by the performance of the product, but by the product's ability to change culture. Since DIU began, it has not had to "shop" for customers with problems; customers have been coming to it. This is partially due to a well-advertised rollout of the organization that had DIU staff visit each stakeholder and potential user to establish a customer base. However, it is also due to the military's recognition of the benefits DIU provides.

DIU has won the support of key DOD officials, including former Secretary of Defense Jim Mattis and some in Congress (Kliman and Thomas-Noone 2018). The most recent budget request reflects this support from DOD: the Pentagon's FY 2019 budget request asked for an increase in DIU's budget from the requested \$30 million in FY 2018 to \$71 million in FY 2019 (Williams 2018), a number that does not include the contributions DOD customers make to prototype projects.

## Lessons

**Creating a new organization within a large bureaucracy that has historically been resistant to change may be necessary to pioneer new acquisition strategies.** DIU was one of two DOD organizations that were created to test the use of opportunities for commercial solutions and the OTA for Prototype Projects to accelerate DOD acquisition processes. Although DIU has faced opposition from Congress and some parts of DOD, especially early in its operation, the recently proposed expansion of the program by DOD and adoption of methods developed by DIU by other branches of the military suggest DIU has been successful in helping reform DOD procurement methods, especially for smaller systems.

**DIU's history also shows that if an organization is found not to work as expected, it must be reformed quickly.** New organizations frequently have problems that can be corrected if acted upon quickly. If a failing program flounders for several years before being canceled, it wastes time and money. Course corrections require strong political leadership.

**Compared to cost-plus contracts, solutions-based contracts can attract non-traditional suppliers and reduce costs and time associated with development.** For many military procurements, a "good-enough solution" that is quickly fielded is better than a program that meets 100 percent of requirements, but takes a long time to move to production and deploy. Many DIU projects have been implemented for much less money and much more quickly than traditionally procured systems would have taken because companies are able to work with customer agencies to iterate prototypes to meet customer needs and quickly move to production.

## **Appendix D.**

# **Economic Policy Instruments for Space**

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Governments use a variety of economic policy instruments to support the development of specific industries or sectors. In this appendix, we review economic policy instruments available to the U.S. Government to reduce the costs and accelerate the development and procurement of systems needed for civil space exploration, and to foster the development of private space markets. We divide our discussion of economic policy instruments applicable to these goals into four categories: capital subsidies, subsidies for R&D, input subsidies, and purchasing and contracting mechanisms. We also discuss alternative models of government organizations and their potential to help achieve these goals. We compare the efficacy of these policy instruments using theoretical and empirical findings from the literature on public finance and evaluations of specific applications of these instruments. We focus on economic policy instruments only; we do not examine the effects of regulatory changes on the achievement of these goals.

### **Capital Subsidies for Space**

Governments provide capital subsidies to encourage investments by the private sector in specific sectors or projects by reducing their costs of capital. In addition to strategic investment funds, capital subsidies include government-provided loans or loan guarantees offered at better terms than those available from commercial credit markets, as well as tax provisions pertaining to profits and investments that provide more favorable treatment for certain economic activities. The value of a capital subsidy equals the difference between what the company would have paid in private markets for the capital and what it pays under the government programs.

Several rationales have been offered for the provision of capital subsidies. For example, financial institutions may not provide capital to entire classes of potential borrowers because of lack information on creditworthiness; this can be exacerbated if those borrowers have characteristics that have historically led to discrimination. Because the technological and market risks of a potentially promising industry, such as space, may be so great that private sources of finance are reluctant to invest, capital subsidies help these potential borrowers obtain access to capital. This additional capital is intended to spur the development of the industry.

The public finance literature and several empirical studies find that governments may contribute to over-investment in specific industries by providing capital subsidies: the capital may create excess capacity, leading to unsatisfactory earnings and financial failures.

### **Government-sponsored Loans and Loan Guarantees**

Both government-sponsored loans and loan guarantees reduce the cost of a loan to the borrower. Government-sponsored loans are made directly by a government agency to eligible borrowers and provide financing at lower rates than those offered by private banks. Loan guarantees are contractual instruments between the Federal Government, creditors, and a borrower. They obligate the Federal Government to cover some or all of the loss of principal if the borrower defaults on the loan. The U.S. Government uses government loans or loan guarantees for various public policy goals, including supporting the development of new energy infrastructure and technologically challenging programs.

Loan guarantees have not been widely used in the space sector outside of a few failed projects, such as for the IOSTAR Corporation or the X-33/VentureStar project (Davidson 2010). However, several members of the space community have advocated for their increased use, based on successes in risky, capital-intensive projects in other sectors (e.g., DOE's use of loan guarantees for the construction of nuclear power plants). When the prospective loss from a loan guarantee is large, the government usually insists that the company have sufficient capital to cover a substantial share of the investment. Some space companies have argued for government loan guarantees to cover the costs of developing large projects such as new rockets or a private space station. However, the high level of risk and uncertain market demand for a number of proposed projects in space have limited congressional and executive branch interest in doing so.

One variant on loan guarantees is a government-guaranteed completion bond. The bonds are used to provide additional funds to a commercial company to complete a project (Davidson 2010). They give a government the right to step in to complete a project if a commercial company fails to do so. Some governments have set up specialized banks to provide loans at subsidized rates for specific public policy purposes, such as supporting the development of space companies (Davidson 2010). Such banks have performed poorly compared to private sector banks and have been subject to high default rates (Caprio et al. 2004).

### **Tax Incentives**

Federal, State, and local governments have employed tax incentives to spur investment and R&D in high technology industries, including space. These programs are designed to increase the amount of capital available to companies by reducing corporate taxes through such mechanisms as tax credits or a reduction in overall tax liability. R&D tax credits, for example, can be fully reimbursable: the company is given a credit for all of

its R&D expenditures, even if it pays no tax or if the credit exceeds taxes paid. Credits can also be partially reimbursable: the company is only permitted to receive a credit up to the total amount of taxes owed. Because legal mechanisms exist for start-ups with no tax liabilities to sell tax credits to companies that do hold such liabilities, partially reimbursable tax credits can be an effective policy instrument for supporting R&D, even for companies that have never made a profit.

In addition to existing Federal and State R&D tax credits, some individuals have advanced other proposals for using the tax code to support the development of the commercial space industry, such as the provision of additional tax credits specifically for space-related R&D.

Zero-g/zero tax laws on space activities have been passed by Virginia and Florida, meaning space companies in those States do not have to pay State corporate income taxes on profits from commercial space activities (FAA n.d.) The law in Virginia, passed in 2008, created an exemption from State corporate income taxes for any space transportation company that does business in the State and either launched from the Mid-Atlantic Regional Spaceport or conducted space flight training in Virginia (Virginia Commercial Space Flight Authority 2012). The Florida law is similar (FAA n.d.). Some individuals have proposed that the Federal Government prohibit all States or municipalities from collecting sales taxes on products made in space (Rohrabacher 2003).

The government also permits the use of flow-through shares as another form of tax relief. Purchasers of shares in companies that are publicly traded and have heavy upfront capital expenditures on risky projects can deduct part or all of the original purchase price of the shares against qualified expenses, provided that the issuer agrees not to claim these as expenses for corporate income taxes (Davidson 2010).

While tax incentive programs may help increase spending on space R&D or investment in space products, these programs may not be enough to spur investment beyond what would have occurred independently. They also serve to shift taxes from favored industries to companies in other sectors, distorting rates of return across economic activities. In the case of zero-g/zero tax laws, profit-making commercial activities in space have been so small that it is difficult to envision these laws as having an appreciable effect on the growth of commercial space industries. They may have affected, however, corporate decisions on where to site their activities.<sup>5</sup>

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<sup>5</sup> Orbital ATK (now Northrop Grumman Innovation Systems) reportedly located its Taurus II launch vehicle operations in Virginia because of Virginia's laws restricting liability for space companies and Virginia's space tax policies (FAA n.d.).

## **Support for Research and Development for Space**

The U.S. Government uses a wide range of policy instruments and programs to support R&D, including for activities in space. Beyond the R&D tax credits discussed above, the six primary economic policy instruments to support R&D for space-related technologies are research grants, Small Business Innovative Research awards, cooperative agreements, Cooperative Research and Development Agreements (CRADAs), Space Act Agreements (SAAs), and R&D contracts. R&D contracts are subject to the FAR Part 35, while grants, cooperative agreements, CRADAs, and SAAs are governed under the Federal Grant and Cooperative Agreement Act of 1977 as well as OMB circulars on grants and cooperative agreements.

### **Research Grants**

Grants from NASA provide financial or other types of assistance to a third party for projects that support a public purpose based on NASA's statutory functions; these are used in situations where NASA and the Federal Government do not expect to substantially participate in the project (NASA 2014). Grants cannot be used for acquisition programs. Commercial firms cannot derive a profit from grants, nor can they charge a fee for services on a grant. NASA has the legal authority to give four types of grants: education grants, training grants, facilities grants, and research grants. Facilities grants require specific authorization from Congress.

Research grants can be awarded for solicited or unsolicited proposals. Solicited grants are chosen from responses to Broad Agency Announcements (BAA) concerning available grants. NASA requires solicited grants to be competitively selected whenever possible. Unsolicited grants are not competed; however, they require that an idea be innovative and evaluated by NASA technical staff prior to the award. If a grant is expected to result in a product that will be sold to non-Federal entities, NASA requires cost sharing. For grants that do not require cost sharing, the Federal Government receives a royalty-free, nonexclusive and irrevocable license for all knowledge and data produced under the grant, which can be shared freely with the public. For grants with cost sharing (whether voluntary or required), knowledge and data generated by the grant may only be used by the government for experimental, evaluation, research and development purposes.

### **Small Business Innovation Research Grants**

SBIR grants are research grants employed by the U.S. Government to stimulate the development of small technology companies. The grants provided under this program support R&D efforts of small companies working to develop technologies that have commercial potential. The program provides funds in three phases: Phase I awards cannot exceed \$150,000 and are meant to prove a technology's feasibility and commercial potential within a 6-month period; Phase II awards offer up to \$1,000,000 over 2 years and



are meant to support continued R&D and efforts to bring the technology to market; Phase III is unfunded but provides opportunities for companies to sell their products to the Federal Government when applicable. Any Federal agency that awards more than \$100 million in R&D grants annually to external sources must make at least 3.2 percent of the total value of awards granted in the form of SBIR grants (sbir.gov n.d.).<sup>6</sup>

While the SBIR program has had many successes, several interviewees, some of them recipients of SBIR grants, stated that the grants are often too small to provide effective support for the development of commercial technologies for space. Interviewees also noted that many of commercial space technologies have development cycles that are quicker than the time needed to successfully obtain and use SBIR grants.

### **Cooperative Agreements**

Cooperative agreements have the same functions (including financial assistance) and restrictions as R&D grants, though they involve substantial technical cooperation with NASA, such as the use of NASA personnel’s technical expertise, NASA facilities, or NASA-owned equipment. Cooperative agreements are especially useful when the recipient requires use of NASA facilities to surmount a defined technological hurdle. In general, if a commercial firm is expected to receive substantial benefits (e.g., commercial applications of the technology) from a grant or cooperative agreement, the firm must share in the total cost of the project with NASA (NASA 2014). Cooperative agreements with commercial firms are often but not always used “to support research and development projects, for technology transfer from the government to the recipient, or to develop a capability among U.S. firms to potentially enhance U.S. competitiveness” (14 CFR 1274.102).

### **Cooperative Research and Development Agreements**

CRADAs are legal agreements designed to facilitate technology transfer from Federal laboratories to private industry. A company can approach a Federal laboratory with a proposal requesting use of government facilities, intellectual property, or researchers to develop a technology for commercialization. Under a CRADA, the company keeps any intellectual property (IP) developed but issues the government a non-exclusive, non-transferable, irrevocable, royalty-free license to that technology.

A CRADA is not a contracting instrument, grant, or cooperative agreement, and as such cannot involve the transfer of funds from the government to a company for work performed; additionally, it is not subject to the FAR. CRADAs require the work to be

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<sup>6</sup> In fiscal year 2017, NASA spent \$199 million on SBIR and Small Business Technology Transfer (STTR) programs (NASA 2018, BUD-3). NASA’s 2017 Phase I SBIR and STTR solicitation received 1,621 proposals from small business, from which NASA selected 399 Phase I awards; 133 Phase II SBIR awards were given in 2017 (NASA 2018, ERT-52).

collaborative, where both the company and the government contribute resources. The company may be required to contribute funds to the government for the project, in addition to facilities, IP, or labor. Between FY 2010 and FY 2014, NASA did not sponsor any CRADAs, but instead used Space Act Agreements (discussed below) to accomplish the same purpose CRADAs serve.

### **Space Act Agreements**

Under the 1958 National Aeronautics and Space Act and subsequent re-authorizations, NASA is able to enter into “contracts, leases, cooperative agreements, or other transactions (51 USC 20113(e))” for any purpose related to its missions. NASA’s Other Transaction Authority, referred to as a Space Act Agreement (SAA), allows it to enter into agreements that are legally distinct from contracts, leases, grants, and cooperative agreements, although certain restrictions apply. SAAs are meant to mirror agreements between two private commercial entities, meaning that elements of the contract, such as reporting requirements and intellectual property rights, can be negotiated, although SAAs have their own administrative and accounting costs. Using an SAA allows the company and government to avoid the administrative and accounting costs associated with the FAR and other Federal procurement statutes (Cassidy et al. 2018), which can make the agreement more attractive to private entities, including small businesses, and can reduce overhead costs related to reporting requirements. NASA has active SAAs with commercial companies, non-profit organizations, and State and local governments.

For NASA, the SAA is a mechanism that can be used only when a contract, grant, or cooperative agreement would not satisfy NASA’s needs. SAAs cannot be used to procure systems; any system developed through an SAA must be procured using the FAR. As described below, NASA can utilize three types of SAA with domestic entities: funded, reimbursable, and non-reimbursable.

#### **1. Funded SAAs**

Under funded SAA grants, NASA has the authority to transfer appropriated funds to a company in exchange for the development of goods or services that NASA could not obtain using other contracting mechanisms. Under a funded SAA, NASA makes payments to companies only after development milestones have been met; payments are fixed (NASA OIG 2014). To use a funded SAA, NASA may not specify system requirements; doing so would make NASA the principal beneficiary of the program, which would subject it to the FAR. In keeping with this provision, NASA has followed up its funded SAAs with fixed priced procurement contracts under the FAR to procure launches and other services. Since funded SAAs became feasible in 2006, NASA has issued only 15, with a combined

value of roughly \$2 billion (NASA OIG 2014).<sup>7</sup> The majority of these SAAs have been for either the COTS or Commercial Crew programs; NASA currently has two ongoing funded SAAs with SpaceX and Sierra Nevada for the Commercial Crew Integrated Capability program (NASA 2017).

## 2. Reimbursable SAAs

Reimbursable SAAs are used by third parties to reimburse NASA for the use of NASA facilities and unique capabilities, such as wind tunnels or engineering expertise. Reimbursable SAAs cover either the full or partial cost to NASA of providing the facility or service and are not subject to OMB circulars on cooperative agreements and Federal assistance (Dunn 2009). NASA enters into these agreements only when they do not conflict with NASA's mission or ongoing programs. NASA is permitted to undertake a reimbursable SAA with a foreign entity; for example, NASA and Ames Research Center have a reimbursable SAA with Virgin Galactic intended to support capabilities for LauncherOne (Messier 2017).

## 3. Non-reimbursable SAAs

Non-reimbursable SAAs are used when both NASA and a third party mutually benefit from an agreement. Each participant in a non-reimbursable SAA, including NASA, covers the costs of its part of the agreement, without exchanging funds. These agreements are used for a wide range of activities, including information and data exchanges from private research that NASA has supported. NASA can undertake a non-reimbursable SAA with a foreign entity; these agreements are also not subject to the Office of Management and Budget's circulars on cooperative agreements and Federal assistance.

One example of a non-reimbursable SAA is the Lunar CATALYST program, run by NASA to provide competitively-selected companies (Astrobotic Technology, Masten Space Systems, and Moon Express) with engineering support for robotic lunar landers (NASA Advanced Exploration Systems 2014). Such programs are designed to spur commercial development of systems that can later be used by both the commercial sector and NASA, though NASA regularly pays a non-trivial amount (e.g., \$10 million for the Lunar CATALYST program) (NASA 2017).

## **R&D Contracts**

NASA has increasingly used R&D contracts governed by FAR Part 35 to either fully fund or share the costs of developing technologies. The most notable recent use of this mechanism is for prototype development of the Gateway's habitat through the NextSTEP program (NASA 2014). Under FAR part 35, NASA has been able to offer companies fixed-

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<sup>7</sup> This report appears to have missed at least one funded SAA with Red Planet Capital, Inc. in 2006. The value of that agreement was approximately \$10 million, much less than the overall total amount of funded SAAs.

priced, milestone-based contracts. Because the program is ultimately intended for NASA acquisition, these contracts allow additional oversight during development, while not overburdening companies with requirements. Another example is NASA's Tipping Point program, which co-funds industry-developed space technologies that can foster the development of commercial space capabilities and benefit future NASA missions (NASA Public-Private Partnerships: Tipping Point Solicitations & Awards n.d.).

## **Input Subsidies**

The U.S. Government has also supported commercial space activities by offering the resources and services needed for space operations for free or at fees well below the cost of those services. NASA offers three types of input subsidies: access to launch facilities at below market rates, access to the ISS for subsidized testing of products to be used in space, and reduced or eliminated launch costs for experiments and testing equipment in space.

### **Subsidized Access to NASA Ground Facilities and Launch Services**

In an effort to stimulate commercial space launch providers, NASA leases launch facilities and provides support for launches at less than fair market value or even cost through enhanced use leases. Under enhanced use leases, NASA leases underutilized assets to potential users for extended periods of time (Davidson 2010).<sup>8</sup> NASA also provides input subsidies through the provision of services, usually formalized through Space Act Agreements (McAlister 2016).

### **Subsidized Access to the ISS and Space**

The U.S. Government provides subsidized launch services, integration, and access to the ISS for demonstration projects and R&D activities. It covers the costs of running experiments and testing on the ISS, including the costs of astronaut time. These input subsidies are intended to support potential commercial activities, when participants are not yet willing or able to cover the full costs of the activity.

Besides access to the ISS, NASA operates two major in-kind subsidy programs for space access. The first, NASA's CubeSat Launch Initiative, provides opportunities for universities, high schools, and non-profits to fly small satellites by booking excess capacity on launches. The small satellites test technologies developed by these groups before they enter the commercial market (NASA 2018).

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<sup>8</sup> For example, the price paid by SpaceX under the company's lease of launch pad 39A at the Kennedy Space Center only covers the cost of maintenance, operations, utilities, and commodities. For commercial launch providers that use NASA services, like SpaceX, NASA only charges the direct cost incurred during the course of the operation; it does not attempt to recoup sunk costs or the savings to the user of not having to build the asset that has been leased (Roberts and Lambing 2014).

The second major subsidy is the Flight Opportunities Program, through which NASA provides companies and organizations access to sub-orbital space and high-altitude environments to stimulate the development of commercial suborbital and small launch vehicles. NASA provides U.S. researchers grants to purchase launch services from approved commercial vendors of suborbital reusable launch vehicles; vertical take-off or vertical landing vehicles; parabolic aircraft flights; and high-altitude balloons. Other support programs, such as NASA's Tipping Point program, can be used by industry to purchase launches through the Flight Opportunities program.

Several companies interviewed as part of this project noted that without subsidized launch support, they would be unable to test their products in space, and hence would be unable to bring their products to market. While input subsidies are useful for helping companies investigate the viability of activities in space, current arrangements do not provide incentives for companies to wean themselves from these subsidies, nor do they provide market tests of the economic viability of activities undertaken without support. For example, it is not clear how many experiments would be conducted by companies on the ISS in the absence of launch and other input subsidies.

### **Access to NASA technologies**

Interested parties are permitted to use NASA technology patents through auctions and negotiated agreements (Davidson 2010). Auctions sell access to patents at market-clearing prices. NASA is also at liberty to negotiate patent agreements at less than market prices if there is a large potential economic impact from the recipient's use of the patent.

### **State Provision of Space Infrastructure**

Space authorities have been set up by States to support space industries and in some instances to build and operate facilities, like spaceports, in support of space industries (Davidson 2010a). California, Florida, New Mexico, Oklahoma, and Virginia have all set up State space authorities. In the case of California and Florida, which have large, existing space industries, the activities of their authorities extend to general support, even funding support, for space enterprises rather than just focusing on spaceport infrastructure (Davidson 2010a). State, county, or municipal support for spaceports has been subject to sharp criticism for spending tax dollars for little return.<sup>9</sup>

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<sup>9</sup> New Mexico's State government and two counties spent \$220 million to build Spaceport America, which has yet to attract much in the way of launch business since opening in 2010 (Burrington 2018). Oklahoma's space port, Burns Flat, has been used by only one commercial space company, Rocketplane, which took \$18 million in subsidies from the State of Oklahoma before filing for bankruptcy in 2010 (Pound 2016).

## **Purchasing and Contracting Mechanisms**

The U.S. Government, including NASA, purchases goods and services according to the FAR. The FAR provides a range of options for the purchase of goods and services by the U.S. Government and contracting procedures for each. Below we discuss four categories of contracting mechanisms, each of which has several variations. NASA also awards hybrid contracts that mix categories.<sup>10</sup>

### **Cost-plus Contracting**

For the purchase of goods and services that entail substantial technological development risk, like many systems procured by NASA (e.g., the SLS rocket and the Orion capsule), the U.S. Government uses cost-plus contracting mechanisms. These mechanisms reassure contractors that costs of time and materials used to develop a new technology, including those used to explore avenues that are ultimately unsuccessful, are reimbursed. Cost-plus contracting protects the government by preventing price gouging by companies that take advantage of the high degree of uncertainty in developing new technologies, making it difficult for the government to determine whether it is being charged a fair price.

Government agencies that procure products incorporating new technologies often set detailed requirements for goods and services. These types of contracts employ a considerable amount of government design and oversight. In some instances, providers build to government designs. The substantial oversight role played by the government provides a high level of control but can also add to cost, potentially through duplication of efforts, as well as extensive government review processes.

### **Fixed-Price Contracting**

To provide the government with goods and services at low costs when technologies are relatively mature, fixed-price contracting is considered more effective than cost-plus contracting. Fixed-price contracting offers providers greater incentive to reduce costs than does cost-plus contracting. In most instances, fixed-price contracting reduces the need for the government to monitor the cost of inputs used to produce the good or service. This can eliminate the need for companies to create detailed auditable systems to account for labor and labor rates.

Increasingly over the last decade, government agencies such as DOD and NASA have employed a form of fixed-price contracting that we refer to as *solutions-based contracting*. In a solutions-based contract, when a government agency plans to procure a system to meet

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<sup>10</sup> For example, to operate the facilities at Goddard Space Flight Center in Greenbelt, Maryland, NASA issued a hybrid cost-plus-fixed-fee/technical-performance-incentive-fee contract, with a cost-plus-fixed-fee and firm-fixed-price indefinite delivery/indefinite quantity component (NASA 2018).

a mission need, agencies release a solicitation for solutions that address the agency's need; this differs from other contracting mechanisms, under which the agency develops a specific request for proposals, which often adds extensive system requirements. Solutions-based contracting equates to asking for the "what" (a hole in the wall) instead of the "how" (a drilling machine). Rather than pre-supposing the technical specifications of mission systems, the government asks industry to propose potential technological solutions, from which the government will select the system to be procured. The government then issues a firm-fixed-price, milestone-based contract to develop the system. A follow-up fixed-price contract can be used for procurement of products. Solutions-based contracting allows companies to propose technologies they may be able to sell on the commercial market, thus potentially allowing the government to share development costs with private sector customers. It also helps the government reduce procurement time and cost by eliminating the additional acquisition and monitoring costs potentially added by cost-plus contracting. Cost savings from an industry solution that sufficiently satisfy mission needs (though potentially not 100 percent of the government requirements) often outweigh any drawbacks associated with using the non-100 percent solution.<sup>11</sup> In some cases where NASA has used a solutions-based contract, NASA has pursued additional contracts with program participants to gain greater insight into and control over development to ensure systems meet NASA's safety requirements.

### **Advance Purchase Agreements**

Under an advance purchase agreement, the government agrees to pay a fixed price for a contracted service once it has been developed. NASA has used advance purchase agreements as a procurement mechanism that follows fixed-price milestone-based development contracts (e.g., as used in the Evolved Expendable Launch Vehicle and CRS programs). In general, use of advance purchase agreements is restricted because of the legal requirements to competitively bid each procurement of a system and to demonstrate that the product can sufficiently meet government requirements before guaranteeing the purchase of a product. Moreover, NASA purchases depend on appropriations; because

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<sup>11</sup> One example of effective solutions-based contracting was the COTS program. It was designed to permit NASA to stimulate the development of new launch vehicles and capsules for delivery of cargo to the ISS. NASA held a competition under which companies presented designs and proposed costs to deliver cargo to the ISS. NASA provided the two later winners of the competition, Orbital ATK (now Northrop Grumman Innovation Systems) and SpaceX, with funds to defray some of the costs of developing launch systems and delivery capsules. Once those were developed, NASA used ISS Cargo Resupply Service (CRS) contracts to establish firm-fixed prices for deliveries to the ISS. This two-part contract was especially important because the companies were able to estimate the cost of providing the service after they had information on the system achieved in the development cycle.

funds are appropriated annually, in most instances NASA cannot commit to a purchase in a future budget year.

### **Prizes, Challenges, and Competitions**

Private organizations and governments have set challenges, prizes, and competitions for organizations to develop solutions to a problem or accomplish a specific task. These mechanisms allow NASA to only expend funds after a technology has been deemed successful, reducing the risk to the government. Prizes can draw ideas and organizations that do not typically conduct work for the government, potentially attracting more innovative technologies. These mechanisms can help the government stimulate responses to high-risk challenges in a cost-effective manner.

Prizes, challenges, and competitions have drawbacks. Because these mechanisms rely on the interest of participants for results (i.e., a company is not being directly paid or otherwise funded to develop a technology), well-qualified potential participants may choose not to participate because they lack the means to support their efforts while competing for the prize. The most qualified participants may choose to work on projects where they are assured of a steady source of income rather than compete for a prize they may fail to win. In some cases, participants' investments exceed the prize purse. As such, prizes may not always attract the highest caliber groups.

## **Organizations to Facilitate R&D and Procurement**

### **Organizations to Facilitate R&D**

U.S. Government officials have found that agencies are often averse to experimenting with new approaches or riskier technologies given the possibility of system or program failure. To combat this aversion to risk, leaders of these agencies have sometimes created units to fund technologies that are out of the mainstream or less well developed. These units are often charged with encouraging lateral innovations through creative combinations of technologies that would not usually be considered, thus funding research that would be unlikely to receive funds through traditional grant mechanisms (Peña et al. 2017).

These units employ a variety of funding mechanisms—including grants, contracts, cooperative agreements, and OTAs—depending on the particular activity they are supporting, and provide funding at any stage of research they deem fit. The key difference between these units and traditional funding organizations is that they focus on ideas that would be highly unlikely to be funded through traditional channels. At times, such units have provoked institutional resentment and opposition from other parts of the agency or from other parts of the Federal Government. They are often at risk of being eliminated unless they have strong political support from agency leadership as well as from the President and Congress. Examples of these units include the Defense Advanced Research



Projects Agency (DARPA), the Intelligence Advanced Research Projects Agency (IARPA), and Advanced Research Projects Agency-Energy (ARPA-E).

Currently, NASA’s NIAC Program funds “visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts” (NASA “NIAC Program” n.d.). However, NIAC has generally been considered too small to make a substantial difference in developing technologies that affect larger NASA programs; it funds early stage technologies at TRL levels of 1 to 3 at about \$7 million a year. It also does not have programs in place to move successful projects to higher TRLs (Peña et al. 2017).

### **Organizations to Facilitate Procurement**

The U.S. Government has established organizations to modify or adapt commercial or other technologies to solve specific problems for the government. These organizations are tasked with reducing costs and accelerating procurement. One example of such an organization is the Strategic Capabilities Office (SCO) within DOD. SCO works with combatant commanders to identify problems. It then develops a solicitation for solutions, rather than a requirements document, which is released for bid. These solicitations do not presuppose a specific technology to solve a problem: vendors are encouraged to suggest technological solutions. Proposed technological solutions may then go through several rounds of prototyping to winnow out less promising solutions. SCO focuses on pre-existing technologies that can be easily adapted to solve the problem; technologies may come from the commercial sector or may already be used within the military. After identifying a promising technology, SCO works directly with the company to adapt the technology to best meet DOD’s needs. SCO uses the OTA for prototype projects (10 USC 2371b) to promote rapid development of a technological solution. Under this OTA, once a prototype has been selected, it is moved onto a procurement contract without rebidding the contract, reducing procurement timelines.

If appropriately structured, an organization such as SCO can reduce procurement timelines by employing solutions-based contracting rather than requirements-based contracting. Because of its emphasis on the end product, organizations like SCO focus on finding sufficient solutions—technologies that may meet less than 100 percent of requirements—but can be deployed quickly and upgraded over time.

### **Organizations to Forge Connections**

The government has also established organizations that scout for technologies, connect government agencies with a technology or product of interest, or speed up contracting. For example, DOD’s DIU was created to identify technologies in the private sector that may be of interest to the government. NASA is currently experimenting with an organization called iTech, which was created to connect small technology companies that

are developing technologies NASA may want to purchase in the future with the VC community.

The major benefits of organizations created to facilitate connections include:

- Access to a wide network of companies, which provides the government with detailed information on the availability of commercial technologies.
- Faster contracting for prototype projects, which leads to quicker procurement.
- Attracting companies that have not previously been interested in selling to the government under traditional government procurement procedures due to lack of awareness or aversion to complicated contracting mechanisms.

### **Independent Government-funded Organizations to Support the Development of Space Industries**

Other governments have established organizations co-funded by the private sector to support the commercial development of a specific industry for the country's economic benefit. In addition to funding R&D, these organizations may support marketing, information exchanges, and common infrastructure used by an industry. Germany's Fraunhofer Institutes and the United Kingdom's Satellite Applications Catapult are examples of such organizations (Appendix C). Some experts have proposed the creation of a similar non-profit either within or outside of NASA to coordinate and support the commercial development of space (Davidson 2010a). Table D.1 lists the economic policy instruments we have discussed in this appendix.

**Table D.1. Potential Economic Policy Instruments for Space**

<b>Category</b>	<b>Instrument</b>
<b>Capital subsidies</b>	Equity subsidies
	Government loans and loan guarantees (e.g., Federal space bank)
	Tax incentives (e.g., zero G zero tax)
<b>R&amp;D subsidies</b>	Research grants
	Small business innovation research grants
	Cooperative agreements
	Cooperative research and development agreements
<b>Input subsidies</b>	Access to ground facilities (e.g., enhanced use leases)
	Access to the International Space Station and space for R&D and testing (e.g., Facilitated Access to the Space Environment for Technology Development and Training)
	Assistance from technology transfer offices
	Assistance with licensing NASA patents
<b>Contracting mechanisms</b>	Cost-plus contracts
	Fixed-price contracts
	Advance purchase agreements
	Funded Space Act agreements
	Reimbursable Space Act agreements
	Non-reimbursable Space Act agreements
<b>Facilitating organizations</b>	Prizes, challenges, competitions
	Organizations to facilitate R&D
	Organizations to facilitate procurement
	Space authority
	Independent government funded organization to support the development of space industries



## **Appendix E.**

# **Establishing a Government Strategic Investment Fund**

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To outline how the U.S. Government might set up and organize a strategic investment fund for space, STPI drew on the experiences of previous technology strategic investment funds sponsored by the United States and other governments, as well as insight from interviews and the literature, to derive the recommendations presented in this appendix.

### **Organization of the Fund**

**If a strategic investment fund is created, it should be set up as a non-profit organization, not as a government-owned company or part of a government agency.** A non-profit organization operates outside the government and is therefore better able to focus on its core mission without being subject to government policy shifts. The non-profit status of the organization should forestall the fund from pursuing rate of return, helping it to stay focused on its mission for the sponsoring agency.

**The fund must have Executive and bipartisan congressional support.** In-Q-Tel has succeeded in part because it has Executive and bipartisan congressional support. RPC was disbanded because it failed to garner the necessary political support from the executive branch and Congress. A government strategic investment fund for space, were it to be created, would need strong bipartisan support from the President and Congress. It would benefit from a well-connected, powerful board, respected by the Administration, Congress, space VC firms, and space start-ups to help ensure this support.

Funding could be provided through a branch of an existing agency—for example, NASA’s Space Technology Mission Directorate (STMD). Alternatively, it could be funded by several agencies that wish to procure commercial technology for use in or for space. These agencies could include not just agencies traditionally interested in space such as the Department of Defense, the National Geospatial-Intelligence Agency, the National Oceanic and Atmospheric Administration, and the National Reconnaissance Office, but agencies that have not traditionally funded space and may benefit from the use of new space technologies and products, such as the National Institutes of Health, National Science Foundation, the Department of the Interior, and the Department of Agriculture. Each agency would submit problem statements in accordance with their contributions to the fund and the ability of the fund to make investments.

**Instead of creating its own fund, NASA could provide additional funding to In-Q-Tel for investments in space technologies.** In-Q-Tel already invests in space technologies of interest to the IC. Additional funding from NASA could be used to expand this program. There are costs and benefits to this approach, the principal cost being that NASA's interests would likely be subordinated to those of the IC. The major benefits would be the elimination of the overhead costs of establishing and operating a new fund, as well as the opportunity to leverage the experience and expertise of In-Q-Tel's staff.

## **Operation of the Fund**

The fund should have direct access to the offices within the customer agencies that will purchase and use the space technologies in which the fund is investing so as to remain fully aware of customer needs. The fund would need to set well-defined targets for technology acquisitions and avoid duplicating government R&D.

**The fund should operate like a VC firm.** It should only invest in companies that plan to bring their technologies to market within 4 to 7 years. If the timeline for bringing the product to market is longer than 7 years, the sponsoring agency should use other mechanisms, like R&D grants, to develop it. The product should have commercial prospects: at least two-thirds of sales should be to non-government customers.

**The fund should always co-invest with private VC firms and should remain a minority investor.** Investments should be kept modest both in dollar amounts and as a fraction of total investment in the company.

The fund should be evaluated periodically, but some time should be given to allow the fund to operate before doing so. The fund's management should be judged on how well it meets the needs of the sponsoring organizations and how often and effectively technologies are integrated into the sponsoring organizations—not on return on investment.

## References

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- Army Venture Capital Initiative (AVCI). 2015. "AVCI". <http://armyvci.org>
- Audretsch, D. 1995. *Innovation and industry evolution*. Cambridge, MA: MIT Press.
- Australian Government: Department of Innovation, Industry, Science and Research. 2011. "Innovation Investment Fund Program Progress Report." September. Canberra, Australia.
- Avnimelech, G. and M. Teubal. 2006. "Creating venture capital industries that co-evolve with high tech: Insights from an extended industry life cycle perspective of the Israeli experience." *Research Policy* 35(10): 1477–1498. <https://myweb.rollins.edu/tlairson/pek/ventcapcoev.pdf>
- Bailey, Natalya. 2018. "Venture Capitalist Trends for NewSpace Companies." *Satellite Today*. August. <http://interactive.satellitetoday.com/via/august-2018/venture-capitalist-trends-for-newspace-companies/>
- Bajari, Patrick and Steve Tadelis. 2001. "Incentives versus Transaction Costs: A Theory of Procurement Contracts." *RAND Journal of Economics*. 32 (3). Santa Monica, California.
- Bender, Bryan. 2018. "Space tugs and fuel depots around the moon?" *Politico*. July 13. <https://www.politico.com/story/2018/07/13/dallas-bienhoff-cislunar-space-development-company-718457>
- Bennis, W., and P. W. Biederman. 1997. *Organizing Genius: The Secrets of Creative Collaboration*. Addison-Wesley Publishing.
- Borda, Gary. n.d. "Opening Statement." as cited in Myers, Gary. 2006. "Symposium Transcript. Intellectual Property Resources in and for Space: The Practitioner's Experience." *Journal of Space Law* 32 (2006): 394.
- Boyle, Alan. 2018. "Acting NASA administrator's parting words: Accept risk wisely, with 'eyes wide open.'" *GeekWire*. April 17. <https://www.geekwire.com/2018/acting-nasa-chiefs-parting-words-accept-risk-wisely-eyes-wide-open/>.
- Bryce Space and Technology. 2017. "State of the Satellite Industry Report."
- . 2018. "Start-Up Space: Update on Investment in Commercial Space Ventures." [https://brycetech.com/downloads/Bryce\\_Start\\_Up\\_Space\\_2018.pdf](https://brycetech.com/downloads/Bryce_Start_Up_Space_2018.pdf)
- Burrington, Ingrid. 2018. "New Mexico's Sad Bet on Space Exploration." *The Atlantic*. March 2. <https://www.theatlantic.com/technology/archive/2018/03/new-mexicos-sad-bet-on-space-exploration/554243/>

- Business Executives for National Security (BENS). 2001. *Accelerating the Acquisition and Implementation of New Technologies for Intelligence: The Report of the Independent Panel on the Central Intelligence Agency In-Q-Tel Venture*.  
<https://www.bens.org/document.doc?id=31>
- Caprio, Gerard, Jonathan Fiechter, Michael Pomerleano, and Robert E. Litan. 2004. “The Future of State-Owned Financial Institutions.” September 1. The Brookings Institution. Washington, D.C. <https://www.brookings.edu/research/the-future-of-state-owned-financial-institutions/>
- Carberry, Sean. 2017. “‘Full speed’ at DIUx, says chief.” FCW. April 21.  
<https://fcw.com/articles/2017/04/21/diux-ndaa-funding-carberry.aspx>
- Carpenter, R., and Petersen, B. 2002. “Is the growth of small firms constrained by internal finance?” *Review of Economics and Statistics*, 84, 298–309.
- Cassidy, Susan, Jennifer Plitsch, and Tyler Evans. 2018. “DIUx and DoD Other Transaction Prototype Agreements: The Fast Track to DoD Funding.” *National Law Review*. February 22. <https://www.natlawreview.com/article/diux-and-dod-other-transaction-prototype-agreements-fast-track-to-dod-funding>
- CB Insights. 2016. “12 Early- And Mid-Stage Startups Backed By The CIA, Pentagon, And US Army.” September 6. <https://www.cbinsights.com/research/intelligence-military-startup-investors/>
- Christensen, Carissa, Mike French, and Raphael Perrino. 2018. *Start-up Space: Update on Investment in Commercial Space Ventures*. Bryce Space and Technology.
- Colombo, Massimo G., Douglas J. Cumming, and Silvio Vismara. December 6 2014. “Governmental venture capital for innovative young firms.” *Journal of Technology Transfer* (2016) 41:10–24. DOI 10.1007/s10961-014-9380-9
- Crane, Keith, B. Corbin, Bhavya Lal, Reina Buenconsejo, Danielle Piskorz, Annalisa Weigel. 2017. *Market Analysis of a Privately Owned and Operated Space Station*. IDA paper P-8247. IDA Science and Technology Policy Institute. Alexandria, Virginia.
- Crunchbase. 2018. “OnPoint Technologies Recent News & Activity.”  
<https://www.crunchbase.com/organization/onpoint/timeline/timeline>
- Crusan, Jason, Marybeth Edeen, Kevin Grohs, and Darren Samplatsky. 2011. “Spaceflight Hardware on a Service Contract.” *ASK Magazine*. February 2. NASA.  
<https://appel.nasa.gov/category/ask-magazine/page/22/>
- Cumming, D. J. and J. G. MacIntosh. 2006. “Crowding out private equity: Canadian evidence.” *Journal of Business Venturing* 21(5): 569–609.
- Cumming, D. J., Siegel, D., Sapienza, H., and Wright, M. 2009. “International entrepreneurship: Managerial and public policy implications.” *Strategic Entrepreneurship Journal*, 3, 283–296.
- Davenport, Christian, and Aaron Gregg. 2018. “Faced with increased criticism, Pentagon slashes cloud computing contract awarded to an Amazon partner.” March 5. *The Washington Post*. Washington, D.C. <https://www.washingtonpost.com/news/the->



switch/wp/2018/03/05/faced-with-increased-criticism-pentagon-slashes-cloud-computing-contract-awarded-to-an-amazon-partner/?noredirect=on&utm\_term=.62c9623f2cea

Davidson, Hoyt, John Stone, Ian Fichtenbaum. 2010a. *Supporting Commercial Space Development: Part 1: Support Alternatives versus Investor Risk Perceptions & Tolerances*. November. Near Earth LLC. New York, New York.

———. 2010b. *Supporting Commercial Space Development: Part 2: Support Alternatives versus NASA Commercialization Priorities*. November. Near Earth LLC. New York, New York.

Department of Energy (DOE). 2016. “Energy Department Analysis: Loan Guarantee Program Launched Utility-Scale Photovoltaic Solar Market in the United States.” October 14. <https://energy.gov/articles/energy-department-analysis-loan-guarantee-program-launched-utility-scale-photovoltaic-solar>

DOE Loan Programs Office. n.d. “Portfolio Projects.” DOE. Accessed February 26, 2017. <https://energy.gov/lpo/portfolio/portfolio-projects>

Dunn, Richard. 2009. “Injecting New Ideas and New Approaches in Defense Systems: Are ‘Other Transactions’ an Answer?” Excerpt from the proceedings of the 6th Annual Acquisition Research Symposium of the Naval Postgraduate School, Monterey, CA.

European Commission. 2016. “Commission and EIF seek Pan-European Venture Capital Fund-of-Funds Managers.” <http://ec.europa.eu/research/index.cfm?pg=newsalert&year=2016&na=na-081116>

European Space Agency. n.d. “Satellite Applications Catapult (UK).” Accessed March 6, 2018. <http://www.esa-tec.eu/satellite-applications-catapult/>

EY. November 17, 2017. *UK SBS PS17086 Catapult Network Review*. Reliance Restricted—For Public Release.

Federal Aviation Administration (FAA). n.d. *State Support for Commercial Space Activities*. [https://www.faa.gov/about/office\\_org/headquarters\\_offices/ast/media/State%20Support%20for%20Commercial%20Space%20Activities.pdf](https://www.faa.gov/about/office_org/headquarters_offices/ast/media/State%20Support%20for%20Commercial%20Space%20Activities.pdf)

Fehrenbacher, Katie. 2015. “Why the Solyndra mistake is still important to remember.” *Fortune*. August 27. <http://fortune.com/2015/08/27/remember-solyndra-mistake/>

Foundation for the National Institutes of Health. n.d. “Brochure for Foundation for the National Institutes of Health.” <https://fnih.org/sites/default/files/final/FNIH%20Capabilities%20Brochure.pdf>

Foust, Jeff. 2011. “Albrecht: NASA has become a “risk-averse feudal empire.” *Space Politics*. November 11. <http://www.spacepolitics.com/2011/11/11/albrecht-nasa-has-become-a-risk-averse-feudal-empire/>

———. 2016. “ULA’s Lunar Vision: Cislunar 1000.” *SpaceNews Magazine*. May 23. <http://www.spacenewsmag.com/feature/ulas-lunar-vision/>

- Fraunhofer Society. 2010. "Annual Report 2010."  
<http://www.fraunhofer.de/en/publications/annual-report.html>.
- GAVI. 2009. "GAVI partners fulfill promise to fight pneumococcal disease." June 12.  
<https://www.gavi.org/library/news/press-releases/2009/gavi-partners-fulfill-promise-to-fight-pneumococcal-disease/>
- Glennerster, Rachel, Michael Kremer, and Heidi Williams. 2006. "Creating Markets for Vaccines." *Innovations*. Winter.  
<https://www.mitpressjournals.org/doi/pdf/10.1162/itgg.2006.1.1.67>
- Government Accountability Office (GAO). 2018. "Decision on Matter of Oracle America, Inc." May 31. B-416061. <https://www.gao.gov/assets/700/692327.pdf>
- . 2017a. *NASA Assessments of Major Projects*. GAO-17-303SP. Washington, DC: Government Accountability Office, May.  
<http://www.gao.gov/assets/690/684626.pdf>.
- . 2017b. *NASA Human Space Exploration: Delay Likely for First Exploration Mission*. GAO-17-414. Washington, DC: Government Accountability Office, April.  
<https://www.gao.gov/assets/690/684360.pdf>.
- . 2016. *Orion Multi-purpose Crew Vehicle: Action Needed to Improve Visibility into Cost, Schedule, and Capacity to Resolve Technical Challenges*. GAO-16-620. Washington, DC: Government Accountability Office, July.  
<https://www.gao.gov/assets/680/678704.pdf>.
- Harmon, Bruce R. and Scott A. Arnold. 2013. *Choice of Contract Type and Other Policy Initiatives for Reducing Contract Prices*. IDA Document NS D-5002. Institute for Defense Analyses. Alexandria, Virginia.
- Kliman, Daniel and Brendan Thomas-Noone. 2018. "Now is the time to take DIUx global." *DefenseNews*. May 24.  
<https://www.defensenews.com/opinion/commentary/2018/05/23/now-is-the-time-to-take-diux-global/>
- Lal, Bhavya, Elena de la Rosa Blanco, Jonathan R. Behrens, Benjamin A. Corbin, E. K. Green, Alyssa J. Picard, and Asha Balakrishnan. 2017. *Global Trends in Small Satellites*. IDA Science and Technology Policy Institute. Alexandria, Virginia.
- Launius, Roger D. 2014. *Historical Analogs for the Stimulation of Space Commerce*. National Aeronautics and Space Administration. Washington, D.C.
- Launius, Roger D. and Howard E. McCurdy (eds). 2018. *NASA Spaceflight: A History of Innovation*. [https://books.google.com/books?id=aM5DwAAQBAJ&pg=PA268&lpg=PA268&dq=NASA+risk+averse&source=bl&ots=XdXcfnXYV-&sig=CufAEVMU\\_Xtp7mq2QcDNTIBq2Eg&hl=en&sa=X&ved=0ahUKEwiV-u7Px4rcAhUQ11MKHafiBgA4ChDoAQhXMAg#v=onepage&q=NASA%20risk%20averse&f=false](https://books.google.com/books?id=aM5DwAAQBAJ&pg=PA268&lpg=PA268&dq=NASA+risk+averse&source=bl&ots=XdXcfnXYV-&sig=CufAEVMU_Xtp7mq2QcDNTIBq2Eg&hl=en&sa=X&ved=0ahUKEwiV-u7Px4rcAhUQ11MKHafiBgA4ChDoAQhXMAg#v=onepage&q=NASA%20risk%20averse&f=false)

- Lockyer, Lisa. 2005. "Presentation on Innovative Partnerships Program." Innovative Partnerships. NASA. October 20. <http://nasawatch.com/archives/2006/02/red-planet-capital.html>
- Lofquist, Tayler. 2011. "A History of Red Planet Capital, Inc." The Fellow Review. Center for the Study of the Presidency and Congress. Washington, D.C.
- Lord, Ellen. 2017. "Current State of Defense Acquisition and Associated Reforms: Testimony before the Committee on Armed Services United States Senate." 115<sup>th</sup> Congress (December 7).
- McAlister, Phil. 2016. "NASA Collaboration with SpaceX's Red Dragon." FISO Telecon. September 21.
- Messier, Doug. 2017. "NASA Space Act Agreements with Virgin Galactic, Moon Express, NanoRacks and More." *Parabolic Arc*. September 5. <http://www.parabolicarc.com/2017/09/05/moon-express-virgin-group-saas/>
- Minniti, Maria. 2008. "The Role of Government Policy on Entrepreneurial Activity: Productive, Unproductive, or Destructive?" *Entrepreneurship Theory and Practice*. <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1540-6520.2008.00255.x>
- National Aeronautics and Space Administration (NASA). 2014. "Broad Agency Announcement NNH15ZCQ001K: Next Space Technologies for Exploration Partnerships (NextSTEP) Amendment 1." [https://www.nasa.gov/sites/default/files/atoms/files/nextstep-baa\\_2014-11-17\\_am1.pdf](https://www.nasa.gov/sites/default/files/atoms/files/nextstep-baa_2014-11-17_am1.pdf)
- . 2014a. *Commercial Orbital Transportation Services: A New Era in Spaceflight*. February. <https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf>
- . 2018. "CubeSat Launch Initiative." NASA.gov [https://www.nasa.gov/directorates/heo/home/CubeSats\\_initiative](https://www.nasa.gov/directorates/heo/home/CubeSats_initiative)
- . 2004. "Fiscal Year 2004 Performance and Accountability Report." NP-2004-11-385-HQ. NASA Headquarters Washington, DC.
- . 2005. "Fiscal Year 2005 Performance and Accountability Report." NP-2005-11-417-HQ. NASA Headquarters Washington, DC.
- . 2018. "Fiscal Year 2019 Budget Estimates." [https://www.nasa.gov/sites/default/files/atoms/files/fy19\\_nasa\\_budget\\_estimates.pdf](https://www.nasa.gov/sites/default/files/atoms/files/fy19_nasa_budget_estimates.pdf)
- . 2017. "List of Active Space Act Agreements (as of December 31, 2017) with Domestic Commercial, State and Local Government, and Non-profit Partners." December 31. [https://www.nasa.gov/sites/default/files/atoms/files/domestic\\_nonfed\\_saas\\_active\\_as\\_of\\_12\\_31\\_2017.pdf](https://www.nasa.gov/sites/default/files/atoms/files/domestic_nonfed_saas_active_as_of_12_31_2017.pdf)
- . 2018. "NASA Awards Contract for Facilities Operations, Maintenance Services." Contract Release C18-004. February 20. <https://www.nasa.gov/press-release/nasa-awards-contract-for-facilities-operations-maintenance-services>

- . 2014b. “NASA Grant and Cooperative Agreement Handbook.” NPR 5800.1. Section A and D.
- . n.d. a. “NASA Innovative Advanced Concepts (NIAC) Program.” <https://www.nasa.gov/directorates/spacetech/niac/index.html>
- . n.d. b. “Public-Private Partnerships: Tipping Point Solicitations & Awards.” [https://www.nasa.gov/directorates/spacetech/solicitations/tipping\\_points](https://www.nasa.gov/directorates/spacetech/solicitations/tipping_points)
- . n.d. c. “Technology Readiness Level Definitions.” [https://www.nasa.gov/pdf/458490main\\_TRL\\_Definitions.pdf](https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf)
- . 2015. “Water Production in Space: Thirsting For A Solution.” October 21. [https://www.nasa.gov/mission\\_pages/station/research/benefits/water\\_in\\_space](https://www.nasa.gov/mission_pages/station/research/benefits/water_in_space)
- NASA Advanced Exploration Systems. 2017. “Lunar CATALYST.” October 31. <https://www.nasa.gov/lunarcatalyst>
- NASA Office of Inspector General. 2018. “Audit of Commercial Resupply Services to the International Space Station.” April. <https://oig.nasa.gov/docs/IG-18-016.pdf>
- . 2014. “NASA’s Use of Space Act Agreements.” IG-14-020. Washington, D.C.: NASA, June 5. <https://oig.nasa.gov/audits/reports/FY14/IG-14-020.pdf>
- National Aeronautics and Space Administration Transition Authorization Act of 2017. 2017. Pub. L. 115-10. 131 Stat. 18. <https://www.congress.gov/bill/115th-congress/senate-bill/442/text>.
- National Institute of Standards and Technology (NIST). 2016. “Federal Laboratory Technology Transfer Fiscal Year 2014: Summary Report to the President and the Congress.” October.
- National Science Foundation (NSF). 2018. “FY 2017 Performance and Financial Highlights.” <https://www.nsf.gov/pubs/2018/nsf18021/nsf18021.pdf>
- Nicosia, Nancy. 2002. *Essays on Competitive Contracting: An Application to the Mass Transit Industry*. PhD Dissertation. Department of Economics. University of California-Berkeley.
- Office of Science and Technology Policy (OSTP). 2017. *Implementation of Federal Prize Authority: Fiscal Year 2016 Progress Report*. Washington, DC.
- Osama, Athar. 2008. “Washington Goes to Sand Hill Road: The Federal Government’s Forays into the Venture Capital Industry.” F&G Brief (1). Woodrow Wilson International Center for Scholars Foresight and Governance Project. January.
- Page, Holden. 2018. “What Big Tech Has Acquired From In-Q-Tel, The CIA’s VC Arm.” *Crunchbase*. June 8. <https://news.crunchbase.com/news/what-big-tech-has-acquired-from-in-q-tel-the-cias-vc-arm/>
- Pegrum, Dudley F. 1963. *Transportation: Economics and Public Policy*. Richard D. Irwin, Inc. Homewood, IL.
- Peña, V., S. Howieson, B. Lal, J. Behrens, B. Zuckerman, M. Merrill, and J. Zhu. *Early Stage Research and Technology at U.S. Federal Government Agencies*. Document D-8481, April 2017. IDA Science and Technology Policy Institute.

- Pound, Jesse. 2016. "The space wait continues for Oklahoma town." *NewsOK*. August 1. <https://newsok.com/article/5511901/the-space-wait-continues-for-oklahoma-town>
- Roberts, Jim and Terry Lambing. 2014. "Innovative Business Agreements and Related Cost & Pricing Methods at NASA in Support of New Commercial Programs." NASA Kennedy Space Center Office of CFO. June. ICEAA National Conference Presentation. <http://www.iceaaonline.com/ready/wp-content/uploads/2014/06/MG-4-Presentation-Innovative-Business-Agreements-and-Related-Cost-Pricing-Methods-at-NASA-in-Support-of-New-Commercial-Programs.pdf>
- Satellite Applications Catapult. "Call for ESA Technology Transfer Network Broker in Germany." December 2013. <https://sa.catapult.org.uk/news-events-gallery/news/call-for-esa-technology-transfer-network-broker-in-germany/>
- Sen, A. 2014a. "Organized to Transform: What NOAA Can Learn From DARPA, ARPA-E and ATP." [https://www.researchgate.net/publication/273128573\\_Organized\\_to\\_Transform\\_What\\_NOAA\\_Can\\_Learn\\_From\\_DARPA\\_ARPA-E\\_and\\_ATP](https://www.researchgate.net/publication/273128573_Organized_to_Transform_What_NOAA_Can_Learn_From_DARPA_ARPA-E_and_ATP)
- . 2014b. "Transformative Innovation: What 'Totally Radical' and 'Island-Bridge' Mean for NOAA Research," Dissertation, George Washington University.
- Small Business Administration (SBA). n.d. "Small Business Investment Company Program Overview." <https://www.sba.gov/sbic/general-information/program-overview>.
- . "About SBIR." Accessed March 26, 2019. <https://www.sbir.gov/about/about-sbir>
- The Tauri Group. 2016. *Start-Up Space: Rising Investment in Commercial Space Ventures*. January.
- Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty). 1967. 18 UST 2410, 610 UNTS 205, 6 ILM 386 (1967).
- United States Congress. 2017. *2017 National Defense Authorization Act*.
- Virginia Commercial Space Flight Authority. 2012. *Strategic Plan 2012-2017*. December 1. <https://rga.lis.virginia.gov/Published/2012/RD363/PDF>
- Webb, Tim, Christopher Guo, Jennifer Lamping Lewis, and Daniel Egel. 2014. *Venture Capital and Strategic Investment for Developing Government Mission Capabilities*. RAND Corporation.
- West, Heidi. 2018. "AFWERX is smart risk for innovative solutions." U.S. Air Force. January 12. <http://www.af.mil/News/Article-Display/Article/1414478/afwerx-is-smart-risk-for-innovative-solutions/>
- Williams, Lauren. 2018. "FY19 budget calls for big boost for DIUx." Defense Systems. Feb 12. <https://defensesystems.com/articles/2018/02/13/budget-williams-dod.aspx>
- Williamson, Oliver E. 1983. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Macmillan Publishers. ISBN 978-0029353608.
- . 1996. *Industrial Organization*. Elgar Pub. ISBN 9781858984889.

- White House. 2010. "National Space Policy of the United States of America." June 28. The White House. Washington, D.C.  
[https://obamawhitehouse.archives.gov/sites/default/files/national\\_space\\_policy\\_6-28-10.pdf](https://obamawhitehouse.archives.gov/sites/default/files/national_space_policy_6-28-10.pdf)
- . 2017. "Presidential Memorandum on Reinvigorating America's Human Space Exploration Program." December 11. The White House. Washington, D.C.  
<https://www.whitehouse.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/>
- . 2018. "Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space." May 24. <https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/>
- . 1991. "U.S. Commercial Space Policy Guidelines." NSPD-3. February 11.  
<http://www.au.af.mil/au/awc/awcgate/nspd3.htm>
- Zapata, Edgar. 2017. "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions." NASA. Washington, D.C.  
<https://ntrs.nasa.gov/search.jsp?R=20170008895> 2017-11-13T20:01:09+00:
- Zider, Bob. 1998. "How Venture Capital Works." *Harvard Business Review*. November-December. <https://hbr.org/1998/11/how-venture-capital-work>

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