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PUBLIC-PRIVATE PARTNERSHIPS: STIMULATING INNOVATION IN THE SPACE SECTOR

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Summary

Governments seeking to expand their capabilities for satellite communications, navigation, Earth monitoring, exploration systems, and other space applications recognize the significant role that the private sector can play in delivering these capabilities at reduced cost and risk through public-private partnerships (P3s). The government sector generally wants to retain some level of control over key capabilities. P3s can provide significant advantages to government agencies by leveraging commercial efficiencies and innovation while sharing risk with the private sector in exchange for profits linked to performance. As space-related P3s proliferate for capital intensive projects and public-private data-sharing models, understanding key challenges and underlying economic arguments from real-world case studies can help lay the groundwork for future success.

Background

A public-private partnership (P3) is an arrangement between a public body or agency (federal, state or local) and a private sector entity to deliver a collective good—a beneficial facility, product, capability or service for use by the public. Both parties commit to shared risk and investment in an agreement where risks and rewards are shifted to the private entity.[1] Each P3 has unique characteristics to accommodate the requirements and operational styles of different organizations as they pool their interests over a defined term. As former NASA Administrator Michael Griffin has expressed it, "Developing public-private partnerships is an art form. It is all about the deal and all stakeholders must have skin in the game."[2] There are many reasons why government decision-makers may turn to a P3 to fill a public sector need. The government might be seeking to provide better public services by introducing commercial sector know-how, innovation or efficiencies. Perhaps the public sector lacks the capacity or bandwidth to deliver services or infrastructure in a timely manner. Or maybe, the government faces budget constraints and prefers to reduce upfront capital exposure. Ideally, a P3 provides a win/win whereby the government partner receives private capital investment, innovation or know-how and the private partner reaps profits.

This paper:

- explores reasons why public sector space stakeholders may want to pursue a P3 model for delivering services, infrastructure, and innovation
- proposes a phased approach for strategizing, planning, and implementing P3 delivery models along with guiding principles of neutrality, transparency, accountability, and governance.
- examines case studies, including successful and less than ideal P3 scenarios (e.g. where the government gives up too much control or where the private sector assumes too much risk), and offers lessons which can guide future decision-makers to develop better P3 delivery models.

Both the Obama and Trump administrations emphasized the importance of private investment when considering how to provide a public or collective good such as critical infrastructure. This emphasis extends to space as the National Space Policy of 2010* and the National Aeronautics and Space Act of 1958† (as amended) support the use of P3s to meet the U.S. government's objectives to promote a robust and competitive commercial space sector.

P3s are traditionally associated with public infrastructure such as toll roads, wastewater treatment, and public buildings. However, innovative partnerships, drawing upon the strengths of both government and commercial companies, address a broad range of sectors well beyond transportation, including space. This variety explains why P3s have no single, widely accepted recipe for success.

P3: Key Objectives

When a public-sector entity considers a P3 arrangement, it should articulate the objectives. Within the space sector this could include:

- Mission Support—to advance science, space exploration, or national security and defense.
- Functional Support—such as communications, Earth observation, space logistics.
- Technology Advancement—such as prototyping or developing new technologies.
- Space Industrial Base—to promote a competitive and robust commercial space sector

Traditional public infrastructure projects are structured across a range of P3 project delivery models to provide functional support—from operation and maintenance to concession agreements (see Figure 1). By contrast, space industry P3 delivery models typically include various arrangements for sharing risk and know how through cooperative research, Space Act Agreements (SAAs), or longer term development agreements. The current emphasis appears to be leveraging commercial sector innovation and agility (see Figure 2). Perhaps over time the space sector will introduce more traditional P3 functional support models such as:

- **Example: Future Low Earth Orbit (LEO) Modules/ Habitat ("Concession" P3 Model).** NASA could potentially apply a concession arrangement to replace the ISS with one or more commercial modules. The space module(s) could be owned by the U.S. government and designed, built and operated by one or more commercial companies for a specific period of time. Several commercial companies, including Axiom Space, Bigelow Aerospace and NanoRacks, have already expressed interest in the provisioning of space modules to replace the existing International Space Station (ISS). Note that if these commercial modules were ***owned***, built, operated and maintained by the commercial sector then this would shift the business model from a P3 model to full privatization.
- **Example: Future Space Tug ("Design, Build, Finance & Maintain" P3 Model).** A "space tug" satellite could be built and financed by the commercial sector. The P3 agreement could guarantee the space tug a certain amount of business over a specified period of time. Near the end of life, the space tug could revert to being wholly owned by the commercial company, thereby offloading "end of life" risk such as responsibilities for decommissioning and de-orbiting. In return, the commercial sector, could attract additional revenue streams from other customers for as long as practical before end of life disposal.

For now, however, the space sector is undergoing rapid change, and it makes sense that government/commercial sector research and innovation collaborations are popular. In considering applicability to the space sector, planners should be aware of the need to configure each P3 to accommodate the needs, abilities, resources, and objectives of the parties involved. Planners should also be aware of P3s' mixed record of success.

* The National Space Policy of 2010 encourages federal departments and agencies to: actively explore the use of inventive, nontraditional arrangements for acquiring commercial space goods and services to meet United States Government requirements, including measures such as public-private partnerships, hosting government capabilities on commercial spacecraft, and purchasing scientific or operational data products from commercial satellite operators in support of government missions.

† 51 USC § 20112(a) notes that the Administration shall: (4) seek and encourage, to the maximum extent possible, the fullest commercial use of space; and (5) encourage and provide for Federal Government use of commercially provided space services and hardware, consistent with the requirements of the Federal Government.

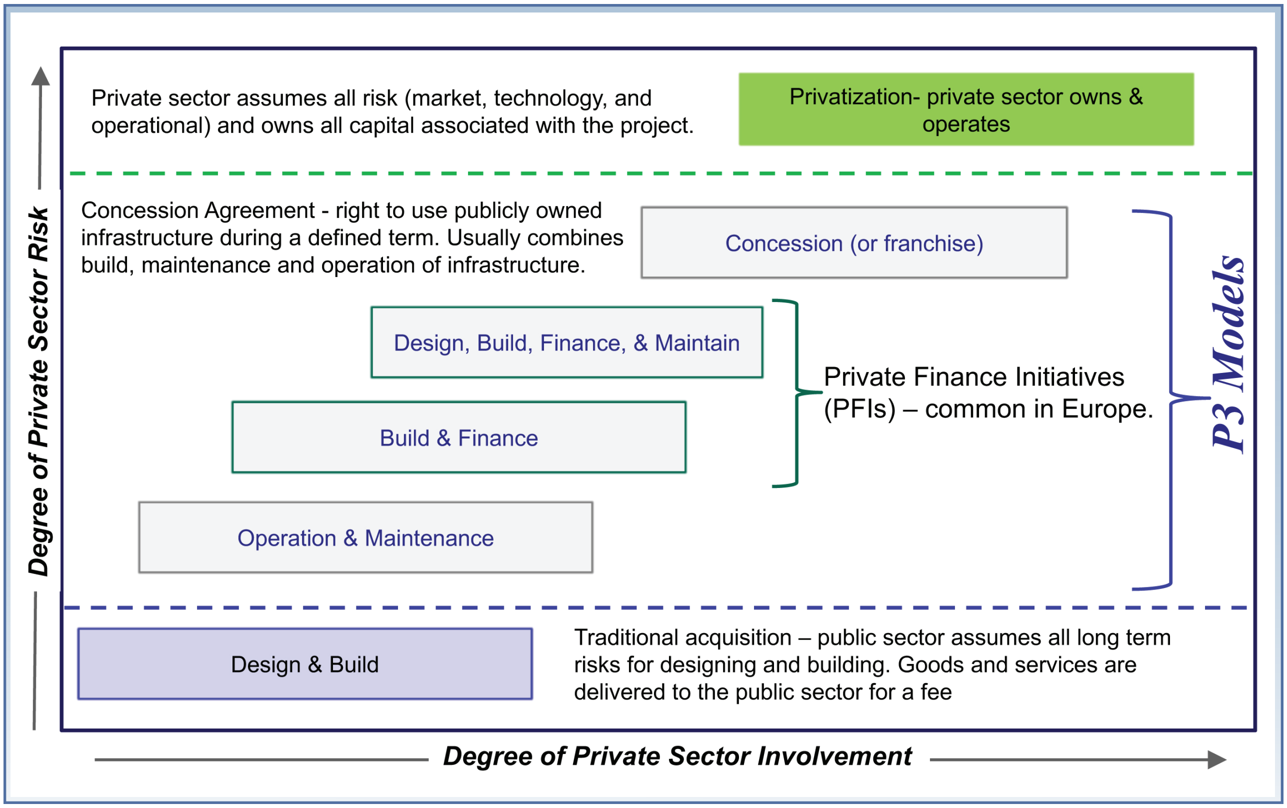

Figure 1: Traditional Public Infrastructure Sector: P3 project delivery models range from private sector design and build to full privatization. Source: Adapted from the Canadian Council for Public Private Partnerships.

P3: Key Strategies

Typically, P3s are pursued by governments for the following reasons:

- **Efficiency Gains.** Improve operations management and leverage the profit-driven efficiencies that the private sector offers in terms of schedule, costs and experience – including state of the art technology.
- **Reduce Life Cycle Costs.** Seek the lowest cost alternatives over the lifecycle of an asset. Attain Value for Money (VfM)*
- **Transfer Risks.** Operational and project execution risks are transferred from the government to the private sector which is often better able to contain costs and manage key milestones on schedule.

In addition to the above three public sector goals which are applicable to almost any industrial sector, the space sector recognizes the importance of P3s to meet certain strategic space imperatives:

- **Innovation and Technology "Spin-Ins."** P3 models can be structured to encourage innovation. Historically the space industry has spun off new technologies such as precision GPS, memory foam, and digital camera sensors. Now the space sector is attracting investors from other industries and realizing the benefits of "spin-in" technologies such as cloud computing, 3D printing, and artificial intelligence. NASA is currently seeking game changing technologies for a range of applications (see "NASA Tipping Point Space Technologies," page 8).
- **Alignment with Space Policy Goals.** The National Space Policy of 2010[3] encourages the use of P3s to promote a "robust commercial space industry." NASA is now encouraging entrepreneurship, catalyzing commercial space development, and strengthening the

* Governments often apply Value for Money (VfM) analysis to determine whether a P3 makes sense. VfM compares the net present value of the life-cycle procurement cost if the project were to be funded, financed, built, operated, and maintained by the public sponsor (the "Public Sector Comparator") with the net present value of the likely private bid under the P3 option (the "shadow bid").

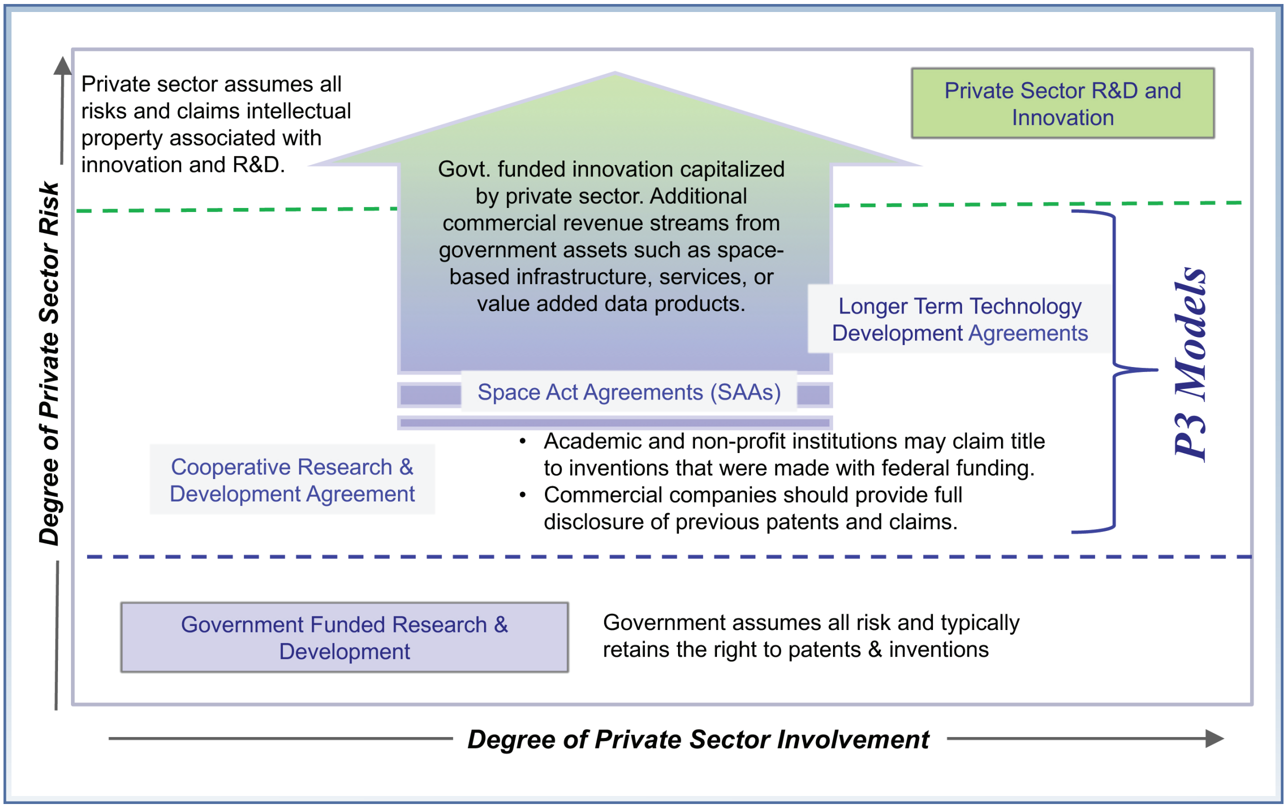

Figure 2: Space Sector P3 Delivery Models: The space sector is focused on sharing innovation and risk with the private sector. There is a fluid range of risk and participation between the public and private sector. Various types of cooperative grants, space act agreements, and long term development agreements have the potential to "spin-off" additional revenue streams for the commercial sector. This may also include sharing or assigning intellectual property or data rights to the private sector for further capitalization.

U.S. space industrial base through public-private partnerships.

The private sector pursues P3s for the following reasons:

- **Return on Investment (ROI).** In exchange for taking on public sector risk, the private sector can expect a return on investment (ROI). Typically, the higher the risk then the greater the expected ROI.
- **Gain Competitive Advantage.** Leverage commercial technologies and intellectual property through a P3 arrangement to mature and advance the technology and gain market traction with key public sector customers.
- **Create Additional Revenue Streams.** The private sector has the ability to create additional revenue streams from unique government assets such as space-based infrastructure, services, or data. For instance, a private sector company, such as Accuweather, repackages large amounts of National Weather Service (NWS) weather data and adds value-added services and analytics for a fee to the private sector. Another example is the potential for launch providers to use the same launch vehicles that might serve NASA missions to carry tourists to space. A productive co-existence is possible between private sector profit interests and public sector mission needs.

"Government must understand what motivates industry and assume an MBA perspective—what is acceptable in terms of risk, payback, and overall capital investment?"

—Michael Griffin, former NASA Administrator

P3: Key Elements

The term "Public-Private Partnership" is often used, incorrectly, as interchangeable with traditional private sector procurement contracts, causing many in both the public and private sector to confuse the issues. The key elements of a P3 model are different from a traditional procurement model in the following ways:

- **Funding.** Public funds are not dispersed at outset. Instead, a P3 private partner receives periodic payments based upon reaching specific milestones, perhaps tied to technology maturation, technological advancement, or a contractual formula.
- **Duration.** P3s often extend beyond construction or deployment and often include operations and maintenance.
- **Requirements.** Performance versus Design. P3s should focus on performance rather than design requirements. Performance requirements are based upon stakeholder expectations and define what needs to be accomplished to meet the objectives of the project. There is often less potential for a commercial partner to innovate and optimize when striving to meet overly specific design details.
- **Risk Allocation.** Traditional procurement risk is borne by the public sector. P3s, on the other hand, offer a way for risk to be shared with the private sector.

Intellectual Property and Data Rights

What are the provisions for intellectual property rights for the results of joint research or a P3? The answer: it depends. However, NASA's Human Exploration & Operations Mission Directorate notes that a critical success factor for the Commercial Orbital Transportation Services (COTS) program using a Space Act Agreement (SAA) implementation, is the ability for private companies to "get their ROI" or return on investment. These private sector rights to intellectual property can help reap substantial commercial contracts downstream. NASA notes that:

> When engaging in a public-private partnership, it can be important for the commercial partner to retain ownership of the products and be able to sell to a broader market. In this case, forfeiting the government's rights to intellectual property was a key component of establishing the PPP.[4]

A case-by-case analysis is required to determine whether work to be performed by the Partner (which could be commercial, academic or other) under the SAA is being performed for NASA (as opposed to being performed by the commercial partner for its own benefit). If the Partner is not performing work under the SAA for NASA, but is instead participating in the collaborative activities for its own benefit, then NASA's title-taking authority does not apply. Even under those situations where NASA's title-taking authority applies, there are waiver provisions. And NASA "liberally grants waivers to SAA partners for commercializing the waived invention." Since NASA is entitled to a government purpose license of the technology, they do not give up much by allowing these waivers.

P3s have several common elements, including leveraging the strengths of the public and private sectors, appropriate risk transfer, transparent and flexible contracts and alignmentof policy goals.

—Findings and Recommendations of the Special Panel on Public-Private Partnerships, Committee on Transportation & Infrastructure, U.S. House of Representatives, January 2014

Beyond patents, the U.S. space enterprise is progressing towards data sharing models to leverage public sector assets in space and the commercial sector's ability to provide customized value-added data products. There are many examples which are beyond the scope of this paper. However good examples include weather enterprise data sharing; the National Geospatial Agency's more recent interest in sharing historical sensor data with commercial start-up companies; and a potential future partnership between commercial Space Data Association and a federal civil entity which could assume authority.

Proposed Process: Strategize, Plan, Implement, and Share

P3s have received considerable attention, including in national policy, as a potential solution to the ever-present

NASA Tipping Point Space Technologies

NASA's Space Technology Mission Directorate (STMD) "Tipping Point" solicitation is designed to work with the private sector within certain strategic thrust areas across a wide range of technology readiness levels. The idea is to create a "sustainable pipeline" across a range of technology maturity levels. A technology is considered at a tipping point if an investment in a demonstration of its capabilities will result in a significant advancement of the technology's maturation, high likelihood of infusion into a commercial space application, and ability to successfully bring the technology to market.

Recently, NASA partnered with eight U.S. companies to advance small spacecraft and launch vehicle technologies that are on "the verge of maturation." The results were fixed-priced contracts including milestone payments tied to technical progress and require a minimum 25 percent industry contribution. Technologies could address robotics, in-space manufacturing and assembly of spacecraft, small spacecraft propulsion systems, small satellite launch systems, etc.

Source: https://www.nasa.gov/directorates/spacetech/solicitations/tipping_points

triad of space development challenges: high cost, high risk, and long lead-times. But P3s are not a magic tool that eliminates these challenges. Rather, they provide an avenue for better managing the challenges using the best qualities offered by each participant. A successful outcome is dependent on applying these qualities effectively and consistently. The following proposed planning steps can contribute to a successful P3 structure::

- Determine how the partnership is expected to improve the cost, schedule, or performance of a space system or service.
- Clearly identify the scope and roles of the P3 partners.
- Introduce a decision framework supported by lessons learned (failures and successes) that realistically represents risks, contingencies, and stakeholder requirements.
- Based upon the decision framework, balance stakeholder needs and expectations to optimize benefits and fairly allocate risks for all participants.
- If a viable solution is evident, develop a contract acceptable to all parties.

Although each P3 is different, there are lessons to be learned from the collective experience of such arrangements across different sectors of activity. The lessons apply to varying degrees based on the nature of the potential P3, with a short-term P3 to sponsor a conference or run a prize competition likely requiring less stringent review than one that has open-ended financial liability or mission risk. Several lessons and supporting examples are presented below.

Throughout the P3 lifecycle (see Figure 3), decision-makers should focus on the following principles:

- **Neutrality.** Value for Money (VfM) should be calculated without bias and result in an estimation which does not artificially inflate or deflate P3's value under various scenarios.
- **Transparency and Accountability.** Government decision-makers should establish a structure and process for P3 screening, VfM analysis, and ongoing management and oversight. These well established best practices will go a long way toward engendering trust with public stakeholders and P3 partners. OMB Circular A-11[5] also requires that federal agencies submit non-routine financing proposals (such as P3s) for review of scoring impact to evaluate the overall value.
- **Governance.** While not discussed in detail here, appropriate checks and balances should be established during the different stages of the P3—from project approval through implementation. A P3 should be properly structured to avoid any real or perceived conflicts of interest during planning, project delivery and regulation.

1 ***Strategize. Market Assessment, Forecast, and Business Model Concept***

NGA Case Study—Calibrate Investment to Fit Budget and Contract Risks: The National Geospatial Agency (NGA) Enhanced View (EV) Program, a ten-year public-private partnership between the U.S. Government (USG) and Digital Globe and GeoEye. Each company was awarded a $3.55 billion agreement. The agreement had a ten-year term, consisting of nine one-year options exercisable by NGA, and subject to congressional appropriations and the right of NGA to terminate or suspend the contract at any time. Unfortunately for GeoEye, in 2012 NGA decided to terminate its agreement due to funding constraints and in 2013 GeoEye was acquired by Digital Globe.

Lessons Learned: Before agreeing to a major, long-term partnership, government should conduct a comprehensive review of a commercial partner's business plan including market forecast, market risk, related cost and revenue projections for all parties. Commercial companies should calibrate their expectations to fit budget and contract realities or seek greater upfront commitments. Avoid having critical missions depend on private business models that are overly optimistic or uncertain.

EELV Case Study—Conduct Independent Due Diligence and Market Studies: The Evolved Expendable Launch Vehicle (EELV) Program, a partnership of the U.S. Air Force, Boeing, and Lockheed Martin, with SpaceX added in early 2016. The U.S. Air Force (USAF) started the EELV program during the 1990s to assure access to space for DoD and other U.S. government payloads and to make government space launch more affordable and reliable. During the mid-1990s when initial EELV discussions and planning occurred, the space industry was expecting a large international market for commercial satellites, particularly large communication satellite constellations, and therefore, for launch vehicles.[6] The winning contractors would gain "an enhanced competitive position in the international launch vehicle market from DoD's investment in the program." However, these market projections proved to be wildly optimistic. In fact, several large LEO satellite constellations conceived in the 1990s never launched or went bankrupt shortly after the satellites launched. During a hearing for FY2017 Budget Request for National Security Space, General John Hyten noted that after 92 launches since EELV inception only 14 "in the entire history of the program" were for the commercial sector and emphasized "that is why it is a public/private partnership because the commercial sector is not there right now."

As of early 2018, there are several new planned "mega-constellations" (e.g., OneWeb, SpaceX, and LeoSat) and

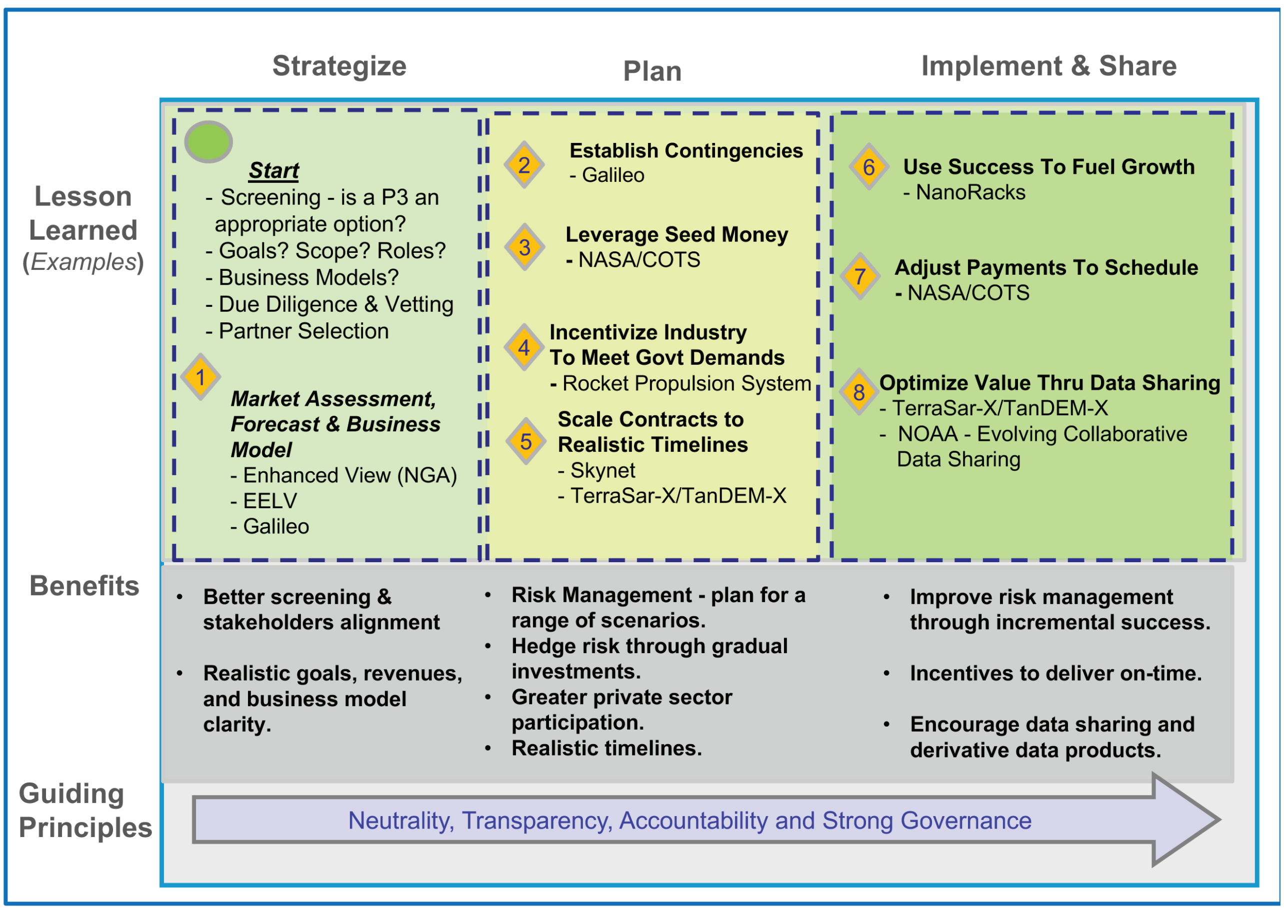

Figure 3: Lessons Learned Through P3 Case Studies. Each diamond represents a specific P3 space sector case study discussed below.

these constellations might help to "close the business case" for new launch-related P3 investments. However, if these constellations do not materialize the resulting commercial satellite and launch market pressures could potentially jeopardize space P3 business cases in even tangentially related areas.

Lessons Learned: Government should seek to understand the industry partner's business case and conduct an independent due diligence to validate demand forecasts and cost of launch services in a limited market. Likewise, industry must understand its own risks and limitations for market capture when investing in development of launch systems and establishing a partnership with the government.

Galileo Case Study—Creating a Shared Vision: The Galileo Satellite Navigation System involved a collaboration of the European Union, the European Space Agency, and an industry consortium of eight companies called "European Satellite Navigation Industries" which was tasked with developing and building the satellites and components for the ground segment.[7] The partnership, based upon a cost and risk-sharing contract, planned to construct, deploy, and operate a constellation of 30 navigation satellites. Industry was to incur two-thirds of the deployment costs and all of the operating costs. The public committed to all of the development costs and the remaining one-third of the deployment costs.[8] The consortium and EU entered the partnership with different ideas on how the satellite constellation could be used to generate revenue. In addition to the challenges of competing with the U.S.'s free GPS navigation signals, value-added commercial services to bolster private revenues were uncertain, which created rifts in negotiations. The private sector partner withdrew from its Galileo funding commitments in 2007 and subsequently the EU assumed responsibility for the construction of the Galileo positioning system. Galileo's early history struggling with P3 development highlights the critical need for business model clarity early during the formation of P3 partnerships. Without such clarity, it is unlikely that the private sector is willing to assume any risk.

Lessons Learned: During the early stages of P3 conceptualization it is important to create a shared vision or framework for project goals. This will serve as the benchmark to ensure the realization of joint objectives, clarify business models and projected revenue streams. Also identify key assumptions and conduct sensitivity testing.

2 *Plan: Establish Contingencies*

Galileo Case Study—Changing Requirements: The Galileo Satellite Navigation System's original partnership was terminated in 2007 by the public sector after negotiation breakdowns and considerable schedule delays. Political decisions occurring on a shorter timeframe than the project duration created strain on the partnership as the terms of the contract were altered.[9] This caused considerable delays because of ongoing conflicts over work distribution. While political pressures are unavoidable in dealing with democratic governments, future partnerships may do better to agree on fixed terms and strong upfront commitments, with contingencies in place for changes in funding or unforeseen technical challenges.

Lessons Learned: Establish contingencies for changing requirements.

3 *Plan: Leverage Seed Money for the Development of a Private Sector Capability and Select Two or More Partners to Encourage Competition and Hedge Risk*

NASA/COTS Case Study—Investing in Partners: NASA's Commercial Orbital Transportation Services for International Space Station (ISS) activity, provided by SpaceX, Orbital ATK, and Sierra Nevada Corporation. The partnership, based upon a cost and risk sharing contract, calls for industry to develop, own, and operate their own space transportation systems for first generation resupply contract. NASA leveraged seed money, with commercial partners funding over 50%. Pay-for-performance fixed milestone payments helped control cost and minimize schedule delays. SpaceX invested 53% and the U.S. government invested 47% for the development and demonstration of a commercial transportation system; and Orbital invested 58% and the U.S. government invested the remaining 42%.[10]

NASA's interest in enhancing competition among existing commercial partners offers distinct advantages, including: competitive pricing, a broader base of innovation and lower market risk if one commercial partner leaves the market. The NASA COTS program is just one more example where space sector P3s introduce somewhat unique market dynamics compared to more traditional infrastructure P3s. In a highway project, for example, the government partner is less compelled to broaden the competitive base of potential commercial partners because the existing public infrastructure market is already broad with many buyers and sellers.

Lessons Learned:

- Federal agencies use P3 arrangements to essentially act as a "venture capitalist." Early seed funding allows the project to grow. Once the project is operating well, the government can step back.
- A portfolio with multiple partners offers a blend of different capabilities, and helps provide a balanced approach to technical and business risks.[11] Moreover healthy competition encourages cost efficiencies and often better products.

4 *Plan: Incentivize Industry to Meet Government Demands*

RPS Case Study—Strengthening Strategic Capabilities: Rocket Propulsion System (RPS), a collaboration involving the U.S. Air Force, SpaceX, and Orbital ATK.

As part of the Air Force plan to transition away from Russian RD-180 propulsion systems, the Air Force established the RPS program to facilitate the development of propulsion systems that would enable two or more domestic, commercially viable launch providers to meet national security space requirements. In early 2016, the Air Force awarded Other Transaction Authority contracts (OTAs)* to four providers (Aerojet Rocketdyne, Orbital ATK, SpaceX, and ULA) for development of booster and upper stage engines. "OTAs have proven effective as a vehicle for public-private partnership (PPP) to bring down cost."[12] All U.S.-based P3 examples (NGA, NASA, and USAF) were developed using OTAs for cost and risk sharing.

The P3 OTAs required that winning companies contribute at least one third of the total development cost for each of the projects. The RPS program has proven successful; all four providers have made significant progress on their propulsion systems. The RPS program demonstrates that government funding combined with industry investment is an effective way to develop strategically important domestic capabilities to meet stringent DoD demands.

Lessons Learned: P3s can be designed to incentivize industry to meet the more stringent demands of a government partner and strategically reduce foreign reliance on key strategic capabilities – such as access to space.

5 *Plan: Scale contracts to realistic timelines and extended success.*

Skynet Case Study—Realistic Timelines: The Skynet 5 satellite communications project, a partnership of the United Kingdom (U.K.) Ministry of Defense (MoD) and Paradigm Communications, involves a 20-year contract signed in 2003 for service delivery of a secure military telecommunications network, with the provision to sell spare capacity to select foreign governments and NATO. An unintended consequence of a 20-year deal between the commercial sector, Airbus, and the U.K. MoD is that the MoD may have ceded too much control. The MoD is now short on expertise and resources in the sector, and it is likely the ministry will appoint a contractor to help set requirements and undertake other tasks. While longer contract terms may be required to make more capital-intensive P3s viable, the risks associated with lock-in to long-term deals could be accentuated by the potential move to shorter satellite life spans. Paul Estey, executive vice president of engineering, manufacturing and test operations at SSL noted that "the 15-year model is obsolete… There's so much change going on in the telecomm business that we'll have to refresh payloads much faster than 15 years."[13]

Lessons Learned: Avoid commitments that are longer than technology refresh cycles or that cede too much control and put at risk needed government expertise.

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* **Other Transactional Authority**
Title 10, United States Code (U.S.C.), section 237lb allows the Department of Defense (DoD) to enter into transactions for prototype projects using a legal instrument other than a contract, grant, or cooperative agreement. This legal instrument, known as an "other transactions" agreement (OTA) allows defense agencies and other federal agencies to negotiate terms and conditions specific to their project. OTAs are often used for P3 arrangements and offer flexibility which can help agencies attract commercial partners.

Section 845 of the FY1994 National Defense Authorization Act (NDAA) requires industry to provide at least one-third of the funding for OTA projects. Doug Loverro, Deputy Assistant Secretary of Defense for Space Policy, noted that DoD is "encouraging our OTA industry partners to contribute at a level higher than one-third. Even at a one-third contribution, however, the Department is receiving an excellent return on its RPS investments. The ultimate incentives for those investments is clearly access to the future National Security launch market, which CAPE estimated at $80B in 2013." *(Source: March 15, 2016; NDAA FY 2017; Subcommittee on Strategic Forces; Hearing on FY 2017 Budget Request for National Security Space).*

TerraSAR-X/TadDEM-X Case Study—Incentives for Extended Success: Germany's DLR Space Administration partnered through a cost and risk-sharing contract with Airbus Defence and Space GmbH and subsidiary Infoterra GmbH/Airbus DS Geo GmbH. Airbus's "twin" satellites TerraSAR-X and TanDEM-X produce images using a synthetic aperture radar (X-band) with one-meter resolution providing accurate digital elevation models. The lifetime of the German Earth observation satellites, TerraSAR-X/TanDEM-X, was intended to be approximately 5-7 years, but it has been 10 years since the launch of TerraSAR-X and it is still flying and producing valuable data for scientists as well as the commercial sector. The success of this P3 is partially predicated on the contract's ability to scale with the mission's longevity. The private sector, Airbus, assumed some of the initial risk of developing and deploying the satellites, but is now rewarded with even more data and longer-term cash flows than were expected.[14]

Lessons Learned: Scale contracts to the mission's longevity and provide incentives to commercial sector if satellites exceed expected lifetime. Set up distribution channels across the partnership base to fully exploit government sector and commercial sector demand for both primary and value-added products.

6 *Implement: Use Success to Fuel Incremental Growth*

Nanoracks Case Study—Incremental Growth: Nanoracks provided in-orbit services to NASA and the International Space Station (ISS) through a cost and risk-sharing contract. NanoRacks hardware was funded by private investors, with no funding from the U.S. government. Nanoracks developed a "pay-back" to NASA for use of onboard resources on the ISS. NanoRacks incrementally grew from basic research racks on ISS to a CubeSat pod deployer to the first-ever private airlock system on ISS.

The International Space Station has served as a powerful management and test bed for how the government and private sector can undertake space exploration together. Both sides contribute what they do best. In NASA's case, that is resources and hardware already paid for by the taxpayer and available for further utilization. In NanoRacks' case, that is the capital and expertise in attracting and working with customers in a cost-efficient manner.—Jeffrey Manber, CEO NanoRacks LLC

Lessons Learned: Incremental growth through success. Developing a close working relationship with the government partner can help to establish longer-term project growth.

7 *Implement: Carefully Structure Technical and Financial Milestones and Measure Success Criteria for Meeting Milestones*

NASA/COTS Case Study—Structure Milestones: NASA prepared a detailed Lessons Learned Report of COTS (April 2017)[15] and specifically called out the following areas for further improving key project metrics and milestones – including:

- Establish both technical and financial milestones.
- Link progress payments to specific milestones.
- Develop milestone performance success criteria with more specific detail.

In addition to the above lessons learned, Michael Griffin, former NASA administrator, noted that "the entire deal was thrown out of balance" because NASA did not adjust payments when SpaceX's and Orbital's launch schedules were deferred.[16] In an audit report (June 13, 2013) NASA's Office of Inspector General recommended that NASA should reduce future financial risk and "ensure that contractual agreements for the commercial cargo providers are updated to reflect the lead times required to meet any revised launch dates. If launch dates slip, NASA should adjust contract work plans to ensure that the authorized lead times and NASA payments reflect the revised schedules.[17]

Lessons Learned: Adjust payment schedules to reflect schedule slippage. Sometimes the delivery of goods or services is delayed. It is important that the government partner monitor delivery schedules and adjust payments.

8 *Implement: Optimize Value through Data Sharing and Additional Market Channels*

TerraSAR-X/TanDEM-X Case Study—Optimizing Market Channels: The P3 agreement between DLR and Airbus lays out clear marketing channels to fully exploit the market demand for data products. The government partner, DLR, provides SAR data to the scientific community, while the commercial partner, Airbus, exclusively distributes to the commercial sector through its GEO-Information division – including providing value-added products including 3D urban simulations and Digital Elevation Models.

Weather Data Sharing Case Study—Evolving Data Models: Weather data, based upon value-added services and analytics, could be provided for fee to the public and private sector. Conrad C. Lautenbacher, CEO, GeoOptics, Inc.[18] noted that the environment is right for a productive co-existence and synergy between the commercial and government weather stakeholders due, in part, to three key drivers:

1. Small & Nano Satellites - the commercial sector has ushered in the significant advantages of small and nano satellites to perform mission critical functions – including lower costs, greater resilience and increased agility.
2. Private Weather Data "Swim Lane" - the need for weather data extends well beyond public safety which has long been the traditional swim lane for government. Private sector weather data customers, such as airlines, utilities, commodity investment companies, TV stations, and Internet users often need different customized products.
3. Broader acceptance and commitment to private sector participation to provide new technologies and weather solutions. The *Weather Research and Forecasting Innovation Act of 2017,* Public Law 115-25 (April 18, 2017) was designed to "expand commercial opportunities for the provision of weather data." The new law (Section 302 (d) (3) includes a provision requiring NOAA to "determine whether it is in the national interest to develop a governmental meteorological space system... if a suitable, cost-effective, commercial capability is or will be available."

Lessons Learned: Data can be shared between the public and private sectors based on its intended application. Both public and private sector parties should agree to how the data is disseminated such that each can benefit without hurting the other.

Comparing P3 Experiences Internationally

Lessons learned will continue to accumulate as the space sector continues to leverage commercial sector know-how and capital for space projects on a global basis. P3s are already well established in the areas of satellite telecommunications, satellite imagery, and space transportation. It is reasonable to expect other P3 relationships to emerge over time, such as weather, space situational awareness, and space traffic management.

As demonstrated by some of the examples discussed above, Europe has significant experience with public-private partnerships – often referred to as Private Finance Initiatives (PFIs) – see Figure 1. In general, the U.S. is less experienced with PFIs, a subset of P3s. This is due in part to the U.S.'s well-established municipal bond market of approximately $3.7 trillion, of which a vast portion is allocated for public infrastructure financing.[19] When the Federal, state and local governments can borrow from private capital markets at lower rates than private partners in potential P3s, there is a financial hurdle that limits P3 viability. However, P3s are rapidly gaining traction within the space sector as NASA, NOAA, and others become more familiar with how to engage the commercial sector.

The U.S. civil and defense space sectors are becoming increasingly familiar and adept with OTAs. The OTA vehicle has proven effective for building partnerships with industry, reducing both time and acquisition costs, creating a more commercial friendly environment, and avoiding some requirements of the traditional Federal Acquisition Regulations (FAR) which can be daunting to commercial companies unaccustomed to contracting with the government.

The experience of Russia's space industry with P3s offers an interesting contrast. While the U.S. has made significant progress "privatizing" the space sector and establishing successful public-private partnerships such as NASA's COTS program, Russia's efforts are somewhat spotty. After the collapse of the Soviet Union in 1991, the Russian aerospace industry was partially privatized and made progress through public-private partnerships. However, between 2009 and 2017, the Russian space sector experienced a troubling series of launch failures. Ostensibly to address these failures as well as to consolidate and improve efficiency, the Russian government began to "re-nationalize" the space sector.

Russia's interim privatization of some of its space industry allowed the Russian military industrial base to benefit from public-private partnerships, at least for a while. According to retired Brigadier General Bruce McClintock, one rationale for shifting the sales of Russia's RD-180 engine to a commercial company may have been "the intent to gloss over the Russian government connection." Ultimately a "culture of patronage prevailed" and commercial companies established during the 1990s and 2000s, never separated far from the Russian government, returned to government control.[20] Perhaps they could be referred to as Potemkin P3s.

Conclusion

The space economy, once the sole domain of wealthy countries, has rapidly transitioned to a complex ecosystem of public and private entities. Along the way, government and commercial sectors have learned by doing, recognizing and incorporating key successes and lessons learned from past partnerships. Stakeholders must sort through a myriad of complexities, conflicts, and contingencies to shape an acceptable agreement. Most stakeholders recognize that this process is more art than science. Yet there is potential to achieve greater efficiency without sacrificing transparency and accountability by utilizing a decision framework supported by a broad understanding of past experiences in multiple sectors. As the space sector engages in more P3s, more lessons will emerge as partners strategize, plan, and implement. In the meantime, the following lessons, from the case studies discussed above, should continue to resonate with future P3 arrangements:

- The government partner must conduct a comprehensive review of a commercial partner's business plan including market projections, market risk, and related cost projections. These factors may impact the ability to reliably deliver on time and within budget. Avoid business models that are overly optimistic or uncertain.
- Create a shared vision among stakeholders.
- Establish contingencies for changing requirements.
- Strategically leverage seed money for private sector development and encourage healthy competition by selecting multiple partners.
- Use the partnership to incentivize industry to meet the more stringent demands of the government partner.
- Scale contracts to the mission's longevity and extended success. Be wary of commitments that are longer than technology refresh or capital reinvestment cycles.
- Use success to fuel incremental growth and to build longer term trusted partnerships with commercial sector partners.
- Carefully structure technical and financial milestones and measure success criteria for meeting milestones, including adjusting payment schedules to reflect any slippage.
- Optimize value through shared data agreements between the public and private partners – focusing on a range of intended applications and niche markets.

P3s will continue to test traditional approaches to space acquisition and operations. They can demonstrate significant advantages such as improving delivery schedules, quality of service, and innovation. Capital-intensive P3s will continue to experience successes and failures as both the public and private sector become more adept at crafting optimal arrangements. The future also holds great promise for public-private data-sharing models as this type of arrangement will begin to spur innovation and extract the most utility from space-derived data products.

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References

[1] Syracuse University; Public-Private Partnerships: Benefits and Opportunities for Improvement Within the United States; 2017. http://eng-cs.syr.edu/wp-content/uploads/2017/04/P3Report.pdf

[2] Interview with Michael Griffin, April 24, 2017.

[3] Barack Obama, "National Space Policy of the United States of America," June 28, 2010 (https://www.nasa.gov/sites/default/files/national_space_policy_6-28-10.pdf).

[4] NASA - Human Exploration & Operations Mission Directorate Chief Knowledge Officer "Lessons Learned Report of Commercial Orbital Transportation Services (COTS); April 2017.

[5] OMB Circular No. A–11 "Preparation, Submission and Execution of the Budget"; Executive Office of the President; Office of Management and Budget; July 2017.

[6] U.S. Government Accountability Office "Access to Space: Issues Associated with DoD's Evolved Expendable Launch Vehicle Program," GAO/NSIAD-97-130, July 1997.

[7] The original consortium had eight members, among them Alcatel Alenia Space (France), Thales (France), Fimeccanica (Italy), EADS Astrium (UK and Germany), and Galileo Sistema y Servicios (Spain).

[8] Masafumi Hashimoto, *Public-Private Partnerships in Space Projects: An Analysis of Stakeholder Dynamics*, Massachusetts Institute of Technology, 2009.

[9] Stefan Barensky, "Galileo Public-private Partnership Crashes to Earth," *Politico*, May 9, 2007.

[10] NASA, Commercial Orbital Transportation Services: A New Era in Spaceflight, NASA/SP-2014-617, February 2014, p. 95 (https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf).

[11] NASA, Commercial Space Transportation, "COTS Final Report" (https://www.nasa.gov/content/cots-final-report).

[12] Air University, Maxwell AFB, AL; Fast Space: Leveraging Ultra Low-cost Space Access for 21st Century Challenges; December 22, 2016.

[13] Kendall Russell, "Satellite Manufacturers Stress Collaboration to Overcome Industry Challenges," *Via Satellite*, March 9, 2017.

[14] German Space Agency, "Excellence in Space: 10 Years of TerraSAR-X," June 2017 (http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-22816/#/gallery/27214).

[15] Commercial Orbital Transportation Services (COTS): Lessons Learned for Commercial Capability Development Partnerships (April 2017).

[16] Interview with Michael Griffin, April 24, 2017.

[17] NASA Office of Inspector General, "Commercial Cargo: NASA's Management of Commercial Orbital Transportation Services and ISS Resupply Contracts," Report No. IG-13-016, June 13, 2013 (https://oig.nasa.gov/audits/reports/FY13/IG-13-016.pdf).

[18] Phone interview with Conrad C. Lautenbacher, June 25, 2017.