The Eisenhower School
for National Security and Resource Strategy

Academic Year 2021
Space Domain Industry Study

Final Report:

Renewing U.S. Great Power Competitiveness in Space

21 May 2021

National Defense University
Fort Lesley J. McNair
Washington, D.C.

25-P-0123

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Executive Summary

This report culminates a semester-long study of the challenges, threats, and opportunities the United States faces in the space domain. The Space Domain Industry Study at the Eisenhower School for National Security and Resource Strategy at the National Defense University for the academic year 2020-2021 pursued the following overarching research focus areas:

Given recent Department of Defense (DoD) space policy reforms, renewed great power competition, and the rapid growth of commercial space activity:

a. How should the U.S. improve its ability to rapidly field operational space capabilities through industrial speed and agility to address Chinese and Russian counterspace threats?

b. How should the U.S. improve its ability to sustain and enhance the market health of the space industrial base by facilitating globally competitive, sustainable business plans with improved innovation?

Human space activity stands at a historic inflection point. A proliferation of counterspace systems and escalating competition among military space powers threaten a domain that underwrites U.S. military strength and powers the global economy. U.S. leadership in space is increasingly in doubt, and the nation must act immediately to build and sustain a long-term national competitive advantage in space.

The DoD and its U.S. interagency and international partners can accomplish these objectives through action along four lines of effort.

Line of Effort 1: Rebalance U.S. Space Force (USSF) Resourcing

This report finds the amount, character, and investment objectives in the United States Space Force (USSF) Fiscal Year (FY) 2021 President's Budget and Program Objectives Memorandum do not align with Cornerstone Responsibilities outlined in the new USSF Capstone Publication. The USSF budget must be fundamentally altered to reflect its first priority—preserving U.S. freedom of action in space. The USSF budget should: (1) increase the total obligation authority across the Future Years Defense Program; (2) increase Budget Activity (BA) 6.4 funding toward expanded prototyping efforts; and (3) invest a more significant portion of Research, Development, Test, and Evaluation (RDT&E) funding in systems that preserve freedom of action in space to counter Russian and Chinese space threats vs. modernizing legacy capabilities. The USSF should also pursue a consolidated budget structure and retrain its acquisition workforce to master new acquisition authorities and tools with an "Advanced Space Acquirer" course.

Line of Effort 2: Reorient Select Defense and Intelligence Space Missions Toward Commercial Solutions

The growing commercial space economy provides DoD and the U.S. Intelligence Community (IC) with increased opportunities to meet operational needs through commercial capabilities. This reorientation could significantly increase fielding speed and agility. However, broader adoption of commercial capabilities requires specific analysis to determine which mission areas are best positioned to harvest commercial capabilities and which commercial business cases are likely to survive and outpace government-centered strategies. The continued advancement of commercial space also requires routinely updated regulatory frameworks. To this end, the National Space Council (NSpC) should lead the interagency in assembling feedback from space domain industry advisory groups to ensure policies promote the expansion of the commercial space sector. Finally, the DoD and the IC can better capitalize on industry investment by forming Public-Private Partnerships (P3) that cultivate new commercial space markets.

Line of Effort 3: Refocus R&D Enterprise Toward Defense Space Challenges

Only through increased, consistent, and secure investment in Research and Development (R&D) can the U.S. move beyond the incremental improvement of existing capabilities to "leap ahead" advancements that will sustain U.S. space advantage. The DoD must refocus investments to maintain and build the defense R&D enterprise while also developing and fielding capabilities that counter rising U.S. space threats. Building the enterprise will both strengthen space innovation capabilities and increase speed and agility for fielding future capabilities. The DoD and USSF R&D enterprise should (1) focus investment toward solving defense-specific space challenges; (2) capitalize on University Affiliated Research Centers (UARCs), Federally Funded Research and Development Centers (FFRDCs), and National Laboratory relationships; and (3) invest in a space-focused workforce by cultivating Science, Technology, Engineering, and Mathematics (STEM) talent.

Line of Effort 4: Reshape Interagency and International Partnerships

The U.S. must continue to lead the development of the "rules of the road" for civil, military, and commercial space missions. This will require greater U.S. interagency coordination and expanded international space partnerships that increase interoperability and pool investments. Additional coordination and funding are needed to ensure the Department of Commerce (DoC) is adequately resourced for the Space Traffic Management (STM) mission. Space Traffic Management provides an opportunity for U.S. leadership of expanded international partnerships through the designation of the DoD's Unified Data Library (UDL) for foreign partner use. To counter China's growing investment in space, the U.S. could expand space-related cooperation with trusted allies like Japan. Expanded space partnerships should include co-development of dual-use space technologies, payload hosting, and collaboration on solutions for space debris. Finally, the U.S. must lead the international effort to set space norms and standards for responsible behavior in space. Without U.S. leadership in the conversation on norms, adversaries are poised to take the lead.

Recommendations

LOE-1: Rebalance USSF Resourcing

1: The United States Space Force (USSF) should align its budget according to priorities outlined in the recent Capstone Publication

2: The USSF should implement a consolidated budget structure and a new financial management platform that preserves budget execution oversight and insight under a consolidated structure

3: The USSF should institute an "Advanced Space Acquirer" course that informs the acquisition workforce on new best practices and instills needed cultural shifts

LOE-2: Reorient Select Space Missions Toward Commercial Solutions

4: The USSF should evaluate where traditional military capabilities and operational concepts could be enhanced or replaced with commercial solutions

5: The National Space Council (NSpC) should advocate for the commercial space domain industry and synchronize U.S. interagency policies toward building space domain industry health

6: The USSF should utilize the Public-Private Partnerships (P3) model to leverage commercial capabilities for speed and agility

LOE-3: Refocus R&D Enterprise Toward Defense Space Challenges

7: The DoD should rebalance R&D investments toward long-term defense needs

8: The USSF should establish a USSF-sponsored UARC to advance innovation and research areas that enable warfighter capabilities

9: The USSF should establish an annual Staff Years of Technical Effort (STE) allocation for FFRDCs and UARCs

10: The DoD should aggregate all DoD STEM-based scholarship programs at a single, easily searchable website; fund marketing programs to promote the scholarships

11: The DoD should invest in greater P3 at military academies to increase space-related STEM degree throughput

12: The DoD should develop a DoD STEM Reserve Officer Training Corps (ROTC)-like scholarship program for STEM-capable human capital for the National Space Innovation Base

LOE-4: Reshape Interagency and International Partnerships

13: Congress and the Executive Branch should properly resource the Department of Commerce (DoC) for the Space Traffic Management (STM) mission

14: The U.S. should designate Japan as a Five Eyes-equivalent space partner and explore expanded opportunities for R&D co-investment, payload hosting, and operational integration

15: The DoC should designate the UDL as the authoritative repository for STM data and offer this capability as a globally available service to enhance STM cooperation

16: The NSpC should coordinate and affirm an official U.S. position on space norms

17: The Department of State (DoS) should lead an allied space norms proposal in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) that promotes responsible behavior, STM, and debris mitigation

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Foreword: Space from the Outsider-Insider View

This report concludes a semester-long study of U.S. space challenges and opportunities by the "Space Tigers" during the Academic Year 2020-2021 Space Domain Industry Study at the Eisenhower School for National Security and Resource Strategy (Eisenhower School). Our cohort includes a diverse mix of 17 mid-career professionals from across the Department of Defense (DoD) and U.S. interagency partners. We are active-duty officers from all branches of the U.S. military, including National Guard and Reserve Components, and career civilians at DoD, the Department of State, the Department of Homeland Security, and the Intelligence Community (IC). While some in our group had previous space experience, most had little exposure to space before January 2021. We were predominately "outsiders" to space domain challenges.

After courses in the broader Eisenhower School curriculum in Strategic Leadership, Economics, Strategy, Industry Analysis, and Strategic Acquisition, we spent a semester interacting with a broad set of space experts in government and industry. We met with panels of bold space theorists, analysts from think tanks, and industry executives from the largest DoD prime contractors to the smallest entrepreneurial space startups. We interviewed state and local government leaders promoting space industrial base growth in their cities and states. We connected with federal government leaders from the National Aeronautics and Space Administration (NASA), the IC, the Department of Commerce (DoC), and the newly created U.S. Space Force (USSF) and U.S. Space Command (USSPACECOM) to understand how the growing space industrial base could help solve current space challenges in the U.S. Government. We were thoroughly engaged in the full context of space from the government and industry perspectives. In short, we quickly became space "insiders."

Our year at the Eisenhower School was almost entirely virtual. Before our academic year began, many in our class had already fought on the front lines of the 2019 Coronavirus Disease (COVID-19) pandemic as first responders, by distributing supplies or by constructing temporary hospitals. This experience shaped our interaction with the Eisenhower School curriculum by providing real-world insight into the challenges of national mobilization and strategic resourcing. Our overarching lesson was that COVID-19 forever changed our world. We understand that recovering from COVID-19 and building national resilience toward future pandemics will require significant resources and could likely out-prioritize near-term U.S. Government investment in space. The focus on great power competition in space may not be the same as in late 2019 when USSPACECOM and the USSF were created.

While the U.S. focuses on pandemic and economic recovery programs, great power competitors have used the last year to deepen their investment in space capabilities. Indeed, the recent fielding of counterspace systems by China and Russia portend intensified space-oriented competition. After a semester-long study of space challenges and opportunities from the U.S. Government and industry perspective, the Space Tigers concluded that the continued international race for military, civil, and commercial leadership in space is the defining competition of the 21st century—one that the U.S. cannot afford to lose.

From this sense of urgency, and from our unique "outsider-insider" point of view, we humbly offer the analysis and recommendations in this report. We hope the report provides senior U.S. Government leaders with a set of resource-informed solutions that will make the most of every future taxpayer dollar toward sustaining U.S. leadership in space.

Eique futura spatium,
The "Space Tigers"

Lt Col Andrew D. Anderson, U.S. Space Force
Mr. Christopher S. Bey, U.S. Marine Corps
Mr. Matthew A. Burkholder, National Geospatial-Intelligence Agency
Mr. Kenneth J. Burton, Department of State
CDR Kelly A. Deutermann, U.S. Coast Guard
LTC Quinton E. German, U.S. Army National Guard
LtCol Christopher G. Grasso, U.S. Marine Corps
LTC Elizabeth J. Helland, U.S. Army
Mr. George E. Lawson, U.S. Army
Mr. Jamie S. Marsh, U.S. Air Force
Mr. Branden D. Packer, Department of State
Ms. Kerrie L. Pate, U.S. Secret Service
Lt Col Nicole M. Petrucci, U.S. Space Force
Lt Col Natasha S. Taylor, U.S. Air Force
CDR Michael P. Trumbull, U.S. Navy
Ms. Tracy M. Whittlesey, Office of the Secretary of Defense
CDR William M. Wilson, U.S. Navy

SPACE DOMAIN INDUSTRY STUDY FACULTY

Dr. Clark Groves, Eisenhower School for National Security and Resource Strategy
Ms. Lourdes Duvall, National Geospatial-Intelligence Agency
Ms. Elizabeth Phu, Office of the Secretary of Defense

Student and Faculty Acknowledgements

First and foremost, we would like to thank our Space Domain Industry Study faculty team for their time, talents, and efforts in helping us learn about this special space domain. From the seasoned warrior to the new scholar, they pushed us and challenged our basic assumptions and understanding of the course curriculum, always encouraging us towards greatness.

Thank you, Dr. Clark Groves, for sharing your knowledge and passion for space with us. We will never be able to think of space without thinking of you first. Thanks to you, we all know why space matters and why we must act now to protect it. Thank you, Ms. Lourdes Duvall, for supporting us this year and making sure our Industry Study trip was a success. You kept us on schedule and fostered an environment for us to share our ideas. Thank you, Ms. Elizabeth Phu, for helping us better understand acquisition from a space perspective. We are all better writers because of you. All three of you brought out the best of us in our studies this year.

A special thanks to the countless government and industry professionals who took time out of their busy schedules to join us in our virtual classrooms to speak about the many issues facing the Space Enterprise. We thoroughly enjoyed the lively discussions, insights, and question-and-answer sessions provided to our seminar. We took a lot away from these engagements and hopefully succeeded at applying what we have learned to our research papers and group presentations.

Thank you to the numerous businesses, industry, and government representatives in Colorado who hosted us during our two-week Industry Study trip this spring. Our Industry Study cohort, known as the "Space Tigers," was amazed at the dedication and hard work shown for the space domain industry. We are impressed by the quality of individuals and teams representing the space domain industry and the innovation that is taking place. We came away from that trip with a better understanding of the USSF and its major industrial and government partnerships.

Finally, we are grateful for the Eisenhower School and its mission. Spending this past year together has opened our eyes to strategic issues of national importance. We all understand the significance of this school and hope it continues to carry out its mission for generations to come. As graduates of the Eisenhower School, we intend to uphold the legacy of this exceptional academic institution by applying the wealth of knowledge and experiences we have gained over the past year in our future endeavors as the next generation of strategic leaders.

Industry Study Outreach & Field Studies

In-Person Discussions, Pentagon (TS-SCI):

Mr. John Hill	(Acting) Assistant Secretary of Defense for Space Policy
Lt Gen Nina Armagno	Headquarters U.S. Space Force, Director of Staff
Mr. Shawn Barnes	Assistant Secretary of the Air Force for Space Acquisition and Integration
Mr. Kevin Ruse	Battlespace Awareness and Security Program, OUSD(S&I)
Brig Gen Troy Endicott	National Security Council, Director for Space Policy
Dr. Jeff Crowder	Office of Management and Budget, National Security Division

Virtual Presenters:

Mr. Douglas Loverro	Loverro Consulting, President
Mr. Charles Bolden	Former NASA Administrator
Mr. Alvin Drew	NASA, Defense Liaison
Mr. Jason Derieth	NASA, Program Executive, Innovative Advanced Concepts
Mr. Thomas Pittman	NASA, Assistant Director for Strategy, Goodard Space Flight Center
Ms. Laura Delgado Lopez	NASA, Science Missions, Commercial Experiences
Mr. Jay Jenkins	NASA, Science Missions, Commercial Experiences
Dr. Anna Normand	Congressional Research Service
Ms. Danielle Bernstein	Aerospace Corp., Principal Director of Federal Programs Directorate
Mr. Russ Rumbaugh	Aerospace Corp., Systems Director for Space Policy & Strategy
Mr. Tom Stroup	Satellite Industry Association, President
Ms. Therese Jones	Satellite Industry Association, Senior Director of Policy
BGen (Sel) Timothy Sejba	Air Force Program Executive Office for Space Development
Mr. Kevin Coleman	FAA, Deputy Associate Administrator, Commercial Space Transportation
Mr. Martin Holmes	Office of the Undersecretary of Defense, Policy, Commercial Remote Sensing
Ms. Jessica Tok	Office of the Undersecretary of Defense, Policy, Space Policy
Mr. Dave Gauthier	NGA, Senior Executive Director of Commercial & Business Operations
Dr. Henry Hertzfeld	George Washington University, Research Professor
Dr. Diane Howard	Department of Commerce, Chief Counsel for Space Commerce
Mr. Richard Buenneke	Department of State, Senior Advisor for Space Policy
Mr. Gregg Walsh	Microsoft Corporation, Digital Advisor, National Security Group
Mr. Peter Garretson	American Foreign Policy Council
Mr. Bruce McClintock	RAND, Lead, Space Enterprise Initiative; Policy Analyst
Dr. Bonnie Triezenberg	RAND, Senior Engineer
Ms. Blake Bullock	Northrop Grumman, Vice President National Security Systems Business Unit
Mr. Steve Mare	Northrop Grumman, Director ESPAStar Product Operating Unit
Mr. Tim Rumford	Northrop Grumman, Manager, Space Security Business Development
Mr. Tim Osowski	Northrop Grumman, Fellow, Nimbus Chief Engineer
Mr. Jonathan Davis	Northrop Grumman, Manager, Space Security Business Development
Mr. Alec Robinson	Northrop Grumman, Fellow, Space Mission Architect
Mr. Jared Rieckewald	Northrop Grumman, Director, Space Logistics Business Development
Mr. Warren Frick	Northrop Grumman, Mansger, Launch Vehicle Business Development
Mr. Dan Wiles	Northrop Grumman, Mansger, Space Vehicle Integration & Test
Dr. Daniel Blevins	NRO, Ground Enterprise Directorate Chief Architect
Mr. Aaron Klein	NRO, Geospatial-Intelligent/Army Special Programs Office
Maj Christopher Romano	NRO, Chief Engineer Radar Enhancements
Mr. Raymond Gammon	NRO, Signals Intelligence Outreach
Mr. Justin Esher	L3-Harris, Chief Architect, Space Superiority
Mr. Stephen Stankevich	L3-Harris, MOSSAIC Mission Architect

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Field Studies Travel, In-Person / On-Stie, Colorado

Day-1, Mon, 19 Apr -- Denver (Lockheed-Martin satellite manufacturing facility)
Lockheed-Martin-Space (TS-SCI)
- Senior Host: Vice President/General Manager, Lockheed Martin Space, Kay Sears
- Factory tour; Accelerator tour; New Approach to Military Space Roundtable with VPs & SMEs

Day-2, Tue, 20 Apr -- Denver (CO National Guard HQ)
(am) **Colorado Office of Economic Development (OEDIT)**
- Senior Host: Lieutenant Governor Diane Primavera
- *Colorado Aerospace: Nexus of Business, Government, R&D Institutions Panel*
    - Jay Lindell, Aerospace & Defense Industry Champion, Colorado OEDIT
    - Reggie Ash, Chief Defense Development Officer, Colorado Springs Chamber & EDC
    - Greg Dorman, Legislative Director, Colorado Dept of Military and Veterans Affairs
    - Dave Eddy, CO Site Director, Boeing; Board Chair, Colorado Business Roundtable
    - Dan Powers, Executive Director, CO-LABS
    - Alires Almon, Founder Deep Space Predictive, Chair Colorado Business Roundtable

(pm) **Colorado National Guard and the Space Mission**
- COL Tod Fenner, Commander, 168th Regiment, CO Army National Guard
- Col Michael Lockette, Commander, 233 Space Group, CO Air National Guard

Day-3, Thu, 22 Apr -- Colorado Springs
(am) **BlueStaq**
- Senior Host: CEO BlueStaq, Seth Harvey
- Rebecca Decker, COO; Geoffrey Carrigan, ACCESS Program Manager

(pm) **Catalyst Campus**
- Senior Hosts: CEO Catalyst Campus, Patrick Barrett; Kevin O'Neil, Founder
- Space CAMP USSF Software Factory; BG Kevin Whale, RCAF, Advisor to Space Operations Command; SMC CANOPY; SMC Defensive Cyber Operations for Space

Day-4, Wed, 21 Apr – Denver
Sierra-Nevada Corp
- Senior Host: Senior VP for Strategy, Steve Lindsey, former NASA Astronaut & Commander
- Tim Woods, VP, IAS Programs; John Wagner, VP, Government Relations

Day-5, Fri, 23 Apr – Denver
(am) **Maxar**
- Senior Host: Maxar CEO and President, Dan Jablonsky
- Robert Curbeam, Senior VP, Space Capture; Jon Love, VP Strategic Growth; Karen Cox, VP Government Relations and Public Policy

(pm) **Advanced Space**
- Senior Host: CEO, Bradley Cheetham

Day-6, Mon-26-Apr -- Colorado Springs, Peterson (TS-SCI)
(am) **USSPACECOM**
- Senior Host: GEN James Dickenson, Commander, USSPACECOM
- Robert Thomas, Director, Capabilities and Resources Integration, USSPACECOM J8
(pm) **US Space Force**
- Senior Host: LtGen Stephen Whiting, USSF, Commander, Space Operations Command (SpOC)

- Michael Dickey, Director Force Design Integration Office
- DELTA-2 Mission (Space Domain Awareness)
- Threat Brief

(pm) **US Army 1 SAT OPS Brigade**

Day-7, Tue, 27-Apr -- Colorado Springs, Schriever (TS-SCI)
US Space Force Operational Units
- Senior Hosts: Colonel-level unit commanders
- DELTA-7 (ISR)
- DELTA-8 (SATCOM-PNT)
- DELTA-9 (Space Defense)

Day-8, Wed-28-Apr – Denver, Buckley (TS-SCI)
US Space Force Operational Unit and Garrison Support
- Senior Hosts: Colonel-level unit commanders
- DELTA-4 (Missile Warning)
- Buckley Garrison Mission Support Group Commander

Strategic Environment – The Need for Renewed U.S. Great Power Competitiveness in Space

This moment is an inflection point…We are in the midst of a fundamental debate about the future direction of the world.[1]

President Joseph R. Biden, Jr.

Human space activity stands at a historic inflection point. The proliferation of counterspace systems and escalation of competition among military space powers threaten a domain that underwrites U.S. military advantage and powers the global economy. Space capabilities are deeply integrated into every facet of U.S. and allied military operations, and the Global Positioning System (GPS) alone enables an estimated $1.4 trillion in U.S. economic activity.[2] Meanwhile, the global space industrial base is increasingly entrepreneurial; new business ventures promise ubiquitous internet coverage, asteroid mining, and even space tourism. Several independent estimates anticipate rapid space domain industry growth, potentially to $3 trillion by 2040.[3] On the civil side, space exploration is on the verge of a renaissance. The U.S., China, and the United Arab Emirates recently conducted near-simultaneous exploration missions to Mars.[4] At a time when space holds immeasurable value to humanity, it is also increasingly at risk of disruption by irresponsible behaviors or hostile actions.

Growing Threats to U.S. Space Leadership

The escalating great power competition among the U.S., Russia, and China has extended to the space domain. At the end of the Cold War, the Department of Defense (DoD), the National Reconnaissance Office (NRO), and the National Aeronautics and Space Administration (NASA) held the unrivaled advantage and unthreatened freedom of action in space. Today, the U.S. is no longer the uncontested space power. Like the U.S., adversaries now consider space capabilities critical to warfighting, projecting national power, and garnering influence.

Russia and China are aggressively fielding and integrating advanced military space systems to amplify military capabilities across all domains. These nations are also integrating space capabilities with terrestrial systems to create multi-domain battlespace awareness and combat capabilities. New Chinese and Russian space systems include intelligence, surveillance, and reconnaissance capabilities and Position, Navigation, and Timing (PNT) alternatives to the U.S. GPS. In 2015, China established a fifth military service, the "Strategic Support Force," which integrates space capabilities across cyber, electronic, and psychological operations to bolster joint operations across the spectrum of conflict.[5]

While the expansion and integration of military space capabilities by China and Russia are concerning, a more alarming trend is the proliferation of new counterspace threats. Cold War-era military and intelligence space capabilities predominately supported the nuclear enterprises of the U.S. and Soviet Union. The risk of nuclear escalation or retaliation restrained these space powers from actively deploying counterspace systems. China's 2007 demonstration of a kinetic Anti-satellite (ASAT) capability marked a clear erosion of restraint and stability. The nuclear redlines and norms of behavior that characterized the Cold War no longer apply. Great powers are fielding space capabilities to enhance warfighting advantage in other domains, but they are now testing and demonstrating counterspace systems to achieve in-domain superiority. These new threats have fundamentally transformed space into a distinct warfighting domain. Previously unthreatened space capabilities created a decades-long U.S. asymmetric warfighting advantage. Now, the U.S. joint force's dependence on undefendable space assets has recast this advantage as a glaring vulnerability.

China and Russia are deploying a range of military counterspace capabilities that could hold U.S. and allied space programs at risk. North Korea and Iran are also actively building counterspace capabilities. Adversary systems include space-based, terrestrial, and high-altitude military counterspace capabilities designed to deny, degrade, destroy, and disrupt U.S. space operations. This presents a grave threat to the space systems that underwrite the U.S. and allied military and economic power. In recent Senate testimony, General James H Dickinson, the Commander of U.S. Space Command (USSPACECOM), described China's counterspace capabilities and strategy:

> China is developing a broad complement of jamming and cyberspace capabilities, directed energy weapons, on-orbit capabilities, and ground-based ASAT satellite missiles that can achieve a range of effects. China will attempt to hold U.S. space assets at risk while using its own space capabilities to support its military objectives and overall national security goals.[6]

Notable examples of adversarial ASAT technologies and activities include China's *Shijian*-17 robotic "grappling arm" and a Russian co-orbital kinetic ASAT that recently conducted tests near a U.S. satellite.[7] Under these pacing threats, the DoD can no longer assure freedom of action in the space domain. If the United States Space Force (USSF) cannot rapidly field new capabilities to overcome these and other counterspace systems, the U.S. and allied military power could be significantly diminished in the face of rising adversaries. The U.S. has a limited but rapidly closing window to regain space advantage and ensure continued space leadership.

Status of Great Power Competition in Space

The U.S. continues to be the world's largest investor in space, but it now faces intensified competition from China and Russia. According to Euroconsult, the U.S. budget for space in 2020 totaled $48 billion. China maintained its second-place ranking, with an estimated $8.9 billion budget, representing approximately a threefold increase since the early 2000s.[8] China recently surpassed the U.S. economy in Purchasing Power Parity (PPP) and is leveraging a "military-civil fusion" strategy to coordinate and streamline national investment toward military capabilities.[9] Meanwhile, Russia lags economically but leads in space experience and builds upon its historical advantages to punch above its economic weight with new space activity intended to promote national prestige and challenge U.S. freedom of action.

With growing space investment by China and Russia, the long-term trajectory of U.S. space leadership will be increasingly contested. Given the question of continued U.S. leadership in the space domain, the Space Domain Industry Study team compared elements of national competitiveness between the space industries of the U.S., China, Russia, and Japan. Japan was analyzed from the lens of increasing partnership opportunities, while China and Russia were viewed as persistent competitors. A complete analysis of each country using Michael Porter's national competitiveness "diamond" framework is included in Appendix A of this report.[10] Research findings indicate that the U.S. commercial space domain industry holds a significant competitive advantage over all other major space powers. America's experience in World War II underscores Science and Technology (S&T) investment as essential to maintaining American primacy in all domains. This realization led to America's establishment of a unique national security technology investment and innovation ecosystem that fuels U.S. leadership across military, civil, and commercial space capabilities. For the U.S., the four main components of Porter's national competitiveness "diamond" model are mutually supportive and reinforce continued U.S. competitiveness as a leading space power. This positive assessment of current U.S. space domain industry competitiveness and current advantages formed the basis of recommendations in this paper that leverage these strengths to sustain U.S. leadership in advancing the space frontier.

Despite current U.S. space domain industry leadership, China's coordinated, long-term, and streamlined resourcing across military and civil sectors has produced rapid gains in space competitiveness. This research assessment of space industries aligns with other defense-related estimates: China represents the "long-term pacing threat" to continued U.S. space industry leadership. Similarly, Russia's space industry strengths rely on its legacy of Cold War space competition with the U.S. This residual capability, coupled with dedicated resourcing and national focus, could continue to produce disruptive threats to peaceful international space activity. According to President Putin, Russia will continue to pursue investments "where the Kremlin believes it can still hold a comparative advantage over the West."[11] Like cyberspace, space is a domain where Russia can pursue relatively inexpensive but high-impact asymmetric warfare to disrupt U.S. objectives.[12]

A Future Without U.S. Space Leadership?

China's investments and focus on space superiority should concern every nation that thrives under the current U.S.-led rules-based international order. The Space Domain Industry Study team explored a potential alternate future scenario where China successfully executed its national strategy and solidified space dominance without a counter-response from the U.S. and its allies. In a future with Chinese preeminence in space, its growing counterspace capabilities could hold all U.S. military and intelligence satellites at risk. This vulnerability would likely restrain traditional U.S. military power projection and eliminate the long-held U.S. joint force conventional advantage. Under these premises, China and Russia could take advantage of reduced U.S. power projection and increase "gray zone" activity. Taiwan's independence could be at risk, and Russia would likely expand its influence into Eastern Europe.

On the economic side, China would continue to use its coordinated and streamlined "military-civil fusion" approach to promote the competitiveness of Chinese space firms in global markets. Subsidized by the Chinese Communist Party (CCP), Chinese firms would outpace U.S.-based companies for the global market share of space-based services and manufacturing. With this growing market share, China could provide competitive, low-cost space services to developing countries in exchange for increased geopolitical and economic leverage in global political institutions like the United Nations. The Chinese version of SpaceX's "Starlink," or "StarNet," and China's "*Beidou*" PNT system could foster a consortium of countries that rely on Chinese-built space infrastructure. These capabilities would likely filter the internet and allow only censored, pro-Chinese viewpoints while also enabling the CCP to monitor all traffic and surveil their citizens for dissident views. As the developed world grows increasingly dependent on space-based services, such as global broadband, China's leadership in space could lead developing companies to adopt Chinese technology standards and interfaces, closing them off to increased partnerships with the U.S. and Western democracies.

China's active future presence in cislunar orbital regimes (between Earth and the Moon) would provide a foothold in the growing $3 trillion space commerce economy and a staging point for new national security threats beyond U.S. surveillance reach. China's *Chang'e* lunar exploration program could mature beyond robotic probes and lunar landers to eventually consist of a full-fledged lunar base with on-site manufacturing capability. Access to frozen water on the lunar surface could enable China to create low-cost propellants in space and drive another evolution in space launch with China at the center. The CCP's military-civil fusion strategy and investment in dual-use space technology could create confusion regarding their true intentions and capabilities in cislunar regimes. China could then use its growing space advantages to promote national prestige and expand CCP influence. Beijing could point to its increasing military, civil, and commercial space successes as evidence that its centrally planned "state capitalism" economy is the superior model for long-term technological leadership.

The new race for long-term competitiveness in space among the U.S., China, and Russia is the defining contest of the 21st century. Unlike the first space race, this new contest will set the conditions for a domain that now underwrites global economic activity and modern life. The race for space competitiveness will have significant consequences for comparative military capabilities, national prestige, economic strength, and global diplomatic balance among leading international powers. In other words, it will cut across all measures of national power. Furthermore, the outcome of this race could also determine if space indeed remains free for global use and exploration, as was envisioned by the 1967 Outer Space Treaty, or if the domain takes on a hostile character that reflects leadership and control by authoritarian regimes.[13] The importance of continued American leadership in space requires new action that leverages U.S. advantages toward building long-term space competitiveness.

U.S. Advantages – The Opportunity for Renewed U.S. Great Power Competitiveness in Space

Space represents what is exceptional about the United States of America. We are characterized by a spirit of adventure, risk, and entrepreneurialism. When our national security is threatened, we respond. When challenges seem overwhelming, we strive. When we experience a setback, we double our resolve. It is who we are.[14]

Jim Bridenstine, Former NASA Administrator

In a speech establishing April 24th as China's National Space Day, President Xi stated, "to explore the vast cosmos, develop the space industry, and build China into a space power is a dream we pursue unremittingly."[15] The CCP is aggressively investing in national space capabilities to make this dream a reality. China has even partnered with Russia on a replacement for the International Space Station (ISS). China's focused, centralized resourcing approach has quickly aligned military, private industry, and state-owned enterprises toward a goal of space leadership.

In stark contrast, the U.S. public sector is characterized by a "political economy" environment shaped by shared powers, layered decision making, and ambiguous or overlapping authorities and responsibilities. This system was intentionally designed to be slow to coalesce behind a singular vision, but it can move with overwhelming and enduring strength once it is unified behind a threat. A decentralized public sector limits federal power and promotes competing interests and agendas across agencies. Decentralization sets the conditions for agency competition and policy innovation. The subordination of government authority to law further restrains government power and upholds private sector intellectual property (IP) protection. A decentralized public sector and the rule of law foster a strong and vibrant free-market private sector—arguably the single greatest U.S. center of gravity and source of national power.

Public sector decentralization and a free-market economy set the foundation for a uniquely American approach to challenges: public-private partnerships (P3). This model is initiated by the government establishing strategic goals and interagency priorities, providing initial seed funding, or cultivating diverse cross-sector relationships. It then relies on private-sector ingenuity and the free market to build innovative, impactful, and lasting solutions to national issues. In *America Inc.?*¸ Linda Weiss describes the "national security state" as an enduring P3 that, since World War II, has "dominated in high-risk, breakthrough technologies and emerging industries…and continues to secure the foundations for a high-technology commercial sector…in order to sustain U.S. military-political primacy."[16]

Another strength of the U.S. system is its global attraction. The economic strength and democratic principles at the heart of the U.S. system draw international allies and partners to the degree that authoritarian powers cannot match. This attraction yields a competitive advantage and establishes the U.S. as an indispensable champion of the rules-based international order and a coalition-builder to solve pressing global issues. These unique American strengths:

decentralization, the P3 approach to policy solutions, and international attractiveness create a dynamic system that overcame great power competition in the 20th century. As the Space Domain Industry Study team explored resource-informed solutions to the current challenge of space competitiveness, we specifically built recommendations that could work along with these U.S. advantages, thus maximizing return on public investment toward meeting the new 21st-century contest of national leadership in space.

Congress and national leaders have recently initiated several major organizational changes within DoD to regain U.S. military space advantage over great power competitors. The USSF was established in 2019 to answer the growing field of space threats that could challenge U.S. freedom of action in space. Four months before the creation of the USSF, the U.S. re-established USSPACECOM as the eleventh combatant command to deliver space combat power to joint and combined military operations. Along with the standup of the USSF, Congress directed the new USSF to propose a new alternative acquisition system specifically dedicated to space systems. Less than one year earlier, the Space Development Agency was established to accelerate the military space capabilities necessary to ensure U.S. technological and military advantage in space for national defense. The monumental scope of recent DoD organizational change points to the intense pressure for the U.S. military to regain its traditional capability advantage over potential space adversaries. While these organizational changes laid the groundwork for recovering U.S. military space advantage, the DoD must build on this organizational change by fielding space capabilities with increasing speed and agility—surging new systems that counter Chinese and Russian space threats. Furthermore, the DoD must build future capacity for space capability speed and agility by partnering with the U.S. industry in ways that promote the long-term vibrancy of the growing commercial space sector.

The DoD and other U.S. agencies must approach great power competition in space as a long-term national mobilization challenge. Assuming only modest near-term budget growth, building and sustaining space competitiveness will require focused resourcing and close partnerships between U.S. agencies and private industry, the non-profit sector, academia, and international partners. Accordingly, the Space Domain Industry Study team recommends the lines of effort in this paper as a resource-informed approach to improving space competitiveness that leverages U.S. advantages. These lines of effort include actionable recommendations for the U.S. agencies, the DoD, and the USSF that involve focused investments and relationship-building. In addition to these lines of effort, the National Space Council (NSpC), chaired by the Vice President, should continue as an enduring element across presidential administrations and drive a sustained focus on building long-term national space competitiveness.

Research Thesis: Given the growth of space threats posed by great power competitors, the U.S. must act immediately to maintain a long-term national competitive advantage in space. To this end, the DoD must increase the speed and agility with which it fields operational space capabilities while simultaneously enhancing the long-term health of the U.S. space industrial base. The DoD and its U.S. interagency and international partners can accomplish these objectives through action along four lines of effort: (1) rebalancing USSF resourcing, (2) reorienting select DoD space missions toward commercial solutions, (3) refocusing the DoD Research and Development (R&D) enterprise toward space challenges, and (4) reshaping interagency and international partnerships.

Lines of Effort – Building and Sustaining U.S. Great Power Competitiveness in Space

LOE 1 – Rebalance USSF Resourcing

Don't tell me what you value. Show me your budget, and I'll tell you what you value.

Washington D.C. Maxim

The recent creation of the USSF reflects the new military imperative to defend U.S. freedom of action in the space domain. Emerging space threats posed by great power competitors demand a fundamental shift in the USSF resourcing. Legacy Air Force Space Command space capabilities increased the lethality of the U.S. joint force operations through precise PNT, missile warning, and survivable tactical and strategic communications. The current USSF investment posture reflects the need to modernize these legacy systems to ensure continued support to joint operations and strategic users. However, these legacy systems historically operated in a benign space environment. With rapidly proliferating peer competitor threats, U.S. space superiority is no longer assured. The USSF must field new capabilities with increasing speed and agility to counter Chinese and Russian counterspace systems. To this end, an increasing portion of the USSF Research, Development, Test, and Evaluation (RDT&E) budget must reflect the new military priority to preserve U.S. freedom of action in space through new capabilities and modern technology infrastructure.

This section analyzes the Fiscal Year (FY) 2021 RDT&E budget according to the stated priorities in the USSF Capstone Publication. Overall, it finds a disconnect between USSF Cornerstone Responsibilities and the amount, character, and investment objective of RDT&E funding across the FYDP. Unfortunately, the need to modernize space capabilities that support joint force requirements will constrain any attempt to shift the RDT&E profile without significant budget topline growth. Under this constraint, the USSF should improve acquisition agility by pursuing a consolidated RDT&E budget structure and by modernizing its acquisition workforce with an "Advanced Space Acquirer" course.

<u>Align USSF RDT&E Investments to Strategic Priorities</u>

Recommendation 1: *The USSF should align its budget according to priorities in the recent Capstone Publication*

The Space Domain Industry Study assessed USSF RDT&E investments in the FY2021 President's Budget (PB) and Program Objectives Memorandum (POM) against the recently published USSF Capstone Publication. Our intent was to determine if the overall level of USSF RDT&E investment and the breakout of this portfolio according to BA codes and program elements matched the priorities articulated in USSF strategic guidance. This analysis first required combining the RDT&E portion of the USSF PB and POM, which is segmented according to BA codes in DoD budget justification documents according to the codes presented in Table 1 below.[17]

Table 1: DoD RDT&E Budget Activity Codes and Descriptions

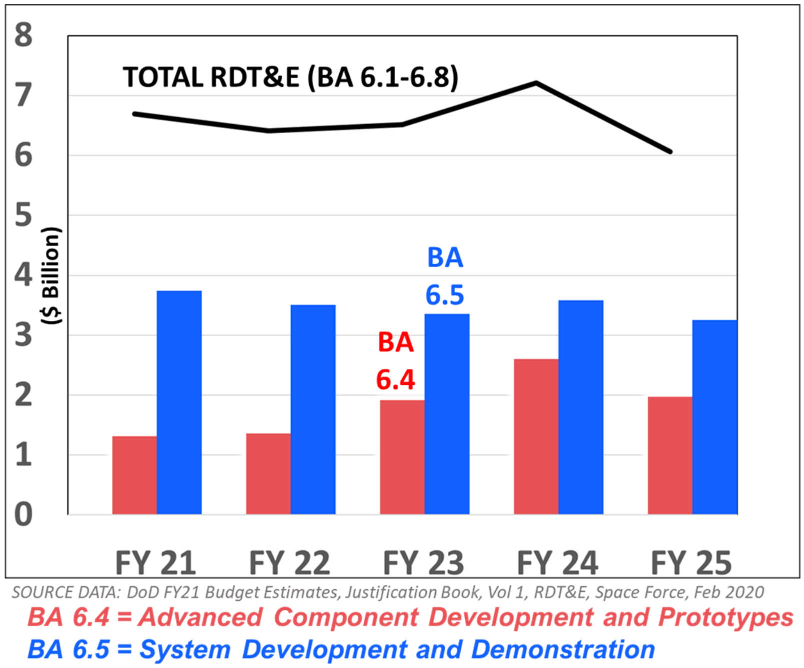
Code	Description
6.1	Basic Research
6.2	Applied Research
6.3	Advanced Technology Development
6.4	Advanced Component Development and Prototypes
6.5	System Development and Demonstration
6.6	RDT&E Management Support
6.7	Operational System Development
6.8	Software and Digital Technology Pilot Programs

Source: Department of Defense, *Financial Management Regulation (DoD 7000.14-R)*, Volume 2B, March 2016; telephone conversations and email communications between CRS and Office of Management and Budget (OMB) staff, most recently on October 1, 2020.

The USSF FY21 PB and POM listed program elements and funding levels across the FYDP according to these BA codes. Appropriately, most of the USSF RDT&E PB and POM was comprised of BA 6.4 and 6.5 funding for development and fielding of space capabilities by acquisition program offices. The distinction between 6.4 and 6.5 funding also provides high-level insight into the time horizon for RDT&E investments. Whereas 6.4 funding is devoted to accelerating technology transition from laboratory to operational use through "evaluation of prototypes in realistic operating environments," 6.5 reflects technological maturity "near or at planned operational system levels."[18] Thus, a comparative assessment of 6.4 and 6.5 funding can yield a high-level assessment of relative investment levels toward evaluating new solutions (BA 6.4) versus maturing technology toward well-defined operational systems (BA 6.5).

Assessing investment levels in the FY21 USSF RDT&E budget reveals several important takeaways. First, the overall funding level of unclassified USSF RDT&E may not match the new emphasis on countering Chinese and Russian counterspace threats by fielding systems with greater speed and agility. The Capstone Publication argues that "the U.S. must adapt its national security space capabilities to deter and defeat aggression and protect national interests in space." The overall decrease in USSF RDT&E funding across the FYDP, as represented by the dark green total line shown in Figure 1 below, does not match this heightened emphasis on developing new capabilities that can achieve this adaptation. Deterring and defeating rapidly evolving space threats will require the USSF and other DoD space organizations to field systems with increasing speed and agility, which will, in turn, require increased RDT&E investment across the FYDP.

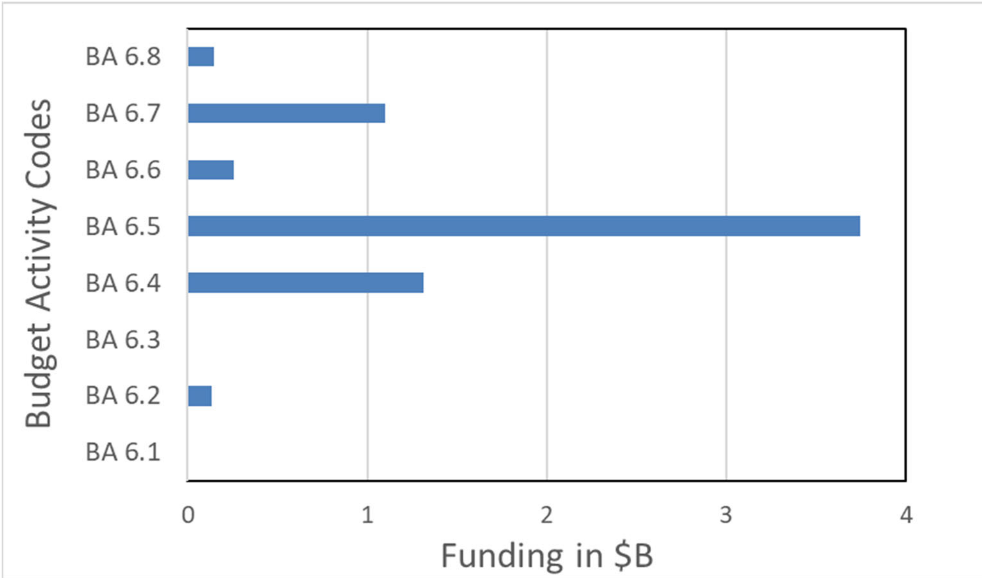
Figure 1: Total RDT&E Budget and Budget Activities 6.4 and 6.5 Across FYDP



A second takeaway from an assessment of RDT&E funding according to BA codes suggests that the character of USSF investments is not balanced according to the type of RDT&E activity needed to counter Chinese and Russian counterspace threats. As shown in Figure 2 below, a significant majority of RDT&E investment is comprised of BA 6.5, meaning it funds systems "near or at planned operational system levels." This overbalance in BA 6.5 in FY21 suggests that RDT&E investments are funding systems that are predominately in late-stage development where technological baselines are relatively fixed. In contrast, BA 6.4 funding is devoted to accelerating technology transition from laboratory to operational use through the evaluation of prototypes in realistic operating environments. The prototyping focus of BA 6.4 suggests that this specific RDT&E category must be prioritized to promote the agile development of new systems to counter emerging space threats. The amount of BA 6.4 funding increases across the FYDP, which is an appropriate trend.

Finally, an assessment of the programs in the USSF RDT&E portfolio suggests that USSF RDT&E investment objectives do not align to the prioritized Cornerstone Responsibilities outlined in the Capstone Publication. For this part of the analysis, program elements within the RDT&E portfolio were binned according to the three Spacepower Cornerstone Responsibilities: preserve freedom of action, enable joint lethality and effectiveness, and provide independent options in, from, and to space.[19] Specifically, our analysis assumed that the preservation of U.S. freedom of action involves characterizing actors in the space domain, defending U.S. space systems against Chinese and Russian counterspace threats, and offensively controlling the space systems of these competitors or adversaries when needed.

Figure 2: Total RDT&E Breakout by Budget Activity (FY2021)



SOURCE DATA: DoD FY21 Budget Estimates, Justification Book, Vol 1, RDT&E, Space Force, Feb 2020

Systems were aligned with "enable joint lethality and effectiveness" if the capabilities they provide predominantly support U.S. joint force operations led by other geographic or functional commands. The Capstone Publication states that the third Spacepower Cornerstone Responsibility, "providing independent options" could be accomplished by a variety of systems. For example, independent options could include "actions as benign as the launch or repositioning of a space capability [that] can assure international partners or signal U.S. resolve to strategic competitors."[20] Table 2 below provides a breakout of program elements within the USSF RDT&E BA 6.4 and 6.5 portfolios according to Cornerstone Responsibilities.

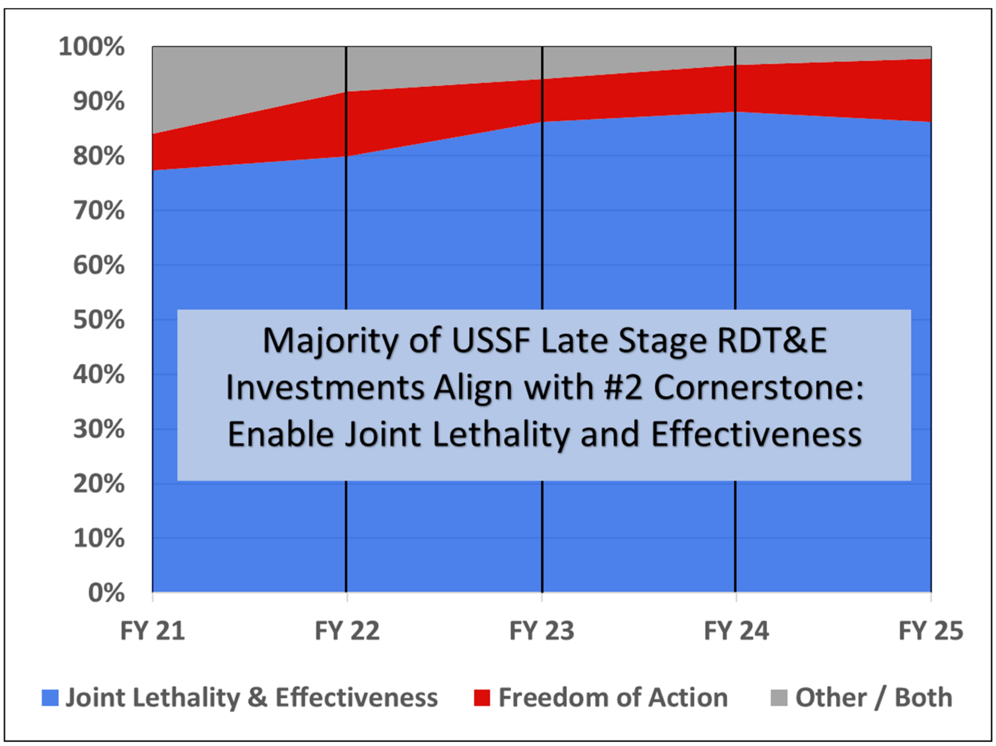
Table 2: Program Elements within FY2021 RDT&E Budget Activities 4 and 5, Binned According to Spacepower Cornerstone Responsibility

Preserve Freedom of Action in Space	Enable Joint Lethality and Effectiveness	Unknown / Both
• Space Situational Awareness Systems • Space Situational Awareness Operations • Counterspace Systems • Space Control Technology	• GPS User Equipment • GPS IIIF • EO / IR Weather Systems • Weather System Follow-on • Advanced Extremely High Frequency (AEHF) MILSATCOM • Polar MILSATCOM • Next Generation OPIR • Protected Tactical Enterprise • Protected Tactical SATCOM Evolved Strategic SATCOM	• Space Systems Prototype Transitions • Space Rapid Capabilities Office • National Security - Launch

The USSF Capstone Publication introduces "preserve freedom of action in space" as first among the three USSF Cornerstone Responsibilities, stating that it is "a fundamental role of the U.S. military, and specifically, the USSF…[and] an operational imperative in peace and war."[21] This Cornerstone Responsibility captures the new USSF imperative to counter emerging in-domain threats from China and Russia. However, Figure 3 below shows that RDT&E investment in the second Cornerstone Responsibility of "enable joint lethality and effectiveness" receives a vast majority of combined BA 6.4 and 6.5 funding, averaging around 80 percent across the FYDP.

USSF RDT&E investments are overbalanced toward systems that support traditional roles of U.S. military space capabilities: PNT, Overhead Persistent Infrared (OPIR), and Strategic and Tactical Satellite Communication (SATCOM). These three mission areas directly support U.S. joint force operations but are traditionally comprised of large, high-performance satellites that are relatively defenseless against emerging space threats. Part of the growing cost of recapitalizing these systems could involve equipping these systems with additional resilience capabilities, such as active or passive defenses. Given the recent proliferation of Russian and Chinese threats to space systems and the growing reliance on space capabilities by the U.S. joint force, the USSF RDT&E budget should reflect increased investment toward the first USSF Cornerstone Responsibility across the FYDP.

Figure 3: Combined Budget Activity 6.4 and 6.5 According to USSF Cornerstone Responsibility (FYDP)



SOURCE DATA: DoD FY21 Budget Estimates, Justification Book, Vol 1, RDT&E, Space Force, Feb 2020

Given this imbalance of RDT&E funding between the first two Cornerstone Responsibilities, a few important assumptions and caveats must be emphasized. First, this assessment only analyzed unclassified portions of the USSF budget. Second, this analysis used the FY21 budget, the most recent publicly available budget as of April 2021. This budget was built prior to the release of the Capstone Publication in August 2020.

The preponderance of USSF RDT&E investment toward joint lethality and effectiveness suggests that validated requirements from geographic and functional Combatant Commands other than USSPACECOM currently drive most USSF future investments. While USSF Title 10 responsibilities involve organizing, training, and equipping forces and capabilities for employment by Combatant Commands, the Joint Capabilities Integration Development System (JCIDS) process establishes requirements according to future capability gaps across Combatant Commands and the Joint Force. Until USSPACECOM-led analysis of capability gaps drives more JCIDS-validated requirements, the USSF can expect that most of its budget will be consumed by the modernization of legacy capabilities that enhance U.S. joint force power projection. Without a significant shift in RDT&E investments toward preserving freedom of action in space, USSF operational leaders must provide honest assessments to DoD, executive branch, and congressional leadership and advise where current capability limitations prevent the accomplishment of this new Cornerstone Responsibility.

Overall, the Space and Industry Study team recommends realigning USSF RDT&E in three ways: (1) increase total USSF RDT&E across the FYDP; (2) increase BA 6.4 funding toward expanded prototyping efforts; and (3) invest a larger portion of RDT&E in systems that preserve freedom of action in space to counter Russian and Chinese space threats. Assuming these investment shifts must be made under relatively modest budget growth, we recommend the USSF make the most of limited resource flexibility in two ways: (1) increase budget and requirements agility and (2) institute an "advanced space acquirer" course that equips space acquisition professionals with new authorities and contracting tools to rapidly acquire commercial capabilities.

Increase USSF Budget Agility through Budget Line-Item Consolidation

Recommendation 2: *The USSF should implement a consolidated budget structure and a new financial management platform that preserves budget execution oversight and insight under a consolidated structure*

The DoD budget structure implemented in 1961 is fundamentally ill-suited for 21st-century great power competition. China is rapidly modernizing its national-level resourcing approach to better incorporate fourth industrial revolution technology into advanced weapon systems. Beijing's "Made in China 2025" and "military-civil fusion" efforts are recent initiatives to focus national resourcing and achieve three broad goals: build technological leadership in various strategic fields, synergize civilian and military economies, and streamline the integration of Artificial Intelligence (AI), nanotechnology, advanced robotics, and quantum computing into military capabilities.[22] In contrast, the process that guides U.S. DoD procurement – the Planning, Programming, Budgeting, and Execution (PPBE) system – has remained virtually unchanged for 60 years.[23]

Fielding space systems with greater speed and agility will require more flexibility for acquisition program managers and lower-echelon acquisition organizations to adapt military capabilities against rapidly evolving threats. This acquisition flexibility could involve modifying program baselines to incorporate innovative technologies. In many cases, these modifications would require shifting funds between program elements in the budget. Under the PPBE system, DoD Financial Management Regulations (FMRs) specify a dollar value threshold for internal reprogramming actions between Budget Line Items (BLIs). Reprogramming actions above this threshold require prior approval by congressional defense committees. Currently, this threshold is the lesser of $10 million or 20 percent of the program element.[24] For the FY2021 budget, this reprogramming approval policy essentially means that the vast majority of the $102 billion in RDT&E funding devoted to developing capabilities is effectively locked in place for up to three years (budget execution years and the preceding budget approval year). This "lock-in" can inhibit the budget agility that rapidly evolving mission areas need to respond to emerging threats or onboard promising technological innovations. The USSF could increase budget agility with a more consolidated program element structure that allows internal funding realignments within mission area portfolios without high-level DoD, Office of Management and Budget (OMB), or congressional defense committee approval.

One possible implementation of a consolidated BLI structure could group around 20 current program elements in the FY2021 USSF RDT&E budget into seven new consolidated BLIs representing mission area portfolios: SATCOM, Enterprise Ground Systems, PNT, Space Control, Space Domain Awareness (SDA), Weather, and Space System Prototypes (shown in Figure 3 of Appendix C). This construct also groups programs by similar BA code or "color of money;" for example, all programs in the envisioned Space System Prototype portfolio are currently BA 6.4. Each consolidated BLI or mission-oriented "portfolio element" could be structured with internal Budget Program Activity Codes (BPACs) representing each acquisition program within that portfolio.

Along with BLI consolidation, the Office of the Secretary of Defense (OSD) Office of the Comptroller should implement an updated decision framework for internal realignment authority within consolidated BLIs (Figure 3 of Appendix C). Internal realignments shift funds between BPACs within a BLI during budget execution year and typically do not require prior congressional approval. Realignment authority within a portfolio could be made adjustable based on portfolio context (threat area, congressional interest, historical performance, etc.). BLI consolidation and flexible realignment authority would effectively replace the "one size fits all" reprogramming threshold with a more flexible structure that varies budget agility by mission area. For example, portions of the USSF budget designed to leverage rapidly advancing technology or commercial innovation, such as a new consolidated Space System Prototype portfolio, could be set with a 50 percent realignment threshold. Other more mature consolidated portfolios could be kept at a 10 percent realignment threshold, effectively preserving the 10 percent reprogramming threshold status quo. This BLI consolidation construct would enable resource adjustments within select portfolios without waiting for the time-consuming reprogramming approval. Ultimately, this increased flexibility could yield more agile and efficient portfolio program management. This structure would enable program managers to resolve emergent funding issues, such as quickly adjusting to evolving threats or responding to changes in programmatic risk, in a way that maintains capability development schedules.

BLI consolidation proposals within the DoD have been unsuccessful because the program-based structure of the budget provides DoD principals and congressional committees with a valuable oversight mechanism.[25] With BLIs structured by individual programs, executive and legislative branch principals have the detailed insight and control needed to shape the budget and control budget execution. Viable program element consolidation in a political economy environment thus requires a corresponding increase in budget execution information by principals who hold oversight authority: OSD and the OSD Comptroller, in addition to OMB and Congress.

Preserving current levels of principal insight and oversight under BLI consolidation requires an updated financial management platform where internal realignments within consolidated BLIs can be monitored and controlled in real-time. This new platform would ideally capture portfolio budget execution data with "dashboards" for each BLI. This dashboard could provide budget principals with the necessary information needed to track realignments within that BLI. It could streamline approval for some BLIs while maintaining current approval authorities for other portfolios or programs. The goal would preserve budget oversight and insight by OSD, OMB, and congressional defense committees while also streamlining decision-making for resource trades among programs and allowing more budget flexibility for limited portions of the budget. A conceptual model for an updated financial management platform is depicted in Figure 2 of Appendix C.

The total USSF RDT&E portfolio represents only 1.4 percent of the entire DoD FY 2021 budget.[26] Restructuring this appropriation around consolidated BLIs will give the USSF the budget agility needed to develop capabilities that respond to the growing field of space threats. This policy change would ultimately have an outsized impact on preserving the U.S. space-enabled joint and coalition warfighting advantage. As USSF develops the future POM, it should consider working with the OSD Comptroller, OMB, and congressional defense committees to consolidate RDT&E program elements according to broad mission areas. More analysis on USSF RDT&E BLI consolidation and a supporting financial management oversight platform to enable this recommendation is included in Appendix C of this report.

Modernize the USSF Acquisition Workforce with Advanced Training

Recommendation 3: *The USSF should institute an "Advanced Space Acquirer" course that informs the acquisition workforce on new best practices and instills needed cultural shifts*

Fielding operational capabilities with increasing speed and agility requires an acquisition workforce that can effectively leverage recent acquisition authorities and emerging best practices. Over the last several years many acquisition authorities, policies, and best practices have surfaced across the DoD to field new capabilities with greater speed and agility. These new authorities include the Section 804 middle tier acquisition pathways, the revamped DoD

Instruction 5000.02 Adaptive Acquisition framework, and new software appropriation categories. In addition, many DoD offices have demonstrated success partnering with non-traditional defense contractors using Other Transaction (OT) agreements, Broad Agency Announcements (BAAs), and Cooperative Research and Development Agreements (CRADAs). Finally, initiatives like AFWERX and SOFWERX leverage public-private partnerships to access entrepreneurial sectors of the industrial base to explore and solve current and future defense challenges.

USSF should “level set” its space acquisition workforce by ensuring broader familiarity with these new authorities and best practices. New acquisition tools, along with ways to better leverage traditional contracting methods, should be better institutionalized throughout the workforce. In addition, USSF workforce development should foster a culture that strengthens the operator-acquirer relationship and reinforces a different risk-opportunity balance given the rapidly advancing space threats.

As the USSF establishes its human capital vision, it should look to the successful track record of U.S. Special Operations Command (USSOCOM) and create a dedicated advanced acquirer training course for acquisition professionals, like USSOCOM’s Joint Special Operations University, Introduction to Special Operations Acquisition Course. An advanced space acquirer course would level-set the space acquisition career field by exposing the workforce to underutilized tools, new authorities, and best practices for rapid space acquisition. This course would include focused case studies specifically related to successful rapid prototyping and fielding in space and other domains. This course would also include interaction with space operators to foster a “laser focus” on the unique challenges of the space domain.

The USSF can also apply cultural insights from Special Operations Forces (SOF) acquisition to promote agility, risk tolerance, and a closer operator-acquirer relationship. The current USSOCOM Acquisition Executive attributes the culture to having “an amazingly consistent leadership philosophy for the last 20 years: Clearly communicate your expectations for risk management and empower the team to make decisions at the appropriate level.”[27] This leadership philosophy is based on the five tenets of USSOCOM acquisition: speed, risk tolerance, scale, inclusivity, and relationships.[28] Also, SOF operators participate in integrated product teams throughout the acquisition process, from requirements development to acquisition strategy planning, through the operational test and evaluation phase.[29] This operator involvement relationship also contributes to a healthier risk-opportunity mindset in each phase of the program.[30] USSF leadership should similarly promote consistent “space acquisition core tenets” and increase operator involvement throughout the acquisition process to build an acquisition culture that prioritizes speed and agility.

LOE 2 – Reorient Select DoD Space Missions Toward Commercial Solutions

The USSF must leverage the technologies and approaches at the frontier of this commercial expansion and move quickly to both reap the benefits of improving capability and affordability, and to be an enabling partner for American industry.[31]

General Raymond, USSF Chief of Space Operations

The growing commercial space economy provides DoD and the U.S. Intelligence Community (IC) with increased opportunities to meet operational needs through commercial capabilities. Capitalizing on these emerging capabilities will require critical analysis of space missions to determine how commercial services could be integrated into military operational concepts. However, it is critical to emphasize that such a reorientation of DoD and IC missions toward commercial capabilities could significantly increase fielding speed and agility.

This section explores key factors involved in improving the potential for harvesting commercial capabilities to meet current and future military space missions. These include: “pull” and “push” commercial space markets to supply products and services important to the DoD/IC; systematically and routinely streamline commercial space regulatory frameworks; and, cultivate Public-Private Partnerships (P3) to expand commercial space markets.

<u>“Pull” and “Push” Commercial Space Markets to Supply Products and Services Important to the DoD/IC</u>

Recommendation 4: *The USSF should evaluate where traditional military capabilities and operational concepts could be enhanced or replaced with commercial solutions*

Given the increasing promise of the space industry, DoD and IC leaders must become increasingly attuned to developments in the commercial space sector. They must learn to effectively interact with commercial markets to “pull”—create reliable DoD demand—and “push”—provide seed-funding and insights into defense-specific needs—commercial space firms to supply products and services important to DoD. The promise is enormous, and worth the effort.

As of 2019, the global space economy was estimated at $366 billion, reflecting a modest 5.6 percent average annual growth rate since 2009.[32] Several independent assessments anticipate rapid future growth, potentially to $3 trillion, by 2040.[33] The former Director of the Office of Space Commerce (OSC) at the U.S. Department of Commerce (DoC) highlighted the potential for growth of new commercial technology and business models for broadband internet, space tourism, small satellite manufacturing, and OSAM. New commercial demand for space services is beginning to alter upstream value-chain infrastructure development activity. For example, demand for global broadband internet through proliferated low earth orbit satellite constellations has shifted satellite manufacturing toward production models that resemble high-volume automobile manufacturing more than traditional low-volume satellite production. SpaceX's "Starlink" program now constructs over 120 satellites per month.[34]

Burgeoning growth in venture capital funding is fueling new commercial space activity. Private venture capital investment in the space industry has grown over twenty-fold in five years, from less than $200 million in 2014 to over $4 billion in 2019.[35] Despite this private investment interest, the space industry still shows many weaknesses that reflect the challenges inherent in new commercial space ventures. Bryce Technologies notes that many space ventures have yet to demonstrate profitability and sustainability even after years of start-up investment.[36] Furthermore, a recent "leveling off" of the number of entrepreneurial space companies receiving venture capital funding indicates that prospective investors are waiting to see how prospective companies perform. As Bryce notes, "only a few of the hundreds of space startups financed since 2015 have reached profitability."[37] Appendix B provides an additional analysis of the current state of the space industry.

Not all new commercial space ventures will succeed A key factor that favors adopting commercial space technologies for military missions is the combination of non-DoD market business viability, plus military mission relevance. Missions like onboard servicing, assembly, and manufacturing (OSAM), small satellite manufacturing, and cislunar operations not only have military applications, but have enormous potential for commercial business cases. Therefore, in these cases, the DoD and IC should routinely assess the state of commercial investment in these potential markets to determine where commercial business cases are likely to survive and outpace government-centered strategies.

Furthermore, some DoD and IC space capabilities will always be inherently governmental. Missions like nuclear-hardened strategic communications will require exquisite production by traditional DoD and IC prime contractors. As a result, orienting DoD and IC mission areas toward commercial capabilities will require DoD and IC leaders to differentiate operational capabilities by mission assurance approach. Legacy space capabilities, like strategic communications or missile warning, may require traditional mission assurance through system design insight and may therefore not be appropriate for rapidly-adopted commercial capabilities. On the other hand, missions like SDA may rely on a "layered" mission assurance approach. In this case, adopted commercial systems provide an added layer of capability that augments, but does not replace, core mission capability. In a diverse architecture that combines commercial and U.S. Government systems, the DoD and IC should consider accepting more operational risk for the additional capabilities that commercial systems can provide. Where dual-use applications exist and business plans are beginning to succeed—such as small satellite manufacturing—orienting DoD and IC missions in ways that leverage commercial capabilities can reap significant benefits. Adopting commercial capabilities can save non-recurring engineering investment and allow the DoD and the IC to field systems with increased speed and agility.

SpaceX's Starlink small satellite production represents an example where DoD/IC space missions could fulfill government space system needs. As of 2018, the U.S. Government contracts drove nearly 45 percent of all satellite manufacturing revenues—mostly for large, exquisite DoD satellite systems built by a consolidated field of large DoD contractor prime integrators.[38] In essence, satellite manufacturing in the U.S. is heavily defense-oriented.

However, SpaceX's assembly line production capability represents an opportunity for the DoD and IC to leverage a commercially oriented production line by modifying Starlink satellites with simple DoD or IC sensors for Space Domain Awareness or protected communications. This example represents commercial capability "pull" to enhance a DoD or IC mission set.

The commercial space industry has demonstrated that it can solve U.S. Government space needs through a commercial service model instead of wholly procured systems. Two decades ago, the United Launch Alliance and the NASA Space Transportation System (STS) dominated the U.S. Government launch market. Concurrent with the decision to end the STS program, NASA broadcast its future vision to contract launch services from commercial providers for transportation to and from the International Space Station. Along with this vision, NASA contracted with SpaceX for future launch services to the ISS. Importantly, this contract included $1.6 billion in upfront funding for a service that SpaceX had yet to demonstrate. This NASA funding arrived just twelve hours before SpaceX would have been unable to make payroll.[39] In addition to saving the company, NASA funding gave private investors confidence in the future profitability of the SpaceX business plan. NASA also advocated for policies and statutes that promoted the use of commercial launch services by U.S. Government agencies, such as the Commercial Space Launch Competitiveness Act.[40] Less than a decade after receiving the NASA ISS transportation contract, SpaceX supplanted ArianeSpace as the top global space launch provider and restored American leadership in space launch market share.[41] The NASA-SpaceX relationship demonstrates the other way the DoD and IC can "commercialize" current internal missions. Instead of commercial capability "pull," the DoD and IC "push" commercial solutions by broadcasting the need for a commercial solution for a current mission area and providing the critical seed funding to establish a viable business plan.

The DoD and IC should routinely assess current mission areas for opportunities to adopt commercial, state-of-the-art capabilities. In this model, typical barriers include changing the traditional risk model of an internal mission. For example, contracting with SpaceX for a parallel production line of Starlink satellites with slight military modifications may be technically possible, but the contractor may demand a firm-fixed price-type contract. Traditional satellite acquisition occurs under cost-type contracting, which provides the U.S. Government program office with detailed design insight for mission assurance and risk reduction purposes. Leveraging the commercial capability "pull" model may require a different satellite acquisition risk management approach that relies less on detailed engineering design insight. Instead, commercial "pull" capabilities can mitigate risk through continual technology refresh by the service provider, through increased speed of adoption, and through increased flexibility to switch commercial service providers at contract expiration.

Determining new opportunities for commercial capability "push" may be more difficult. This model requires foresight into commercially viable markets that do not yet exist. Once potential markets are identified, this model relies on a sponsoring agency outlining the vision and providing the critical seed funding to jumpstart the commercial business plan. In the NASA-SpaceX example, NASA relied on market insight that suggested commercial launch services could be possible despite no market yet existing. This insight could include assessing the sector's technological readiness, the potential venture capital investment to fund a new commercial business plan, and the potential steady-state revenue stream needed to sustain a viable commercial business plan.

Both commercial capability adoption techniques demand closer partnerships and active communication channels between the DoD and IC and non-traditional sectors of the space industry, especially when considering potential new mission areas. Entrepreneurial space ventures are exploring commercial business cases for OSAM and cislunar access.[42] While these potential future capabilities have clear overlap with possible U.S. Government needs, the lack of a developed commercial market could preclude the DoD and IC from adopting a "push" or "pull" approach. Also, more commercial and U.S. Government test cases in these mission areas may be necessary before the DoD and IC define clear requirements that can focus industry investment. The DoD and IC must continually pulse the development of these new commercial concepts through proactive engagement with the space industry. The newly instituted "Space Pitch Day" is an example of the DoD, specifically the USSF, harvesting unsolicited commercial solutions to current space challenges.[43] This forum allows small businesses to present solutions and potentially receive on-the-spot Small Business Innovation Research (SBIR) funding for further prototyping or concept development.

Systematically and Routinely Streamline Commercial Space Regulatory Frameworks

Recommendation 5: *The NSpC should advocate for the commercial space industry and synchronize U.S. interagency policies toward building space industry health*

Growing the U.S. commercial and defense space base enables continued DoD access to innovations that are cheaper, faster, and more responsive to global threat demands. The NSpC provides a powerful voice that can set the direction of U.S. regulatory and security policy. A favorable regulatory environment combined with an optimized space security classification system is critical for U.S. space industry growth. The NSpC is critical to balancing national security interests while ensuring the health of the space industrial base. NSpC coordination assures Executive Branch leadership in directing U.S. agencies to set conditions that are favorable for industry.

At least seven agencies regulate space activities, including launch and re-entry, radiofrequency use, and remote sensing activities. Regulators play a critical role in decreasing launch risks such as accidents and debris mitigation. However, agencies often set conflicting policies that run counter to industry interests. Agencies must prioritize the health of the U.S. space industrial base by not creating unnecessary administrative obstacles that stifle new U.S. commercial entrants in the global space market. A key supporting action would be to direct agencies to continue refining and streamlining space regulations by reaffirming Space Policy Directive-2 on Streamlining Regulations on Commercial Use of Space. The NSpC should coordinate and unify regulatory actions across the Executive Branch to increase proactivity and optimize regulations. This regulatory oversight would balance security and safety with maintaining commercial economic primacy.

The impacts of new regulations on space industry trade and investment are often overlooked. The International Traffic in Arms Regulations (ITAR) is a prime example. To ensure the U.S. space industrial base remains the largest and best in the world, the U.S. must support the ability of its manufacturers to export space products and services to allies and partners around the globe. Yet the complexity and slow pace of the U.S. export licensing regulatory regime, combined with an instinct to restrict emerging and sensitive technologies, unduly inhibits U.S. commercial and defense space companies' ability to trade internationally. To maintain U.S. space industry health, speed, and agility, the NSpC should mandate ongoing reviews of U.S. regulatory frameworks to ensure appropriate consideration of national security objectives and the space industrial base. Additionally, over classification of emerging technologies unnecessarily restricts trade opportunities. This is true under both the Department of State's (DoS) ITAR as well as the DoC's Export Administration Regulations (EAR). To correct this, the DoS and DoC must be scoped to reduce over classification and resourced to continually review and reduce export restrictions as technologies become more widely available. These agencies must also be resourced to address an influx (and backlog) of licensing reviews and approvals.

To ensure U.S. policy priorities better support the national space industrial base, space industry partners need a clear feedback mechanism at the highest levels of the Executive Branch. The NSpC should reconstitute the former User Advisory Group (UAG) to be the primary industry and government consortium to inform policymaking on industry growth. The UAG membership included commercial space industry leaders, Executive Branch members, and academia representatives all serving two-year terms. Moreover, the NSpC should continue to host space forums to collaborate with a larger constituency of space industry participants on space-related national security challenges. The insights gained from this outreach ensure the NSpC can better prepare the industry and Executive Branch for the future of U.S. national security space requirements.

Growing the space industrial base requires better communication between Defense agencies and space industry participants. As introduced above, over classification of space information is a multi-faceted problem. Access to classified work remains a barrier for the space-sector small business community. The DoD and USSF must continue their efforts to make classified work more accessible to space-interested entrepreneurs. The NSpC could assist the DoD and USSF and use the Small Business Administration to create streamlined facility clearance policies and coordination. Without quicker and more reliable access to space programs, small space-based businesses cannot partner directly with the USSF and other space-focused defense agencies.

The U.S. space industry must grow rapidly to maintain economic primacy and ensure America continues to lead in an era of great power competition. Increased partnering with the commercial space sector will drive space industry expansion while providing speed and agility to U.S. national security pursuits.

<u>Cultivate Public-Private Partnerships (P3) to Drive Commercial Expansion</u>

Recommendation 6: *The USSF should utilize the P3 model to leverage commercial capabilities for speed and agility*

Securing and ultimately modernizing U.S. space infrastructure requires the USSF to cultivate P3 with the commercial space sector. Partnering ranges from traditional contracts to P3 with small, mid-tier, and prime contractors. Industry partnerships will enable the DoD to leverage innovative commercial space capabilities across the entire value chain more efficiently and at a reduced cost. Compared to traditional contracts, a P3 model is typically longer in duration and often includes operations and maintenance. The requirements focus on performance versus design, and the government shares risk with the private sector.

An example of a successful space P3 is NGA's commercial imagery program, "Enhanced View." The Enhanced View program was a ten-year P3 between the U.S. Government, Digital Globe, and GeoEye. Initially awarded in 2010, this partnership included nine one-year renewable options. The NGA later expanded the P3 to allow multiple additional providers to satisfy an increased demand for imagery. One such venture includes Maxar's $600 million capital investment to build and launch the WorldView Legion constellation that will image the Earth at faster rates than its legacy satellites "in anticipation of future government demands for high revisit imagery."[44] Overall, the Enhanced View P3 was successful, and the NRO is applying lessons learned to make subsequent P3 agreements better by including more firms. USSF should follow this example in other areas.

Another P3 opportunity for the USSF rests in partnering with innovation incubators to identify and shape emerging technologies. For example, the Catalyst Campus for Technology and Innovation in Colorado Springs provides "a collaborative ecosystem where industry, small business, workforce training, entrepreneurs, startups and venture capital intersect with the aerospace and defense industries to create community, spark innovation and stimulate business growth."[45] Using Catalyst Campus as a launch point, space-related companies like Bluestaq leveraged SBIR program funding to develop innovative products that advance U.S. space capabilities. Bluestaq used a contractor-owned contractor-operated model to develop a Unified Data Library (UDL) architecture enabling central data access across DoD. The USSF uses AFWERX and the soon-to-be-launched SpaceWERX "in partnership with Air Force Research Lab (AFRL) and the National Security Innovation Network (NSIN) in developing the SBIR Open Topics to increase the efficiency, effectiveness, and transition rate of the SBIR program."[46] Expanding partnerships with existing innovation incubators while actively seeking opportunities for new ones will posture the USSF to shape and harness new commercial space technologies.

Cooperative research and development agreements (CRADA) provide another avenue for partnership with innovative small businesses. A CRADA enables a government laboratory and a non-federal party to collaborate on research and development towards new technologies."[47] CRADAs provide small businesses with limited resources access to U.S. research facilities, equipment and expertise. The U.S. benefits from expanded research collaboration and potentially the realization of a mission-enhancing invention. The NGA's 2015 Commercial Geospatial Intelligence (GEOINT) Strategy states that CRADA's will be used to increase "collaboration with commercial GEOINT companies in order to meet rising customer demands for more timely and persistent imagery, analytics, and contextual information."[48] Capella Space, a company that provides Earth observation data on demand, and the NGA established a CRADA in 2020 that extends Capella's research capability in exchange for NGA access to Capella's Synthetic-Aperture Radar (SAR) data and analytics services. This was NGA's first research partnership with an American small satellite SAR data company. "[49] The USSF should consider exploiting CRADAs for future work.

Partnering with industry to modernize U.S. space architectures will accelerate the commercialization of space, furthering the speed and agility DoD requires to sustain a U.S. space advantage throughout the era of great power competition. To retain maximum flexibility, USSF should reorient its current commercial strategy towards incorporating more nontraditional contracts, SBIRs, and CRADAs to exploit and develop game-changing emerging innovations.

LOE 3 – Refocus R&D Enterprise Toward Defense Space Challenges

Many foreign leaders, including Chinese President Xi Jinping and Russian President Vladimir Putin, view strong indigenous science and technology capabilities as key to their country's sovereignty, economic outlook, and national power.[50]

- U.S. Intelligence Community - 2019 Worldwide Threat Assessment

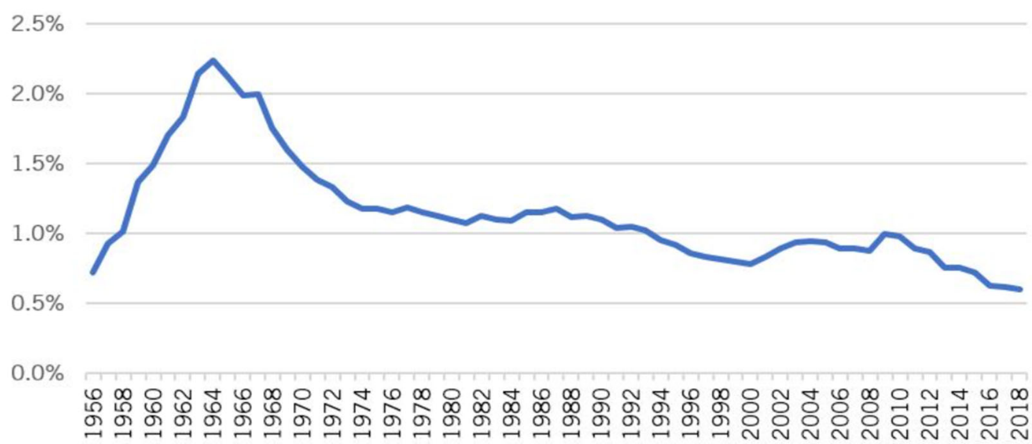
To better harness growing opportunities while meeting evolving threats in the space domain, the U.S. must commit to and adequately invest in a whole-of-nation approach to innovation, which necessarily includes investment in the R&D ecosystem. Maintaining a long-term competitive advantage over great powers requires government investment in partnerships with academia and early S&T efforts (basic and applied research) to conceive concepts and technologies beyond the scope of commercial interest. Focused DoD R&D investment sets the foundation for future speed and agility and long-term competitiveness of the U.S. space industrial base. To this end, the DoD and USSF should increase R&D investment focused on defense-specific space challenges; capitalize on University Affiliated Research Centers (UARC), Federally Funded Research and Development Centers (FFRDC), and lab relationships; and invest in a space-focused workforce by cultivating Science, Technology, Engineering, and Mathematics (STEM) talent.

U.S. Innovation Investment Trends

While the U.S.'s advantage in space today stems from its entrepreneurial National Security Innovation Base (NSIB) and innovative culture, that should not imply the current innovation system is optimally designed and functioning. Instead, many of today's successes rely on historical investments. Though the U.S. has innovation-focused policies, the innovation policy system is fragmented and under-optimized. This disjointed "system" largely represents America's long-standing neo-classical economic belief that markets will drive innovation and federal intervention limits market efficiency.[51] However, this approach does not adequately account for market failure associated with private industry's reluctance to underwrite basic research costs—a critical innovation input.

Although the federal government intervened after World War II and through the Cold War to offset this basic research market failure by creating federal labs and academic research initiatives, current trends indicate the U.S. is moving away from this model. Foote and Atkinson note and the below figure highlights that "the U.S. Government invests less in R&D compared to the size of the economy than it has in more than 60 years."[52]

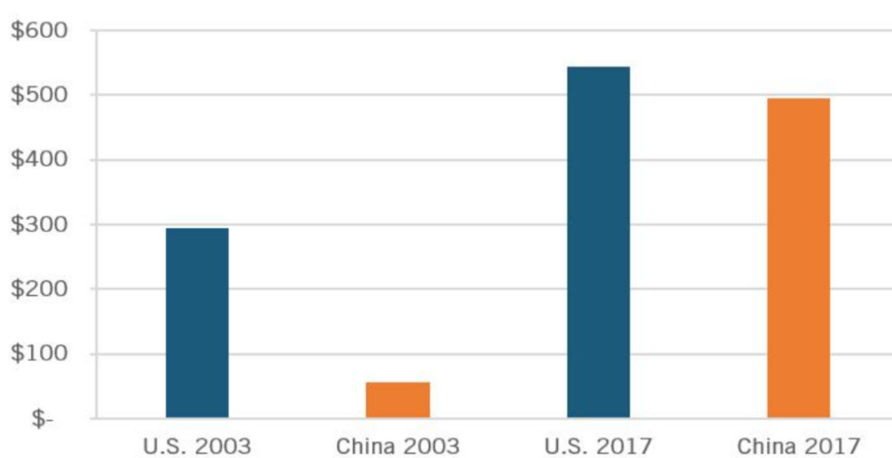
Figure 4: Federal R&D as a Share of GDP



SOURCE DATA: "Federal Support for R&D Continues Its Ignominious Slide," Information Technology and Innovation Foundation, August 12, 2019

Further complicating the issue, federal R&D funds are increasingly focused on specific mission objectives rather than supporting fundamental research to advance scientific knowledge. Meanwhile, countries like China learned a different lesson from the era of U.S. innovation leadership and adopted America's original approach. China's expenditures on R&D have increased an average of 18 percent each year since 2003. Figure 5 below illustrates R&D outlays (government and business) in PPP terms. China's government R&D increased by 330 percent while U.S. Government R&D investment grew by 2 percent over the same period. Chinese business-funded R&D grew by 726 percent while U.S. business R&D increased by only 39 percent over the same period.[53] If current trends continue, China will surpass U.S. federal spending on R&D by 2023.[54]

Figure 5: U.S. and Chinese R&D Spending, 2003 & 2017 (billions, PPP)



SOURCE DATA: "Federal Support for R&D Continues Its Ignominious Slide," Information Technology and Innovation Foundation, August 12, 2019

Only through increased, consistent, and secure investment in R&D can the U.S. move beyond the incremental improvements of existing capabilities to those showing disruptive potential. Given short-term domestic political interests, individual administrations will be challenged to adopt policies and strategies that will meaningfully increase investment in innovation. While perhaps a lofty goal, educating the American public on economic growth (innovation) drivers and necessary inputs could help change cultural attitudes toward federal investment in basic research.

R&D Investment Focused on Long-Term, Defense-Specific Space Challenges

Recommendation 7: *The DoD should rebalance R&D investments toward long-term defense needs*

Although it is difficult to provide an unclassified analysis of space-focused R&D investment funding goals, it is clear that the DoD alone owns certain aspects of the space problem set and must adequately invest in those mission areas. With the current strategy noting a requirement to develop counterspace capabilities, DoD and USSF should increase R&D efforts toward these and other defense-specific space challenges. This new look on R&D investment requires DoD to open the aperture on its historic earth-centric approach to the domain—taking a much bolder perspective that considers threats and opportunities in cislunar space and beyond.

On-orbit propulsion performs a crucial function for current space systems, and it will become increasingly important for future systems. DoD should leverage the R&D work that NASA is currently underwriting in its deep-space exploration programs and apply a defense-focused lens.[55] Efforts in the field of Nuclear Thermal Propulsion (NTP) provide promise. When compared to chemical propulsion, NTP produces twice the thrust per mass of propellant. Thus, advancements in NTP could prove vital for national security systems requiring enhanced on-orbit maneuver speed, agility, and longevity.

Another R&D focus area for DoD should be military-grade sensors and components for small satellites (SmallSats)—specifically those with little to no current commercial application. Future on-orbit space surveillance network sensors provide one such example of a capability ripe for increased R&D investment. DoD should also increase R&D focus and investment in other enhanced SmallSat capabilities and their integration into the greater national security space architecture.

While DoD focuses on defense-specific R&D efforts to help fill an existing void, it should place commercial integration opportunities at the forefront. One example would be intentionally designing military-grade sensors and payloads to permit seamless integration with commercially available buses. Ensuring integration on the development and design end will reduce retrofit timelines and provide a more responsive capability.

<u>USSF Should Capitalize on UARC, FFRDC, and National Laboratories Relationships</u>

Recommendation 8: *The USSF should establish a USSF-sponsored UARC to advance innovation and research areas that enable warfighter capabilities*

Recommendation 9: *The USSF should establish an annual Staff Years of Technical Effort* (*STE) allocation for FFRDCs and UARCs*

One way the U.S. can sustain and enhance the market health of the space industrial base is through strengthening and capitalizing on relationships with not-for-profit (NFP) R&D entities, particularly UARCs, FFRDCs, and National labs. Specifically, the USSF needs its own UARC to sponsor its own allocation of STE to work directly on the space domain. Capitalizing on these relationships will help the U.S. Government compete now and into the future in the space domain and during this era of space competition.

UARCs are well-established entities that can help the DoD space enterprise as it has helped other DoD Services over the past half-century. They are "not-for-profit, private-sector organizations that are established and funded to meet special long-term engineering, research, development, or other analytic needs that cannot be met as effectively by government or other private-sector resources."[56] UARCs have "access, beyond that which is common to the normal contractual relationship, to Government and supplier data, including sensitive and proprietary data, and to employees and installations equipment and real property."[57] UARCs have been integral to the U.S. Government's competitive advantage in R&D. UARCs "must be affiliated with a university, must have education as part of their overall mission, and have greater flexibility to compete for public and private R&D contracts."[58] These unique differences provide the USSF with increased opportunities and varied paths to target and increase R&D.

The USSF should also capitalize on FFRDCs and research labs. While UARCs and FFRDCs are similar in characteristics, they are not the same. An FFRDC is a "special type of government-owned, contractor-operated research centers—commonly referred to as "GOCOs"—that conduct R&D and related activities in support of a federal agency's mission."[59] FFRDCs have some restrictions and may not compete with the private sector for federal R&D contracts.[60] The National Laboratories have been around for more than seventy years and have served as leading institutions for scientific innovation.[61] These 17 U.S. National laboratories can help the USSF with the Space Domain by tackling the "critical scientific challenges of our time."[62] The USSF should take advantage of these unique and rich resources because they can provide a competitive edge against the competition.

There are many advantages and benefits to working with UARCs, FFRDC, and labs for the space enterprise, as shown in Figure 6. They can provide the government something they currently do not possess—game-changing ideas and research along with experts in critical space and technology fields. In 2016, the Defense Business Board concluded that the "FFRDCs/UARCs provide high quality R&D and technical support to DoD."[63] They provide objectivity and independence, as well as talented, experienced, and technical expertise that space acquisitions programs and missions require. [64] Both also help eliminate conflicts of interest by fully disclosing their activities.[65] Additional benefits and roles include being an honest broker and technical advisor, building critical prototypes, developing requirements, and performing and developing model-based engineering.[66] There are challenges when working with UARCs, FFRDCs, and labs. These challenges can range from higher costs, limited resources, competition with the private sector, and mission creep. While UARCs and FFRDCs have challenges, the benefits outweigh them if the service uses the organization properly.

Figure 6: Benefits & Challenges of UARCs, FFRDCs, and Labs

Benefits	Challenges
Game-Changing Ideas	High Cost
High Quality R&D	Limited Resource
Objectivity & Independence	Competition with Private Sector
Talented Experience	Mission Creep
Honest Broker	

SOURCE DATA: Mark E. Gallo. "Federally Funded Research and Development Centers (FFRDCs): Background and Issues for Congress. CRS. Updated April 3, 2020. Page 1

The DoD space enterprise must expand its use and funding of these critical entities. UARCs typically receive only around $6 million per year for R&D.[67] While FFRDCs receive an average of 10 percent of the federal government's total budget for R&D.[68] These figures account for the total Federal Government R&D and not the space mission specifically. The DoD space enterprise needs to prioritize space domain R&D funding increases to maximize future USSF capabilities.

While the government has invested in private NFP entities and labs for the past 50 years, the DoD space enterprise should maximize this relationship for the Space Domain.[69] Doing so will be challenging in an era of tightening budgets. Still, the government cannot afford to stagnate as China and Russia pursue the space domain with energy and determination. Capitalizing on these key relationships and partnerships is critical because America's adversaries do not have the same robust NSIB capabilities.

The USSF should establish a new space UARC capability. While 13 federal agencies currently sponsor or co-sponsor 42 FFRDCs and 13 UARCs, none are affiliated with the new USSF or space domain.[70] Some may argue that the USSF can continue to use the Air Force's UARCs and that the space mission will be supported without having its own dedicated partner or sponsor. Unfortunately, the space domain is too important to national security and our current way of life to play second fiddle or take a back seat. Having a USSF sponsored UARC shows that the Space Domain is vital, and investing in short-term and long-term R&D is critical for the country.

There are viable solutions already available to the USSF. Colorado's emergence as a space innovation cluster and growing space start-up industry makes the University of Colorado a prime candidate for a USSF UARC. Another possibility would be the Space Dynamics Laboratory at Utah State University sponsored by the Missile Defense Agency. Establishing a USSF UARC will send a clear message to U.S. allies and adversaries that the DoD space enterprise, particularly the USSF, is fully dedicated to space R&D to preserve technological overmatch. It will also help bridge the gap between fast-moving private industry technology and potential national security applications. Finally, having a USSF UARC will improve the government's ability to sustain and enhance the market health of the space industrial base by providing another space resource from which everyone can use and learn.

For the long-term, the USSF needs to establish an annual dedicated Space allocation of STE with FFRDCs and UARCs for working on specific space domain issues and concerns. Unfortunately, FFRDCs and UARCs are not an unlimited resource the DoD Space Enterprise can use at will. Congress sets limits and restrictions on the amount of money and STEs the DoD can use each year.[71] So, increasing the UARC and FFRDC space mission support could hinder or take away from another mission. There is a solution. The USSF should work with DoD and members of Congress to establish a specific amount of money and STE allocation each year for space missions. The nuclear modernization mission is currently trying to establish the same allocation system due to its critical mission. The space mission could partner with the nuclear mission and pass the policy together to establish allocations for these vital areas. While this will take some time, it is worth the effort to institute the Space Domain as a critical player when it comes to working R&D issues with UARCs, FFRDCs, and research labs.

Invest in a Space-Focused Workforce by Cultivating STEM Talent

Recommendation 10: *The DoD should aggregate all DoD STEM-based scholarship programs at a single, easily searchable website; fund marketing programs to promote the scholarships*

Recommendation 11: *The DoD should invest in greater P3 at military academies to increase space-related STEM degree throughput*

Recommendation 12: *The DoD should develop a DoD STEM Reserve Officer Training Corps (ROTC)-like scholarship program for STEM-capable human capital for the NSIB*

Reinvigorating national enthusiasm for space-based STEM careers goes beyond the near-term threat posed by China and Russia in space; it is America's only path to sustaining the long-term lead in great power competition with fewer natural and human capital resources when compared to its competitors. The space industry is hurting for qualified professionals to staff software engineering, data engineering, systems engineering, system administration, spacecraft software engineering, spacecraft navigation engineering, and astrodynamics engineering jobs.[i]

[i] High volume vacant job titles sourced from Maxar, Bluestaq, and Advanced Space vacancies. Sixty percent of Maxar's 197 vacancies are engineering positions, 100% of both Bluestaq and Advanced Space vacancies are engineering.

For space, in particular, a qualified, skilled workforce is critical to building complex space systems and injecting new ideas and concepts into growing space commerce, national security space, and even space doctrine. Better targeting of scholarship and industry-based pipeline programs by the U.S. Federal Government can profoundly affect U.S. staffing opportunities for the most in-demand space jobs needed for current and future national security challenges. Increasing STEM human capital is the primary means of expanding the R&D and space capability development efficiency required for agile space domain superiority in a competition defined by technical prowess.

The current pipeline for human capital into the space industry is smaller than other STEM-based fields and requires more impactful recruitment activities. Participants in the U.S. space industry have unique labor requirements, significantly narrowing the pool of eligible human capital. Until broad changes are made to the security classification of government space programs, nearly all participants are required to be U.S. citizens and hold advanced security clearances. Making the space recruitment prospect even more daunting, neither the Federal Government nor defense prime contractors can compete with the generous compensation packages offered by the largest technology companies (non-space focused technology companies or defense prime contractors) to the nation's most talented engineers. Consequently, the defense primes heavily recruit former military and civil service members to staff their space programs—ensuring they bring in "mission-oriented" professionals with the requisite security clearances who meet their citizenship requirements. Because the pool of eligible candidates for space-focused engineering jobs is narrowed from the already small pool of U.S.-based STEM-capable human capital, the U.S. must generate awareness and enthusiasm for mission-based STEM careers through newly revitalized accession paths for the NSIB. The long-term health of the NSIB and space great power competition advantage is at risk without immediate changes to increase the recruiting pipeline for both the Federal Government and defense primes.

Based on a 2016 World Economic Forum report, China now produces 4.7 million STEM graduates per year – amounting to 8.3 times the number of U.S. STEM graduates, as shown in Figure 7.[72] While surely not all of those graduates are fueling the Chinese space program, China's rapid space capability ascent cannot be completely disconnected from the CCP's investment in STEM education and their accomplishments to date in the space domain. China's activities provide a healthy reminder of what is possible when appropriate levels of STEM education investments are made. Graduates with degrees in STEM fields are foundational to securing national competitive advantage in space innovation – a reality China worked diligently towards and one the U.S. can quickly rebuild with the right programs and policies.

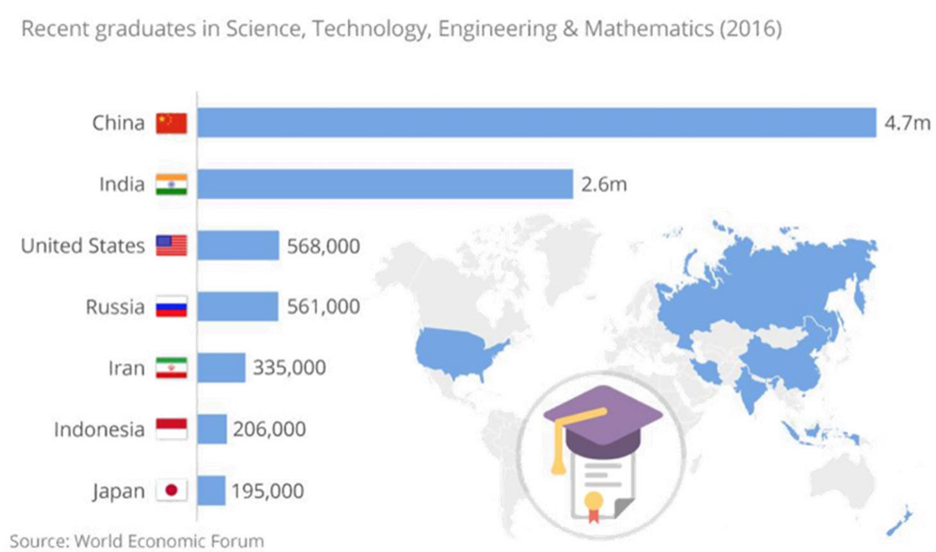
In contrast to China, the U.S. has STEM education incentive programs, but they are minimally funded and under publicized. China has created a proverbial avalanche of STEM graduates while the U.S. now produces a small stream. The U.S. already has several space-related STEM collegiate scholarship programs that funnel technically trained civilian graduates into targeted agencies. Examples include:

- The Stokes Educational Scholarship Program
- The Cyber Scholarship Program
- The Science, Mathematics and Research for Transformation (SMART) Program

- Training Within Industry (TWI)
- Palace Acquire

All have small annual cohort sizes (ranging from approximately 10-30) and are generally poorly publicized. These programs (and the likely many others like them) can be great national resources for enhancing the NSIB talent pool. Space-focused services and agencies must inventory all the Defense and Intelligence STEM-based undergraduate scholarship programs, aggregate the scholarships at a single, easily searchable website, and build new marketing programs to promote the scholarships and follow-on DOD and Intelligence STEM space careers. Better consolidation and marketing of the available programs will provide early "hooks" for technology-competent, mission-oriented civilians entering the NSIB early in their careers.

Figure 7: Countries with the Most STEM Graduates



SOURCE DATA: World Economic Forum, "Human Capital Report 2016," Infographics and Sharables Section

One particularly effective approach to broadening the pool of STEM-capable human capital is through P3 at Federally-funded academic institutions. The U.S. Air Force Academy and U.S. Military Academy (West Point) are the primary service-based schools producing officers destined for the modern space domain. West Point is currently building a Cyber & Engineering Academic Center via public private partnerships focused on building the knowledge base and leadership in highly technical and multi-domain battlefields.[73] A high percentage of military academy graduates depart the services after the obligatory five-year service academy payback period, particularly those with highly marketable skillsets. Early exposure and partnering with targeted NSIB industry companies will serve as prime recruiting opportunities to keep that talent working in the mission-oriented space domain for years to come.

Beyond enhancing the programs already established for targeted civil and military recruits, it is time for the DoD and IC to invest in a STEM ROTC-like scholarship program to boost the pipeline for technically capable human capital to serve at FFRDCs, Defense Advanced Research Projects Agency (DARPA), and civil agencies like NASA, NOAA, Department of

Energy (DoE), and NGA. The program would be similar to the military's ROTC scholarship program by providing higher education to a large cadre of future Defense and IC space professionals via the U.S. accredited university system. Establishing such a program would supply STEM-educated human capital with service obligations to the space-related national security state agencies. A STEM ROTC-like program has the potential to grow the number of STEM-educated citizens and participants exponentially while creating a base of human capital that, after leaving obligated service, would be wholly capable of contributing to the commercial space industry.[74]

The quality and quantity of the U.S. STEM-capable workforce are foundational to building speed and agility into the Federal Government's and space industry-writ large's attempt to beat the pacing threat posed by China and Russia. A pronounced shortage of qualified human capital was cited throughout numerous Industry Study discussions with small start-ups, mid-tier primes, large defense industrial base primes, and USSF Deltas. In particular, a shortage of software engineers and computer science expertise was noted as a common theme. The recommendations discussed above promote and incentivize STEM education while reducing the cost of advanced degrees for U.S. citizens, which is a primary barrier to entry.[75] The U.S. must increase the production efficiency of a STEM-capable workforce to succeed in great power competition with China and Russia.

LOE 4 – Reshape Interagency and International Partnerships

The United States, in concert with its allies and partners, has the opportunity to shape the future of space over the next thirty years - if it takes action today.[76]

- Atlantic Council: The Future of Security in Space, April 2021

In 1957, following a galvanizing "Sputnik moment," the U.S. took action to secure its position as the leading global space power. This resulted in an unmatched military space architecture that for many decades provided the U.S. a distinct warfighting advantage over its adversaries. In the space domain, a unipolar and well-resourced U.S. did not need to partner with other nations to advance innovation, gain operational capabilities, or sustain superiority in space. Today, great-power rivals China and Russia aggressively seek to undermine U.S. space leadership. "Flying solo" is no longer an option. The U.S. must reshape its alliances and partnerships to achieve speed and agility in rapidly fielding comprehensive space capabilities. In addition, responsibilities among the many elements in the U.S. space enterprise must be better coordinated, deconflicted, and fully resourced. Finally, the U.S. must provide global leadership in space norms development efforts. Since it often pays to get one's own house in order first, the first issue examined will be interagency space responsibilities.

<u>Differentiate Interagency Responsibilities to Maximize Space Warfighting</u>

Recommendation 13: *Congress and the Executive Branch should properly resource the DoC for the Space Traffic Management (STM) mission*

National Space Policy Directive-3 (SPD-3) directed the Department of Commerce (DoC) to assume civil and commercial space traffic management (STM) responsibility as part of its space commerce regulation role.[77] However, lack of a clean appropriations transfer and lingering ambiguity over STM mission roles and responsibilities has caused tension between the DoD and the DoC. This tension detracts from the urgent need to enhance U.S. STM capabilities in support of commercial space sector growth. This role and responsibility conflict has also restrained the DoD from focusing its space domain awareness (SDA) capabilities toward answering emerging space threats. Part of this agency tension stems from the fact that the systems and data used for the STM and SDA missions are virtually identical. DoD and DoC leaders must clearly delineate STM and SDA roles and responsibilities to solve this ambiguity, especially where capabilities and data could be shared to enhance each mission.

Additionally, the Executive Branch must request that Congress fully resource the DoC for the STM role. Although the DOC Office of Space Commerce (OSC) requested $15 million in FY2021 funding to begin the STM mission, it received only $10 million.[78] This shortfall, combined with a "pilot" designation of the OSC's STM activities, indicates less than total Congressional commitment. The DoC should be fully resourced with the requisite staff and budget for the space system integration, data sharing, and monitoring activities necessary to accomplish the STM mission. If the DoC is not adequately resourced to assume and maintain the STM mission. The USSF would need to continue covering the STM mission requirement, which would degrade its focus on SDA capabilities for space warfighting.

Reshape International Partnering to Leverage Combined R&D Investments and Promote Interoperability

Recommendation 14: *The U.S. should designate Japan as a Five Eyes-equivalent space partner and explore expanded opportunities for R&D co-investment, payload hosting, and operational integration*

Recommendation 15: *The DoC should designate the UDL as the authoritative repository for STM data and offer this capability as a globally available service to enhance STM cooperation*

International partnerships have been a longstanding element of U.S. civil space missions. The 1958 National Aeronautics and Space Act encouraged NASA to cooperate with other countries.[79] Twenty-first century great power competition requires the U.S. to expand international partnerships beyond civil space cooperation to military missions. According to USSF Director of Staff, Lt Gen Nina Armagno, "The U.S. doesn't go anywhere alone, we don't do it alone around the world, and we certainly don't do it alone in space."[80] Expanded space partnering with key allied nations can enhance the speed, agility, and resilience of U.S. space capabilities. The Space Domain Industry Study team explored opportunities to enhance space partnerships with Japan to counter increased great power competition from China. Japan's proximity to China, its regional influence, economic strength, and full spectrum space capabilities make it an ideal candidate for increased space partnerships across R&D investments, manufacturing, and operational military capabilities.

Japan's status as the world's fourth most significant space power and long history of civil space cooperation with the U.S. offers opportunities to partner towards national security objectives and mutual space industrial base health.[81] Furthermore, Japan clearly recognizes the value of stronger military space partnerships with allies. Japan's 2018 National Defense Planning Guidance (NDPG) emphasizes the space domain as a vital security interest of Japan.[82] Furthermore, the NDPG sets clear expectations for future military space partnering. It directs Japan's Self Defense Force (SDF) to work with the U.S. to ensure superiority in the use of "space at all stages from peacetime to armed contingencies."[83]

Space partnering with Japan could help offset China's rapidly escalating R&D investments. A recent Nikkei study found 40 percent of Japanese companies had budgeted record amounts for R&D to invest in AI and other high-tech innovations.[84] Expanded R&D partnering in space with Japan would complement the U.S. NSIB and enhance combined technological leadership in space system development. Japan is a global leader in automation, artificial intelligence, robotics, and manufacturing. Japan's overall R&D investment growth demonstrates a commitment to long-term technological leadership. Over the last six years, Japan has dramatically increased national R&D investments and is among the top five leading nations in space program investment.[85]

The U.S. should also explore manufacturing and operational partnering for space missions. Potential areas for expanded partnering include:

- Expanded PNT
- Commercial SSA/SDA integration
- Bilateral sensor-payload hosting
- Collaboration on the development of space debris solutions.

In addition to providing resiliency of remote sensing architectures and orbital diversity for sensors, co-hosting offers added deterrence against hostile ASAT actions by increasing the likelihood of multi-national response. Further, there is an emergent opportunity to leverage Japanese robotics expertise for space debris removal. The 2020 memorandum of agreement between the and USSF and Japan to host a U.S. SDA optical sensor payload on planned JAXA launches in 2023 and 2024 is a model for future potential payload hosting partnerships for mutual space capability enhancement.[86]

To increase international space partnerships through data sharing, the DoC should designate the USSF Unified Data Library, introduced in LOE 2, as the official U.S. combined repository for STM. Endorsement of the UDL as a globally available service would increase collaboration among a growing number of space-faring nations and ultimately lead to a more effective international STM capability. The UDL already supports over 20 countries with data management, imagery, signals, and STM at the unclassified to top-secret level. One challenge to the international adoption of the UDL is a fee structure that may require foreign nations to pay for access to data that had always been "free." On the other hand, UDL users will benefit from the increased service quality inherent in more widespread use. Foreign governments may have concerns with the control and dissemination of the data they share through the UDL. However, the UDL allows for data owners to contribute their information to the system and limit the data as necessary to ensure security and IP controls. Any UDL user can control the dissemination to the collective groups.[87] Despite possible implementation challenges, the UDL provides a promising opportunity to bolster international space partnerships through STM mission data sharing.

Reshape Space Norms with Allies and Partners to Sustain U.S. Great Power Competitiveness

Recommendation 16: *The NSpC should coordinate and affirm an official U.S. position on space norms*

Recommendation 17: *The DoS should lead an allied space norms proposal in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) that promotes responsible behavior, STM, and debris mitigation*

Space has recently become contested, congested, commercial, and more complex, but it is still a rapidly evolving domain. In all domains, norms of behavior are an essential buttress for stability, safety, and sustainable use by all participants. As the leading beneficiary of the space domain, the U.S. has the most to gain and lose by a lack of constructive "rules of the road" for space. This reality is driving a debate on the need for updated treaties and norms. However, in the hierarchy of U.S. national security interests, the short-term imperative to preserve U.S. freedom of action must come first. In the long-term, norms will set the critical foundation for domain stability and universally accepted behaviors in space. The U.S. must therefore approach international space norm development in a manner that prioritizes military advantage in the near-term. Paradoxically, there is a near-term pressure for the U.S. to lead the international space norms debate or be supplanted by great power competitors. As the USSF surges new capabilities to counter emerging Chinese and Russian space threats, it must have the leeway to develop new tactics, techniques, and procedures that will ultimately sustain continuing military advantage against space threats. On the other hand, diplomats need substantive proposals to rally space-faring nations around a U.S.-centered vision for norms. Navigating the norm paradox thus introduces a dilemma for U.S. diplomats and military leaders. Negotiating this dilemma will require full consideration of the opportunities and risks involved in space norm development. It will also demand a new degree of coordination between those leading international norm discussion and those responsible for maintaining warfighting advantage in space.

Numerous opportunities are associated with the U.S. leading efforts to reach international consensus on norms and standards for space operations. U.S. leadership helps protect national interests in the long run by establishing common definitions, understandings, and behaviors across the range of civil, commercial, and military actors. As tensions continue to rise with China and Russia, a missed assessment or notification could be misinterpreted by either and deemed as a hostile act. Norms "clarify misbehavior, thereby helping to isolate, limit and sanction malign behavior."[88] Even though norms, principles, and standards are non-binding, as countries agree to them, they reduce the risk of catastrophic orbital collisions. They set the stage for more rapid detection and attribution of actions in space that constitute anomalies or threats. The U.S. and its allies thus benefit by being able to more quickly recognize and attribute adversarial actions and impose punitive or corrective measures.

The risks related to setting international norms and standards for space are also numerous. The short-term risks and the long-term risks create a dilemma. In the long-term, without American leadership, the U.S. risks allowing other actors to define space norms. Great-power rivals, China and Russia, have already proposed the creation of a UN *Treaty on the Prevention of the Placement of Weapons in Outer Space,* which, if adopted, will restrict the ability of the U.S. and its allies to pursue counterspace and space defense options while preserving adversarial counterspace gains.[89] If U.S. rivals prevail in these efforts, without widely accepted norms that benefit allied military and industrial freedom of operations, then America's space competitiveness and leadership would be eclipsed at the speed at which China's capabilities are expanding. As global sentiment has increased in favor of establishing international norms and standards for space operations, the U.S. has gained a reputation in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS, the primary international space cooperation forum), for not supporting any recent proposals. This was true even when calls for the development of space debris and collision avoidance measures were presented by allies, such as the European Union.[90] In addition, the U.S. disengaged from norms negotiations with the FVEY partners, Japan, France, and Israel, in 2010.

The long-term benefits of adopting international standards are clear. However, there is a dilemma in the short-term. Before agreeing to international standards, U.S. agencies, especially the U.S. Space Force, must first realistically consider what leeway is required in space operations to guarantee freedom of maneuver in space for offensive and defensive space operations. Since space has only very recently been declared a warfighting domain, there is still much to be learned about space warfighting doctrine. If the U.S. agrees too rapidly on norms, it could, via its own diplomatic efforts, forestall critical options for freedom of maneuver defense priorities.

The Biden Administration will likely experience increasing pressure from allies and industry partners to play a prominent role in establishing the "rules of the road in space." The National Space Policy, communicated in a Presidential Memorandum on December 9, 2020, and SPD-3, National STM Policy, released in June 2018, directed U.S. agencies to develop a range of space operation norms, best practices, and standards. These directives specifically included a focus on behavioral norms to avoid on-orbit collision that were to be developed, coordinated, and promoted with allies and partners.[91] SPD-3 also calls for expanded U.S. engagements to increase support and adoption for space norms and standards of behavior in multilateral fora.[92] In addition, pressure for coordinated international action will continue to grow given the adoption of the UN "Resolution on Reducing Space Threats Through Norms, Rules, and Principles of Responsible Behaviors"[93] introduced by the United Nations General Assembly on December 7, 2020. This resolution calls on States to "avoid and mitigate the potential impact on peace and security arising from accidents, miscommunication, or a lack of transparency."[94]

To optimize American international standing on space norms, the U.S. cannot be the lone voice and cannot wait too long. Any U.S. proposal must be developed in concert with the most trusted U.S. spacefaring partners. While USSF warfighters refine their doctrine and tactics, U.S. diplomats should leverage the FVEY Alliance and Japan to negotiate an initial draft of international space norms sometime soon. FVEY is ideal because of its members' geographic diversity and ability to secure support for a resulting proposal in Europe, Asia, and the Western Hemisphere from major and minor spacefaring nations alike. Japan's involvement is critical as a significant space power, regional leader, likely addition to the FVEY or an expanded SPEY alliance, and soon-to-be participant of the CSpOC. Also, the FVEY alliance with partners, including the European Space Agency, can assist in securing more comprehensive support for norms proposals while helping reduce the likelihood of significant issues or barriers to future adoption by a range of allies and partners. Once the initial group has reached an agreement, they must use an existing international body to present the draft and recruit other countries to join. The United Nations provides the ideal forum for global engagement, as the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) is one of the largest United Nations bodies with 95 member states.[95] Coordination efforts should also engage both established and emerging government and space industry players to consider actions needed to enable and promote more agile, flexible space policies and solutions.

Navigating this dilemma will require robust, whole-of-government coordination, mandated at the highest levels. This places a premium on the continued leadership of the White House team at the NSpC. It will require the full support of the USSF and engagement with all relevant U.S. agency stakeholders. Stakeholders include NASA, the IC, the Departments of State, Defense, Energy, Commerce, Homeland Security, Transportation, FAA, and the FCC.

They require close coordination with USSF and the USSPACECOM to define U.S. space stability objectives, end states, opportunities, policies, and messaging. Such efforts must ensure compromises for an agreement are reached between primary U.S. space security stakeholders within the DoD and the IC, or a greater U.S. agreement is unlikely.[96] This whole of nation effort to develop norms and standards will also benefit from close coordination with industry, academics, and S&T partners, to ensure that norms serve the broadest range of U.S. security and prosperity interests. The need for nuanced U.S. leadership on the development of responsible space behavior will only increase as great power competitors field destructive counterspace capabilities while aggressively courting other nations to sign on to norms specifically intended to inhibit long-term U.S. space advantage.

Conclusion

This report culminates a semester-long study of the challenges, threats, and opportunities the U.S. faces in the space domain. The Space Domain Industry Study explored these topics from various viewpoints: the national security leader perspective, the industrial base health perspective, and the firm profitability and sustainability perspective. Synthesizing challenges and opportunities across these diverse perspectives yielded fresh insight on how to approach the growing national challenge of building and sustaining U.S. great power competitiveness in space. Moreover, appreciating both the common and conflicting interests among these three perspectives provided a rich appreciation for the challenges of policy entrepreneurship.

China and Russia's recent proliferation of advanced counterspace systems now places U.S. space capabilities at risk, threatening U.S. military strength and the global economy. These great power competitors are also pursuing coordinated national investment strategies that enhance national power and prestige with full-spectrum military, civil, and commercial space capabilities. The outcome of this new competition for space preeminence will cut across all elements of national power—it is a race that the U.S. cannot afford to lose.

Robust and decentralized S&T investment, public-private partnerships, and broad alliances overcame the great power challenges of the 20th century. The U.S. must re-ignite these natural advantages to answer the long-term challenge posed by great power competition in space. The DoD and its U.S. interagency and international partners must renew national space competitiveness by leveraging the expanding space industrial base to field operational capabilities with greater speed and agility. Additionally, U.S. agencies should pursue policies that promote the long-term expansion and health of the burgeoning commercial space sector.

This report includes four critical lines of effort and seventeen resource-informed recommendations that comprise an initial approach toward building national competitiveness in space. This approach involves focused resourcing and relationship-building by U.S. agencies, including private industry, non-profit sector, academia, and international partners. These lines of effort are:

(1) Rebalance USSF resourcing
(2) Reorient select DoD space missions toward commercial solutions
(3) Refocus the DoD Research and Development enterprise toward space challenges
(4) Reshape interagency and international partnerships.

Our recommendations provide an initial foundation for additional policy development and action toward building and sustaining U.S. competitiveness at this critical inflection point in human space activity.

Appendices

Appendix A: Porter's Diamond Analysis of Major Space Powers

A.1: United States of America

The Michael Porter's Diamond Model is a diamond-shaped framework that focuses on explaining why certain industries within a particular nation are competitive internationally, whereas others may not be. Porter contends that a company's ability to compete in the international arena is based primarily on an interrelated set of advantages that certain industries from within different nations possess, which include: (1) Factor Conditions; (2) Demand Conditions; (3) Related and Supporting Industries; and (4) Firm Strategy, Structure and Rivalry. Porter asserts that if all four of these factors are favorable, then it forces domestic companies to innovate, improve and flourish continuously. Adding that each component in the model makes up the "essential ingredients for achieving international competitive success."[97] The subsequent competitive advantage that results helps to better position a company when aiming to compete internationally with some of the world's largest competitors for greater market share on a global scale. Additionally, there are two other components that have been included in this model: the role of Government and Chance. Together these two components shape the national environment in which companies are established and learn how to compete within their respective industry.[98] Using the Porter's Diamond Model, an analysis of the U.S. Space Industry has been conducted to gain a better understanding of how the U.S. compares to other spacefaring nations, specifically an emerging key ally in space, Japan, as well as two other nations competing for superiority in space: Russia and China.

Factor Conditions

A nation's factor conditions, or the unique environmental and production inputs that lead to the competitive advantage of a particular industry, can be categorized further as key (specialized) and non-key (non-specialized) factors – both involve substantial and sustained investments. Some key elements include skilled labor, capital, and infrastructure, all relevant for maintaining a competitive advantage in a particular industry. Non-key factors, which are crucial to sustaining a competitive advantage in a specific industry, include raw materials and unskilled labor. Today, the U.S. Space Industry enjoys a wide variety of both favorable and unfavorable factor conditions. An example of this is highlighted by assessing U.S. human capital resources, which includes a large population mixed with a range of both highly skilled and unskilled labor. Another example is that the U.S. unemployment rate for April 2021 is 6.1 percent, reflecting strong employment levels despite the global pandemic.[99]

The U.S. Consensus Bureau is tracking the U.S. population at 331,449,281 as of April 1, 2021 [100] – the number of U.S. citizens ranks as number three in the world behind China and India, which rank as numbers one the two in the world respectively.[101] The quantity and quality of U.S. diversity demographics and population are fundamental to its competitive advantage.[102] However, the U.S. is also experiencing a lower birth rate coupled by an aging population. These two factors are starting to impact the total workforce available, which is further compounded by current immigration policies adversely impacting the number of eligible personnel available to join the workforce. A workforce with robust STEM capabilities is critical to sustaining U.S. preeminence. Today, however, the STEM activities of the DoD are a small and diminishing part of the nation's overall science and engineering enterprise, which has a significant impact on the nation's competitive advantage in the U.S. space industry. However, America's ability to produce, sustain and protect research in key technological and knowledge areas are an area of strength, which is vital to its defense and national security.

Another favorable factor condition is American colleges and universities maintain global leadership and are internationally recognized as offering the best education, with strengths in business, science, and technology.[103] As it pertains to the space industry, the U.S. colleges and universities system is recognized internationally for providing the best STEM programs in the world. Massachusetts Institute of Technology (MIT), Stanford University, California Institute of Technology (Caltech), and Carnegie Mellon University are all examples of some of the top technical institutions in the U.S. that all offer extensive STEM education programs. However, one of the areas of concern since the beginning of the 1980s is American students have been performing well below average in STEM disciplines compared to foreign STEM students and there is a growing concern that STEM proficiency is declining in America.[104] Recent reports show that there have been modest improvements in Americans' basic STEM skills over the past couple of decades, but the U.S. continues to fall behind many other countries, with only about 20 percent of college-bound high school students being ready to take courses required for a STEM major at the undergraduate level.[105] Although the U.S. may currently lag other nations in basic STEM skills, it has the resources and means to improve in this area by incentivizing its citizens through its K-12 STEM education programs to pursue STEM subjects and seek higher education in STEM at one of America's world-renowned colleges or universities. Additionally, these STEM programs offer internships, funding for scholarship programs, and loans for STEM students. Finally, another favorable and unique factor the U.S. has over other rival nations is its inherent ability to attract its foreign-born top graduate students in the STEM fields who would prefer to stay in the U.S. to continue their research and work for U.S. high-tech and aerospace firms because of the social and academic freedoms they are afforded in the U.S.[106]

The last critical factor condition that helps the U.S. to sustain its competitive advantage in the space industry is its ability to invest due to the nation's capital resources. The U.S. is one of the world's richest nations, and as a democracy with a highly developed capitalist economy; it allows for extensive investment from corporations to individuals. The GDP is $21.43 trillion, with a per capita of $55,809, which is "equivalent to 442 percent of the world's average."[107] The U.S. banking system is mature, and the dollar is the number one currency traded on the global stage. In addition, according to the Forbes 2021 "Midas List," 69 of the world's top 100 Venture Capitalists, in terms of launching highly valued and well-funded high-tech startups, most top-funded high-tech startup companies are based in the U.S. Furthermore, in 2020 and 2021 there has been a new wave of space companies going public through Special Purpose Acquisition Company (SPAC) investors. The U.S. is experiencing a growing increase in private investors investing in the space industry due to advances in technology creating new business opportunities, such as reusable rockets decreasing launch costs and the miniaturization of satellite technology.[108] The capital factors help to influence U.S. market advantages. Angel investors, private equity firms, and large U.S. corporations are flooding the sector with funding to help prop up companies to advance launch vehicles, antennas for small satellites and to establish a permanent presence on the moon and launching human missions to Mars. The other side of the coin is the U.S. is increasing its national debt exponentially, which is compounded further by the unanticipated added debt incurred from the impacts of the global pandemic.[109]

Demand Conditions

Demand conditions in the Porter's Diamond Model involve such factors as demand, market size, market growth, and sophistication. These characteristics help companies create a competitive advantage by creating a demand for firms to innovate faster and create more advanced products than those of foreign competitors, such as in the rocket launch sector of the space industry. Space continues to drive human innovations and the current demand for conducting business in space is expanding rapidly. The unifying factor for all current commercial projects in space is the need to create new technologies and infrastructures to manage space missions of any size.[110] Timely and reliable communication is an essential aspect to all U.S. military missions, which is why the U.S. has shifted its focus to investing in C4ISR (Command, Control, Computer, Communications, Intelligence, Surveillance, and Reconnaissance) satellites, which use AI and autonomous systems to analyze, and sort captured images. Additionally, the demand for data and increased demand for bandwidth for emerging and disruptive technologies is growing at an exponential rate. Consequently, companies are in the process of building an infrastructure in space to support these new technologies by launching large-scale constellations of thousands of satellites into LEO to provide global services or "Internet of Things" services to connect machines and systems together directly.[111]

Related and Supporting Industries

The related and supporting industries component of Porter's Diamond includes those industries that both, directly and indirectly, support the space industry as well as help contribute to a competitive advantage. There are several industries in the U.S. that fall within this scope. However, the ones with the most impact are the aerospace and high technology (high-tech) companies that offer advanced technology and services. The aerospace industries, including military and commercial, impacts the U.S. competitive advantage greatly. The U.S. leads the global stage of aerospace, and "is the largest in the world and offers a skilled and educated workforce, extensive distribution systems, diverse offerings, and strong support at the local and national level for policy and promotion."[112] The aerospace industry directly contributes to the space industry for suppliers and means of transportation. The second related industry is the commercial technology and services industry. More of these corporations are investing and utilizing space to support their customers and shareholders. Amazon leadership has created Blue Origin, Tesla has created Space-X and Starlink, and Facebook is creating global Wi-Fi spots using satellites, and Google is branching into planetary imagery. All of these corporations are investing in the U.S. space industry and creating a strong competitive advantage.

Firm Strategy, Structure and Rivalry

The greatest impact on a nation's competitive advantage in any industry is how companies choose to compete domestically with their rivals – domestic rivalry is instrumental to international competitiveness since it forces companies to develop, innovate and improve to maintain a competitive advantage within their industry. Competition is the name of the game, and it drives companies to innovate, expand their products, or be left behind in the dust. An example of this domestic rivalry is in the design, manufacturing, and launching of rockets and spacecraft. Now that NASA is an advocate for commercializing space, including privatizing space operations, the U.S. has a growing number of private firms such as SpaceX, Blue Origin, and Orbital Sciences competing for a commercial future in space beyond NASA contracts and satellite launches, which includes space tourism and sustaining colonies beyond Earth.[113]

The greatest U.S. advantage is its economic structure, which is a capitalist market in a democratic society, enabling companies to invest, provide capital and debt financing to the U.S. space industry. Additionally, the U.S. has a stable government that follows established national and international laws, rules, and regulations. Many commercial space companies and related industries, such as high-tech firms, have found that co-locating their production sites with similar companies has an additive effect on their profits. Skilled laborers are attracted to these high-tech cluster sites that help to spur domestic rivalry amongst U.S. companies advancing space and technology innovation. Examples of these high-tech sites located throughout the U.S. include southern California, Colorado, Texas, Florida, and the Washington DC, Maryland and Virginia Metropolitan Area (DMV). These space clusters help to further competition in the U.S. while simultaneously allowing growth.

Government

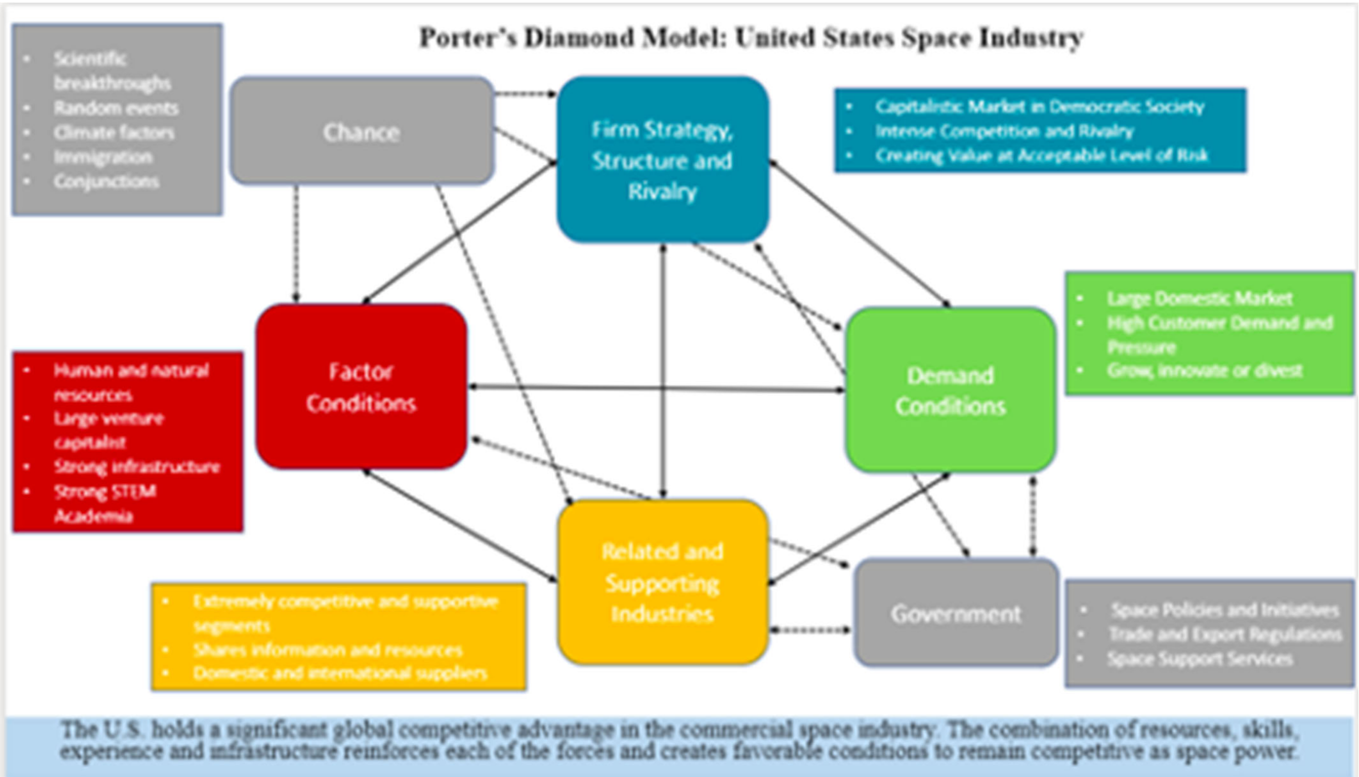
Governments cannot create competitive industries, only companies can create their own competitive advantage. However, governments can and should encourage and push companies to raise their ambitions and achieve a higher level of competitiveness. The U.S. Government does this well primarily through NASA's role in fostering the emerging commercial space industry and stimulating demand conditions for new technologies in space. This role is also shared with the FAA, Office of Commercial Space Transportation, and the Office of Space Commercialization of the DoC. However, the U.S. Government must continue to enact supporting policies that ensure the U.S. sustains a dominant position in commercial space activities. The Departments of Commerce, Energy, and Transportation, along with NASA, must continue to execute a coordinated strategy to develop U.S space commerce and to incorporate space commodities and resources into the larger U.S and global economy to ensure U.S. entrepreneurs can achieve large returns from commercial space enterprises. Additionally, the NSpC has been reconstituted to oversee the three main areas of U.S. space activities—national security, civil space, and commercial space, in an effort to promote U.S. interests in space. A commercial company's ability to innovate and remain competitive internationally cannot be left to private industry. The U.S. Government must continue to promote domestic rivalry by enforcing anti-trust laws and encouraging change.[114] Innovation is key to the U.S. maintaining its competitive advantage in space and to countering its rivals who aim to displace the U.S. as the world's leader in space innovation and use of space for economic development. One of the U.S. strengths is it established the USSF and expanded its role in protecting U.S. commercial and civil space capabilities, commerce, and civil infrastructure in the space domain, similarly to how the U.S. Navy protects global maritime commerce. The U.S. Government has a more lethal force, stronger coalition of spacefaring nations, advances in high-tech innovation, and a culture of performance that generates decisive and sustained U.S. military competitive advantages. However, one of the areas the U.S. Government can improve is in the development of the future STEM workforce by enhancing funding for educational programs at all levels. Additionally, the U.S. needs to build closer ties with domestic and allied suppliers of parts and subcomponents to improve the resilience of the space supply chains.

Chance

The role of chance is often included in the Porter's Diamond Model as the likelihood that such external events such as war and natural disasters can negatively affect or benefit a country or industry. These events are beyond the control of the U.S. Government or the individual companies themselves. The impacts created by chance may lead to advantages or disadvantages for companies of any given industry. For example, the novel 2019 Coronavirus (COVID-19) pandemic has disrupted the commercial space industry and has serious implications for some important NASA missions and critical hardware. Specifically, NASA has had to temporarily halt most production and testing of its Space Launch System (SLS) mega rocket and Orion capsule, which together are critical in getting astronauts to the moon and Mars.[115] Additionally, NASA estimates the production challenges and setbacks in the launching schedules caused by the COVID-19 pandemic will cost the agency over $3 billion. In addition to the increased costs associated with the pandemic, launch dates for several NASA missions and commercial space industry missions have been delayed by ten months to two years.[116]

The combination of resources, skills, experience, and infrastructure reinforces each of the forces and creates favorable conditions to remain competitive as a space power. The U.S. holds a significant competitive advantage in the commercial space industry due to the favorable conditions that drive its domestic companies to continuously innovate, improve and flourish. The six forces of the Porter's Diamond Model are mutually supportive and reinforce the U.S. ability to remain competitive and sustain superiority in space. See *Figure A1* below for model reference.[117]

Figure A1. U.S. Space Domain Industry – Porter's Diamond Model



A.2: China

Factor Conditions

China has several national advantages and disadvantages for factor conditions. While China has a high number of STEM graduates annually that contribute to their advancements in the space sector, they also have many unskilled laborers. These conditions contribute to the middle-income trap. Wages are growing to the point that the growth potential from export-driven manufacturing is exhausted before productivity boosts from the innovative capability to compete with developed countries in higher value-chain industries. It will stay in this type of economy until the GDP per capita rises, which will be difficult as a quarter of China's population is assessed in poverty.

China does have a diverse supply chain for its industries. There is no "buy China" equivalent, and they do not have an issue with buying resources from global markets. However, this may be due to the dependence on others for many raw materials, like oil and minerals.

Additionally, it is the world's largest importer of soybeans and meat because less than 10 percent of its land is arable due to water scarcity to feed its large population making up a fifth of the world's population. Also, China lacks substantial energy resources making it the world's largest importer of energy.[118] However, China does have fairly good geography, relatively easy modes of navigation, and secure borders.

Demand Conditions

IP rights are not protected nor respected by the same laws as other countries. The Chinese culture encourages replication and refinement of other's technologies as copying something is viewed as showing respect to the originator. China has an overall goal of Great National Renewal that is clearly outlined in national documents by the CCP. The focus is on solving the most significant problems for the Chinese people, such as poverty and resulting in space not being as heavily resourced. It is just one of the multiple efforts toward national renewal. However, space is a domain China hopes to leverage to improve its intelligence capabilities, similar to the C4ISR capacity the U.S. possesses with its satellite constellations.

China has a global brand image problem, and while it is not new, the hostility toward them is rising. "Made in China" on products can impact Space foreign market sales. While proclaiming peaceful intentions, China has heavily invested in space infrastructure while not following space norms. One example is the 2007 direct ascent kinetic ASAT test on their satellite that created substantial debris and orbital fouling.

Related and Supporting Industries

The number of domestic companies in the "commercial" space market has increased substantially in the last decade. China has more than 75 commercial space companies, and more than half were founded in the last seven years. Over 45 of these companies are located in the economic exclusion zones of Beijing. Several are also located in Shenzhen.[119] These companies produced the second most launches worldwide in 2020.[120] Aiding the space industry is China's goal to become the global leader in AI, and it is the main driver for industrial upgrading and economic transformation. Combined with the Chinese manufacturing expertise in robotics, automation, and quick replication timeline and lax regulatory measures could allow China to surge ahead in space dominance.

Firm Strategy, Structure, and Rivalry

There are many commercial space companies in China that are state-owned entities (SOEs) and receive support and funding from the Chinese government. This perpetuates rivalry between commercial firms because there is only one buyer, the Chinese government. Despite China's economic advancements, it remains a developing economy with its one creation of state capitalism lacking sustained innate innovation. This situation results in being a second-mover in most technology. The result is the CCP dominates space with its state-run enterprises with a high probability of corruption and a reliance on foreign innovation from which it can bootstrap. Due to a global image problem, China has formed a consortium of space-capable countries like Russia. This allows China to benefit from Russia's experience and technology in space and gives Russia an injection of funding for its struggling economy.

Government

The CCP excels in generating long-term strategy that is great for messaging and focus but not always attainable. Additionally, the lack of social and civil accountability to its citizens and the military-civil fusion creates distrust and oppressive state behavior. Any IP obtained by the government is passed to its corporations along with political and financial support. With China's vast economic clout, especially in manufacturing, it can coerce other Asian countries. To cement this position, China uses alternative multinational forums that do not have a U.S. presence to promote norms and standardization of space. The economy and society are state-controlled, which means that government is a pervasive force throughout all determinates, hindering innovation.

Chance

There is always an element of chance in any industry. Natural disasters and global pandemics can prevent and slow industrial growth. However, in the case of China, their economy was the first to be hit by the COVID-19 outbreak, the first to be locked down, and the first to begin an economic recovery. Although China's GDP has shown growth during the pandemic, with China's declining working-age population, this economic rebound could ultimately result in high levels of debt and decreasing return to capital growth.[121] Additionally, tensions between Taiwan and the Chinese government are rising, and a kinetic conflict could take focus and resources away from modernizing its economy, including its advancements in space.

China's Belt and Road Initiative (BRI) extends into the space domain and its success will continue to be dependent on the relationships China forms with other nations. Currently, China is experiencing success with its efforts to partner with Russia in space and in doing so China will gain a wealth of experience and technology. China is betting on its partnership with Russia to launch and operate a space station successfully. Existing launch locations limit capabilities, but the safety of its citizens has not been a concern in the past as they work to establish a launch site dedicated to human space flight.

A.3: Russia

Factor Conditions

Russia's population as of 2021 is 142.3 million and has steadily decreased over the last twenty years with low birth rates and an aging male population.[122] Russia is the world leader in energy exports, including oil and natural, which serves as the primary source of revenue for the Russian government and is critical to Russia's economic stability. Porter's diamond analysis considers natural resources as basic factors that do not advance competitive advantage. The World Bank estimates that Russian energy exports abroad have a total value of $75 trillion in U.S. dollars and account for more than eighty percent of Russian exports abroad.[123]

Porter classifies advanced factor conditions as those factors that generate a competitive advantage for a nation with highly specialized factors towards a particular industry. Russia's labor force composition includes two-thirds of the labor force employed in the services sector, with twenty-five percent in industry and six percent in agriculture.[124] Demographic trends in Russia from an aging workforce and unusually high death rates from alcoholism continue to reduce the available workforce. While two-thirds of the Russian labor force has a college degree or tertiary education, Russia falls behind China, India, and the U.S., with an educational focus on skilled expertise in science, engineering, and technology required in the competitive space industry.[125]

From an economic perspective, U.S. sanctions levied against Russia create roadblocks for international investors and diminish the chances of significant expansion into international financial markets by preventing Russian companies from accessing Western credit markets.[126] Lack of investment and continued deterioration of existing infrastructure facilities have been the main limitation in expanding the Russian economy and led to Russia dropping to 95th globally in terms of economic development.[127] Following a decline in defense and space budgets triggered degradation to infrastructure and Russian space facilities.

Demand Conditions

When analyzing the sophistication levels and home market demand, Russia's consumer market and government-controlled policies have changed dramatically over the last two decades. Russian consumer trends characterized by a period of growth, disposable incomes, and credit availability increased consumer demand for products and services.[128] This trend has declined over the last five years, where incomes have declined, and the population's debt-burden will challenge producers to provide the same level of products and goods without the same demand level.[129]

Nations have developed national competitive advantages by innovating and developing products with high standards. In the global market arena, Russia has not fully realized a national advantage in this regard for two reasons: (1) Russia has a very limited export market for advanced products compared to other nations (as addressed above), and (2) Russia also has a limited level of national innovation among all of its markets relative to other nations – especially in small business innovation. Russia invested less than one percent of its GDP toward innovation in 2019.[130] Looking back further, from 2007 through 2015, Russian small businesses only accounted for between one and five percent of these innovations.

Competitive nations generally leverage small business innovations to produce national advantages. The main reason for Russia's lack of small business innovation is the low activity of entrepreneurs. This can be explained by the higher risks of doing business in Russia due to corruption and lack of incentives.[131] Further, Russia's lack of innovation is caused has been further exasperated by global and national crises in the economy from both international sanctions and COVID-19.[132]

Related & Supported Industries

Energy is the leading industry in Russia's economy. Russia's access to global markets has declined and resulted in a stagnation of the Russian economy driven by a failure to diversify its exports, relying heavily on hydrocarbons, oil, and weapons. The Russian government has a large and sophisticated defense sector, and it is a major arms exporter. Russia will use these supported industries to advance partnerships with nations with whom they have established arms agreements.

Russia has failed to evolve its space program in a new space market characterized by state and non-state and actors with commercialization shifts in space that have reduced the market share for Russia's legacy platforms and space infrastructure. Moreover, with the technological advancements and commercial availability of more cost-effective launch and services platforms, Russia lacks the modernized space architecture and national space policies to advance national strategic space objectives at the speed of relevance.

Firm Strategy, Structure and Rivalry

Russian economic sectors are characterized by a small number of highly concentrated state-controlled firms managed by the government, which retains ownership, including energy, defense, and financial institutions.[133] Business strategy is often secondary to government policy and corruption, leading to a lack of competitiveness and innovation. As a result, state-controlled and supported firms are incentivized with subsidies and are less efficient, with labor productivity as low as thirty percent of the sector average in some industries.[134]

Russia's economy faces several structural issues that make the economy rigid and less competitive. The International Monetary Fund (IMF) has identified several structural challenges that the Russian government should address to make the Russian economy more competitive, including a need to reform public procurement, reduce barriers to trade and foreign investment, and increase fiscal transparency and accountability.[135]

Government

The Russian government continues to focus its national space policies on its public space sector instead of private space companies.[136] Despite the establishment of Roscosmos State Corporation in 2015, Russia has failed to advance significant space sector technological advancements. The primary factor is economic stagnation with reduced budgets and resources available to replace legacy space platforms and infrastructure.

The Russian government will continue to seek international partnerships to advance its competition with the U.S. and reverse its current glide path as a declining space power. Russia will also seek opportunities when necessary to partner with China as an alternative to Western influence and dependence. The recent announcement of Russia and China's partnership to build a lunar space station is one example where Russia is willing to partner with China to provide an international space market in lunar space to rival U.S. capabilities.

Chance

With Russia's weak economic outlook, the role of chance could negatively impact the country. COVID-19 has resulted in negative momentum for the Russian economy, with potential growth continuing to contract. Despite monetary and social policies that have been in place by the Russian government, unanticipated spikes with new variants of the COVID-19 will impact the Russian economy. Furthermore, Russia's dependence on energy exports will impact the Russian economy as the price of oil rises and falls with demand. As more countries move towards clean energy, reduced carbon footprint, and reduced dependency on oil, the Russian economy will be impacted by the reduced demand in the energy market.

A.4: Japan

Factor Conditions

In terms of factor conditions, Japan has several national advantages and disadvantages. Limited natural resources and raw materials are available domestically, as Japan is a relatively small island with an area comparable to California.[137] However, its proximity to other large markets in the IndoPacific region gives it access to import the materials it needs and export its own goods into these markets. Japan has excellent domestic innovation in technology with particularly advanced capabilities for minimizing Size, Weight, and Power (SWaP). SWaP is incredibly important for space to fit payloads into fairings, maximize mission life, and minimize launch weight. Japan's Tanegashima Space Center is located at 30 degrees latitude, so efficiency in launch mass is important to reach desired final orbit destinations.

Japan has strengths and related growing challenges in human capital. It has a highly skilled, highly educated workforce, but demographic shifts including a declining birthrate have reduced the pool of skilled labor. Furthermore, while the U.S. and China have grown their annual graduates in STEM, Japan's have declined each year since its peak in 2001.[138] Japan needs a thriving, diverse talent pool of STEM expertise to compete with other nations in commercial and national security space. Capital resources are also a potential challenge for future space investments, with Japan's national debt and deficits accounting for 235 percent of annual GDP—the largest debt-to-GDP ratio of any country.[139]

Demand Conditions

With regards to demand conditions, Japan has a very demanding and sophisticated domestic customer base which has led to a competitive advantage in in high technology markets because buyer needs have pressured companies to innovate.[140] Michael Porter used Japan as his man example when talking about demand conditions. In Japan, "tightly constrained requirements of the Japanese market have forced companies to innovate."[141] This factor has helped the country succeed in many areas.

Japan is the third-largest economy in the world and one of the most stable democracies in the world.[142] Japan buyers are sophisticated, well educated, and are leading the demand for Asian market growth in many different markets. With a population of 126 million people and a $38,400 GDP per capita, Japan is very primed to push future innovation markets to success.[143] The Space Industry within Japan is doing well when compared to other countries in Asian Pacific region because of its consumer factor.

The Japanese Space Industry also has to deal with a mature system of laws and regulations and particularly stringent environmental regulations.[144] Japanese Government is very concerned about the environmental issues facing the world today and they are doing their best to regulate this area.[145] This condition while demanding is making industrial base and government agencies look for opportunities to innovate and improve their manufacturing and production facilities.

Government procurement time is also a condition that affects the Japan market. The majority of government procurements are conducted via "competitive tendering procedures" which extend the length of the process.[146] This demand condition must be factored into the competitive advantage equation. Due to the Space Industry being dominated in Japan by the government, procurement times must be considered and accounted for in planning.

Related & Supported Industries

Japan's leadership in supporting and related industries aids its continued space sector advancements. Known for its cutting-edge electronics, advanced materials, and machine tooling industries, Japan successfully leverages these supporting industries for both direct and indirect application to space system engineering. Given the domestic availability of supporting products and the associated skilled workforce, Japan can fill domestic demand for many of its critical space sector needs.

Since many domestic suppliers of electronics serve as individual global competitors, they keep pace with market innovation needs and Japan's space sector is uniquely positioned to take advantage of the spillover benefits. Although these firms compete against each other in the global market, they are still open to collaborative partnerships when applied to national challenges, like those presented by JAXA.

Japan also leverages its advanced materials and machine tooling industries to propel its leadership in the space sector. Although a large portion of Japan's advanced materials research and development focuses on innovations in the electronics industry, the space sector benefits from the carry over. As an example, Japan is currently using advanced materials originally developed for other applications to design and build on-orbit electric propulsion systems for SmallSats.[147]

Historically, Japan tapped into its robust machine tooling industry for space system applications. While the country maintains a leading role and net exporter of machine tooling resources, it also acknowledged the growing demand for additive manufacturing capability. Several of Japan's largest machining firms transitioned to hybrid (subtractive and additive) manufacturing approaches to better meet the needs of high-tech sectors, to include the space sector.[148]

Firm Strategy, Structure and Rivalry

Michael Porter stated that "A nation's competitiveness depends upon the capacity of its industry to innovate and upgrade."[149] The overall strategies, structures, and rivalries found within Japanese firms offer unique challenges and opportunities to that capacity.

The general organizational structure of Japanese firms closely parallels western counterparts with familiar executive, managerial, and line organizations; however, decision-making tends to be more decentralized and participatory, following a highly evolved and complex set of social rules and norms. This paradigm can increase communications across the firm's hierarchy, enhance collaboration, and facilitate process innovations across production lines. It also can lead to increased participation across the workforce and bolster loyalty within the firm. The structure and culture are not without negatives: these can result in slower decision cycles.

Major corporations follow a clustering or grouping strategy known as keiretsu.[150] Some of the most successful firms have significant horizontal integration to allow access to capital and domestic marketing access (Mitsubishi) or vertical integration (Toyota) to gain control, efficiencies, and stability of supply chains.[151] Rivalry and competition across firms are intense and have led to significant innovations as firms attempt to gain market share, spurring innovation and automation. The rivalry is particularly pronounced in the automotive and consumer electronics sectors. Known for tight quality control and a significant manufacturing base, Japan continues to drive demand and competes well internationally, and is the world's third-largest automotive industry.[152]

As an island nation, Japanese markets have been historically insular and focused on the domestic market. This focus has led to "Galapagos Island Syndrome," where unique product adaptations suit the domestic market but may not have international appeal. However, its aerospace industry's focus is global and benefits from collaborative international partnering.

Government

Since 2013, Japan's government has been promoting policies to encourage companies and people to join the space industry. This democratization of the industry has led to significant growth in startups exploring ventures in space; space has become a solid pillar in Japan's industrial segmentation.[153] Japan's recent policy entrepreneurship toward space is critical: large companies, like Mitsubishi Heavy Industries, Mitsubishi Electric Corporation, and Kawasaki Heavy Industries, have participated in the global space industry for decades. Japan's national goal to double their space industry by 2030 – and their ensuring resourcing of that goal – is paying dividends. For example, Syspective is a SAR Earth Observation (EO) startup that came out of a high-risk R&D government program that is drawing fawning attention from investors and markets in anticipation of what is to come.[154] Syspective would not have been possible without renewed government focus on space and the need for increased investment and access to add to Japan's national competitiveness.

Japan has a rich history in civil space activities, which gives its recent pivot toward commercial space some gravitas: its first successful satellite launch was in 1970, it was a partner in building the ISS, and it had three space agencies merge into one to create JAXA in 2003. Japan's existing space infrastructure, particularly through JAXA's Space Innovation through Partnership and Co-Creation (J-SPARC) initiative, allows for startup support via R&D agreements with commercial companies. While Japan has solid presence in space via their civil activities, their recent policy actions have allowed for increased commercial activities that will benefit their national competitiveness in the space arena.

Chance

Chance impacts can have an outsized impact on any industry depending on the timing, applicability, and location of a chance event. "The discontinuities created by chance may lead to advantages from some and disadvantages for other companies." [155] For example, following Japan's World War II defeat, the Japanese industrial base recovered remarkably quickly through modernization of formerly discriminatory policies to increase their labor pool and focus raw material production. The outbreak of another nearby war in Korea stimulated Japan's recovery even further as they could produce equipment and supplies for the U.S. nearby rather than the U.S. having to ship supplies across the Pacific Ocean.

Natural disasters, global pandemics, and terrorist attacks are examples of negatively impacting chance events on Japanese industries. For example, an earthquake and follow-on Tsunami led to the 2011 Fukushima Daiichi Level 7 nuclear disaster, which led to the evacuation of 465,000 residents, 138,000 destroyed buildings, and $360 billion in economic losses.[156] Given that Japan is a geographically small and isolated nation, it must ensure safety protections are incorporated in all of their industry system designs to allow mitigation strategies for chance events.

Additional Japan Information:

While the U.S. has led the world in total R&D investments over the last 50 years, China's R&D spending is projected to surpass the U.S. in the upcoming year. Spacefaring allies that make significant R&D investments would make strong partnering candidates, most notably Japan.[157] While Japan spends significantly less than either the U.S. or China, they are third in the world in total R&D investment and lead both nations in terms of the total number of researchers and in R&D spending as a percentage of GDP. Michael Porter stated that "A nation's competitiveness depends upon the capacity of its industry to innovate and upgrade."[158] Examining relative advantages using the Porter's Diamond Model analysis previously outlined in this appendix, Japan appears well-positioned and committed to increasing this capacity.

The timing to refocus space partnering with Japan to include mutual national security objectives is ideal. Recent amendments to Japan's Basic Space Law coupled with increasing regional security threats (China), have also increased national space partnering opportunities. In addition, Japan's 2018 National Defense Planning Guidance (NDPG) removes the traditional strategic domain boundaries of land, air, and sea and prioritizes cross-domain defense by leveraging space and cyber capabilities.[159] To achieve this Multi-Domain Defense Force capability, the 2018 NDPG emphasizes the Space domain as a vital security interest of Japan. In conjunction with cyberspace and satellite communications, space systems are indispensable enablers that "organically fuse capabilities in all domains."[160] Further, the NDPG sets clear expectations for future partnering. The Guidance directs Japan's Self Defense Force (SDF) to work with Japan Aerospace Exploration Agency (JAXA) and the U.S. to ensure "superiority in the use of space at all stages from peacetime to armed contingencies."[161] The NDPG also stipulates that the SDF will "strengthen capabilities including mission assurance capability, the capability to disrupt opponent's command, control, communications, and information and to leverage civilian technologies and work to enhance cooperation."[162] .

Notably, the global problem of space debris is being commercially pursued by the Japanese startup Astroscale (headquartered in Japan with offices in the U.S., U.K., Israel, and Singapore) and will foreseeably present a defense and national security utility.[163] Bilateral incentives to address this problem area could serve to spur space market health.

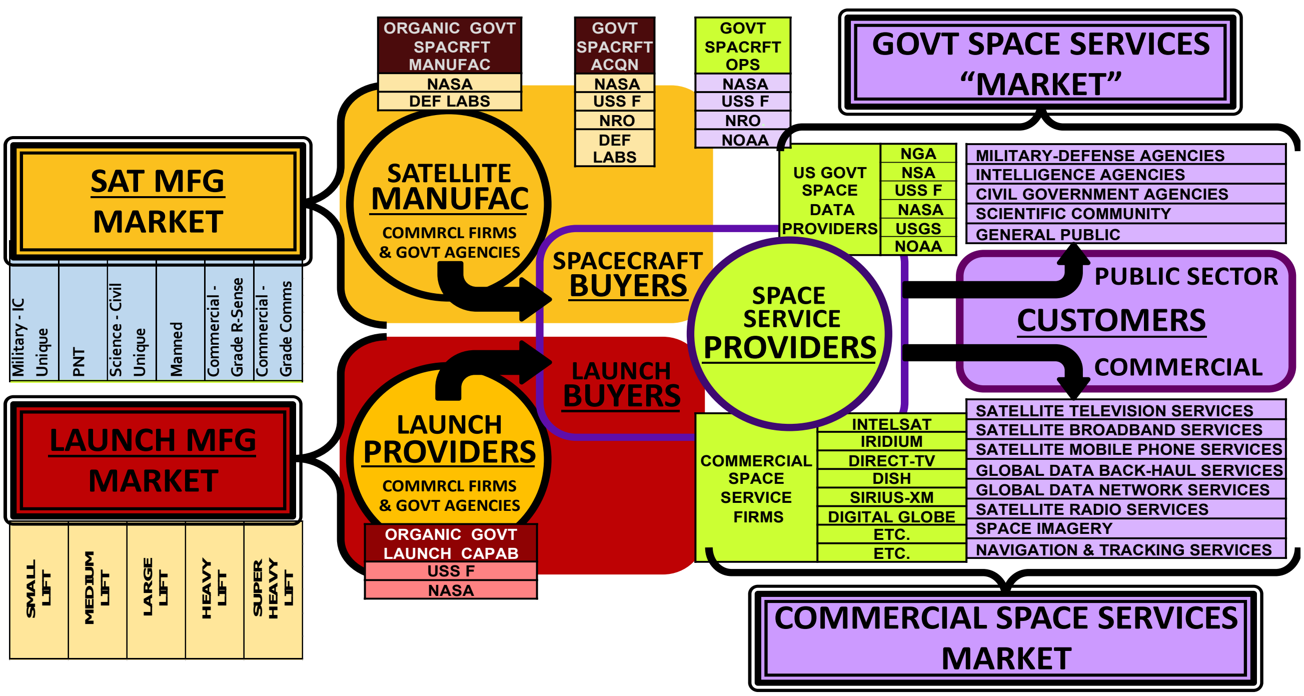
Traditionally focused on scientific missions, Japan's national aerospace and space agency, JAXA's role now includes industrial promotion and national security. In March 2015, creating a new strategy titled *Ensuring National Security and Helping Make Society a Safe and Secure One*, which emphasizes developing satellite systems to help attain national security goals and increase resilience and responsiveness of space systems.[164] With a mature space infrastructure and the legal barriers to national security cooperation removed Japan is politically poised for expanded civil and military space partnership with the United States.

Appendix B: Additional Analysis

Space Industry Definition

As described in Joint Pub 3-14, "space operations are those operations impacting or directly utilizing space- and ground-based capabilities to enhance the potential of the U.S. and multinational partners."[165] The space industry supports these operations through an industrial base primarily comprised of aerospace and defense companies.[166] These aerospace and defense companies are competing in manufacturing and services sectors that included launch, satellite manufacturing, and services (see Figure B1)[167]. Emerging in the space industry are advancements from commercial aerospace partners, such as SpaceX. For example, SpaceX heavily influenced the industrial base through the investment and advancement of launch technologies. These advances have decreased the cost of launch and provided a successful example of the ability to bring innovative technologies to market through the P3 model.

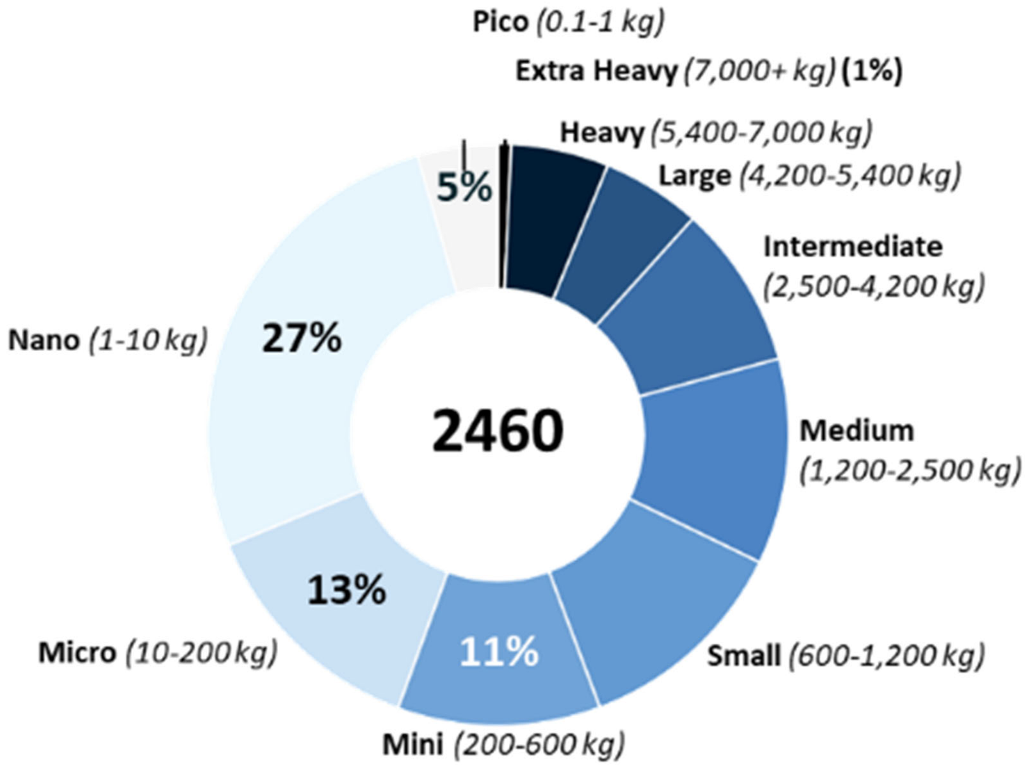
Figure B1: The Space Industrial Base



Dr. Clark Groves, Space-Counterspace Industry Study, Eisenhower School, National Defense University, 2020

A very high barrier to entry remains for nations to create or re-create a commercial space manufacturing base (economic investment, technical effort, human capital development).[168] Commercial space manufacturing includes spacecraft (e.g., launch, satellites, and robotics) and supporting operations from ground systems. They are dual-use sectors with an entanglement between the commercial and defense markets as most of the money spent now moves through the commercial market.[169] The U.S. is the largest spacecraft manufacturer with $6 billion of revenue in 2015 with 86 attempted launches and 262 spacecraft.[170] Its ground systems, the Earthbound infrastructure that transmits directions to satellites and receives data they collect, received more than $100 billion in revenue in 2015.

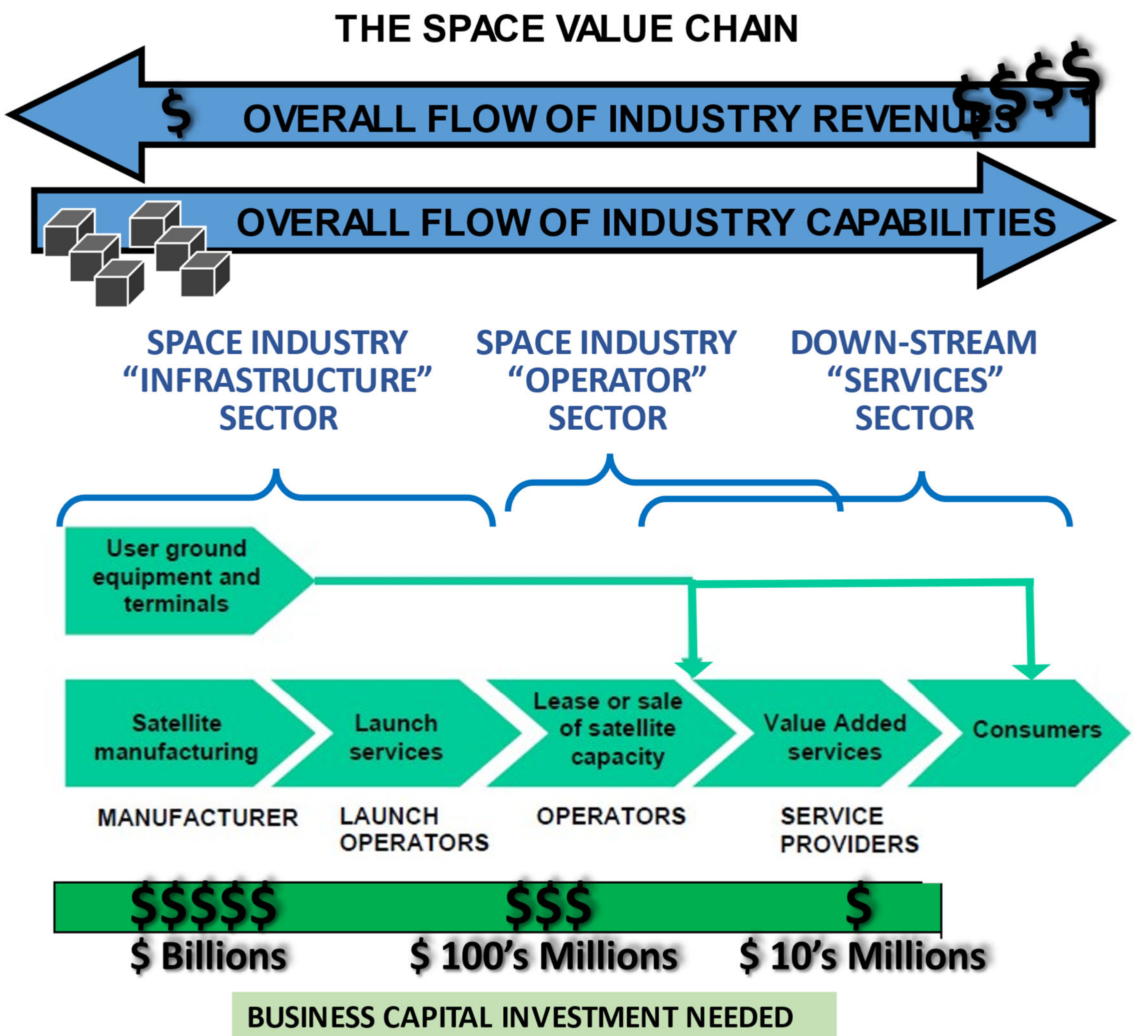
Figure B2: 2019 Fielded Satellites by Size



Commercial space manufacturing markets almost always have limited competition (few competing firms, i.e., oligopoly or monopoly), with low production volumes (10 or fewer units per year), and very high unit costs (~$100 million+ per satellite or launch vehicle)[171] However, this is changing in the U.S. (and globally). P3 has helped drive commercial innovation, lowering the cost of launch and commercial space manufacturing. Also, the capability of smaller satellites has increased at a lower cost, as depicted in the Satellite Industry Association's *2020 State of the Satellite Industry Report* (Figure B2). From 2014 to 2019, the number of satellites in operation increased by 77 percent, from 1,381 to 2,460. Most were small satellites operated in LEO, as depicted in the graphic. Of these satellites in operation, the U.S. operates over 1,000, some in partnership with other nations.[172]

The U.S. 2020 National Defense Space Strategy emphasizes the importance of sustaining a healthy and competitive U.S. space industrial base. Economic factors have a profound impact on the space value chain.[173] The first relates to the uneven circulation of revenue in the space value chain. As depicted in the Space Value Chain graphic below (Figure B3), the space industry sector, including spacecraft manufacturing and ground systems, requires substantial ($ billions) of capital.[174] Downstream in the value chain, the service providers require the least but make the most revenue.[175] This uneven circulation makes it harder for new spacecraft manufacturing entrants upstream in the space value chain. Over time, this may correct itself through innovation, assuming greater launch and spacecraft cost and manufacturing efficiencies.

Figure B3



Dr. Clark Groves, Space-Counterspace Industry Study, Eisenhower School, National Defense University, 2020

Appendix C: Excerpts from Student Papers

Driving Budget Agility: Modernizing PPBE for Future Defense Challenges," Lt Col Andrew Anderson, Acquisition Research and Writing, Eisenhower School, 2021

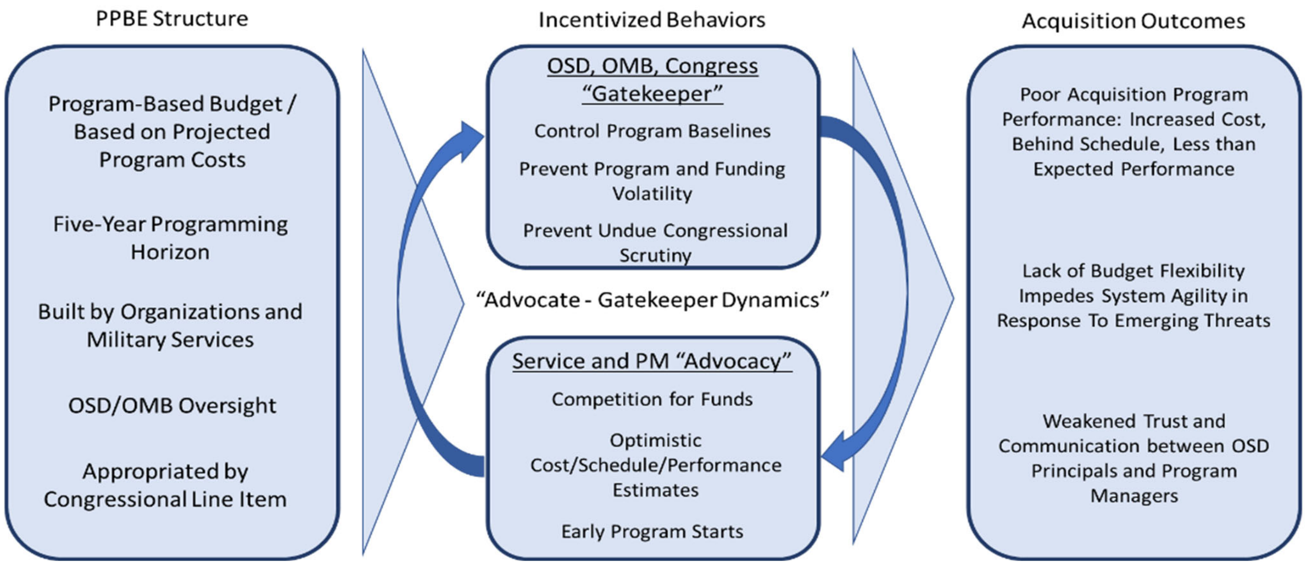
The DoD budget structure implemented in 1961 is fundamentally ill-suited for 21st Century great power competition. China is rapidly modernizing its national-level resourcing approach to better incorporate fourth industrial revolution technology into advanced weapon systems. Its "Made in China 2025" and "military-civil fusion" efforts are intended to build technological leadership in various strategic fields, synergize civilian and military economies, and streamline the integration of AI, nanotechnology, advanced robotics, and quantum computing into military capabilities.[176] In contrast, the underlying structure and process that guides DoD procurement: the PPBE system, has remained virtually unchanged for 60 years.[177]

Reversing the recent erosion of the U.S. joint force conventional advantage will require more flexibility for acquisition Program Managers (PMs) and lower-echelon acquisition organizations to adapt military capabilities against rapidly evolving threats by incorporating emerging technologies readily available in the commercial market. Such acquisition flexibility requires budget and resource execution agility, that is, the ability to shift funding within the current DoD accounting structure during the budget year. To accomplish these goals, the new USSF, through DoD, recently sought permission from OMB and Congress to adopt a streamlined resource allocation system that allows consolidation of the discrete building blocks that comprise the DoD budget: BLIs or "program elements."

Viable program element consolidation in a political economy environment requires a corresponding increase in information by principals who hold budget oversight authority: the OSD and the OSD Office of the Comptroller, in addition OMB and Congress. Streamlined resource flexibility thus requires a new contract between budget principals and agents where increased budget flexibility is exchanged for more real-time awareness of program performance, mission area threats, and commercial innovation opportunities that could counter emerging threats.

The PPBE budget structure, the advocate-gatekeeper behaviors incentivized by this structure, and the acquisition outcomes from these behaviors are summarized in Figure C1 below. The program-based DoD budget structure provides a mechanism to resolve the principal-agent problem between Congress and DoD, and between DoD and PMs. This program-based structure also creates conflicting incentives based on differing interests and definitions of acquisition success. Competition for budget share drives advocacy behavior by PMs and Services and gatekeeper behavior by OSD, OMB, and congressional defense committees. Competing incentives yield the poor acquisition performance highlighted in countless Government Accountability Office (GAO) reports and reform efforts. Competing incentives can also erode trust between budget principals and agents. Most importantly, the lack of resource flexibility that flows from the advocate-gatekeeper dynamic impedes acquisition agility. The PPBE process can prevent PMs and Services from making the necessary portfolio trades to effectively manage risk and respond to emerging threats by capitalizing on innovation and rapidly advancing technologies.

Figure C1: PPBE Structure, Behaviors, and Outcomes



The current strategic environment demands greater DoD resource agility. Technological disruption and great power competition will increase the rate at which security threats evolve to expose weaknesses in U.S. joint force capabilities. Lower levels of the program management chain of command, PMs and Program Executive Offices (PEOs), must be empowered with authority to manage future operational risk by flexibly shifting resources across a mission area portfolio within the budget execution year.

The public accountability required of budget principals will likely keep a program-based DoD budgeting structure process in place. Given this reality, budget agility requires a new contract between principals and agents that adjusts budget resource flexibility by consolidated portfolio while still preserving the desired level of oversight and insight necessary for that mission area. Along with BLI consolidation, OSD Comptroller could implement an updated framework for internal realignment authority. Internal realignments shift funds between BPACs within a BLI during budget execution year and typically do not require congressional prior approval. Realignment authority within a portfolio could be adjustable based on portfolio context (threat area, congressional interest, historical performance, etc.). BLI consolidation and flexible realignment authority would effectively free the majority of the DoD budget from a "one size fits all" reprogramming threshold to a more flexible structure that varies budget agility by mission area.

The Portfolio Resource Management (PRM) platform, a conceptual knowledge management system that could accompany BLI consolidation and preserve DoD budget principal oversight and insight in a consolidated budget structure, is diagrammed in Figure C2 below. Every consolidated portfolio element would have a unique PRM resourcing profile summarized in a "dashboard." The PRM dashboard would contain portfolio background information to include an overview of the mission area and detail of all programs (individual BPACs) within that portfolio. Background information would also include an overview of the major risk areas, OSD, OMB, or congressional interest areas within that portfolio. Each portfolio element would have a unique cumulative internal realignment threshold for resource trades among programs within that portfolio (10 percent, 20 percent, 30 percent etc.).

Each portfolio PRM dashboard would provide current and historical information regarding all resource trades within that portfolio. Each internal realignment action within a BLI would include a brief rationale that summarizes the specific story behind the internal realignment. For example, “a specific threat assessment drove a specification upgrade that increases the program cost estimate,” or “a sub-contractor can no longer deliver a satellite component as scheduled, driving a schedule slip that increases program cost.” Access to this background information for every internal realignment would allow budget principals to track the background and evolution of long-term portfolio resource issues. Importantly, this background information would not be a substitute for communication between stakeholders but rather a channel or mechanism for more effective communication and awareness regarding portfolio issues between all budget stakeholders.

Secondly, each portfolio PRM dashboard would have a detailed history of each program’s current and past financial performance within a portfolio. It would outline program obligation and expenditure rates, show the record of all internal and prior approval reprogramming actions, and identify past efforts to mitigate cost, schedule, performance, or future threat risk. The third and most important element of a PRM platform is an adjustable internal realignment threshold and a set of customizable and updateable restrictions on internal realignment activity that might affect OSD, OMB, or congressional staff interest areas. For example, a specific requirement for a satellite program within a broader mission area portfolio links to another joint force system. As another example, a critical sensor for that satellite system is currently manufactured in a particular congressional district. Any realignment within a portfolio activity that could impact specific interest areas would be restricted without congressional prior approval. Ideally, congressional defense committees to adjust the internal realignment authority of each portfolio on an annual basis. Adjustable realignment authority would counteract advocacy and gatekeeper behaviors uncovered in this report by incentivizing responsible threat response, risk management, resource stewardship by PMs and PEO, as well as proactive communication between program leaders with OSD, OMB, and congressional staffs.

Figure C3 below shows how a PRM platform fits together with BLI consolidation for the USSF and an updated decision-making process for internal BLI realignments and congressional prior approval reprogramming. This example uses programs in the USSF RDT&E budget consolidated by mission area. In this case, 20 original RDT&E program elements are consolidated to seven new BLIs representing mission area portfolios. Each BLI or portfolio element is structured with BPACs representing each acquisition program within that portfolio. Each new BLI has a custom cumulative internal realignment threshold and could have gates that would restrict certain BPAC realignments based on DoD or congressional interests.

In this revised decision framework, the USSF Integrating PEO would have realignment authority over all consolidated BLIs and could, for example, approve a realignment between two of the four programs within the Space Control portfolio up to a cumulative threshold equal to 40 percent of that BLI. All internal realignments could be tracked for stakeholder awareness within the PRM platform. Once the 40 percent cumulative realignment level is reached, OSD Comptroller and OMB approval is needed for any further internal realignments within the Space Control BLI, and approval could be granted through the PRM. Finally, any reprogramming actions between BLIs would be restricted, as now, to the lesser of $10 million or 20 percent of the portfolio. Any internal realignment activities that affect a restricted BPAC would also need prior congressional approval. This decision structure maintains OSD, OMB, and congressional defense committee oversight at current levels for pre-determined portions of the portfolio but allows increased budget agility elsewhere. For example, portions of the USSF budget designed to leverage rapidly advancing technology or commercial innovation, such as the Space System Prototype portfolio, could be set with a 50 percent realignment threshold and no realignment restriction.

The PRM platform proposed here complements BLI consolidation and an updated realignment approval framework to streamline resourcing and improve budget agility throughout the DoD. Importantly, this platform achieves BLI consolidation while maintaining the interests of budget principals. OSD, OMB, and congressional defense committee staff can maintain oversight of acquisition programs with improved insight into real-time resourcing realignments within portfolios. Adjustable internal realignment thresholds could improve flexibility for tailored portions of the DoD budget or reward responsible resource stewardship by PMs.

Meanwhile, a PRM approach improves the time scarcity problem outlined above. OSD, OMB, and congressional defense committees can restrict realignment authority for high-interest portfolios or problem areas while giving other areas of DoD budget more resource flexibility with a higher realignment threshold. The PRM platform conceptualized in this paper could serve as a streamlined communication channel that could improve overall budget agility without sacrificing DoD budget principal oversight.

DoD budget process modernization could begin by prototyping the PRM platform and realignment framework on the USSF RDT&E portfolio, as demonstrated in this report. This total portfolio represents only 1.4 percent of the entire DoD FY year 2021 budget. [178] Applying this concept across an entire Service RDT&E budget would allow a comprehensive assessment of its potential to improve budget agility DoD-wide.[179] Importantly, implementing a pathfinder BLI consolidation initiative and an updated realignment framework would not require statutory change. Program elements are defined by OSD Comptroller accounting structure and congressional defense committee expectations. Successful demonstration of a pathfinder system could serve as a basis for improving confidence in such a consolidated BLI approach among OSD, OMB, and congressional defense committees. If successful, BLI consolidation could be implemented across DoD as a PPBE structural update that could improve budget agility across weapon system acquisition.

Figure C2: Conceptual Model of a PRM Platform

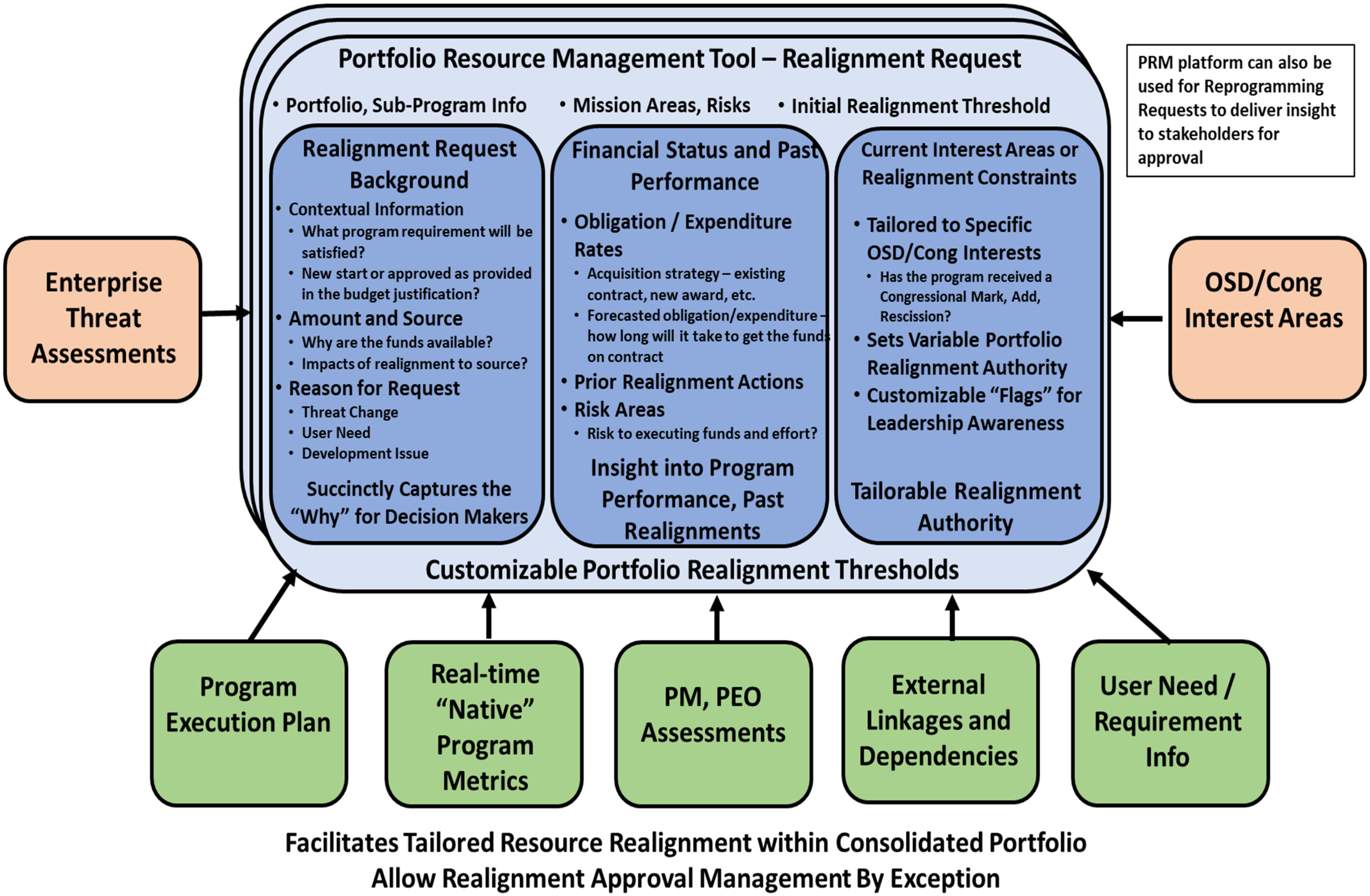
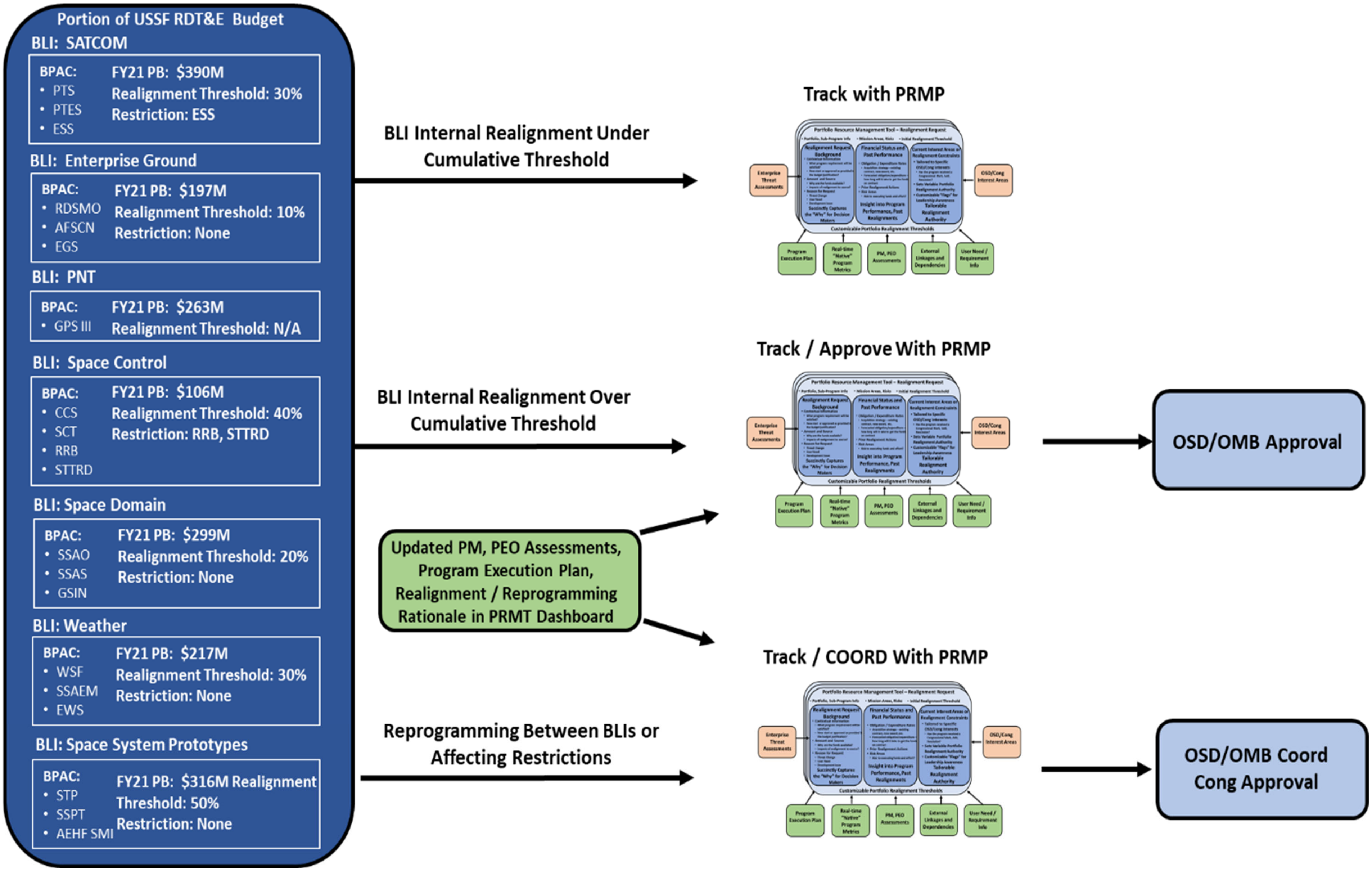


Figure C3: Conceptual Model of an Updated Realignment/Reprogramming Decision Framework with PRM



Acronym List

AFRL	Air Force Research Lab
AFWERX	Air Force Innovation Program
AI	Artificial Intelligence
ASAT	Anti-satellite
BA	Budget Activity
BAA	Broad Agency Announcement
BLI	Budget Line Item
BPAC	Budget Program Activity Codes
BRI	Belt and Road Initiative
C4ISR	Command, Control, Computer, Communications, ISR
CCP	Chinese Communist Party
COVID-19	2019 Coronavirus Disease
CRADA	Cooperative Research and Development Agreements
CSpOC	Combined Space Operations Center
DARPA	Defense Advanced Research Projects Agency
DMV	Washington DC, Maryland and Virginia Metropolitan Area
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DoS	Department of State
EDC	Economic Development Center (Colorado)
EHF	Extremely High Frequency
EO	Earth Observation
EO/IR	Electro-Optical/Infra-Red
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FD	Foreign Disclosure
FFRDC	Federally Funded Research and Development Centers
F	Financial Management Regulation
FVEY	Five Eyes Alliance
FY	Fiscal Year
FYDP	Future Years Defense Program
GAO	Government Accountability Office
GDP	Gross Domestic Product
GEOINT	Geospatial Intelligence
GOCO	Government-Owned, Contactor-Operated
GPS	Global Positioning System
IC	Intelligence Community
IMF	International Monetary Fund
IP	Intellectual Property
ISR	Intelligence, Surveillance, and Reconnaissance
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency

JCIDS	Joint Capabilities Integration Development System
J-SPARC	JAXA's Space Innovation through Partnership and Co-Creation
K-12	Pre-Undergraduate Education: Kindergarten-Twelfth Grade
LEO	Low Earth Orbit
LOE	Line of Effort
MILSATCOM	Military SATCOM
MIT	Massachusetts Institute of Technology (MIT)
NASA	National Aeronautics and Space Administration
NASC	National Aeronautics and Space Council
NDPG	National Defense Planning Guidance
NFP	Not-for Profit
NOAA	National Oceanographic Atmospheric Administration
NRO	National Reconnaissance Office
NSIB	National Security Innovation Base
NSIN	National Security Innovation Network
NSpC	National Space Council
NTP	Nuclear Thermal Propulsion
OEDIT	Office of Economic Development and International Trade
OMB	Office of Management and Budget
OPIR	Overhead Persistent Infrared
OSAM	On-orbit Servicing and Manufacturing
OSC	Office of Space Commerce
OSD	Office of the Secretary of Defense
OT	Other Transaction
P3	Public-Private Partnerships
PB	President's Budget
PEO	Program Executive Office
PM	Program Manager
PNT	Position, Navigation, and Timing
POM	Program Objectives Memorandum
PPBE	Planning, Programming, Budgeting, and Execution
PPP	Purchasing Power Parity
PRM	Portfolio Resource Management
R&D	Research and Development
RDT&E	Research, Development, Training and Evaluation
S&T	Science and Technology
SAR	Synthetic-Aperture Radar
SATCOM	Satellite Communication
SBIR	Small Business Innovation Research
SCG	Security Classification Guide
SDA	Space Domain Awareness
SDF	Self Defense Force (Japan)
SLS	Space Launch System
SMART	Science, Mathematics and Research for Transformation
SME	Subject Matter Expert
SOF	Special Operations Forces

SOFWERX	Special Operations Forces Innovation Program
SPAC	Special Purpose Acquisition Company
SpaceWERX	(Prospective) USSF Innovation Program
SPD-2	Space Policy Directive-2
SPD-3	Space Policy Directive-3
SPEY	Space Eyes Alliance
SSA	Space Situational Awareness
STE	Staff Years of Technical Effort
STEM	Science, Technology, Engineering and Mathematics
STM	Space Traffic Management
STS	Space Transport System
STROTC	STEM Reserve Officer Training Corps
SWaP	Size, Weight, and Power
TWI	Training Within Industry
UARC	University Affiliated Research Center
UDL	Unified Data Library
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
USSF	United States Space Force
USSOCOM	U.S. Special Operations Command
USSPACECOM	United States Space Command
VP	Vice President

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